PERFORMANCE OF TOMATO CULTIVARS (*Solanum lycopersicum* L.) IN DIFFERENT SOILLESS CULTURE SUBSTRATE UNDER PROTECTED CONDITIONS

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Horticulture (Vegetable Science)

By

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Transforming Education Transforming India

LOVELY PROFESSIONAL UNIVERSITY, PUNJAB

2022

DECLARATION

I hereby declare that the thesis entitled **"PERFORMANCE OF TOMATO CULTIVARS (*Solanum lycopersicum* L.*)* IN DIFFERENT SOILLESS CULTURE SUBSTRATE UNDER PROTECTED CONDITIONS"** submitted for **Doctor of Philosophy in Horticulture (Vegetable Science)** to the School of Agriculture, Lovely Professional University is entirely original work and all ideas and references are duly acknowledged. The research work has not been formed the basis for the award of any other degree.

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CERTIFICATE-I

This is to certify that the thesis entitled, **"PERFORMANCE OF TOMATO CULTIVARS (*Solanum lycopersicum* L.) IN DIFFERENT SOILLESS CULTURE SUBSTRATE UNDER PROTECTED CONDITIONS"** submitted to the Faculty of Technology and Sciences, Lovely Professional University, Phagwara, Punjab in partial fulfillment of the requirement for the degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **Horticulture (Vegetable Science)** embodies the results of a piece of bonafide research carried out by **Nikhil Ambish Mehta** under my guidance and supervision. To the best of my knowledge, the present work is the result of original investigation and study. No part of this thesis has ever been submitted for any other degree or diploma or published in any other form. All the assistance and help received during the course of investigation and the sources of literature have been duly acknowledged by him.

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Date: 11-11-2022 **(Dr. Ramesh Kumar Sadawarti)**

CERTIFICATE-II

This is to certify that the thesis entitled **"PERFORMANCE OF TOMATO CULTIVARS (*Solanum lycopersicum* L.*)* IN DIFFERENT SOILLESS CULTURE SUBSTRATE UNDER PROTECTED CONDITIONS"** submitted by **Nikhil Ambish Mehta (Registration No. 41700289)** to the Lovely Professional University, Phagwara in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **Horticulture (Vegetable Science)** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an external examiner.

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ACKNOWLEDGEMENT

All praises to almighty God, the cherisher and sustainer of the world, master of the day of judgement, who bestowed me the health and courage to undertake these studies

I gratefully acknowledge the enthusiastic cooperation, venerable gratitude extended by my esteemed chairman of my advisory committee Dr. Ramesh Kumar Sadawarti, Dean, School of Agriculture, LPU, Phagwara Punjab for his highly imaginative and unending inspiration, valuable guidance, sound counseling, meticulous suggestion sustained interest and above all his positive attitude towards my abilities which made the achievements of this goal a challenging, rewarding and stimulating experience.

My heartfelt gratitude is due to Dr. Savita and Dr. Monisha Rawat from LPU Phagwara for valuable guidance,boosting my morale and inspiring me always and scholarly suggestions, constructive criticism and affection throughout my course work and research programme.

I am highly grateful to all the Faculty and staff members of School of Agriculture, Faculty of Technology and Science, LPU Phagwara, for their constant encouragement, support and guidance during the study programme. I shall be failing in my duties if I do not acknowledge the assistance and cooperation provided to me during the study and research work by the staff of Central library, Lovely Professional University.

With profound sense of gratitude, I found myself lucky enough to reciprocate the help and sincere cooperation offered by my colleagues S. Gurpreet Singh and S. Jasbir Singh Brar at Hi-Tech Vegetable Centre Moga and special thanks to Dr. Damandeep Singh, Project officer at Centre of Excellence for Potato at Dhogri Jalandhar.

I am overwhelmed with rejoice to avail this opportunity to evince my profound sense of gratitude to my parents, my elder sister, my wife and my daughter and all my well-wishers for their measureless prayers, everlasting love and constant encouragement throughout the period of my study.

All those who care for me may not have got a mention, but none shall ever be forgotten.

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LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA, PUNJAB

Title	**:**	**PERFORMANCE OF TOMATO CULTIVARS (*Solanum lycopersicum* L.) IN DIFFERENT SOILLESS CULTURE SUBSTRATE UNDER PROTECTED CONDITIONS**
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ABSTRACT

Protected cultivation has great potential in northern India, where the extreme temperature, unpredictable heavy rainfall and problematic soil conditions have affected the year around availability of tomato crop in the different agro climatic zones of the region. The soil is the most economical growing media for growing all the tomato cultivars, but in the case of problematic soils (saline soils/soil borne insect-pest problems), the soilless substrate can be a better option for commercial cultivation of tomato. Therefore, this study was conducted under protected structure at Hi-Tech Vegetable Centre, Bir Charik, Moga, Punjab during two seasons in 2018-19 and 2019-20 with an objective to standardize the best economical growing media and to evaluate best tomato cultivars under protected conditions. The experiment was conducted with 6 promising tomato cultivars (*viz*., P1-Heemshikhar, P2- US-2853, P3- NS-4266, P4-Punjab Gaurav, P5-Punjab Sartaj, P6-Punjab Swarna) under poly-house structure with Six different media substrate treatments [M1-Soil as control, M2- Cocopeat only, Cocopeat+ Vermicompost in ratio {(M3- 2:1, v/v) & (M4-3:1, v/v)}, Cocopeat + Vermiculite + Perlite in ratio (M5- 3:1:1, v/v) and (M6- 6:1:1, v/v)] were used. The maximum 2.05 B:C ratio has been recorded in NS- 4266 cultivar (P3) which was statistically significant than check cultivar (P1). The economic yield of NS-4266 was (6.08 Kg/plant) higher in the soilless growing media (M3) with the combination of Cocopeat + Vermicompost (2:1, v/v) has the best growth and yield contributing attributes for tomato cultivation. The maximum 2.01 B:C ratio was recorded under control media (M1), So the soil is the best and most cost-effective growing media for tomato cultivation whereas media combination (M3) cocopeat + vermicompost (2:1, v/v) recorded with 1.97 B:C ratio had given the most economical yield among all the soilless growing media. Whereas (M-6) Cocopeat + Vermiculite + Perlite (6:1:1, v/v) is the second best growing media combination, which can also be employed as a cost-effective soilless growing medium when compared to other commercial growing media can be exploited for further research experiments.

***Keywords*:** Cultivar, growing media, protected cultivation, soilless, substrate, and tomato.

LIST OFABBREVIATIONS

Abbreviation		Meaning
%	:	Per cent
@	:	at the rate
B:C	:	Benefit Cost ratio
°C	:	Degree celcius
C.D.	:	Critical difference
cm	:	Centimeter
cm^2	:	Square centimeter
CRD	:	Complete Randomized Design
CEC	:	Cation Exchange Capcacity
DAT	:	Days after transplanting
dS/m	:	deciSiemens per meter
et al.	:	*Et allii* (Co-workers)
EC	:	Electrical conductivity
ETc	:	Evapotranspiration of crop
Fig.	:	Figure
g	:	Gram
Ha	:	Hectare
Ha^{-1}	:	Per hectare
i.e.	:	That is
kg	:	Kilogram
K	:	Potassium
Km	:	Kilometer
L.	:	Linneous
m	:	Meter
mg	:	Milligram
ml	:	Milliliter
N	:	Nitrogen
No.	:	Number
NS	:	Non-significant
P	:	Phosphorus
ppm	:	Parts per million
TSS	:	Total Soluble Solids
T	:	Ton
t/ha	:	tons per hectare

Graphical Abstract

Title of the thesis: Performance of tomato cultivars (*Solanum lycopersicum* L.) in different soilless culture substrate under protected conditions.

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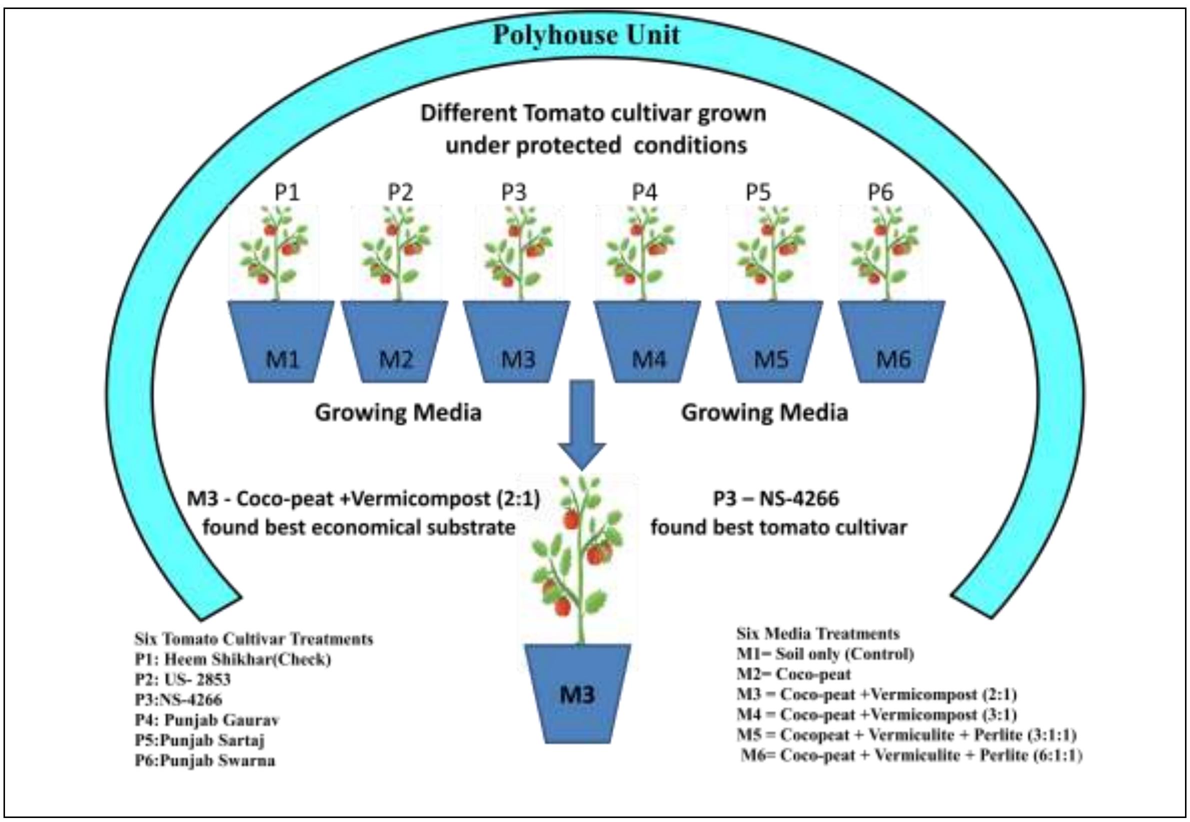
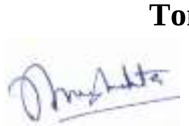
Summary of graphical abstract:

Tomato cultivar NS-4266 is the best high yielding cultivar grown under protected conditions and combination of cocopeat and vermicompost (2:1, v/v) used as growing media produces the most economical media among all the media treatments.

Graphical abstract:



Tomato cultivars in soilless culture substrate under Polyhouse.



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CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is the second important crop in the family-Solanaceous after the potato crop, with over 300 species grown in tropical and subtropical regions around the world. It is a warm-season crop that originated in Peru. Tomatoes are a common fruit vegetable whose fruits are consumed in a variety of ways, including raw as salad in breakfast meals or cooked as a vegetable. Tomato fruits particularly rich in esential minerals like potassium and calcium. Tomato fruits constitute of ash 8.75%, water 94.17 (g/100g), moisture 91.18 (g/100g), total protein 17.17 (g/100g), lipid 4.96 (g/100g) and carbohydrate 5.96 (g/100g). It is important as protective food, rich in minerals due to the supply of vitamin A and C, secondary metabolites and antioxidant pigments like lycopene (the red pigment in tomato fruit) which is a strong anti-carcinogen, (Ali *et al.*, 2021, Fentik 2017, Knapp and Peralta 2016)

The tomato production is approx. 186.80 million MT in the world with an area of 5.05 million hectares having a productivity of 37.50 t/ha. The China ranks first with 34.67 % of world production with 64.77 million MT with the area of 1.11 million hectares with the productivity of 58.5 t/ha, while India ranks second position with 11.08 % of the world production, with producing 20.71 million MT tomato under the area of 0.81 million hectare with the productivity of 25.58 t/ha, whereas Turkey ranked third with 13.20 million MT production grown in the area of 0.18 million hectares and with yield of 72.6 t/ha. The USA ranked fourth with the production of 12.23 million MT in the area of 0.11 million hectares having productivity of 110.7 t/ha. (Anonymus, 2022). In India area under tomato crop is higher in Odisha and Madhya Pradesh (MP) and followed by Karnataka, Andhrapradesh, Gujrat and Punjab. The highest productivity of tomato crop is in Andhra Pradesh (44.50 t/ha.) followed by Himachal Pradesh (42.88 t/ha.) (Anonymus 2018). Punjab has 10168 hectares areas with a productivity of 24.9 t/ha. under tomato cultivation grown in open field conditions in the district of Amritsar, Patiala, Kapurthala and Tarn-tarn. Presently, the area under protected cultivation is 150 hectares in Punjab, of which 125 hectares area is under vegetable cultivation (Anonymus, 2021).

The cultivation of indeterminate tomato is the most intensive form of crop production which is profitable only when grown under protected cultivation with proper crop management practices. Under the protected cultivation in Canada, the production of tomato per unit cultivated area is higher i.e., 50 kg/m^2 per annum, which is 8 to 10 times higher than that of open field crops. Tomato has a large number of varieties for open as well as greenhouse conditions (Mitchell *et al*., 2019). Soilless culture allows for more accurate control on the irrigation water with high water use efficiency and other growth-production parameters, which is essential for plants, such as EC, pH, of growing media and temperature of root zone, as well as greater productivity and a superior benefit-cost ratio (Putranta *et al*., 2019).

Soilless cultivation is the advanced modern cultivation technique used to get higher productivity with better quality production from high value crops, in which either we use inert organic substrates like coco-peat, peat moss, a bark mixture with wood chips and vermicompost etc. or inorganic substrate like vermiculite, perlite, rock wool etc. (Natarajan *et al.,* 2018). Different types of container-based system like Dutch pot system or grow bags or trough system growing media used in the different composition or mixture form along with feeding nutrient solution to crop plants for its nourishment to maximize quality production studied by (Gruda *et al*., 2006 and Gruda, 2009).

To get maximum quality yield with having high nutrient use efficiency and utilizing other input resources efficiently, the soilless farming is used for intensive commercial cultivation. A mixture of coco-peat, vermiculite and perlite is getting more success worldwide than rock wool, because coco-peat is light-weight medium, easily available, cheaper than rock wool, has biodegradable property and is environment friendly also (Dannehl *et al*., 2015 and Jankauskiene *et al.* 2015). The yield of tomato is higher in soilless substrate than soils due to high CEC and nutrient holding capacity of growing media. The soil is being replaced by soilless media substrate for commercial tomato cultivation under protected conditions in many parts of world, because the soilless media is insect-pest free, having high nutrient & water holding capacity and also reusable with minimum addition of media annually (Gullino & Garibaldi, 1994), (Subramani *et al.*, 2020). These soilless substrate cultures, when used in precision farming under protective cultivation with fertigation technique have high fertilizer use efficiency, water use efficiency and no pesticide residues. The nutritional composition of peat and coir differed significantly (Suvo *et al*., 2016 and Dyamurshayeva *et al*., 2017).

Tomato fruits grown in organic growing media exhibited higher dry matter, vitamin C, and quality than those grown in rockwool substrate as comparison to rape straw, peat, and pine bark substrates. The organic growing media produced higher quality and quantity tomato fruit as comparison to inorganic growth media. The total yield and number of fruits per plant of tomato higher when the plants grown in combination of peat moss + rice husk ash(RHA), while the highest TSS of fruits harvested recorded under the coconut fiber(CF) substrate. Fruit properties such as fruit weight, fruit hardness, TSS, titratable acidity, ascorbic acid, and lycopene were affected by the soilless growing media, but not dry matter content of tomato fruits. (Truong *et. al*., 2015, 2017, 2018).

Under the background with such available literature, it deserves a further need to generate data on growing media evaluation which is more economical concerning high yielding tomato cultivars under protected cultivation. So need to evaluate the promising tomato cultivars available with better quality of fruits grown with best growing media, which may help in the cultivating tomato under problematic soils or in the area where soil is the limiting factor (Kumar *et al*., 2019). The standardization of preferred media may benefit in the dissemination of this research to the farmers, improving the economic feasibility of producing tomato crops under protected conditions in this region.

The present research work entitled "Performance of tomato cultivars (*Solanum lycopersicum* L.) in different soilless culture substrate under protected conditions" has been designed in view of the challenges faced by tomato growers. Therefor this study was carried out to find out best growing media which can replace soil without affecting growth and yield. Further, evaluation of promising cultivars of tomato for better quality yield can provide better net economic returns to farmers. So, the present study was planned keeping in view the following objectives of the research were as follows:

1. To find out the best tomato cultivars for protected cultivation by evaluating the growth, yield and quality parameters.
2. To find out the best growing media for the growth and development of tomato cultivars for getting higher yield.
3. To find out the best economical growing media suitable for tomato cultivation under protected conditions.

CHAPTER II

REVIEW OF LITERATURE

The present investigation entitled "Performance of tomato cultivars (*Solanum lycopersicum* L.) in different soilless culture substrate under protected conditions" was carried out in polyhouse unit at Hi-Tech Vegetable Centre, village - Bir Charik, district – Moga, Punjab during the years 2018-19 and 2019-20. Reviewing the present field problem for tomato cultivation under protected condition in the region, the study was proposed to find out the best tomato cultivars suitable for the region, which can be grown in best economical soilless growing media standardized under protected conditions. The pertinent literature has been reviewed as per the objectives of the research under heading and sub-heading as follows:

2.1 Effect of media on the growth, production & quality parameters

2.1.1 Effect of growing media on growth parameters

2.1.2 Effect of growing media on the production parameters

2.1.3 Effect of growing media on the fruit quality parameters

2.2 Effect of growing media on economical analysis of tomato cultivars under protected conditions

2.3 Effect of growing media on different parameters of substrate.

2.4 Effect of growing media on leaf elemental content including macro-nutrients and micro-nutrients in tomato leaf

2.1 Effect of growing media on growth- production & quality parameters

The physical qualities of organic and inorganic substrates utilised in a soilless growing media varied dramatically. The air content and retained volume of accessible water in the substrate are affected by these physical qualities. When producing greenhouse crops with different consumption for water and oxygen in the root zone, these variances and parameters must be taken into account.

Luoto (1984) used sensory evaluation and chemical analysis to identify the texture and colour of tomato fruits grown on peat as a growing medium. He observed that the growing medium had a considerable impact on tomato quality, dry matter content, pH, and acidity. He also observed superior quality tomato fruits with the best taste under peat at the start of the harvesting season.

Juan and Daniel (2001) evaluated the performance of greenhouse tomato cultivars grown in soilless culture media in North Central, Florida. In his study they had compared yield and fruit quality of Israeli and Dutch tomato cultivars grown in the greenhouse under various climatic conditions. Tomato plants were transplanted into white polypropylene bags filled with coarse perlite during the experiment. This experiment compared cluster and beefsteak varieties. Other cluster cultivars have lower commercial yields and fruit per plant than 'Champion', 'Taverna'' and 'FA-593'. The cultivar Catherine' and 'FA-574' 'had greater marketable yields than others among the beefsteak cultivars. The greatest yielding cultivars had excellent fruit quality and disease resistance. Growers who want to compete with the product imported from Canada and Europe, can consider the cluster varieties 'Champion' and 'Taverna,' as well as the beefsteak variety 'Catherine.' Tomato cultivars such as Campion, Taverna, and Beefstreak produce higher yields when grown in a soilless growing medium.

Moreno *et al.*, (2014) evaluated the different combination of the vermicompost(VC) and sand (S) (volume by volume ratio) mixture combination for meeting the nutritional requirements of capsicum annum (Hungaro), chile pepper growing under protected conditions. The mixture evaluated comprised of four VC: S ratios of 1: 1, 2: 1, 3: 1, and 4: 1, as well as a 0: 1 control (sand with nutrient solution). The most appropriate mixture for the development of Chile pepper type Hungaro in protected environments was 1: 1 by volume of VC: S.

Jindal *et al*., (2015) compared the performance of different tomato hybrids in a Naturally Ventilated Polyhouse at PAU Ludhiana and found that the hybrid HS-18 significantly better perform than other hybrids in terms of economic traits, suggesting that this hybrid could be commercially exploited for cultivation under protected conditions.

Suvo *et al*., (2016) analysed the effect of four different hydroponic media on plant growth, yield, and nutritional value. Tomato plants were cultivated in a protected soilless system using a variety of substrates such as jute fiber, cotton fiber, and coconut husk, as well as Hoagland solution as a nutritional solution in protected structures. Among these three types of media, the one with Hoagland solution and jute fiber had a better impact on growth and nutritional values than the others. The media combination of jute fiber and Hoagland solution was shown to have the maximum plant height, yield, vitamin C, fruit protein, fat, and fibre content of all.

Sedaghat *et al*., (2017) evaluated how to improve the vegetative growth, yield, and fruit quality of greenhouse tomatoes in a soilless culture substrate system. With the various combinations of cocopeat and perlite growing media utilised in the research experiment, the media containing Coco-peat and Perlite in a 1:1 ratio provided the best vegetative development, early flowering, quality fruits, and tomato yield. These two substrates alter nutrient holding capacity, better cation exchange capacity and optimum moisture and air distribution in the root zone, which affects root formation, nutrient absorption, and plant growth.

Jindal and Dhaliwal (2018) investigated tomato varieties for natural ventilated polyhouses in Punjab. Their research looked at four tomato cultivars. Punjab Sartaj produces a better higher yield in comparison to other tomato varieties like Punjab Gaurav and Punjab Swarna, G-600, and Heemshikhar. The tomato cultivar Punjab Swarna has a lower TSS content than other tomato types. Punjab Swarna also having an orange-colored fruit that rich in carotenoids but low in lycopene.

Bayomi Khaled *et al*., (2020) evaluated 12 tomato genotypes in two growing seasons under greenhouse conditions at the Desert Research Center in Egypt. Plant height, stem diameter, fruit set percentage, and yield per plant were recorded maximum in the genotype S924 under protected cultivation as comparison to different tomato genotypes.

Mamta *et al*., (2022) studied the significant variability in twelve genotypes for several parameters in tomato cultivation under protected cultivation. Under study based on mean performance, the results indicated that Heemsona and NS-4266 are cultivars having good performance for the yield- and growth-related parameters. Although EZ-9003 identified which took minimum days to 50% flowering, average fruit weight, shorter inter-nodal length, higher fruit yield per plant, and fruit yield kg per meter square. The cultivar Punjab Sartaj was superior for number of fruits per plant, and hybrid Yuvraj gives maximum plant height, respectively.

2.1.1 Effect of growing media on growth parameters of tomato cultivars

Uzun *et al*., (2000) evaluated the performance of certain vegetable crops grown under different growing media combination and discovered that using sand: FYM: rice husk combination as a growing medium substrate is best for the growth of vegetable crop in an unheated glasshouse during the late fall season.

Atiyeh *et al*., (2001) investigated the use of vermicompost made from pig manure and the growth medium Metro-Mix 360 as a tomato-growing medium. The vermicompost hampered plant growth due to insufficient aeration, porosity, and high soluble salt concentrations. Tomato seedlings grew faster when Metro-Mix 360 was replaced with 25% and 50% vermicompost and fertigation, respectively, than when the control was used (no fertiliser applied). The benefits of greater porosity, aeration, and water retention combined with high nitrate concentration resulted in increased plant growth in substrate combinations.

Apahidean *et al*., (2002) tested different substrate compositions in polythene bags for tomato growing in polyhouses. The Brown peat (80%), long-term fallow soil (20%), and well-decomposed manure (20%) were incorporated in the new mix, along with primary and secondary nutrients. When the innovative mixture was used alone or with 50 percent parlite and irrigation with 8 liters of water per plant, they noticed improved plant growth and fruit yield.

De Grazia *et al*., (2004) studied sweet pepper seedling growth and quality in two peat-based substrate mixed with different combinations, 60 percent peat + 40 percent perlite and 45 percent peat + 30 percent perlite + 25 percent compost, both mixed with different polymers and irrigated for 12, 24, and 48 hours. In soils lacking in compost, polymer addition increased seedling emergence, uniformity, and growth. Although seed quality improved with the addition of polymers, seedlings grown on this substrate had a lower shoot-to-root ratio.

Hashemimajd *et al*., (2004) studied the effect of different compositions (0, 15, 30, and 45 percent) of vermicompost prepared from raw dairy manure (RDM) used for making pot volume in compost produced from tobacco residue, yard leaf, sewage sludge, rice hull, sewage sludge, yard leaf, and RDM on tomato growth and discovered that all potting mixtures produce more clusters per plant and fruits than the control (soil + sand) treatment.

Nurzynski (2006) studied the greenhouse tomato yields grown in straw and rockwool substrates. The utalization of rye straw and wheat straw (cut into pieces) as substrates for greenhouse tomato has been demonstrated. There is no significant difference in yield parameters when compared to rockwool. whereas, the dry weight, vitamin C, and sugar content of fruit has significant differences. Approximately 70% of straw has been mineralized after a 34-week vegetative period (at the end of the trial). The content of mineral N, P, K, Ca, Mg, S-SO4 and the content of pH and EC on the substrates studied differed slightly during the vegetative season. Wheat straw and rye straw combination of growing media produce higher tomato yields than rockwool substrates in greenhouses.

Surrage *et al*., (2010) studied the different growing media like rockwool, coconut coir, vermicompost and aged pine bark for tomato cultivation. The tomato cultivars grown in coconut coir with combination of vermicompost generated better fruit production as compare to other growing media.

Nair *et al*., (2011) added alfalfa-based organic amendments to growth media (peat: vermiculite: compost (2:1:1) with treatments (0, 0.6, 1.2, 1.8, or 2.4 percent, w/w) and incubated it for 0 to 4 weeks. Study revealed that after at least one week of incubation period, the tomato plants grown in the modified medium showed better plant growth parameters than those grown in the control medium.

An experiment was conducted by Roy *et al*., (2011) in a polyhouse to investigate the effects of organic growing media and plant spacing on the growth and yield of the capsicum cultivar California Wonder in the mid hills of the northwestern

Himalayas. For practically all of the features studied, the Soil: Sand: FYM: Vermicompost (1: 1: 0.5: 0.5) media found to be statistically better medium to the other combinations. All the attributes were better or at par when the depth of the media was kept at lesser depth (15cm) and the plants at wider spacing (50x50cm). As a result, it can be concluded that adding vermicompost and FYM to the soil improved characteristics of the soil and nutrient availability to plants, while crop geometry created a favourable microenvironment for proper plant competition.

Gholamnejad *et al*., (2012) experimented with various cocopeat and vermicompost proportions to improve seed emergence and other qualitative and quantitative features of sweet pepper cultivars (cv. California wonder). The plant weight (fresh and dried), stem diameter, inter-node quantity, leaf area, and height of capsicum cultivars were measured maximum under the treatment of vermicompost + cocopeat in the ratio 3:1 during the experiment.

Kumar and Raheman (2012) evaluated the ratios of vermicompost in the soil mix as well as pot size for producing seedlings of various vegetables for mechanical transplantation. A potting mix of 25% vermicompost and 75% of soil and sand in equal amounts volume in cubical shaped paper pots of 50 cm^3 worked better for large-scale production of paper pot seedlings of tomato, eggplant, and peppers.

In a study on tomato seedling emergence using various proportions of cocopeat and vermicompost by Nasirabad *et al*., (2012) discovered that treatments including vermicompost: cocopeat in ratio of 1:3 significantly affected the fresh weight, seedling diameter; inter node quantity, and seedling length of the tomato.

Ramadani *et al*., (2012) evaluated the different growing media combinations made from commercially available peat, inorganic media, and on-farm organic media affected the growth and development of seedlings of a hybrid pepper. During seedling production experiment the different growing substrates: peat 100 percent + vermiculite 0 percent; peat 75 percent + vermiculite 25 percent; peat 50 percent + vermiculite 50 percent; peat 25 percent + vermiculite have an impact on seedling quality. This study studied the stalk height, root height, leaf number per plant, and leaf surface. The greatest effect on pepper seedling growth parameters was obtained from the organic that was easily available on the farm.

Aktas *et al*., (2013) investigated the effects of cocopeat, split mushroom compost, perlite, volcanic tuff, and sawdust on brinjal growth, yield, and quality. Cocopeat and leftover mushroom compost were used to obtain the highest plant height (82.2 cm) and number of leaves (51.1 and 51.4, respectively).The highest yield came from cocopeat medium, followed by split mushroom compost. Split mushroom compost growing media can be used as a substitute for commercial cocopeat and perlite in greenhouse eggplant development, according to the researchers, because it produces equivalent results.

Rahimi *et al*., (2013) investigated alternative growing medium for tomato transplant production in a greenhouse structure (peat moss, coco-peat, jahrom palm peat washed-sand, and soil), determining that peat moss growing media provided better seedling growth. When coco-peat and peat moss were used alone or in combination with sand, performed better than other growing media.

Abafita *et al*., (2014) looked examined different levels of vermicompost in potting mixtures and discovered that using 20 percent vermicompost had a substantial impact on tomato growth and yield, whereas using lower (10 percent) and higher (40 percent) vermicompost dosages resulted in lower tomato yields. Ahirwar and Hussain (2015) studied vegetable seedlings in vermicompost for improved quality and field performance. They further discovered that changing the growing medium's nutritional balance had a positive impact on growth of the plants.

Spehia *et al*., (2015) In the current study, the productivity of cash crops, particularly vegetables, employment generation, analysis of income and socioeconomic status of small and marginal farmers, as well as any input savings achieved through the use of precision farming techniques, were analysed. A considerable increase in output was seen, even though just 223.18 acres of land had been placed under protected agriculture. As a result, it increased the income for farmers and their families by 4.95 lakh man days (at the level of both farmers and service providers). Improved varieties, better management techniques, protected vegetable growing, and other factors have all contributed significantly to the increase in production of cash crops in Himachal Pradesh.

Mathowa *et al*., (2016) studied the effect of different growing media (germination mix, cocopeat, and hygromix) on the development of tomato seedlings under shaded conditions in a greenhouse setting and discovered that plant height was highest in hygromix but comparable to germination mix, and lowest in cocopeat media.

Rekani *et al*., (2016) evaluated plant germination and growth of sweet pepper in response to various potting solutions. In comparison to soil, seed germination was better in peatmoss and sheep dung. Peatmoss and sheep manure yielded significantly higher growth metrics than soil and Municipal Solid Waste compost when compared to alternative growing media.

Bijeta *et al*., (2018) conducted an experiment in the Himalayan mid hills to examine the effect of growing media and plant spacing on capsicum cv. Orobelle growth and yield. For practically all of the features studied, the media composed of Soil + Cocopeat + Vermicompost + FYM (2:1:0.5:0.5) outperformed the rest of the growing media statistically. All the parameters were better or at par when the plants were spaced at the wider plant spacing (45 x 60 cm). As a result, it can be concluded that incorporating Cocopeat, Vermicompost, and FYM to the soil improved characteristics of the soil and nutrient availability to plants, while crop spacing created a suitable microenvironment for proper plant competitiveness.

Radha *et al*., (2018) studied the viability of partially substituting sawdust and rice husk growing media for coir dust and cocopeat media as a nursery production media. Following the ICAR-IIHR methodology, compost was made by mixing varying ratios of raw coir dust, saw dust, and rice husk. The chemical analysis of compost samples revealed that among the different treatments, T5 (75 percent Raw coir dust + 25 percent Rice husk) had the lowest C/N ratio (37.13), phenols and tannins (155 mg/100gm), and C/N ratio (37.13) at 30 days of composting. The effect of various composts on the germination and survival rate of tomato, chilli, cabbage, cauliflower, and brinjal crops, as well as the use of 5% soil less mycorrhiza in pro trays, were also investigated. In all of the vegetables, T5 (75 percent Raw coir dust + 25 percent Rice husk) had the highest germination percentage and seedling survival. In comparison to other treatments, substitution with 25% rice husk provided the ideal compost for nursery media and produced intact plugs of seedlings of different vegetables.

2.1.2 Effect of growing media on the production parameters of tomato cultivars

Gul and Sevgican (1992) found that tomato cultivated in a glass house with various combinations of growing media like Sand, Perlite, Sawdust, Lava Rock, Wood Shavings, and Decomposed Pine Bark etc. produced earlier and higher yields of tomato. Growing media were found a significant effect especially in terms of early yield and total yield of tomato. Plants grown in various growing media produced higher early and total yields than those grown in soil. Early production and harvested fruit number increased by 97.7 to 244.5 percent and 76.2 to 197.1 percent, respectively, when cultivated in medium over soil. The increase in overall total yield and fruit number harvested ranged from 25.8 to 45.3 percent and 15.2 to 28.8 percent, respectively.

Martinez and Abad (1992) conducted a commercial-scale experiment in a polyethylene greenhouse, with Lorena F-1 tomato cultivar, using growing media with sand, perlite, rockwool slabs, and sepiolite alone or mixed with leonardite (3 percent by volume), and organic fertiliser with 60 percent content of humic substances (dry weight), The pH, EC, and drainage volume of growing media were maintained for all the treatments. Perlite, sepiolite 4/20-mesh Perlite and the other two substrates produced 11.0 and 10.2 kg/sq. m, demonstrating the potential of sepiolite as a new horticultural substrate. The change in physical and chemical properties of material have also been recorded at the end of the growing period; the air-filled porosity of perlite had decreased from 74.5 to 26.1 percent. The growing media perlite and sand were recorded with the lowest EC till the end of the trial.

Abak and Celikel (1994) examined organic and inorganic medium for greenhouse tomato growing. In comparison to rockwool and soil, wasted mushroom compost, volcanic tuff, and peat were employed as comparison media. Peat (25 kg/m^2) produced the most, followed by rockwool (23.3 kg/m2). The characteristics of the substrate and leaves showed that leftover mushroom compost and peat can be used to successfully grow greenhouse tomatoes.

Alan *et al*., (1994) looked at how different growth media and combinations affected tomato yield. They discovered that a mixture of pumice, perlite, and peat (80:10:10) generated 30% more yield than the soil. However, qualitative contents differed between treatments, with perlite containing the most ascorbic acid; peat containing the highest total soluble solids concentration; sand containing the highest acidity; and growing media containing 50 percent pumice + 50 percent sand containing the highest qualitative traits.

With the rapid expansion of hydroponics and substrate culture, Assche and Vangheel (1994) looked at how farming and horticulture techniques have changed through time in West Europe and found that deterioration in soil health due to monocultures is leading to new issues and challenges.

Gul and Sevgican (1994) studied several greenhouse tomato substrates. The substrates included perlite, sand, peat, lava rock (kula), sawdust, and degraded or pulverised Pinus brutia bark. Fruits mature faster in soilless media than they do in soil. TSS, acidity, and fruit size were all substantially higher in the growth media than in the soil medium. The highest yield was observed in the plants grown in peat-sand (1:1), lava rock, perlite, and perlite – sand, respectively. The first harvesting raised perlite-sand yield by 165.2 percent, whereas the second, third, and fourth harvestings enhanced peat-sand production by 76.5 percent, 25.4 percent, and 13.8 percent, respectively.

Atiyeh *et al*., (1999) compared 100% vermicompost to 100% commercial media as a growing medium and discovered that using 50% vermicompost instead of commercial medium resulted in significant improvements in plant height, root biomass, and shoot biomass. Furthermore, the addition of 20% vermicompost to cocopeat increased plant growth and yield per plant compared to the control medium. Atiyeh *et al*., (2000) recorded the impact of replacing commercial greenhouse medium (Metro-mix 360) with various levels (100 percent, 90 percent, 80 percent, 70 percent, 60 percent, 50 percent, 40 percent, 30 percent, 20 percent, and 10 percent, v/v) of earthworm-processed pig manure (vermicompost) on the germination and performance of tomato (Lycopersicon esculentum Mill.) under glasshouse structure.

Yau and Murphy (2000) found that using biodegraded cocopeat as a growth medium increased tomato plant height (2.90 m), number of fruits per plant (70.5), and fruit yield (2.95 kg/plant). Overall tomato yields were shown to be higher with perlite: peat and perlite than with volcanic ash, pumice, pumice: peat, and volcanic ash: peat (Tuzel *et al*., 2001). Tomato performance improved significantly when perlite mixtures were used in the substrate, however harvest was delayed when coco peat was used alone (Traka- Mavrona *et al*., 2001).

Inden and Torres (2004) assessed the performance of tomato plants planted in various media, including rockwool (R), perlites: carbonised rice husks (PCRH), Cyprus bark (CB), cocopeat dust (CD) and coconut coir (CC) under polyhouse conditions. The CD treatment produced the highest fruits per cluster and had the maximum productivity, followed by PCRH treatment.

Janet *et al*., (2004) found no change in tomato yield and fruit weight grown under organic growth media, namely OM1- having 63 percent coconut coir:15 percent vermicompost; OM5- having 85 percent special organic mix:15 percent vermicompost; OM6- having 100 percent special organic mix:natural moist soil.

Zhang and He (2005) studied the effects of ten different soilless culture treatment combinations on the successful production of the tomato cultivar Zhongza No.9. The Maize stalks used in combination with manure and Vermiculite (25 percent: 50 percent: 25 percent) produced the largest fruit (146g) with the least amount of blossom end rot (2.0 percent).

Haddad (2007) observed that tomato plants planted in sand grow higher and have more fresh weight than those grown on perlite or stone pumice, while Lee *et al*., (2007) discovered that red pepper plug seedlings develop better in peatmoss-based substrates. The proportion of vermicompost amendment to potting mixture should vary by variety, according to Roberts *et al*., (2007), because the type of crop or cultivar utilised reacts differently to the vermicompost percentage.

Zaller (2007a) studied the effect of different composition of vermicompost to peat potting substrate on the tomato seedling under controlled climatic conditions in polyhouse. In his study, he evaluated (0, 20, 40, 60, 80 and 100 % vermicompost ratio with peat substrate to know the effect on the fruit yield and quality of the fruits, when transplanted in the polyhouse field with same fertigation schedule. The root: shoot ratio was significantly altered by vermicompost inputs, but yield parameters were unaffected.

Zaller (2007b) discovered that vermicompost can replace peat in potting media as an environmentally friendly choice after examining its impact on tomato cultivar performance. The combinations of the vermicompost with peat growing media had a significant impact on emergence but had little impact on the yield of the tomato cultivars.

The Grunert *et al*., (2008) studied the impact of peat-based growth media as compared to mineral wool, both alone and with coco's derivatives on the root system and yield of tomato plants. In his study, they found that Tomato plants rooted more easily in pure cocopeat than in other media, whereas the growing media, on the other hand, had not much effect on the yield of the tomato plants.

In a greenhouse experiment, Llaven *et al*., (2008) evaluated the effects of earthworm-processed sheep manure (vermicompost) on the growth, production, and characteristics of bell pepper fruits. Six different combinations of vermicompost and soil were used: 0:1, 1:1, 1:2, 1:3, 1:4, and 1:5 (v/v). 21 and 90 days after transplantation, plant properties were measured. After 21 days, the addition of vermicompost improved plant size by 8 cm in the 1:3 vermicompost: soil treatment compared to the unamended soil, but there were no significant differences after 90 days. The 1:2 vermicompost: soil treatment had seven more flowers and the 1:3 vermicompost: soil treatment had four more flowers than the unamended soil after 90 days and the number of marketable fruits per plant in the 1:2 and 1:3 vermicompost: soil treatments were 1.5 and 1.9 times higher than plants grown in unamended soil after 90 days.

Gruda (2009) studied the effect of different growing substrate on the yield and quality fruiyt production of tomato cultivars and found that tomatoes grown in soilless substrates produced greater yields and quality in all growth scenarios, including those when crop production was not possible. According to Hanna (2009) studied the impact of different growing media on the yield of the tomato cultivars. In his study, he concluded that the tomato plants planted on perlite generated a higher total marketable yield than plants grown on pine bark or rockwool.

Sharma *et al*., (2009) standardized the different growing media for growing tomato cultivars under naturally ventilated polyhouse in Hamchal Pradesh. They discovered that the optimal growing media for improved yield (8.33 kg/plant) in naturally ventilated polyhouses was soil: vermicompost: sand (2:1:1) along with the fertigation at 300 kg NPK per hectare. For growing cucumber in naturally ventilated polyhouses in Himachal Pradesh during August-December and February-June, Sharma *et al*., (2009) observed that the highest yield of cucumber cultivar recorded with 8.33 kg/plant under the treatment of soil: vermicompost: sand in ration (2:1:1) paired with fertigation at 300 kg NPK/ha.

Yellavva and Patil (2009) used natural ventilated polyhouses (NVP), naturally ventilated shadow halls, shade houses with misting, and shade houses without misting to test capsicum hybrids Orobelle, Bomby, and Indra. In flowering (33.00 days) and harvesting (86.00 days), NVP showed more qualitative features and precocity than typically ventilated shadow hall.

Borji *et al*., (2010) evaluated four substrates for tomato cultivation under protected conditions: cocopeat, perlite, and two types of date-palm peat (with and without fermentation); perlite; cocopeat: date-palm peat 2 (50 percent v/v) ; cocopeat: date palm peat 1 (50 percent v/v) ; perlite: date-palm peat 2 (50 percent v/v) ; perlite: date-palm peat 1 (50 percent v/v) . Perlite medium produced the highest fruit yield (4.19 kg/plant), while Palmpeat+ perlite media produced the lowest (3.25 kg/plant).

Ghehsareh *et al*., (2011b) investigated the use of date-palm trash and perlite as tomato-growing media (incubated and non-incubated). TSS (6.37 ^{o}B), yield (4.17 kg/plant), and plant height (298.5 cm) were all highest with perlite as a growing medium, although stem diameter (18.45 mm) and biomass were highest with date palm (without incubation) (1.76 kg).

Luitel *et al*., (2012) evaluated different growing media (cocopeat, rockwool, and masato) and different bed sizes (20 cm, 40 cm, 60 cm, and 80 cm) affected tomato production and fruit quality. The number of fruits per plant was found in cocopeat (16), followed by rockwool (15.2). Fruit weight (54.7 g) and yield (571.5 g/plant) were highest on the cocopeat-based substrate, whereas fruit weight (50.4 g) and yield per plant were lowest on the masato substrate (540.7 g). Tomato varieties cultivated in cocopeat substrate yielded more fruit (5.2%) and overall yield (0.7%) than those grown in rockwool substrate. Within growth substrates, there were no significant changes in fruit size or quality. As a result, planting tomato cultivars in a single row at 60 cm bed width is a better way to maximum production and cocopeat growing media is indicated as a viable growing substrate for tomato cultivation to improve production and fruit quality characteristics.

Mazur *et al*., (2012) suggested coconut fibre as an environmentally friendly medium for growing cherry tomatoes because plants cultivated in this coconut fiber medium recorded higher yield than plants grown in mineral wool.

Marquez *et al*., (2013) used 5 combinations of sand, inorganic nutrient solution (control, F1), sand: VCT (F2), sand:C (1:1 ratio, v/v):VCT (F3), sand:VC (1:1 ratio, v/v): VCT (F4), and sand:C:VC (2:1:1 ratio, v/v): VCT (F5) for pepper

(F5). When utilised as a growth media, researchers found that sand: C (1:1 ratio, v/v):VCT (F3) performed best when compared to organic treatments. Plants grown under control (F1), on the other hand, had the highest yield, outperforming F2, F3, F4, and F5 treatments by 26.10, 9.00, 29.47, and 29.05 percent, respectively.

Albaho *et al*., (2014) used M1- peat moss: perlite: vermicompost (35:40:25 percent); M2- peat moss:perlite:vermicompost:coco peat (25:25:25:25 percent); M3- coco peat (100 percent); and M4-peat moss: perlite (50:50 percent) as a control for tomato production in growbags. They discovered that M1 and M2 were the best substrates, and that vermicompost and coco peat were better alternatives to peat moss.

Hussain *et al*., (2014) proposed soilless culture as a preferable option to soil-based agriculture for enhancing crop quality and productivity while also addressing issues such as diminishing per capita land availability.

Aslani *et al*., (2015) evaluated by comparing the effects of two planting substrates, cocopeat (80 percent) + perlite (20 percent) and moss peat (80 percent) + perlite (20 percent), on vegetative growth, flowering rate, fruit quality and yield of bell pepper cultivars and discovered that moss peat had better effects for all vegetative and reproductive factors than cocopeat.

Jankauskien *et al*., (2015) investigated the beneficial effects of several growing substrates on tomato physiological processes, productivity, and quality in soilless culture. When comparing different growing media, tomato cultivar yields are nearly same on cocopeat and rockwool substrates. In another study, tomatoes grown in zeolite with a perlite ratios of 1:1 produced higher yields than tomatoes grown in other growing media (cocpeat with perlite substrate).

Nagaraj *et al*., (2017) investigated the impact of various growing media combinations on capsicum quality, growth, and yield, including cocopeat, rice husk, sawdust: vermicompost (1:1), rice husk: vermicompost (1:1), sawdust: vermicompost (1:1), sawdust: vermicompost (1:1), sawdust: vermicompost (1:1), sawdust: vermicom (62.00 tha-1).

Sayed *et al*., (2015) studied the impact of different soilless culture technologies like hydroponics system having growing media perlite and rice straw on the qualitative and quantitative aspects of pepper plant. They observed that plants grown on straw medium are better than all other media in terms of vegetative growth characteristics, among plant grown under hydroponic with perlite and sandy soil growing media. In comparison to sandy soil, transplanting pepper plants in to the rice straw growing media resulted in considerably higher number of leaves per plant, number of branches per plant, and plant height. The weight of early, marketable, and total yield obtained from plants grown on rice straw was significantly higher than that obtained from plants grown on sand or any other used media, and straw culture was recommended for the high production of sweet pepper and having low water consumption under protected conditions.

According to Agboola *et al*., (2018), tomato is one of the most important vegetable crops farmed in Nigeria and other parts of Africa. Sawdust is used as a growing medium by the majority of African hydroponic tomato farmers due to its availability and affordability. This study found that sawdust can be utilised as an alternate growth medium in tomato planting, as all the growth parameters like plant height, number of leaves, leaf length and width, were affected when compared to plants planted in soil. The result reveled that saw dust can be used for commercial hydroponically grown tomatoes.

Lata *et al*., (2018) investigate the "Effect of growing media and fertigation schedules on growth and yield of cucumber under polyhouse condition." The growing media: garden soil 18 kg/bag + vermicompost 2 kg/bag + cocopeat 2 cm layer on top shows an increase in all growth characteristics (chlorophyll and days to first flower appearance), as well as yield attributes (number of fruits per vine, average fruit weight, and fruit yield per 1000 m2 (11.89 t)). Treatment fertigation at 2 day intervals yielded greater values for all growth characters, including fruit yield per 1000 m2 (9.75 t).

Dhaliwal and Jindal (2018) assessed three tomato types for total yield. In local research trials, Punjab Gaurav and Punjab Sartaj produced average fruit yields of 2244.71 q/ha and 2094.99 q/ha, respectively, which were 19.18 percent and 11.23 percent greater than the control hybrid G-600 (1883.47 q/ha). Fruit yields of Punjab Gaurav (2454.42 q/ha) and Punjab Sartaj (2395.54 q/ha) are greater in multi-location trials than check G-600 (2158.08 q/ha), but G-600 has a higher early yield than both of these types. Punjab Sartaj has higher TSS and Lycopene content than the other tomato types, but lower Vitamin-C and Acidity.

Singh and Singh (2021) studied the indeterminate tomato cultivars treatments included Punjab Sartaj (PAU), NS 4266 and Heemshikahar, coupled with three levels of Recommneded Drip Fertigation (RDF): F1 = 70% of RDF, F2 = 85% of RDF, and F3 = 100% of RDF. The results revealed that applying 100% RDF during the respective years give result to the largest fruit yield (6.10 and 6.68 kg per plant), which was statistically comparable to applying 85% RDF (5.70 and 6.20 kg per plant), but significantly greater than applying 70% RDF (4.94 and 5.62 kg per plant). When compared to different cultivars with 100% RDF, the cultivar NS 4266 had a highest yield per plant (6.68 kg per plant) that was 22.8 % and 29.7 % higher than Heemshikahar and Punjab Sartaj respectively.

2.1.3 Effect of growing media on the fruit quality parameters of tomato cultivars

Soilless culture is a modern plant cultivation technology that uses nutrient solution nutrition and uses either inert organic or inorganic substrate/growing media. Perhaps the most intensive crop cultivation system and economical agriculture bussiness model, which ustalised all input resources efficiently to get maximum crop yields for commercial greenhouse vegetable production.

Gul and Sevgican (1992) found that tomato cultivated under glass house with various combinations of growing media (Sand, Perlite, Sawdust, Lava Rock, Wood Shavings, and Decomposed Pine Bark) produced earlier and greater yields, when compared to production under soil,. Growing media had no effect on the quality of the fruit.

Lee *et al*., (1999) evaluated different growing media rice hull, perlite (fine and coarse granules), carbonised rice hull, and peat moss for improving tomato TSS. The sugar content of the fruits under rice hull increased by 6.0° Brix among different treatments also studied.

Ymeri *et al*., (1999) studied tomato growth and quality parameters using a substrate (Perlite:zeolite (2:1) and slow release fertilisers (SRF) @ 30, 60, and 90 g/plant, and discovered that plants grown on 30 or 60 g SRF had the highest yield but the lowest TSS and titratable acidity, while plants grown on 90 g SRF had the least.

The dry matter content of tomato fruits was higher in cocopeat than in rockwool, but the TSS concentrations & Vitamin C content in tomato fruits grown in cocopeat, which had fewer nutrients, so the quality of fruits were unaffected by the different growing medium effect (Kobryn., 2002).

Arancon *et al*., (2003) utilized vermicompost to treat inorganically fertilised experimental plots to evaluate production and quality of strawberries, tomatoes, and peppers. They discovered that all vermicompost-treated plots had more marketable tomato fruits than solely inorganic plots. Pepper and strawberry plants produced increased shoot weight, leaf area, and total fruit output in the same treatment. They discovered that employing vermicompost increased soil microbial biomass, which could be the likely cause since it resulted in the synthesis of chemicals in the vermicompost that acted as growth promoters independent of nutrient availability.

Zhang and He (2005) conducted an experiment with 10 different soilless culture treatment combinations to see how they affected the successful development of the tomato cultivar Zhongza No.9. Sawdust as a manure-containing substrate (25 percent :75 percent) Maximum ascorbic acid (16.9 mg/100 g), decreasing sugar (4.55%), soluble solids (6.4%), and highest number of fruits/plant (26.3), yield/plant (3.81 kg) while using maize stalks as manure (25 percent :50 percent :25 percent) The highest fruit weight (146g) and lowest blossom end rot incidence (2.0%) were found in vermiculite, while the highest lycopene concentration (48.5 mg/100 g) was found in manure: mushroom residue: maize stalk (25 percent :50 percent ;25 percent).

Toor *et al*., (2006) studied the antioxidant content of tomatoes can vary greatly depending on the environmental conditions inside the greenhouse. The amount of antioxidants present in tomatoes grown in greenhouses can also be increased over the course of the growing season by altering the environmental conditions inside the greenhouses. Throughout the study period, the three cultivars' total phenolic content and antioxidant activity ranged from 169 to 579 mg gallic acid equivalents/100 g dry matter (DM) and 1684 to 3340 μM TEAC/100 g DM, respectively. The three cultivars' mean total phenolic content and antioxidant activity were 62% and 39% higher in the summer (December to February) than in the spring, respectively (September–November). During the course of the trial, the three cultivars' ascorbic acid and lycopene contents varied from 19 to 73 mg/100 g DM and 165 to 252 mg/100 g DM, respectively. In comparison to other research periods, the mean lycopene concentration of the three cultivars was 31% lower in the summer.

Llaven *et al*., (2008) evaluated the effects of earthworm-processed sheep manure (vermicompost) on the growth, production, and quality parameters of bell pepper fruits (Capsicum annum) (cv 'Ancho supremo') in a greenhouse experiment. Six different combinations of vermicompost and soil were used: 0:1, 1:1, 1:2, 1:3, 1:4, and 1:5 (v/v). Fruits from plants grown in 1:3 and 1:4 vermicompost: soil treatments had greater titratable acidity values than fruits from other treatments. In comparison to fruits from plants grown in unamended soil, vermicompost increased soluble solids in pepper fruits > 2 Brix, while their pH was much lower.

Flores *et al*., (2009) studied the nutritional quality and antioxidant activity of pepper grown under different organic soilless growing media with low inputs. They observed that pepper grown under the soilless culture had the higher phenolic and sugar levels than the control treatment.

Ghehsareh *et al*., (2011a) studied the effects of several substrates on tomato growth indices and nutrient uptake in controlled settings, and discovered that TSS was highest in media containing cocopeat and perlite, while other metrics such as nutrient uptake and yield were unaffected.

Kowalczyl *et al*., (2011) evaluated different cultivars of cherry tomato (Dasher F1 and Organza F1), intermediate fruit size tomato (Admiro F1 and DRW 7594 F1), and large fruit size tomato (DRW 7594 F1) were cultivated in three different growing media in a greenhouse with a controlled climate and drip fertilising system. Organic media - coconut fiber and wood fiber were compared to rockwool, commonly used as a standard horticultural medium. Rockwool, a typical horticultural medium, was compared to organic media such as coconut fiber and wood fiber. The cultivar, harvest period, and to a lesser extent, medium quality, were the characteristics of tomato fruits that most distinguished them from one another. Fruits grown on coconut fiber had the highest ratio of sugars to acids. Additionally, these fruits scored higher on specific sensory analysis factors, particularly tomato flavour. The fruits of the Dasher F1 and Admiro F1 cultivars had the highest quality in terms of the content of the studied chemical components and sensory evaluation. It was shown that there was a substantial relationship between the tomato fruit quality parameters and fruit firmness, TSS and sweet taste. Organic acids and soluble solids concentrations were substantially linked with firmness and sweet flavour.

Luitel *et al*., (2012) investigated the effects of various soilless substrate cocopeat, rockwool, and masato) and varied bed sizes (20 cm, 40 cm, 60 cm, and 80 cm width) on tomato output and fruit quality. Cocopeat had the maximum number of fruits per plant (16), followed by rockwool (15.2). The total soluble solids ranged from 5.3 to 5.6 ^{o} Brix (rockwool substrate) (masato).

Helyes *et al*., (2012) studied the irrigation affects the primary antioxidants (lycopene, phenolic compounds, and ascorbic acid) and yield factors of processing tomato. Some plants had regular watering, while others had their irrigation turned off 30 days before to harvest. A rainfed control group was contrasted with both groups. To get an optimal water supply, the daily average temperature was used to compute the daily irrigation volume. Fruits were picked when they were fully ripe and crimson. Ones that were irrigated produced a yield that was much higher than plants that were rainfed. The average fruit weight was more impacted by irrigation than fruit quantity A significant seasonal influence also existed, though it was not as potent as irrigation. A lower Brix number than the rainfed control was the result of better water availability. With the exception of ascorbic acid content, tomato fruit antioxidant concentrations decreased with irrigation.

Abduli *et al*., (2013) investigated the effect of vermicompost on tomato production and found that after 90 days of testing, plant parameters and yield of tomato plants were obtained in growing media having a 1:1 ratio of soil to vermicompost. In addition, vermicompost enhanced the amount of vitamin C and total sugar in tomatoes.

While investigating the effect of growing media on vegetable productivity, Olle *et al*., (2012) found that soilless culture produced higher fruit chemical contents and acidity in tomatoes than soil culture. They also noticed that different vegetables crops recorded higher yield when grown under substrates as compare to crop grown in the soil.

Ahmed *et al*., (2014) The goal of the current study was to use CaCl2 treatments to extend the storage life of tomato fruit after harvest. To assess the effectiveness of post-harvest treatments to extend shelf life, different concentrations of calcium chloride, such as 1% (T1), 2% (T2), and 3% (T3), were created and the fruit were dipped for 1 to 2 minutes. Fruit was stored at room temperature for a total of 30 days after being wrapped in polyethylene (0.6 mm) packaging. Fruit was examined physiologically and chemically over a ten-day period. According to statistical study, storage intervals and treatments have a significant (P0.05) impact on the quality characteristics of tomato fruits while they are in storage. It has been shown that packing 2% calcium chloride in a vented 0.6 mm polyethylene cover is an extremely effective way to reduce storage losses and preserve the quality of food. The discovery has made a substantial contribution to lowering perishable fruit economic losses and providing researchers with data.

Lari *et al*., (2014) investigated the nutrient content of three capsicum varieties (vars. Alonso, Roxy, and Baiela) grown on various substrates, including vermicompost: perlite (1:1), cocopeat: vermicompost (1:1), cocopeat: perlite: vermicompost (2:1:1), Cocopeat: perlite: vermicompost (1:2:1), cocopeat: perlite: ver (1:1). The result showed that capsicum cultivars grown in growing media combination of vermicompost: cocopeat (1:1) had the highest total soluble solids (TSS) and phosphorous, whereas cocopeat: perlite: vermicompost had the highest average potassium and iron (1:2:1).

In a controlled environment, Gungor and Yildirim (2013) investigated the effects of peat, perlite, and sand growing media (1:1:1, v:v:v) on fruit attributes, fruit number, yield, ascorbic acid content, and TSS on particular pepper cultivars. In polythene bags, peat, perlite, and sand (1:1:1) produced the greatest results for pepper cultivars.

Bayomi Khaled *et al*., (2020) in Egypt's Desert Research Center evaluated different tomato genotypes in two growing seasons under greenhouse conditions. TSS percentage was higher in the genotypes S-700, S-710, S-720, and S-740 as compare to other genotypes.

2.2 Effect of growing media on economical analysis of tomato cultivars under protected conditions

Dunage *et al*., (2009) evaluated that trickling irrigation at 60% evapotranspiration provided the most benefit, with a cost ratio of 4.54 and a WUE of 11.90 t ha cm-1, compared to a benefit cost ratio of 4.44 and a WUE of 7.45 t ha cm-1 in tomato under net conditions. Jadhav with his team (1990) found a bigger advantage for the tomato variety Pussa Rubi, with yields of 48t/ha and 32t/ha under trickling irrigation and furrow irrigation, respectively.

Bhat *et al*., (2013) studied the effects of different ready-to-use organic substrates like vermicompost, cocopeat, sphagnum peatmoss, perlite, farmyard manure, and avicumus on tomato, cucumber, and capsicum in a greenhouse structure. A growing media mix of vermicompost: cocopeat: perlite: sphagnum peat moss (2:1:1:1 or 1:1:1:1 v/v) out performed commercial mixes and soil cultivation in terms of economic parameters in tomato, cucumber, and capsicum, while provisionally prepared substrates outperformed commercial mixes and soil cultivation in some parameters.

Biwalkar and Jain (2014) evaluated sweet pepper output in a naturally ventilated greenhouse using three levels of irrigation and fertigation. Green, yellow and red sweet pepper net returns from greenhouse cultivation were calculated as Rs. 83,677.85, 1,20,577.85, and 53,797.85, respectively, with a 50 percent subsidy of Rs. 1,28,794.72, 1,65,694.72, and 98.914.72. Green, yellow, and red sweet peppers had a cost-benefit ratio (B: C ratio) of 1.71, 2.02, and 1.45, respectively, without a subsidy, but 2.76, 3.26, and 2.35, respectively, with a 50% subsidy. The highest economics with B: C ratio (3.53) was found in yellow sweet pepper.

Saurabh *et al*., (2019) found that growing vegetables in soilless media is a viable strategy for lowering the cost of growing vegetable crops under protected settings without sacrificing yield or fruit quality. Soilless cultivation is now commonly used technique for researching plant nutrition in research facilities. Tomato, capsicum, cucumber, peas, and cauliflower are among the crops produced in soil. Substrates used in soilless cultivation must be low-cost, disease-free, and readily available, as well as able to deliver appropriate nutrients to agricultural plants.

Spehia *et al*., (2020) observed that growth media cocopeat + Vermicompost (70:30) produces higher tomato yields when compared to other media combinations, and that it is the most cost-effective. The media combination of cocopeat + vermicompost (70:30 w/w), which was judged the most profitable and cost effective, had the highest benefit cost ratio (2.76), while the media combination of vermiculite + vermicompost (70:30 w/w) had the lowest benefit cost ratio (0.93).

Subramani *et al*., (2020) investigated the impact of soilless growth media on tomato (*Solanum Lycopersicum* L.) yield and quality on tropical island conditions. From the results of the two-year study, cocopeat + saw dust (1:1 v/v) and cocopeat + vermiculite + saw dust (1:1:2) are the best mediums in terms of yield. cocopeat + saw dust (1:1 v/v) was, nevertheless, less expensive than cocopeat + vermiculite + saw dust (1:1:2). Furthermore, cocopeat and saw dust are both economically and environmentally sustainable media for soilless tomato cultivation because they are renewable, readily available, and easy to dispose of. The cocopeat with saw dust in a 1:1 ratio gave higher yield of tomato and most economical growing media as compare to alternative growing media.

Mehta *et al.*, (2022) had studied economical analysis of six different tomato cultivars grown on the six different growing media under protected conditions. The maximum 2.05 B:C ratio has been recorded in NS- 4266 cultivar (P3) which was statistically significant than check cultivar (P1). The economic yield of NS-4266 was (6.08 Kg/plant) higher in the soilless growing media (M3) with the combination of Cocopeat + Vermicompost (2:1, v/v) has the best growth and yield contributing attributes for tomato cultivation. The maximum 2.01 B:C ratio was recorded under control media (M1), So the soil is the best and most cost-effective growing media for tomato cultivation whereas media combination (M3) cocopeat + vermicompost (2:1, v/v) recorded with 1.97 B:C ratio had given the most economical yield among all the soilless growing media.

2.3 Effect of growing media on different parameters of media.

The effects of pH on carnation (cultivars 'Red Debby' and 'Adelfie') cultivated on rockwool were investigated by Voogt, *et al*., (2011). Changing the NH4:NO3 ratio affected the pH. With decreasing pH, the yield of the two first flowering flushes increased. The higher uptake of micro elements at lower pH levels could generate the good yield effect (except for Mo). In comparison to normal plants, Phosphorus levels in selected plants increased dramatically as pH declined.

The sixteen different growing media combinations from peat, coir, vermiculite and perlite were prepared by Arenas *et al*., (2002) to standardize the growing media for tomato cultivations. They found that tomato plants planted in more than 50% coir combination grew slower than peat-grown transplants, which they attributed to more nitrogen fixation by microorganisms and a higher C: N ratio.

Al-Ajmi *et al*., (2009) discovered that zeolite had the best yield and fruit quality of all the inorganic substrates tested (sand (S); perlite (P); zeolite (Z); and mixtures (v/v) of P:S (2:1), Z:P (1:1), Z:S (1:1), and Z:P:S (1:1:1)), possibly due to its high water holding capacity and cation exchange capacity.

According to the study, Jing-xia *et al*., (2010) evaluated different proportions of the peat, sand, and perlite as the growth media to overcome soil salinization, continuous cropping problems, low yield, and relative poor-quality issues in pepper cultivation, and observed that soilless culture showed significantly greater growth & economic potential and early flowering, better yield, and greater fruit quality,'

Mokhtari *et al*., (2013), studied the impact of using empty fruit bunch (EFB) and vermicompost (VC) as organic medium (10% to 40%, v/v) on the quantitative and qualitative characteristics of tomatoes grown in coconut coir dust. They used nutritious solution (electrical conductivity =2.5 mScm-1) as a control in six treatments with 100 percent coconut coir dust (CD) media. They found that employing CD with 20% VC enhanced vegetative development and yield.

Nurzynski (2006) had studied the greenhouse tomato quality yields in straw and rockwool substrates. The utility of rye straw and wheat straw (cut into pieces) as greenhouse tomato substrates has been demonstrated. After a 34-week vegetative period (at the end of the experiment), around 70% of the straw had mineralized, and the pH and EC content of the substrates evaluated had only marginally differences.

Nurzynski (2013) had evaluated the effect of substrates on the nutritional content of greenhouse tomato roots and leaves. Except at the beginning of growing (March), where 95 (organic substrates) and 160 $mgdm^3$ (rockwool) were demonstrated, the level of N-NO3 in organic substrates during tomato vegetation ranged from 220 to 290 $mgdm^3$. Organic substrates had much higher levels of N-NH4, P, K, and Ca than rockwool. During the vegetative period of tomato, the EC values in organic substrates and rockwool were ideal according to the levels suggested for tomato. In comparison to rock wool substrate, organic substrates produced a higher yield of tomato.

Morales *et al*., 2014 employed three composts as plant growing media: green pruning wastes compost (GPC), vermicompost (V), and slumgum compost (SLC). To establish production essays for rosemary, Leyland cypress, lettuce, onion, petunia, and pansy, their key physico-chemical and biological features were researched, and nine growth substrates were prepared. GPC compost and vermicompost both had outstanding physico-chemical properties, making them suitable substrates.

Moya *et al*., (2017) had studied the effects of nutrient solutions with fairly high EC on fertigation parameters, nutrient emissions to the environment, overall crop yield, fruit size distribution, and nutritional and organoleptic characteristics. By modifying the final nutrient content and preserving nutritional balance, a tomato crop was grown in soilless culture with varying degrees of electrical conductivity (EC), 2.2, 3.5, and 4.5 dSm^1. Total and commercial yields were reduced by 5 percent to 19 percent and 3 percent to 22 percent, respectively, when nutrient solutions with a fairly high EC were used. A significant decline in extra-large and giant fruits was also noted, with an average fall of 69 percent to 42 percent. None the less, dietary-related metabolites such as lycopene (6.3%), ascorbic acid (8.8%), total phenolics content (8.3%), and total antioxidant activity (8.3%) were considerably elevated at the highest EC values (11.1 percent). Because of the use of poor-quality water and the accumulation of excess nutrients, EC values of 3.5 and 4.5 dSm1 are routinely measured in drainage solutions in open hydroponic systems and waste solutions in closed systems.

2.4 Effect of growing media on the leaf elemental content of Tomato

After 9 months of cultivation, Nurzynski *et al*., (2001) examine the impact of rockwool, brown peat, and sand growing media on tomato cultivar Cunero with the same amount of fertigation in each media and discovered lower fruit yield as well as lower nitrogen, potassium, calcium, and magnesium content in sand. Nurzynski (2006) studied at the yields of greenhouse tomatoes grown in straw and rockwool substrates. It has been proven that rye straw and wheat straw (cut into pieces) can be used as greenhouse tomato substrates. After a 34-week vegetative period (at the end of the experiment), almost 70% of the straw had mineralized (N, P, K, Ca, Mg, S-SO4).

Nurzynski *et al*., (2012) evaluated the production and quality parameters of tomato fruits when grown on straw or rockwool substrate greenhouse. The full potential of triticale straw as a tomato substrate in a glasshouse was demonstrated. Growing triticale straw + pine bark and triticale straw + peat yielded higher yields than growing in rockwool, but the differences were not statistically significant. Fruit grown on straw substrates had the high dry matter, while fruit grown on rockwool had the least. There were no significant variations in the contents of N, P, K, Ca, and Mg in fruit when compared to the substrates studied. In comparison to rock wool substrate, tomato yields were higher on straw substrates.

Sayel *et al*., (2015) studied the effects of soilless cultivation techniques (perlite, rice straw, and modified plant planted in hydroponic) on qualitative and quantitative parameters. The highest quantities of N and K in leaves were found in sandy soil, whereas the lowest were found in straw culture. However, the opposite was observed in the case of P and Ca. Straw had the largest impact on leaf chlorophyll content, phosphorus percent, and calcium percent in pepper leaves at 120 and 180 days after transplanting.

Truong *et al*., (2017) examined the effect of diverse growth media on tomato varietal performance in the greenhouse, including 1/3 Peat moss: T1: 1/3 rice husk ash: 1/3 coconut fiber; T2: 1/3 rice husk ash: 1/3 coconut fiber; T3: 1/3 cattle manure compost: 1/3 rice husk ash: 1/3 coconut fiber T3: 1/3 rice husk ash, 1/3 coconut fiber (T4) They discovered statistical significance in the media's physico-chemical properties, as well as substantial levels of total primary and secondary nutrients in the plants. In the seedling stage, the media composition had an impact on root and shoot weight.

Truong *et al*., (2018) studied the effect of Vermicompost (VC) and Coconut Fiber (CF) in media on Cherry Tomato (*Lycopersicon esculentun* Mill.) growth, yield, and fruit quality under Net House conditions. The VC with 50% RHS + 50% CF (T1-control) and 0% VC + 50% RHS + 50% CF (RHS) accordingly. VC+ 30% RHS+ 30% CF(T3), VC+ 40% RHS+ 30% CF(T2), VC+ 60% RHS+ 20% CF(T4), VC+ 80% RHS+ 10% CF(T5), and VC+ 100% RHS+ 10% CF(T6) (T6). The results revealed that addition of VC enhanced the pH, EC, N, P, K, Ca, and Mg availability in media and also enhanced the physico-chemical properties of the media. The raising the EC leading to a significantly affect the yield and quality of tomato fruits. The TSS rises as the EC of the growth medium is increased, without affecting yield reduction.

Xiong *et al*., (2017) evaluated different growing media like coconut coir, rockwool, peat and vermiculite growing medium affected the crop production parameters of tomato and physico-chemical parameters of the drainage solution of growing media. The uptake of phosphorus, Sulphur and potassium in tomato plant was better in Coconut coir as compare to rockwool, peat and vermiculite. The fruit yield, fruit weight and total yield was maximum in coconut coir as compare to rockwool, peat and vermiculite They hypothesized that coconut coir may be used to cultivate tomatoes as compare to other growing media

CHAPTER III

MATERIALS AND METHODS

The current study entitled "Performance of tomato cultivars (*Solanum lycopersicum* L.) in different soilless culture substrate under protected conditions" was conducted during 2018-19 and 2019-20. The information about experimental materials and methods has been described as following:

- **3.1** Location and climate
- **3.2** Planting materials
- **3.3** Experimental details
- **3.4** Methodology
- **3.5** Observations recorded
- **3.6** Description of recorded observation
- **3.7** Statistical methods

Fig.3.1: Geo-Location

3.1 Location and Climate

3.1.1 Experimental location

The experiment was carried out at the Polyhouse unit at the Hi-Tech Vegetable Centre, village - Bir Charik, in the vicinity of Moga district, Punjab State, which is located at 30º 43′39.5" N latitude and 75º 07′41.5 E longitude at 329 meter above the mean sea level. The geo location of the experiment has also been mentioned in Fig 3.1.

3.1.2 Climate

Moga district is located in Punjab's agro-climate zone 4, often known as the Western Plain Region. The district's climate can be categorised as tropical and humid. The yearly rainfall is approximately 498 mm, spread out across 24 wet days (Kingra *et al.*, 2017). During the spring season, the weather stays the most pleasant of the year (from mid-February to mid-April). Spring temperatures range from 9°C to 27°C. The temperature can reach 30°C in the autumn (from mid-September to mid-November). Autumn temperatures are normally between 16°C and 27°C. Around 11°C is the minimum temperature. The temperature in the summer (from mid-May to mid-June) can reach a maximum of 48°C (rarely). Temperatures are usually between 35° C to 45°C. Moga receives considerable rainfall throughout the monsoon season (mid-June to mid-September) and occasionally heavy to extremely heavy rainfall (generally during July to September). In the winter, showers from the Mediterranean Sea's Westerly Disturbances may fall on the district. Winters in Moga are mild (November to Mid-March), however it can get fairly cold at times. Winter temperatures range from 0 to 15 degrees Celsius. During the rainy season, the south-west monsoon, which arrives in the first week of July and lasts until the end of September, accounts for 78 percent of rainfall. Approximately 70% of the district's rainfall falls during this time, with the months of December to February accounting for about 18% of total rainfall. Except during the summer season, when it is less than 50%, the relative humidity is often high in the mornings, topping 70%. In the afternoon, the humidity level is lower. The driest time of year is during the summer, when relative humidity in the afternoons is at 25% or less as per the data presented in Annexure IX –XIV with Punjab Remote Sensing Department Ludhiana.

3.2 Planting Material

The research trials were conducted with six potential tomato cultivars: "Heem Shikhar," "US-2853," and "NS-4266" released by private multinational companies, where as "Punjab Gaurav", "Punjab Sartaj" and "Punjab Swarna." has been released by P.A.U Ludhiana (Anonymous, 2019). The seeds of these tomato cultivars were purchased for conducting trials from the private seed shop and seed shop of PAU Ludhiana.

3.2.1 Heem Shikhar

This is a promising cultivar of tomato released by Syngenta Seed India, company. It is an indeterminate type cultivar, having vigorous plant growth, having medium foliage cover with profuse branching and having high yield potential. An average yield of this cultivar is 20 MT per acre (depending on season and cultural practices). Fruits are medium size, oblate shape, with uniform size and excellent shelf life. Maturity of this cultivar is 75 to 80 days after planting and having average fruit weight 65 to 70gm.

3.2.2 US – 2853

This tomato cultivar was released by Nunhems Seed Company (Bayer). It is indeterminate type, fruits are red, round shaped, having excellent shelf life. This cultivar is having maturity 80 to 85 days with average fruit weight 70 to 75gm and having disease resistance to tomato leaf curl virus disease.

3.2.3 NS-4266

This cultivar of tomato was released by Namdhari Seed Company in 2015-16. It is indeterminate type, having vigorous plants, having medium foliage cover and having high yield potential. An average yield of this cultivar is 20-25 MT per acre (depending on season and cultural practices). Fruits are medium size, round shape, with uniform size and better shelf life. Maturity of this cultivar is 80 to 90 days after planting and having average fruit weight 70 gm.

3.2. 4 Punjab Gaurav

The cultivar was released in 2015 by PAU Ludhiana and having ambiguous growth behavior of plants. Fruits are oval in shape, medium in size (90 g), very firm, and have 2-3 locules. TSS content is 4 to 5.5 percent; while lycopene concentration is 4.9 mg per 100 g. Fruits are borne in clusters of eight to nine. The first harvest is 120 days after transplanting, with an early yield of 247 q/acre (harvested until end March) and a total yield of 934 q/acre. Under ambient settings, the fruits have a six-day shelf life and are excellent for both local and distant markets.

3.2. 5 Punjab Sartaj

The cultivar was released in 2015 by PAU Ludhiana and with dark green foliage have uncertain growth behavior. The fruits are round, medium-sized (85 g), firm fruits with 3-4 locules. TSS content is 4 to 5.7 percent; while lycopene concentration is 5.3 mg per 100 g. Fruits are borne in clusters of five to six. The first harvest is achievable 117 days after transplanting, with an early yield of 254 q/acre (harvested till end March) and a total yield of 898 q/acre. Under normal conditions, the fruits have a five-day shelf life and are excellent for both local and distant markets. The variety is resistant to leaf curl virus and can be grown in a polynet house for protection.

3.2.6 Punjab Swarna

The cultivar was released in 2018 by PAU Ludhiana. Plants have an indeterminate growth habit and dark green leaves, making them ideal for growing in protected environments. Fruits are firm, medium-sized fruits with a pointed apex and three locules, orange in colour. Fruits are borne in clusters of 6-8, with a TSS of 3-4 percent and 14mg of carotene per 100g of fresh weight. 120 days after transplantation, the first picking is allowed. It has an early average yield of 166 q/acre and a total yield of 1087 q/acre (harvested till the end of March). It is suited for use at a table purpose.

3.3 EXPERIMENTAL DETAILS

3.3.1 Soilless Growing Media Used

3.3.1.1 Cocopeat

It can hold up to eight times its volume in moisture and degrades slowly, making it ideal for numerous uses. During the season, a good quality low EC cocopeat in brick form was purchased from the market. Rippy *et al.*, (2004) and Nurzynski, (2005)

3.3.1.2 Vermicompost

It is organic compost prepared from fresh cow dung digested by earthworms in aerobic environment and high in microbial population; it was purchased fresh from the market. Truong *et al*., (2015, 2018), and Zaller, (2007a, 2007b)

3.3.1.3 Vermiculite

It is the name given to hydrated laminar minerals that resemble mica (aluminum-iron magnesium Silicates). Horticultural vermiculite is expanded into accordion-shaped pellets made up of numerous layers of thin plates using extreme heat. It is lightweight and helps drainage. It was purchased from the market and is chemically inert, so it will not modify pH. Ramadani *et al.*, (2012), Spehia *et al*., (2020) and Zhand and He(2005)

3.3.1.4 Perlite

It is a naturally occurring mineral that forms as a sort of volcanic glass when volcanic obsidian glass is saturated with water for an extended period of time. The perlite is a dark grayish-white tinted amorphous glass that, unlike a crystal, has no specific shape or structure. It helps to protect the media from extreme temperatures, drain the media, and aerate the roots.

3.3.2 Factors

Two factors at different levels were studied under Factorial randomized block design and treatments used under-designed have been elaborated below:

Factor 1

The treatment with six different media substrate/ growing media in which M-1 will be control treatment.

M_1	:	Soil only (Control)
M_2	:	Coco-Peat
M_3	:	Coco-Peat + Vermicompost (2:1)
M_4	:	Coco-Peat + Vermicompost (3:1)
M_5	:	Coco-Peat + Vermiculite (3:1:1)
M_6	:	Coco-Peat + Vermiculite (6:1:1)

Factor 2

The treatment for tomato cultivars in which six promising cultivars of tomato, in which the cultivar P-1 will be check treatment.

P1	:	Heem Shikhar (Check)
P2	:	US- 2853
P3	:	NS-4266
P4	:	Punjab Gaurav
P5	:	Punjab Sartaj
P6	:	Punjab Swarna

3.3.3: Experiment design and layout plan

Design of experiment	=	Factorial randomized block design
Number of factors	=	Two (Growing media and cultivar)
Number of treatments	=	36
Number of replications	=	3
Number of plants per treatment	=	12
Number of plants per replications	=	432
Number of experimental plants	=	1296
Area of layout plan (Sq.m)	=	500

During the experimental designed, each treatment was replicated three times, so total 36 treatments combinations were formulated by using both factors that have been shown in table 3.1

3.4 Methodology

The experiment was conducted in two seasons in 2018 and 2019. Only the indeterminate varieties of promising tomato cultivars were selected in the experiment as per the combination of tomato cultivars and growing media mentioned as following table 3.1.

3.4.1 Nursery raising

The protrays were used to grow nursery plants with cocopeat as the growing medium. For the Hi-Tech polyhouse nursery, a total of 99 cells of portray was chosen, and one seed per cell was sowed with selected six tomato cultivars according to the treatments (fan and pad system). According to the recommendations of the Centre of Excellence for Vegetables – Kartarpur Punjab, water soluble fertilisers such as NPK-19-19-19 and NPK 12-61-0 were alternately applied for nursery production.

3.4.2 Transplanting of seedlings

The tomato crop with different cultivars was planted in normal grow bags (24cm X 24cm X 40cm) that were set 60 cm x 60 cm apart on raised beds during the years 2018-19 and 2019-20. After 34 and 36 days, the healthy and uniform seedlings were transplanted with each grow bag holding two plants. The seedlings' root systems were carefully protected during transplanting; therefore the protrays were watered one hour ahead of time. The evening hours were used for transplanting in the grow bags containing moist media. For all of the treatments, the crop was kept with a single stem. Standard plant care methods were performed according to the Punjab Agricultural University's Package of Practices for Vegetable Crops (Anonymous, 2017). The crop was give shade with 50 percent shade net (Aluminet) during the initial stage for one month to protect the crop high sun light intensity.

3.4.3 Fertilizer schedule of Tomato

Irrigation and fertilizers were applied to all treatments (cultivars of tomato plants grown in grow bags with different combinations of growing media) through an automatic fertigation system in equal proportion. The fertilizer schedule of Tomato for soilless cultivation as mentioned in table 3.2 was recommended by Centre of Excellence for Vegetables (CEV) at Kartarpur in the year 2017, was applied all treatments with the automation system machine (NetaGet 4G), This machine was used for automatic fertigation for all the treatments in equal proportion and at the same time under the controlled environment of polyhouse unit at the Hi-Tech Vegetable Centre Moga in 2018 and 2019 as shown in the Fig 3.2

Table 3.1 Details of the treatments used for study and layout plan of experiment.

Treat-ments	**Replicat ions**	**Media**	**Tomato Cultivars**					
			P1	**P2**	**P3**	**P4**	**P5**	**P6**
T1 – T6	R1	**M1**	11	12	13	14	15	16
T6 - T12		**M2**	21	22	23	24	25	26
T12 - T18		**M3**	31	32	33	34	35	36
T18 - T24		**M4**	41	42	43	44	45	46
T24 - T30		**M5**	51	52	53	54	55	56
T30 - T36		**M6**	61	62	63	64	65	66
	R2		**P2**	**P5**	**P3**	**P1**	**P4**	**P6**
T6 - T12		**M2**	22	25	23	21	24	26
T18 - T24		**M4**	42	45	43	41	44	46
T1 - T6		**M1**	12	15	13	11	14	16
T30 -T36		**M6**	62	65	63	61	64	66
T12 - T18		**M3**	32	35	33	31	34	36
T24 - T30		**M5**	52	55	53	51	54	56
	R3		**P4**	**P1**	**P5**	**P3**	**P2**	**P6**
T18 - T24		**M4**	44	41	45	43	42	46
T30 - T36		**M6**	64	61	65	63	62	66
T6 - T12		**M2**	24	21	25	23	22	26
T24 - T30		**M5**	54	51	55	53	52	56
T1 - T6		**M1**	14	11	15	13	12	16
T12 - T18		**M3**	34	31	35	33	32	36

As per the tomato crop requirement and standardized fertigation schedule recommended by Centre of Excellence for Vegetables, Kartarpur, the Fertigation was applied in the form of pulse along with irrigation water (3 to 4 times/day) as per the weather condition and sun light intensity. The nutrient requirement was met through below mentioned as per the recommended fertilizers doses. The irrigation & fertigation was accomplished by placing one lateral with arrow drippers along with the treatments as per the fertigation schedule to feed the crop transplanted in grow bags.

Table 3.2: Tomato Fertilizer schedule:

With Pulse Fertigation		**Fertilizers kg per acre every week**						
Physiological Stages	Duration (Days)	NPK 19-19-19	NPK 12-61-0	NPK 0-52-34	NPK 13-0-45	Calcium Nitrate	Ammonium. Sulphate	Magnesium Sulfate
After Planting	0-30	1	1.5	-	1.5	2.5	-	2
Flowering + Fruit Setting	31-90	2	2	-	3	5	2	3
Harvesting	91-120	2	-	2.5	4	5	2	3
Upto end of Harvest	121-300	2	-	2	4	5	1.5	4

*Centre of Excellence for Vegetables, Kartarpur, Dept. of Horticulture, Punjab

- In case of deficiency of Calcium and Magnesium, spray EDTA form of Calcium and Magnesium at the rate 2gm per liter
- Foliar spray of micronutrient like Maganese Sulfate (Mn) @ 2 gm per litre and Boron @ 1 gm per litre once a week
- In case of deficiency, foliar spray of Fe- EDTA + Zn- EDTA @ 1gm per liter.
- To prevent salt accumulations in the growing media, plain irrigation is given once a week with 15 to 20% leaching.
- For flower and fruit setting, spray Planofix (Napthalic Acetic Acid) @ 0.25 ml per liter once in a fortnight.
- For Pollination of tomato, use vibrator for giving vibration to the flowers clusters during morning time daily.

Regular spray of fungicide and insecticides were followed as per the recommendation of "Package and Practices of Vegetables by PAU Ludhiana" (Anonymous, 2019).

Seed Sown portrays in germination chamber	Raising Seedling under Hitech Polyhouse

Transplanting of Seedling in grow bags	Growth of seedling in grow bags

M2-T1 M2-T2 M1-T3 M1-T4 M1-T5 M1-T6

Fig.3.2: Schematic description of experimental polyhouse with the layout plan

3.5 OBSERVATIONS DETAILS:

3.5.1 Plant growth parameters

3.5.1.1 Plant survival percentage

3.5.1.2 Plant height (cm)

3.5.1.3 Days to flower initiation

3.5.1.4 Days to fifty percent flowering

3.5.1.5 Days to first fruit set

3.5.2 Plant production parameters

3.5.2.1 Fruits per cluster

3.5.2.2 Cluster per plant

3.5.2.3 Days to first harvest

3.5.2.4 Days to last harvest

3.5.2.5 Fruits per plant

3.5.2.6 Average fruit weight (g)

3.5.2.7 Locules per fruit

3.5.2.8 Fruit diameter (cm)

3.5.2.9 Yield per plant (Kg)

3.5.2.10 Total Yield (T/ Ha.)

3.5.3 Fruit quality parameters

3.5.3.1 Total soluble solid (TSS; °Brix)

3.5.3.2 Tritrable acidity (%)

3.5.3.3 Lycopene content (mg/100 g)

3.5.3.4 Vitamin C (mg/100 g)

3.5.4 Media parameters before an experiment

3.5.4.1 pH of media

3.5.4.2 Electronic conductivity of media (dS/m)

3.5.4.3 Available Nitrogen Percentage

3.5.4.4 Available Phosphorus Percentage

3.5.4.5 Available Potassium Percentage

3.5.5 Economic Analysis

3.5.6 Leaf elemental content:

3.5.6.1 Macro nutrients

3.5.6.2 Micro nutrients

3.6 Description of recorded observations

The above mentioned field observation including plant growth parameter, production parameters and plant fruit quality parameters were recorded as described as follows :

3.6.1 Plant growth parameter

The following observations were made on each cultivar cultivated in each growing media as per the treatments in each replication on all five plants chosen at random. Under each replication, the average values were calculated as a treatment mean. Below are the characters analysed and the methods used to record the observations.

3.6.1.1 Plant survival percentage

The number of plants that survived two weeks after transplanting were counted in each grow bag in different tomato cultivars as per the treatment for the different growing media. The plant survival percentage was recorded as per the treatments in each replication and their average was worked out.

3.6.1.2 Plant height (cm)

Each treatment's average height from the base level to the tip of the main shoot was measured in centimeters using a measuring scale at 60, 90, and 120 Days after transplant (DAT) and height at last harvest (cm). When analyzing the data, the final height at last harvest was taken into account and average height of the treatments was recorded in centimeters.

3.6.1.3 Days to flower initiation

For each cultivar planted in each growing media, the number of days taken for flower initiation from the date of transplanting was recorded for randomly selected five tagged plants in each treatment with three replications and further, their average was worked out.

3.6.1.4 Days to 50% flowering

The number of days taken to 50% flowering was determined by recording the number of days recorded after days after transplangt until 50% of plants population in a plot experiment has atleast one open flower. So the days taken to 50% flowering was recorded for randomly selected five plants in each treatment with three replications and further, their average was worked out for further analysis.

3.6.1.5 Days to first fruit set

The number of days taken for first fruit set from the day of transplantation was recorded for randomly selected five tagged plants in each treatment with three replications and further, their average was used for further analysis.

3.6.2 Plant production parameters

The observation of plant production parameters of tomato crop under protected conditions were recorded in year 2018-19 and 2019-20, two season as per the following descriptions of parameters:

3.6.2.1 Fruits per cluster

The number of fruits per cluster borne on randomly selected five tagged plants in each treatment with three replications was recorded during each picking. The average number of fruits per cluster upto last harvesting stage was worked out after calculating with total pickings of harvest.

3.6.2.2 Clusters per plant

The number of cluster per plant from randomly selected five tagged plants was recorded during each picking in each treatment with three replications. The average number of cluster per plant upto last harvesting stage was worked out after calculating with total pickings of harvest.

3.6.2.3 Days to first harvest

The number of days taken to first harvest was recorded from randomly selected five tagged plants in each treatment with three replications and their average was worked out for further analysis.

3.6.2.4 Days to last harvest

The number of days taken to last harvest was recorded from randomly selected five tagged plants in each treatment with three replications and their average was carried out for further analysis.

3.6.2.5 Fruits per plant

The numbers of fruits harvested was recorded from randomly selected five tagged plants at each picking. The total quantity of fruits per plant was computed by adding all harvests and dividing by the number of plants and their average was worked out for further analysis.

3.6.2.6 Average fruit weight (g)

The ripened fruits were selected from randomly selected five tagged plants from each treatments and replications. The fresh weight of fruits per plant was recorded with the help of an electronic balance during every picking. The average weight of all the treatments was calculated and expressed in gram per fruit.

3.6.2.7 Locules per fruit

The number of locules per fruit was counted by cutting tomato fruits transversely in the middle from randomly selected five tagged plants in each treatment with three replications. The randomly selected fruits were sliced and examined for cross-sectional shape before being categorized and their average was worked out for further result analysis.

3.6.2.8 Fruit diameter (cm)

The fruit diameter of 10 fruits was recorded from randomly selected five tagged plants in each treatment with three replications with the help of a vernier calliper at the largest bulged section of tomato fruits at the third harvest stage and their average was worked out for further result analysis.

3.6.2.9 Yield per plant (Kg)

The average yield per plant in each treatment was determined by multiplying the average fruits per plant with the total number of fruits borne on same plant. The average data for all three replication in each treatment was expressed in terms of kg per plant and their average was worked out for further result analysis.

3.6.2.10 Total Yield (t/ha.)

The yield per hectare was expressed by multiplying the yield per plant (kg) by the number of plants per hectare, The average data for all three replication in each treatment was expressed in terms of tons per hectare (t/ha) and their average was worked out for further result analysis.

3.6.3 Fruit quality parameters

The quality of the tomato fruits is expressed with the following fruit quality parameters as mentioned like Total Soluble Solids, Titratable acidity, lycopene content and Vitamin-C content.

3.6.3.1 Total soluble Solid (°Brix)

The Total Soluble Solids (TSS) was estimated by Erma hand refracto-meter (0-32 °Brix) as per the methods described by Ranganna's method (1995). The 5 fruits of tomato cultivars were crushed and the juice was poured through cheesecloth then juice is placed on the glass platform of refracto-meter, where the reading was recorded. The TSS was recorded from the randomly selected tagged plants from each treatment and replication and their average was work out. The unit of TSS was expressed in °Brix for the results.

3.6.3.2 Titratable acidity (%)

The fruit pulp of randomly selected fruits of tagged plants was made to 25 grams and fully homogenised in an electric blender. The mixture was filtered to a total volume of 250 ml using Whatman No. 1 filter paper. After that, 50 ml of material was titrated against N/10 NaOH solution using Phenolphthalein as an indicator until it turned pink at the endpoint. Titratable acidity was calculated using 1 ml of N/10 NaOH, which corresponds to 0.0067 grammes of anhydrous citric acid or percent citric acid in juice (Ranganna, 1995). The sugar content was calculated using the leftover filtered solution.

Titratable acidity (%)

$$= \frac{\text{Titre} \times \text{Normality of alkali} \times \text{volume made up} \times \text{Equivalent weight of acid} \times 100}{\text{Volume of sample taken} \times \text{volume of aliquot taken} \times 100}$$

3.6.3.3 Lycopene content (mg/100g)

The lycopene content of twenty ripened tomato fruits from randomly selected five tagged plants from each treatments and replications was determined according to the absorption measurement procedure as the method described by Ranganna's (1995) by adding the crused fruit plup with petroleum ether and extract of total carotenoids analysed with Spectro Photometer at 503 nm.

3.6.3.4 Vitamin C (mg/ 100g)

The Vitamin-C content of twenty ripened tomato fruits from randomly selected five tagged plants from each treatments and replications was recorded by the following method suggested by Ranganna (1995) using the 2,6- dichlorophenol Indophenol dye and titrating the sample extracted in metaphosphoric acid solution with dye to a pink endpoint. As calculated below:

AscorbicAcid

$$= \frac{\text{Titrate} \times \text{Dye factor} \times \text{volume made up} \times 100}{\text{Aliquot of extract taken for estimation} \times \text{Weight of sample taken for estimation}}$$

3.6.4 Economic Analysis (B:C ratio)

The details component of growing media economic analysis are Cost of cultivation, Gross return, Net returns and Benefit – Cost ratio, which was suggested by Chand, A. J. (2014) as follows:

3.6.4.1 Cost of cultivation

The costs incurred from field preparation through tomato harvest including fixed cost and variable cost were calculated and total cost of cultivation expressed as Rs./ ha.

3.6.4.2 Gross Returns

The crop output was calculated per 4000 square meters and the total income was calculated using the market rate of produce at the time of the study.

3.6.4.3 Net Returns

The net returns from the tomato crop grown in different soilless media were computed by subtracting the cost of cultivation from gross returns for each treatment.

Net Return = Gross Return (Rs.) – Cost of Cultivation (Rs.)

3.6.4.4 Benefit- Cost Ratio (BCR)

To determine profitability, a benefit-cost analysis was performed, with the economics estimated at current market rates and the benefit-cost ratio (BCR) determined by using formula of Palaniappan (1985).

BCR = Gross Return (Rs.) ÷ Cost of Cultivation (Rs.)

3.6.5 Media parameters before an experiment

Samples of growing media were taken from the grow bags as per the media treatments during 2018 and 2019 to learn about the state of nutrient content with pH and EC of the different growing media we calculated by Jackson's method 2005.

3.6.5.1 Analysis of growing media samples for Macro and Micro nutrients

To remove any external influences, the typical procedure for analyzing growth media samples involved washing with tap water, then 0.1N HCl, and finally double distilled water. The samples were packed in paper bags and oven dried for 48 hours at 60 5°C in a hot air oven after air drying on filter paper. For nitrogen, phosphorus, and potassium content analysis, the samples were crushed and pulverized in a stainless steel mortar and stored in butter paper bags.

3.6.5.2 Digestion of growing media sample

For the digestion of the growth media, a Di-acid combination prepared by mixing concentrated HNO_3 and $HClO_4$ in a 4:1 ratio was employed for digesting thoroughly grinded samples of a known weight of varied media while following the essential phosphorus and potassium measurement proceduressh Pieper and Barrett

(2009). Nitrogen was estimated using concentrated H2SO_4 and a digestion mixture (potassium sulphate 400 parts, copper sulphate 20 parts, mercuric oxide 3 parts, and selenium powder 1 part), as described in Jackson's (2005) Micro kjeldahl method 1973. To determine phosphorus, potassium and From each of the samples, 0.5 g of grounded material was taken in a HF vessel and 6 ml of nitric acid (HNO_3) was added to it. The samples were placed in rotors and irradiated in the microwave. Then, the solution was cooled down for 20 minutes and screws of the vessel were opened under the fume hood. The solution was diluted with 50 ml distilled water (50 times the sample) and then filtered. Then the filtered solution was subjected to analyze various macro and micronutrients with Inductively Coupled Plasma Spectrophotometer (ICP).

3.6.6 Leaf elemental content:

After the first harvesting step and before the last harvesting stage of the studies, leaf elements content was analysed. The healthy leaves were randomly collected from all directions of selected plants at shoulder height in February to evaluate macro and micronutrient concentrations in the leaves. To create a sample of 100 leaves each replication, leaves from five plants were pooled. The leaves were first carefully rinsed with tap water, then distilled water, and finally 0.01 N HCl and teepol solutions. The leaf samples were dried in the shade and packed in butter paper bags before being dried in a hot air oven at 650°C for 48 hours. The oven-dried samples were ground into powder using a stainless steel grinder and passed through 40-mesh sieves. The samples that were ready for nutrient element estimation were kept in an airtight glass container and used for nutrient analysis later. The samples were re-dried in an oven at 650°C for 24 hours before being analysed for leaf nutrients.

3.6.6.1 Leaf Nitrogen content (percent)

Nitrogen content was estimated with standard procedure by AOAC (2005) and the reagents used for the lab work were as following

a) Digestion mixture (K_2SO_4:$CuSO_4$ (10:1 w/w)

b) H_2SO_4 (conc.)

c) N/100 HCl

d) 4 % Boric acid

e) 40% NaOH

f) Mixed indicator

A solution formed by dissolving 0.5 grammes of bromocresol green with 0.10 grammes of methyl red indicator in 100 millilitres of 95 percent alcohol. The pH of the solution is maintained at 4.5 by adding diluted HCl acid to it.

The digesting flask received 0.5 g of pulverised material from each sample. It was mixed with 2 g of digestion mixture and 10 ml of concentrated H2SO4. The contents of the flask were heated until they turned transparent. In a volumetric flask, the sample is chilled and diluted with distilled water to a volume of 50 ml. Micro Kjeldahl distillation was performed on 5ml of a liquid with 5ml of 40 percent sodium hydroxide solution. The emitted ammonia was absorbed in a boric acid solution containing 2-3 drops of mixed indicator in 20 ml. In a 250 ml conical flask, 10 mL of distillate was collected and titrated with N/100 HCl until the colour changed from blue to pale pink. At this point, the volume of HCl utilised (T) was recorded and is referred to as the titre value (T). The volume of HCl used was also determined by titrating against a solution that did not include the material and was used as the blank reading (B). The following formula was used to calculate nitrogen percentage:

$$\text{Nitrogen in sample (\%)} = \frac{(T-B) \times 0.00014 \times V_1 \times 100}{V_2 \times S}$$

Where,

T is titre value

B is blank reading

S is weight of leaf sample taken (g)

V_1 is total volume make

V_2 is volume used for distillation

3.6.6.2 Estimation of macronutrients (P, K, Ca, Mg, S)

From each of the samples, 0.5 g of grounded material was taken in a HF vessel and 6 ml of nitric acid (HNO3) was added to it. The samples were placed in rotors and irradiated in the microwave. Then, the solution was cooled down for 20 minutes and screws of the vessel were opened under the fume hood. The solution was diluted with 50 ml distilled water (50 times the sample) and then filtered. Then the filtered solution was subjected to analyze various macro and micronutrients with Inductively Coupled Plasma Spectrophotometer (ICP).

3.6.6.3 Estimation of micronutrients (Fe, Zn, Mn, Cu, B, Mo)

From each sample, 0.5 g of grounded material was taken in a H.F vessel and 6 ml of nitric acid (HNO3) was added to it. The samples were placed in rotors and irradiated in the microwave. Then, the solution was cooled down for 20 minutes and screws of the vessel were opened under the fume hood. The solution was diluted with 50 ml distilled water (50 times the sample) and then filtered. Then the filtered solution was subjected to analyze various macro and micronutrients in Inductively Coupled Plasma Spectrophotometer (ICP).

The amount of each nutrient in the samples was calculated as:

Nutrient content (ppm) = ICP value of nutrient x dilution factor

Where, dilution factor = Volume made / Weight of sample taken

Further, macronutrients were expressed into percentage and calculated as below.

Macronutrient (%) = Value in ppm / 1000

Micronutrient = Value in ppm

3.6.7 STATISTICAL ANALYSIS

The experiment was set up using a Factorial randomized block design (FRBD) and pooled data from two years 2018-2019) and 2019-2020 were used to conclude the study after using a standard statistical procedure with the OP Stat Analysis software system developed by H.A.U, Hisar, Haryana, (Sheoran *et al*., 1998) at a 5 percent critical difference (CD) to test for significant differences between treatment means.

CHAPTER IV

RESULTS AND DISCUSSION

The study entitled "Performance of tomato cultivars (*Solanum lycopersicum* L.) in different soilless culture substrate under protected conditions" was undertaken in the polyhouse unit at Hi-Tech Vegetable Centre, village - Bir Charik, district Moga, Punjab during the year 2018 and 2019. The investigation was carried out for comparing various growing media which can be a better alternate of soil without affecting growth and yield. Further, evaluation of promising cultivars of tomato for better quality yield can provide better economic returns to farmers. In this chapter, the results obtained during the study are presented and discussed in light of relevant literature under the following headings and subheadings:

4.1 Effect of growing media on the growth, production and quality parameters of tomato cultivars.

4.1.1 Effect of growing media on growth parameters of tomato cultivars

4.1.2 Effect of growing media on the production parameters of tomato cultivars

4.1.3 Effect of growing media on the fruit quality parameters of tomato cultivars

4.2 Effect of growing media on economic analysis (B:C ratio) of tomato cultivars under protected conditions

4.3 Effect of growing media on different parameters of media.

4.3.1 Effect of growing media on pH of substrate

4.3.2 Effect of growing media on EC of substrate

4.3.3 Effect of growing media on Nitrogen content of substrate

4.3.4 Effect of growing media on Phosphorus content of substrate

4.3.5 Effect of growing media on Potassium content of substrate

4.4 Effect of growing media on leaf elemental content in tomato leaf

The results of each heading and subheading are described as following.

4.1 Effect of growing media on the growth, production and quality parameter of tomato cultivars

For two consecutive years, 2018-19 and 2019-20, the growth and yield performance of tomato cultivars grown in UV stabilized polybags under polyhouse were investigated. The results of the analysis of growth metrics and quality features are as follows:

4.1.1 Effect of growing media on growth parameters of tomato cultivars

The observations regarding plant growth parameters were recorded on each cultivar cultivated in each growing media as per the treatments with each replication on all five plants chosen at random. Under each replication, the average values were calculated as a treatment mean. The details results and discussion as per the different parameters are as below:

4.1.1.1 Plant survival percentage (%)

The plant survival percentage is a very important parameter affected the all the field parameters including economic yield. After two weeks of transplanting of seedlings, the survival of plants number was recorded in each grow bags having different cultivars of treatment concerning the growing media. The data presented in the Table 4.1 and Fig 4.1 revealed that the different growing media significantly affected the plant survival percentage, whereas the effect on the different cultivars was not significant. The interactions of growing media with tomato cultivars were not significantly affect the plant survival percentage.

The data for the different growing media revealed that the maximum 100% plant survival was recorded under growing media M-3 to M-6, whereas the minimum 88.4 % plant survival was recorded in control media M-1. The plant survival percentages have not much impact on the tomato cultivars from P-1 to P-6, the maximum 98.2 % plant survival was recorded in P-2 cultivar, however the minimum 96.8 plant survival was recorded in P-5 cultivars. Aktas *et al*., (2013) found similar results when they investigated about how different growing media affected plant survival percentages. The effect of plant survival percentage was depended upon the nature of growing media and its quality. According to Radha *et al*., (2018), maximum survival rates in the media (75% raw coir dust +25% Rice husk) was recorded as compare to other growing media studied.

Table 4.1 Effect of growing media on plant survival percentage of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	88.9	94.5	100.0	100.0	100.0	100.0	**97.2**
P2 - US-2853	91.7	97.2	100.0	100.0	100.0	100.0	**98.2**
P3 - NS-4266	86.1	97.2	100.0	100.0	100.0	100.0	**97.2**
P4 - Punjab Gaurav	88.9	97.2	100.0	100.0	100.0	100.0	**97.7**
P5 - Punjab Sartaj	91.7	97.2	100.0	100.0	100.0	100.0	**98.2**
P6 - Punjab Swarna	83.3	97.2	100.0	100.0	100.0	100.0	**96.8**
Mean M	**88.4** ^{c}	**96.8** ^{b}	**100.0** ^{a}	**100.0** ^{a}	**100.0** ^{a}	**100.0** ^{a}	
*At CD **(0.05)-** Factor (P) = NS , Factor (M)= 1.762, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

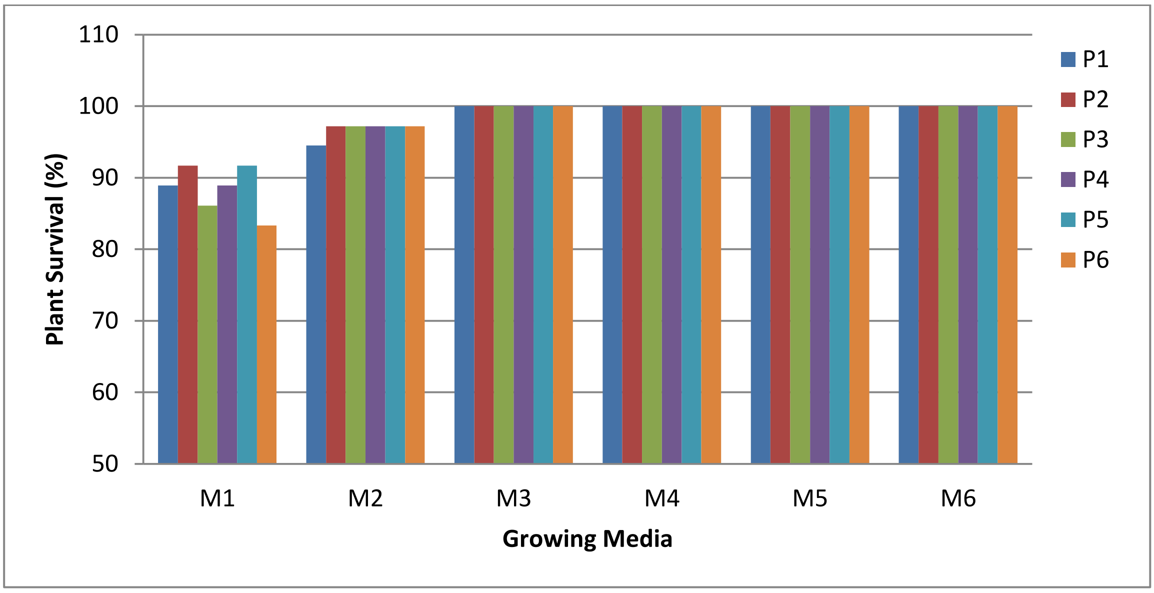

Fig 4.1 Effect of growing media on plant survival percentage

4.1.1.2 Plant height (cm)

Plant height is an important parameter of a crop's growth and development. The final height at last harvest was taken into account while analyzing the results. It is evident from the data presented in Table 4.2 and Fig 4.2 shown that the different tomato cultivar and varied growing media significantly improved the plant height of tomato cultivars, however the interaction between cultivars and growing media (P x M) was not significantly affected the plant height.

The data for the different growing media revealed that the maximum 373.4 cm plant height of tomato cultivars was recorded under growing media (M3) cocopeat + vermicompost (2:1, v/v) treatment, whereas the minimum 359.2 cm plant height was recorded under growing media cocopeat (M-2). Among different tomato cultivars, the maximum 374.8cm plant height was recorded in cultivar NS-4266 (P-3) as compare to check cultivar HeemShikhar (P-1), whereas the minimum 345.3 cm plant height was recorded in check cultivar.

When compared to various alternative media, Atiyeh *et al*., (1999) found that amending media with 20% vermicompost considerably increases plant growth and yield. Plant height was improved under all cocopeat and vermicompost growing medium, according to Ghehsareh *et al*., (2011b) and Luitel *et al*., (2012), probably due to better physico-chemical properties of the media. These findings are in line with those of Sayed *et al*., (2015) and Agboola *et al*., (2018), who discovered that plant height was maximum in a medium containing saw dust when compared to other growing media and that the medium's physico-chemical parameters were ideal for root growth development.

Table 4.2 Effect of growing media on plant height (cm) of tomato cultivar s

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	340.0	340.0	359.7	347.0	346.7	340.0	**345.3^{a}**
P2 - US-2853	353.7	372.3	377.7	376.7	374.0	374.3	**371.4^{bc}**
P3 - NS-4266	372.7	372.3	377.7	376.0	378.0	372.0	**374.8^{c}**
P4 - Punjab Gaurav	367.2	374.3	387.2	367.2	361.2	377.8	**372.5^{bc}**
P5 - Punjab Sartaj	363.0	355.7	375.8	365.8	365.3	359.5	**364.2^{b}**
P6 - Punjab Swarna	359.7	340.3	362.5	351.2	354.7	342.3	**351.8^{a}**
Mean M	**359.4^{a}**	**359.2^{a}**	**373.4^{b}**	**364.0^{ab}**	**363.3^{a}**	**360.8^{a}**	
*At CD **(0.05) -** Factor (P) = 9.719 , Factor (M) = 9.719, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

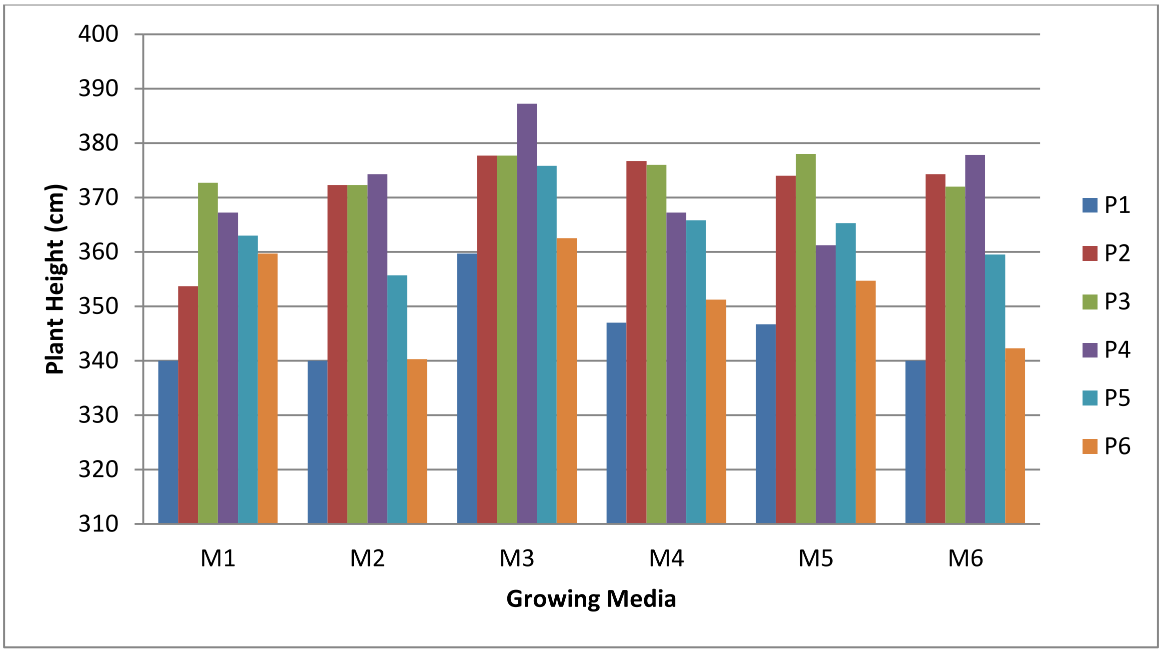

Fig 4.2 Effect of growing media on plant height of tomato cultivars

4.1.1.3 Days to flower initiation

The earliness of cultivar was determined by the number of days it took for flower initiation from the date of transplanting. The days to flower initiation were recorded from 5 randomly selected plants of each treatment and analyzed for results. The data presented in Table 4.3 and Fig 4.3 revealed that the days taken to flower initiation significantly affected by the different cultivars in varied growing media. however the interaction between cultivars and growing media (P x M) was not significantly affected the days taken to flower initiation.

The data for the different growing media shown that the maximum 74 days to flowering initiation were recorded under control media (M-1), however the minimum 70.6 days were recorded under the media M-5 cocopeat, vermiculite, and perlite (3:1:1, v/v). The cultivar Punjab Gaurav (P-4) was recorded with the maximum 86.6 days to flower initiation, whereas the minimum 58.3 days was recorded in P-1 check cultivar and P-2 US-2853 cultivar.

Similar findings have been reported by numerous scientists and researchers; these findings are consistent with those of Nair *et al*., (2011), who found that knowing the days to flower initiation is a key part of determining the earliness of the cultivars. The tomato plants grown in the modified growing medium showed better plant growth parameters than those grown in the control growing medium. Aslani *et al*., (2015) found that the peat moss treatment had better effects for flowering rate and reproductive factors than cocopeat growing media.

Table 4.3 Effect of growing media on days to flower initiation of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	59.7	59.0	58.7	57.7	56.7	58.0	**58.3^{a}**
P2 - US-2853	61.7	58.0	58.0	59.3	56.7	56.0	**58.3^{a}**
P3 - NS-4266	60.0	58.7	58.7	60.0	57.3	59.3	**59.0^{a}**
P4 – Punjab Gaurav	87.0	88.3	87.7	86.7	84.3	85.3	**86.6^{b}**
P5 - Punjab Sartaj	88.0	87.3	85.0	86.0	84.7	84.3	**85.9^{b}**
P6 – Punjab Swarna	87.7	88.3	86.3	86.7	84.0	85.7	**86.4^{b}**
Mean M	**74.0^{c}**	**73.3^{bc}**	**72.4^{b}**	**72.7^{b}**	**70.6^{a}**	**71.4^{ab}**	
*At CD **(0.05) -** Factor (P) = 1.059 , Factor (M)= 1.059, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

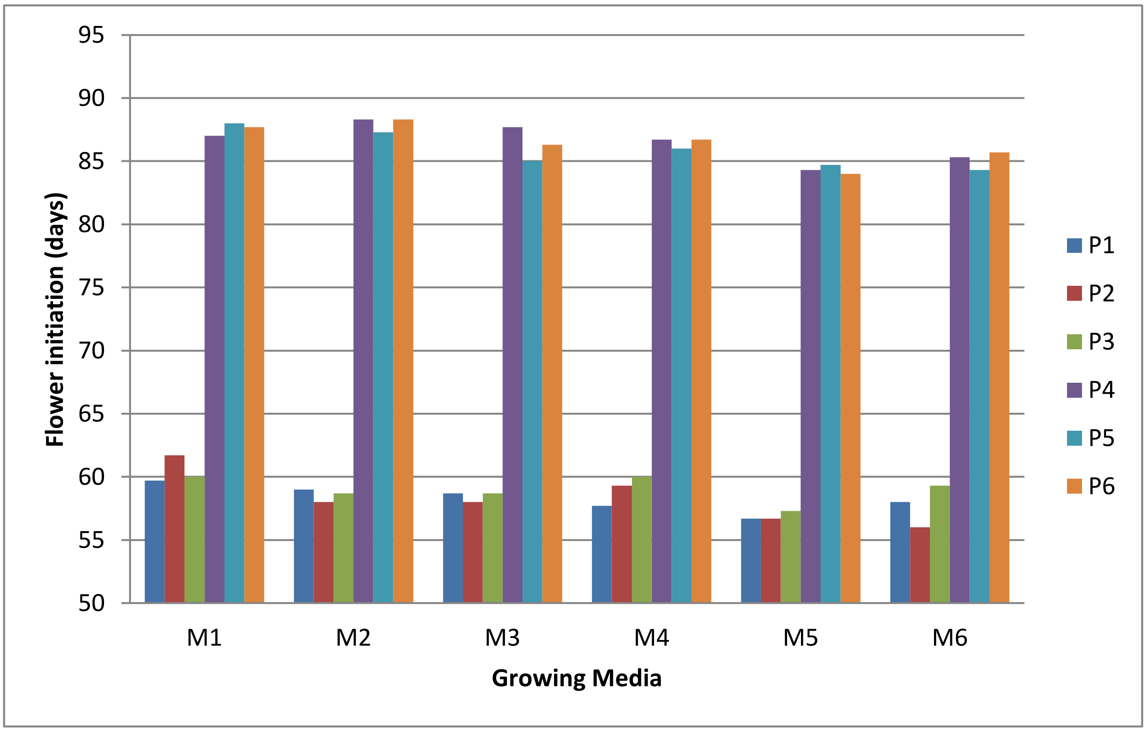

Fig 4.3 Effect of growing media on days to flower initiation of tomato cultivars

4.1.1.4 Days to 50% flowering

The days taken for fifty percent flowering shown statistically significantly results with the different cultivars and varied growing media treatments as presented in the Table 4.4 and Fig 4.4. However, the interaction between cultivars and growing media (P x M) was not significantly affected the days to 50% flowering.

The data for the different growing media shown that the maximum 84.7 days to reach 50% flowering of tomato cultivars were recorded in control media (M-1), whereas the minimum 81.7 days were recorded under media M-5 with cocopeat, vermiculite, and perlite (3:1:1, v/v). The fifty percent of flowering was recorded at the maximum 97.3 days in Punjab Gaurav, whereas the minimum 69.4 days were taken by cultivar US-2853 (P-2) for 50% flowering. The cultivar treatments P4, P-5 and P-6 deviate significantly from check cultivar in terms of days to 50% flowering, while cultivar P-2 and P-3 are comparable to check cultivar P-1 at CD value 0.523.

These findings were consistent with Sedaghat *et al*., (2017) that the media containing Coco-peat and Perlite in a 1:1 ratio provided the best vegetative development, early flowering in tomato crop. Spehia *et al*., (2020) and Mamta *et al*., (2022) also found similar results for yield and growth contributing parameters of tomato.

Table 4.4 Effect of growing media on days to 50% flowering of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	71.0	71.0	70.0	70.7	68.0	69.3	**70.0^{b}**
P2 - US-2853	70.7	70.3	69.7	70.0	67.3	68.3	**69.4^{a}**
P3 - NS-4266	71.3	71.3	70.0	71.0	69.3	70.0	**70.5^{b}**
P4 - Punjab Gaurav	98.0	99.0	97.3	98.3	95.7	95.7	**97.3^{d}**
P5 - Punjab Sartaj	98.0	98.3	96.0	97.0	94.7	95.0	**96.5^{c}**
P6 – Punjab Swarna	99.0	97.7	97.0	98.0	95.3	95.3	**97.1^{d}**
Mean M	**84.7^{d}**	**84.6^{d}**	**83.3^{c}**	**84.2^{d}**	**81.7^{a}**	**82.3^{b}**	
*At CD **(0.05) -** Factor (P) = 0.523 , Factor (M) = 0.523, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

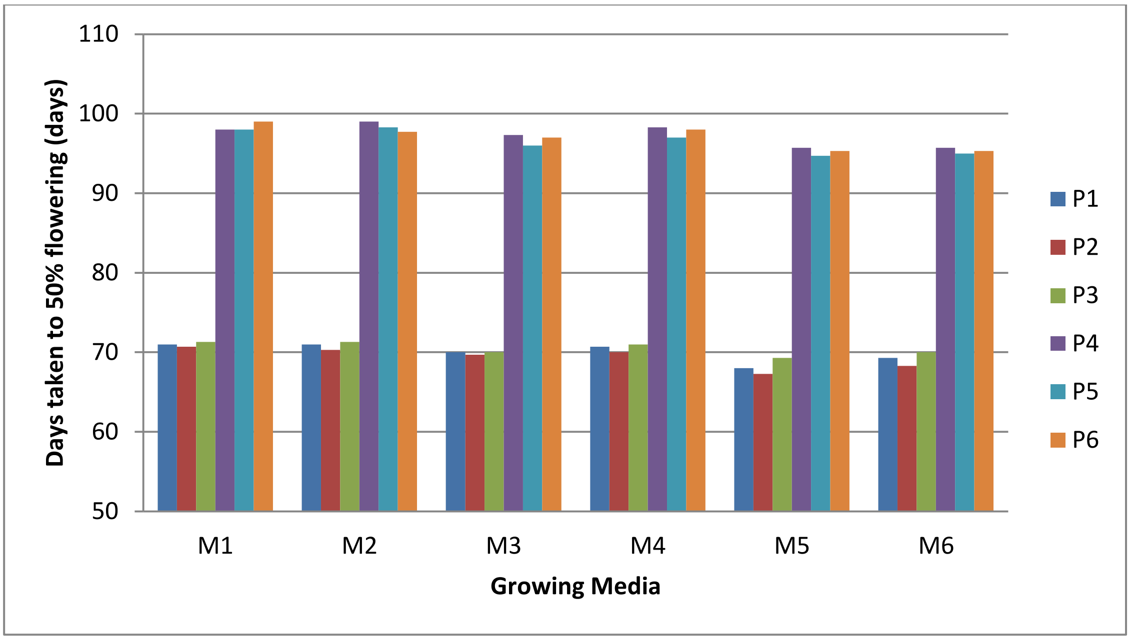

Fig 4.4 Effect of growing media on days to 50% flowering of tomato cultivars

4.1.1.5 Days to first fruit set

The days taken to first fruit set represents the earliness of cultivars and also influences the early yield of the tomato cultivars. The data pertaining with days taken to first fruit set has been presented in Table 4.5 and Fig 4.5. The analysis of data revealed a significant impact on days taken to first fruit set with different cultivars and varied growing media. However, the interaction between cultivars and growing media (P x M) was not significantly affected the days taken to first fruit set.

The data for the different growing media shown that the maximum 80.9 days taken to first fruit set were recorded under M-2 media with cocopeat only, whereas minimum 78.2 days taken to first fruit set were recorded in M-5 media with cocopeat + vermicompost (3:1, v/v). The cultivar Punjab Swarna was recorded the maximum 93.4 days to first fruit set, whereas cultivar US- 2853 was recorded the minimum 65.3 days to first fruit set.

These findings are consistent with Luitel *et al*., (2012a) investigated the effects of the different media (cocopeat, rockwool, & masato) days taken to first fruit set, tomato yield and its fruit quality. Among different growing media, the Cocopeat media had the maximum number of fruits per plant (16), followed by rockwool (15.2) as compare to other growing substrate.

Table 4.5 Effect of growing media on days to first fruit set of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	66.7	67.0	65.7	66.0	66.3	64.7	**66.1^{b}**
P2 - US-2853	66.3	66.3	64.7	65.7	64.3	64.7	**65.3^{a}**
P3 - NS-4266	67.3	66.7	65.0	66.3	65.3	66.0	**66.1^{b}**
P4 - Punjab Gaurav	94.0	95.0	93.7	93.7	91.3	91.7	**93.2^{cd}**
P5 - Punjab Sartaj	93.7	94.7	92.0	93.0	90.7	91.3	**92.6^{c}**
P6 - Punjab Swarna	95.3	95.7	92.7	93.7	91.0	92.3	**93.4^{d}**
Mean M	**80.6^{d}**	**80.9^{d}**	**78.9^{b}**	**79.7^{c}**	**78.2^{a}**	**78.4^{ab}**	
*At CD **(0.05) -** Factor (P) = 0.623 , Factor (M) = 0.623, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

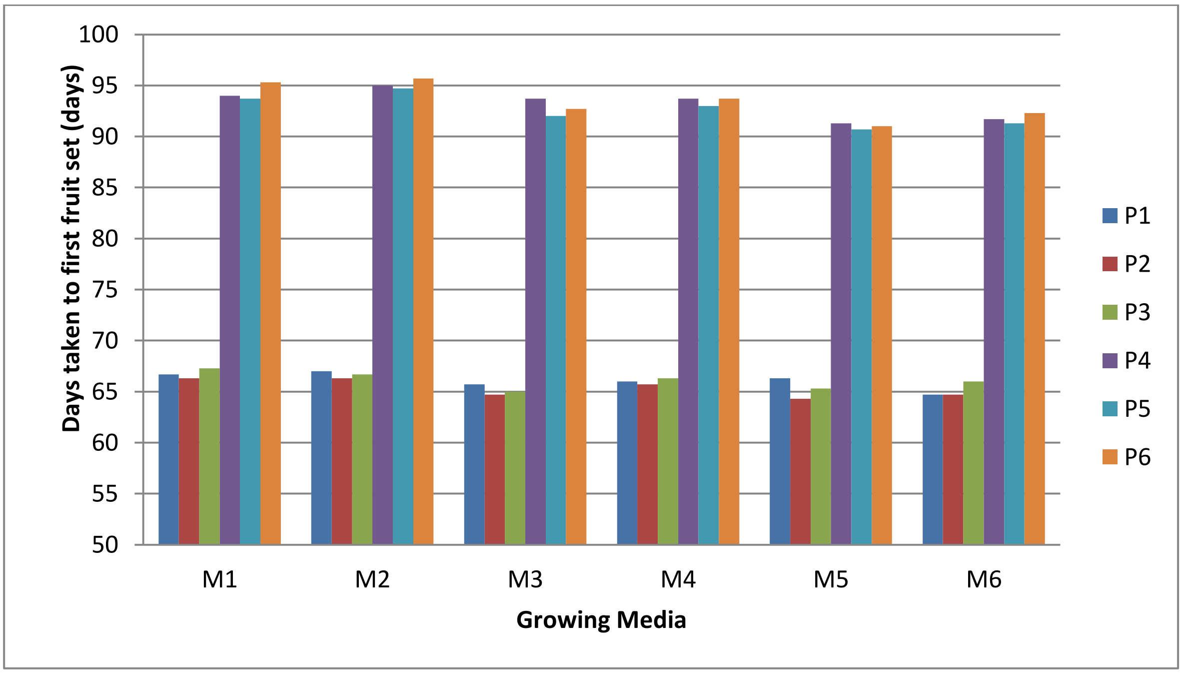

Fig 4.5 Effect of growing media on days to first fruit set of tomato cultivars

4.1.2 Effect of growing media on the plant production parameters

The observations regarding plant production parameters were recorded on each cultivar cultivated in each growing media as per the treatments with each replication on all five plants chosen at random. Under each replication, the average values were calculated as a treatment mean. Below are the details results and discussion as per the different parameters.

4.1.2.1 Fruits per cluster

It is evident from the data presented in Table 4.6 and Fig 4.6 demonstrated that the different tomato cultivars and varied growing media significantly improved the fruits per cluster of tomato cultivars, however the interaction between cultivars and growing media (P x M) was not significantly affected the fruits per cluster.

The data for the different growing media shown that the maximum 6.9 fruits per cluster were recorded in M-6 media, which included cocopeat, vermiculite, and perlite (6:1:1, v/v) as compare to control media (M-1), which were taken the minimum 6.2 fruits per cluster. The maximum 6.8 fruit set per cluster were recorded in NS-4266 and Punjab Swarna, whereas the minimum 6.4 fruits per cluster were recorded in cultivar Punjab Sartaj.

The interaction between cultivars and growing media (P x M) shows the results that predicts the impact of growing media and tomato cultivars interaction with respect of fruits per cluster were not significant. Inden and Torres (2014) studied the performance of tomato plants grown on a variety of media, including rockwool (R), perlites: carbonised rice husks (PCRH), Cyprus bark (CB), coconut coir (CC) and coconut dust (CD). The CD treatment produced the most fruits per cluster and had the maximum productivity, followed by PCRH treatment.

Table 4.6Effect of growing Media on number of fruits / cluster of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	6.0	6.5	6.6	6.7	6.9	7.0	**6.6 ^{ab}**
P2 - US-2853	6.5	6.4	6.6	6.7	6.8	6.9	**6.6 ^{ab}**
P3 - NS-4266	6.3	6.6	6.7	6.9	7.0	7.1	**6.8 ^{a}**
P4 - Punjab Gaurav	6.1	6.4	6.5	6.6	6.7	6.9	**6.5 ^{b}**
P5 - Punjab Sartaj	6.0	6.3	6.4	6.6	6.7	6.8	**6.4 ^{b}**
P6 - Punjab Swarna	6.6	6.9	6.7	7.0	7.0	6.9	**6.8 ^{a}**
Mean M	**6.2 ^{c}**	**6.5 ^{b}**	**6.6 ^{b}**	**6.7 ^{ab}**	**6.8 ^{ab}**	**6.9 ^{a}**	
*At CD **(0.05) -** Factor (P) = 0.249 , Factor (M) = 0.249, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

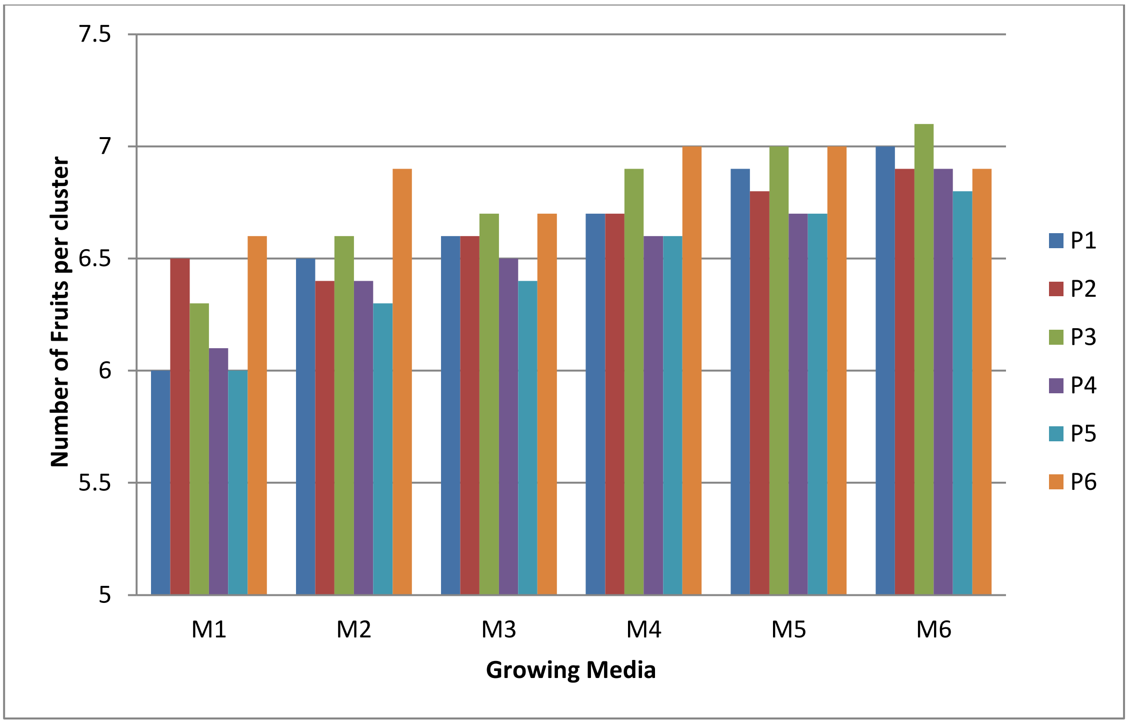

Fig 4.6 Effect of growing Media on number of fruits per cluster of tomato cultivars

4.1.2.2 Cluster per plant

The data presented in Table 4.7 and Fig 4.7 revealed that the fruits per cluster significantly affected by the different cultivars and varied growing media. However the interaction between cultivars and growing media (P x M) was not significantly affected the fruits per cluster.

The data for the different growing media demonstrated that the maximum 11.3 clusters per plant were recorded in media M-3 having cocopeat + vermicompost (2:1, v/v), whereas the minimum 10.7 clusters per plant were recorded under control media (M-1). The tomato cultivar US-2853 was recorded the maximum 11.5 clusters per plant, however NS-4266 cultivar is at par with the check cultivar. The minimum 10.1 clusters per plant were recorded in Punjab Swarna cultivar.

These findings are consistent with Hashemimajd *et al*., (2004) studied the effect of different proportions of vermicompost prepared from raw dairy manure (RDM) used for making pot volume in compost produced from different growing media on tomato growth. Study found that cluster per plant and fruits production was better than soil added with sand and raw dairy manure in terms of biomass production used as controlled media.

Table 4.7Effect of growing media on number of cluster /plant of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	11.1	11.7	12.0	11.6	11.4	11.4	**11.5 [a]**
P2 - US-2853	11.3	11.8	11.9	11.6	11.4	11.5	**11.6 [a]**
P3 - NS-4266	11.1	11.4	11.4	11.3	12.0	11.6	**11.5 [a]**
P4 - Punjab Gaurav	10.3	10.9	10.7	10.6	10.4	11.3	**10.7 [b]**
P5 - Punjab Sartaj	10.4	11.0	11.4	10.8	10.7	10.5	**10.8 [b]**
P6 - Punjab Swarna	9.8	10.3	10.4	10.2	10.0	9.9	**10.1 [c]**
Mean M	**10.7 [b]**	**11.2 [a]**	**11.3 [a]**	**11.0 [a]**	**11.0 [a]**	**11.0 [a]**	
*At CD **(0.05) -** Factor (P) = 0.326 , Factor (M) = 0.326, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

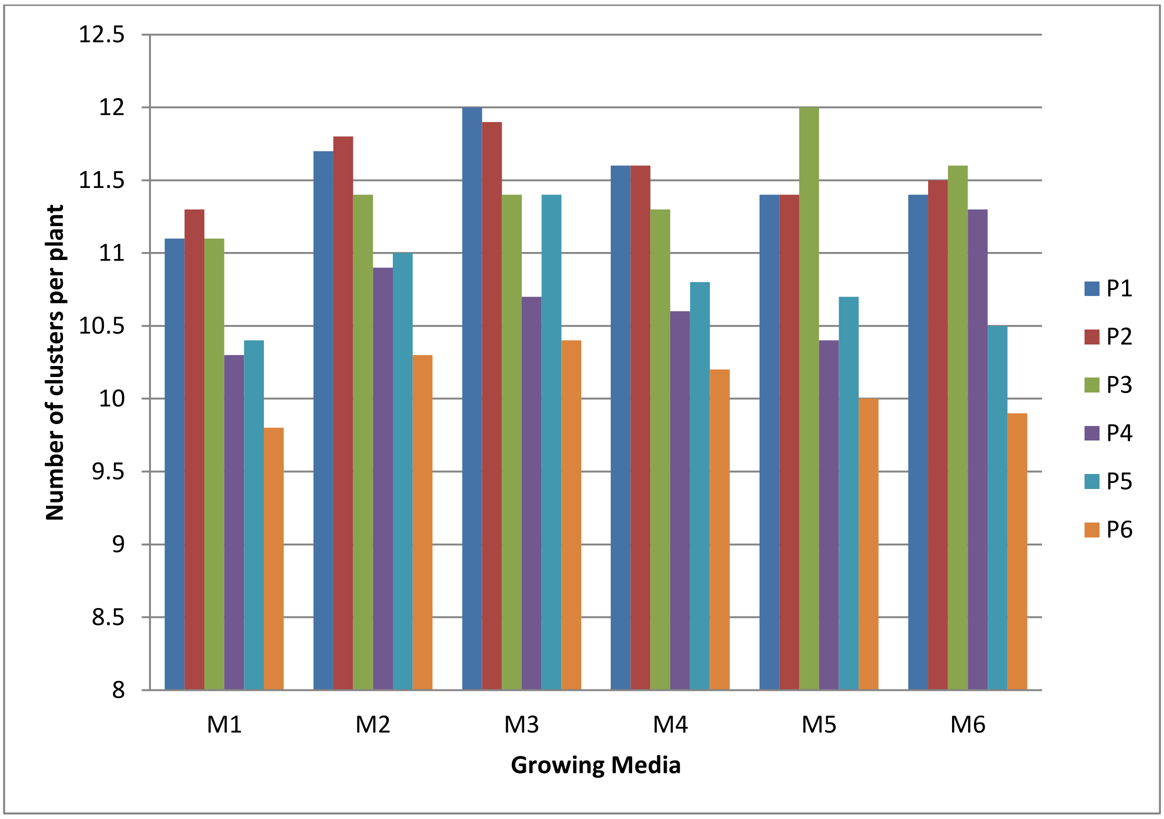

Fig 4.7 Effect of growing media on number of cluster / plant of tomato cultivars

4.1.2.3 Days to first harvest

The days taken to first harvest shown statistically significantly results with the different cultivars and varied growing media treatments as presented in Table 4.8 and Fig 4.8. However, the interaction between cultivars and growing media (P x M) were not significantly affected the days taken to first harvest.

The data for the different growing media presented that the maximum 104.6 days taken to first harvest were recorded under M-2 media with cocopeat, whereas the minimum 101.8 days taken to first harvest were recorded in M-5 media. The maximum 117days taken to first harvest was recorded in cultivars Punjab Swarna, whereas the cultivars P-3 and P-2 took minimum 90.2 and 89.2 days to first harvest, respectively as compare to check cultivar. The cultivar P-4, P-5 and P-6 were at par with days to first harvest.

Similar results were also presented by Jindal and Dhaliwal (2018) that studied tomato varieties for natural ventilated polyhouses and found that Punjab Sartaj give early first harvest of fruits in comparison to other tomato cultivars Punjab Gaurav and Punjab Swarna, G-600, and Heemshikhar.

Table 4.8 Effect of growing media on days to first harvest of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	90.3	91.0	89.0	90.0	89.0	88.7	**89.7**[ab]
P2 - US-2853	90.0	90.0	89.3	89.7	87.7	88.3	**89.2**[a]
P3 - NS-4266	91.0	90.7	90.0	91.0	89.0	89.3	**90.2**[b]
P4 - Punjab Gaurav	118.0	119.0	117.0	117.3	115.0	115.3	**116.9**[cd]
P5 - Punjab Sartaj	117.7	118.0	116.0	117.0	115.0	115.0	**116.4**[c]
P6 - Punjab Swarna	118.3	119.0	116.3	117.3	115.0	116.0	**117.0**[d]
Mean M	**104.2**[cd]	**104.6**[d]	**102.9**[b]	**103.7**[c]	**101.8**[a]	**102.1**[a]	
*At CD **(0.05)** , Factor (P) = 0.517 , Factor (M) = 0.517, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

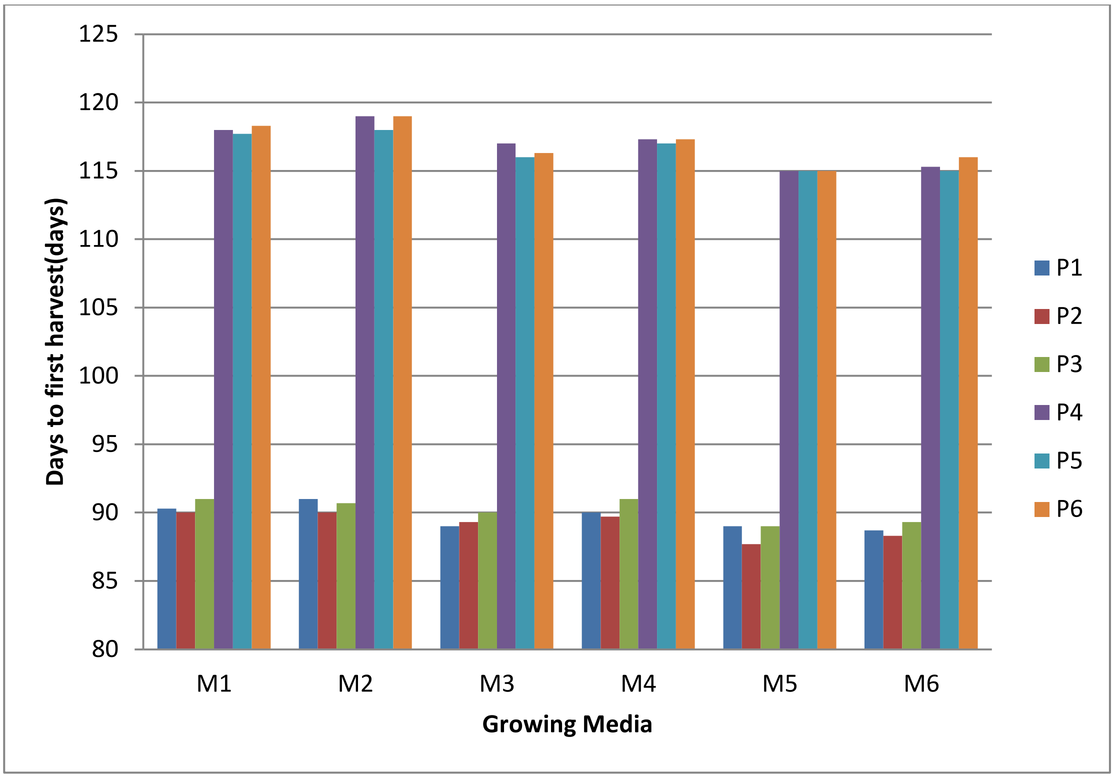

Fig 4.8 Effect of growing media on days to first harvest of tomato cultivar

4.1.2.4 Days to last harvest

The days taken to last harvest represent the total yield of the cultivars, the data presented in Table 4.9 and Fig 4.9 revealed that the days taken to last harvest significantly affected by the different cultivars and varied growing media. However the interaction between cultivars and growing media (P x M) was not significantly affected the days taken to last harvest.

The data for the different growing media demonstrated that the maximum 206.7 days taken to last harvest were recorded in control media, whereas the minimum 204.3 days taken to last harvest were recorded in M-5 media. The cultivars treatment P-4 to P-6 were recorded the maximum 209 days to last harvest, whereas the minimum 201.6 and 202.3 days to last harvest were recorded in cultivars P-2 and P-3 respectively.

Similar results were reported by Jindal and Dhaliwal (2018), they investigated tomato varieties for natural ventilated polyhouses and found that Punjab Sartaj takes less days to last harvest of fruits in comparison to different cultivars of tomato, Punjab Gaurav and Punjab Swarna, G-600 and Heemshikhar.

Table 4.9 Effect of growing media on days for last harvest of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	202.7	201.7	200.3	202.3	203.0	201.0	201.8[a]
P2 - US-2853	202.7	202.3	200.3	202.3	200.3	201.3	**201.6[a]**
P3 - NS-4266	203.3	203.3	200.7	203.3	201.3	201.7	202.3[a]
P4 - Punjab Gaurav	210.3	211.3	208.3	209.7	207.0	207.3	**209.0[b]**
P5 - Punjab Sartaj	210.0	210.3	208.3	209.3	207.0	207.3	208.7[b]
P6 - Punjab Swarna	211.0	209.7	209.3	208.0	207.3	208.7	**209.0[b]**
Mean M	**206.7[c]**	206.4[bc]	204.6[a]	205.8[b]	**204.3[a]**	204.6[a]	
*At CD **(0.05)** , Factor (P) = 0.872 , Factor (M) = 0.872, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

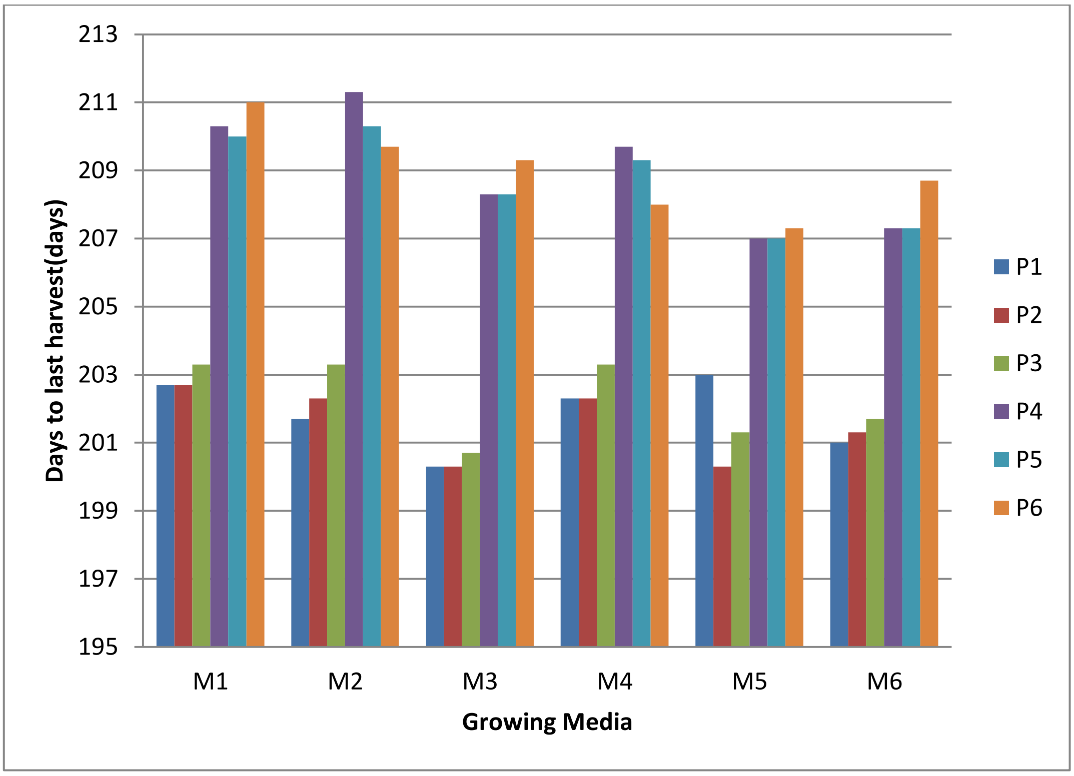

Fig 4.9 Effect of growing media on days for last harvest of tomato cultivars

4.1.2.5 Fruits per plant

It is evident from the data presented in Table 4.10 and Fig 4.10 shown that the different tomato cultivars significantly improved the fruits per plant of tomato cultivars which can be represented in the table with CD value 3.65, however the different growing media and interaction between cultivars and growing media (P x M) were not significantly affected the fruits per plant.

The fruits per plant data for the different cultivars presented that the maximum 86.6 fruits per plant were recorded in NS-4266 cultivar which is at par with US-2833, whereas the minimum 68.7 fruits per plant were recorded cultivar Punjab Sartaj. So, the results predict that cultivars NS-4266 (P-3) was recorded maximum fruits per plant among all the cultivar treatments. The maximum 79.6 fruits per plant was recorded in M-6 media comprising of cocopeat + vermiculite+ perlite (6:1:1, v/v), whereas the minimum 76.2 fruits per plant were recorded in control media (M-1).

In the case of tomato crop, similar results were observed by many scientists and correlate by Helyes *et al*., (2012) that selection of cultivar is very important for getting the maximum number of fruits per plant.

Table 4.10Effect of growing media on number of fruits / plant of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	82.0	83.3	88.0	85.0	88.7	82.7	**84.9^{a}**
P2 - US-2853	88.7	84.7	89.7	82.7	84.0	87.7	**86.2^{a}**
P3 - NS-4266	84.0	86.7	89.7	87.0	87.3	84.7	**86.6^{a}**
P4 - Punjab Gaurav	68.7	69.0	70.3	70.0	69.3	69.0	**69.4^{b}**
P5 - Punjab Sartaj	67.0	68.3	69.3	70.0	69.0	68.3	**68.7^{b}**
P6 - Punjab Swarna	66.7	68.7	70.7	70.0	69.0	68.3	**68.9^{b}**
Mean M	**76.2**	**76.8**	**79.6**	**77.4**	**77.9**	**76.8**	
*At CD **(0.05) -** Factor (P) = 3.658 , Factor (M) = NS, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

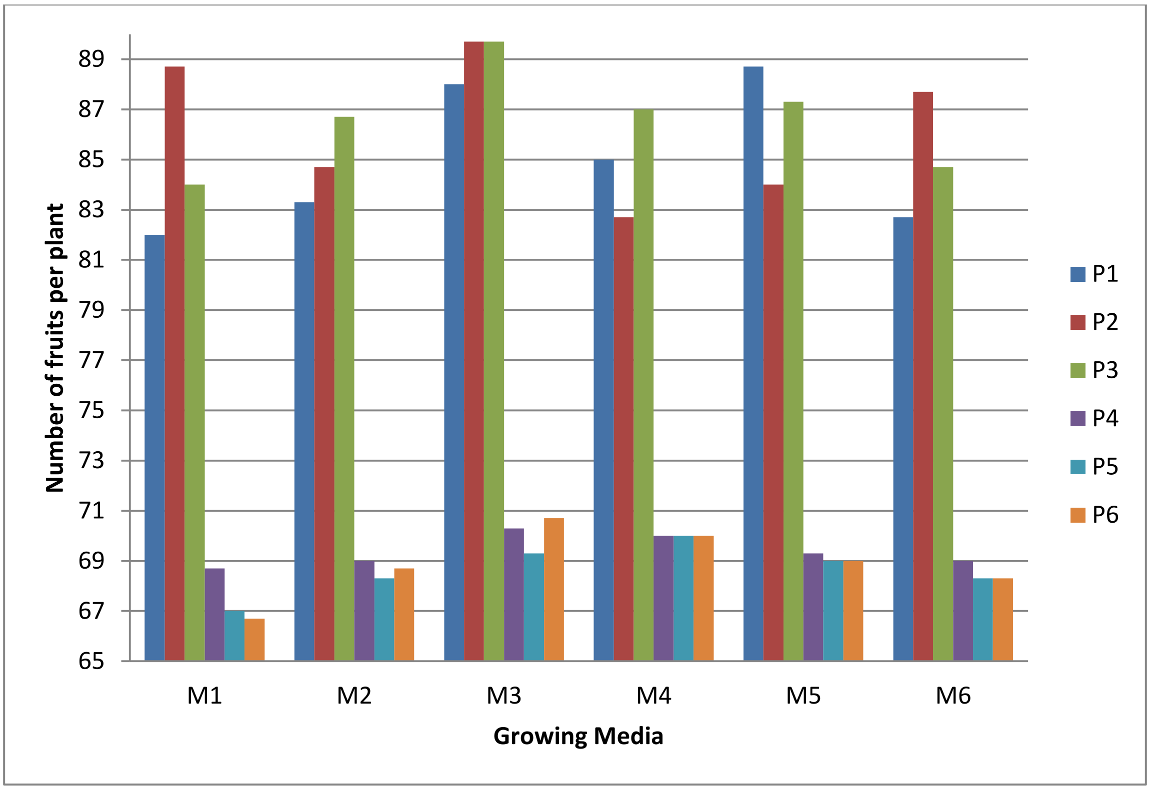

Fig 4.10 Effect of growing media on number of fruits / plant of tomato cultivars

4.1.2.6 Average Fruit weight (g)

A review of the data presented in Table 4.11 and Fig 4.11 revealed that the different cultivars and various growing media were significantly affected the average fruit weight over both years, whereas the different growing media and interaction between cultivars and growing media (P x M) were not significantly affected the average fruit weight.

The data for the different growing media demonstrated that the maximum 61g average fruit weight was recorded in the growing media (M-5) cocopeat + vermiculite+ perlite (3:1:1, v/v), whereas the minimum 58.2g average fruit weight was recorded in control growing media (M-1). The NS-4266 cultivar was recorded with the maximum 61.9 g average fruit weight, whereas the minimum 58.1 g average fruit weight was recorded in Punjab Gourav cultivar.

These findings were consistent with Truong and Wang (2015) studied that adding vermicompost to the medium increased average fruit weight, when compared to the control growing media without vermicompost.

Table 4.11 Effect of growing media on average fruit weight of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	59.1	59.6	61.7	60.7	62.7	60.6	**60.7[b]**
P2 - US-2853	59.6	59.6	61.8	59.6	61.4	60.3	**60.4[b]**
P3 - NS-4266	60.0	60.2	**63.3**	63.0	62.3	62.8	**61.9[a]**
P4 - Punjab Gaurav	57.2	58.3	58.8	58.6	59.1	**56.8**	**58.1[c]**
P5 - Punjab Sartaj	57.0	59.0	58.9	59.5	60.5	60.4	**59.2[c]**
P6 - Punjab Swarna	56.5	58.6	59.5	60.3	59.9	59.6	**59.1[c]**
Mean M	**58.2[cb]**	**59.2[b]**	**60.7[a]**	**60.3[ab]**	**61.0[a]**	**60.1[ab]**	
*At CD **(0.05)** , Factor (P) = 1.126 , Factor (M) = 1.126, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

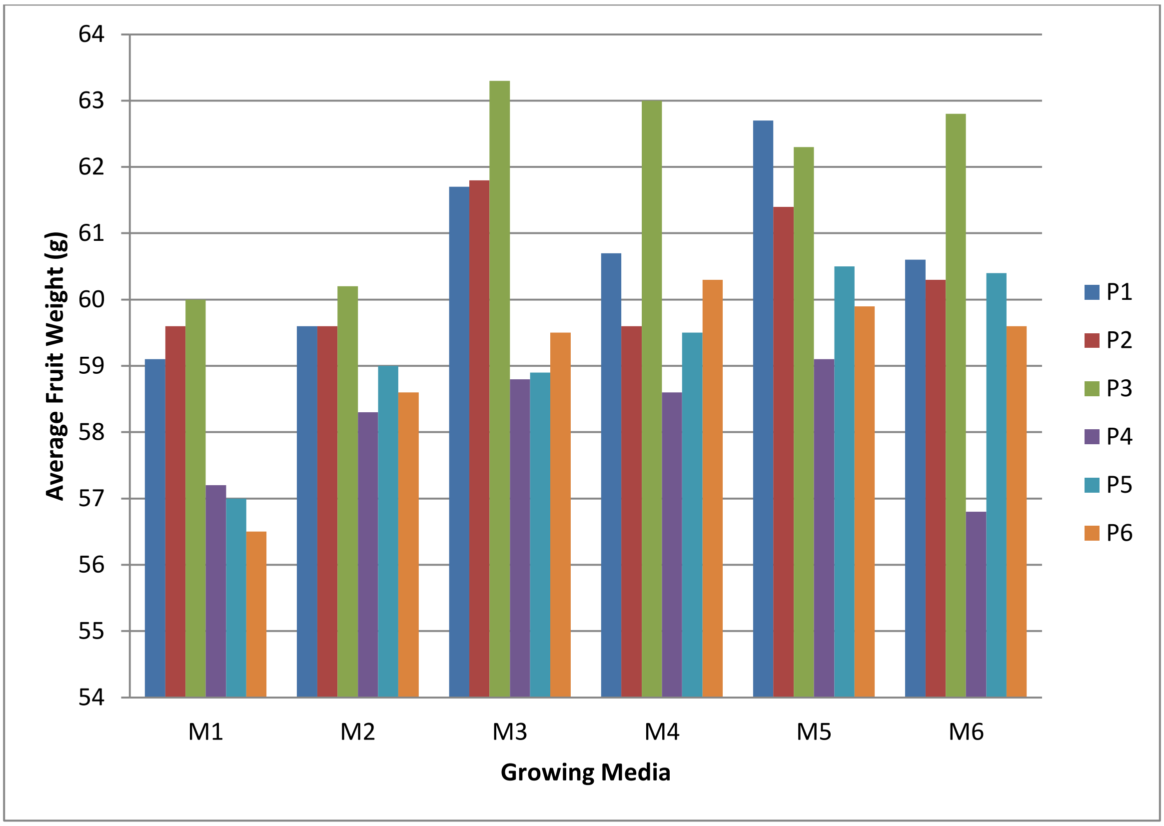

Fig 4.11 Effect of growing media on average fruit weight of tomato cultivars

4.1.2.7 Locules per fruit

The data presented in Table 4.12 and Fig 4.13 revealed that the number of locules per fruits was significantly affected by the different cultivars. However the different growing media and interaction between cultivars and growing media (P x M) was not significantly affected the number of locules per fruits.

The data for the different growing media presented that the maximum 3.3 locules per fruits were recorded in cultivar P-5 (Punjab Sartaj) with as compare to check cultivar P-1, however the minimum 2.4 locules per fruits were recorded in case of P-2 cultivar (US-2853).

The number of locule per fruit is maximum 3.4 were recorded in the interaction between cultivars and growing media treatment of (P-5, M-3) and (P-5, M-5), whereas the minimum 2.3 locule per fruit in case of (P-2, M-1) and (P-2, M-4). Similar results were reported by Jindal and Dhaliwal (2018), in his study they investigated tomato varieties for natural ventilated polyhouses and found that Punjab Gaurav taken less number of locules per fruit in comparison to Punjab Sartaj and Punjab Swarna, G-600, and Heemshikhar, also shown with Fig 4.12.

Fig 4.12 Number of locules per fruit of different tomato cultivars

Table 4.12Effect of growing media on number of locules / fruit of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	2.7	2.8	2.9	2.8	2.8	2.7	**2.8[d]**
P2 - US-2853	2.3	2.4	2.5	2.3	2.6	2.5	**2.4[f]**
P3 - NS-4266	2.9	2.8	2.9	2.9	2.9	2.9	**2.9[c]**
P4 - Punjab Gaurav	2.5	2.5	2.6	2.5	2.5	2.5	**2.5[e]**
P5 - Punjab Sartaj	3.2	3.2	3.4	3.3	3.4	3.2	**3.3[a]**
P6 - Punjab Swarna	3.0	3.0	2.9	2.9	3.0	3.0	**3.0[b]**
Mean M	**2.8**	**2.8**	**2.9**	**2.8**	**2.9**	**2.8**	
*At CD **(0.05) -** Factor (P) = 0.099 , Factor (M) = NS, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

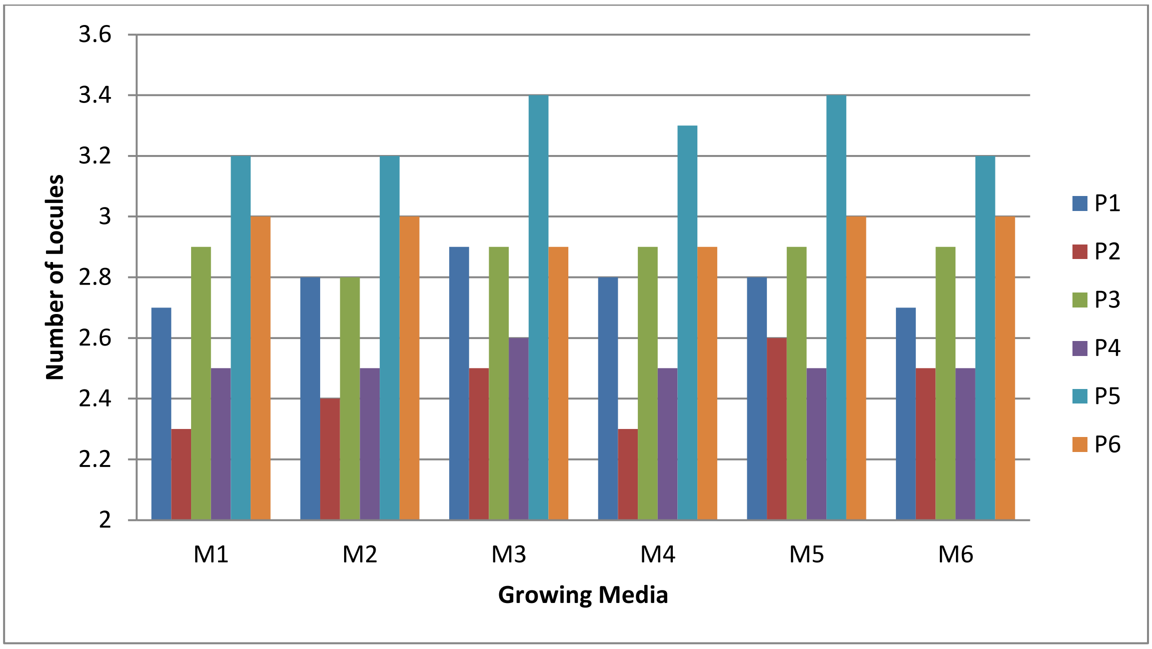

Fig 4.13 Effect of growing media on number of locules / fruit of tomato cultivars

4.1.2.8 Fruit diameter (cm)

It is evident from the data presented in Table 4.13 and Fig 4.14 demonstrated that the different tomato cultivars and varied growing media significantly improved the fruits diameter of tomato cultivars. The interaction between cultivars and growing media (P x M) was also significantly affected the fruits diameter for tomato cultivars.

The data presented the effect of growing media and cultivars on the fruit diameter of tomato that the maximum 7.0 cm fruit diameter was recorded in media treatment (M-3) cocopeat + vermicompost (2:1, v/v) and (M-4) cocopeat + vermicompost (3:1, v/v) which was statistically significant than all other treatments, whereas the control media treatment using only soil as the growing media (M-1) was recorded the minimum 6.2 cm fruit diameter. The maximum 7.4 cm fruit diameter was recorded under Punjab Swarna cultivar, however, the minimum 6.5 cm fruit diameter was recorded in Punjab Gaurav as compare to the check cultivar. This results shows that fruit diameter was likewise affected by cultivar selection.

The data demonstrated the interaction between cultivars and growing media (P x M) that the Punjab Sartaj cultivar grown with growing media cocopeat + vermicompost (2:1, v/v) with treatment (P-5,M-3) was recorded the maximum 7.8 cm fruit diameter, which was statistically significant compared to all other treatments. Whereas the minimum 6.0 cm fruit diameter was recorded in treatment (P-4, M-1) with Punjab Gaurav cultivar grown in cocopeat + vermicompost (3:1, v/v) as compare to others tretments. Lee *et al*., (2007) also recorded the comparable results in red bell pepper. Nagaraj *et al*., (2017) studied different growing media for growth and production of capsicum and found that the growing media cocopeat + vermicompost was recorded the maximum fruit diameter than only cocopeat.

Table 4.13 Effect of growing media on fruit diameter (cm) of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	6.1	6.4	6.9	6.7	6.8	6.6	**6.6^{c}**
P2 - US-2853	6.1	6.4	6.7	6.8	6.5	6.6	**6.5^{d}**
P3 - NS-4266	6.3	6.6	7.1	6.9	6.8	6.7	**6.7^{b}**
P4 - Punjab Gaurav	6.0	6.3	6.7	6.8	6.4	6.6	**6.5^{d}**
P5 - Punjab Sartaj	6.5	7.3	7.8	7.7	7.5	7.6	**7.4^{a}**
P6 - Punjab Swarna	6.1	6.4	6.7	6.8	6.5	6.5	**6.5^{d}**
Mean M	**6.2^{d}**	**6.6^{c}**	**7.0^{a}**	**7.0^{a}**	**6.8^{b}**	**6.8^{b}**	
*At CD **(0.05) -** Factor (P) = 0.42 , Factor (M) = 0.42, Factor (P × M) = 0.102							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

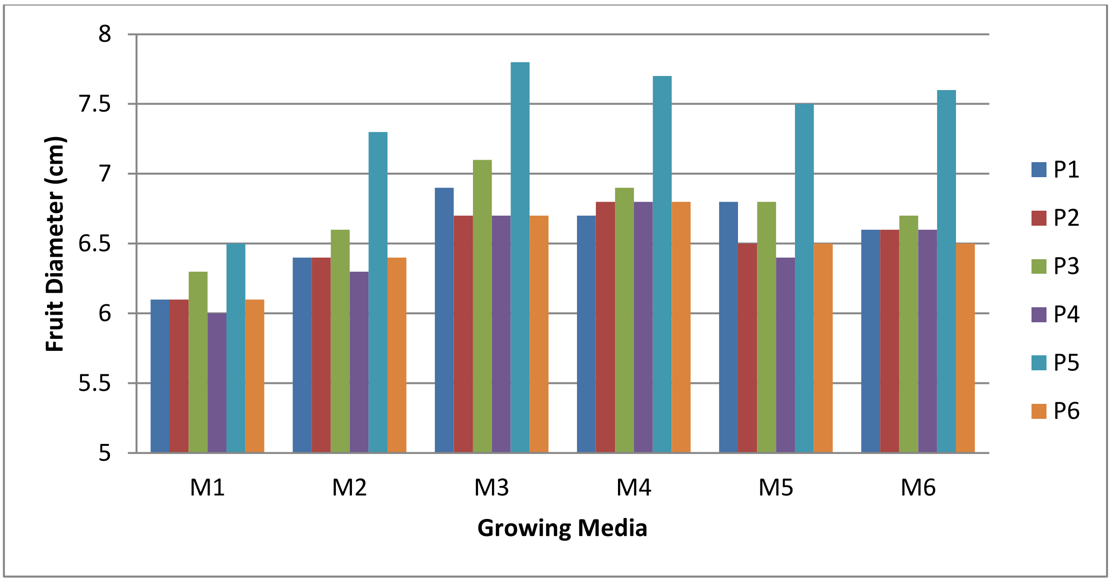

Fig 4.14 Effect of growing media on fruit diameter (cm) of tomato cultivars

4.1.2.9 Yield per plant (Kg)

The results on the influence of different tomato cultivars and varying growing media was significantly effect on fruit yield per plant in both years as presented in Table 4.14 and Fig 4.15. The interaction between cultivars and growing media (P x M) was also significantly affected the fruit yield per plant for tomato cultivars.

The data presented the effect of growing media and cultivars that the maximum 5.65 kg yield per plant was recorded under growing media (M-3) cocopeat + vermicompost (2:1, v/v) and (M-4) cocopeat + vermicompost (3:1, v/v), which were statistically significant over control and all other treatments, whereas the minimum 5.08 kg yield per plant was recorded the treatment using only soil (M-1). There was a considerable variation in total yield per plant between cultivar treatments, the NS-4266 cultivar was recorded the maximum 5.90 kg per plant total yield, however cultivar Punjab Sartaj (P-5) was recorded the minimum 5.25 kg yield per plant.

In the interaction between cultivars and growing media (P x M) demonstrated that the NS-4266 cultivar grown in cocopeat + vermicompost (2:1, v/v) growing media treatment (P-3,M-3) was recorded the maximum 6.08 kg total yield per plant, which was statistically significant over all other treatments, while the treatment (P-5, M-1) Punjab Sartaj grown in Control media was recorded the minimum 4.88 kg total yield per plant. Similar findings with higher yield of tomato per plant were recorded in media enriched with vermicompost, indicating that controlled liberalisation and balanced delivery of nutrients favoured crop growth by Zhang and He (2005); and Sharma *et al*., (2009). Increased flowering, fruit set, and matured fruits can all be attributed to stronger and healthier plants. Borji *et al*., (2010) reported similar results in tomato Perlite medium produced the highest fruit yield (4.19 kg/plant), while Palmpeat + perlite media produced the lowest (3.25 kg/plant). Spehia *et al*., (2020), Mehta *et al*., (2022) and Mamta *et al*., (2022) also found similar results for yield and growth contributing parameters of tomato.

Table 4.14 Effect of growing media on total yield /plant (kg) of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	4.90	5.24	5.60	5.85	5.42	5.31	**5.39^{b}**
P2 - US-2853	5.17	5.26	5.57	5.55	5.20	5.45	**5.37^{bc}**
P3 - NS-4266	5.41	5.80	6.08	6.00	6.07	6.02	**5.90^{a}**
P4 - Punjab Gaurav	5.08	5.28	5.32	5.41	5.34	5.46	**5.32^{bc}**
P5 - Punjab Sartaj	4.88	5.15	5.61	5.34	5.22	5.30	**5.25^{c}**
P6 - Punjab Swarna	5.02	5.31	5.71	5.30	5.55	5.44	**5.39^{b}**
Mean M	**5.08^{d}**	**5.34^{c}**	**5.65^{a}**	**5.58^{ab}**	**5.47^{bc}**	**5.50^{b}**	
*At CD **(0.05) -** Factor (P) = 0.13 , Factor (M) = 0.13, Factor (P × M) = 0.24							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

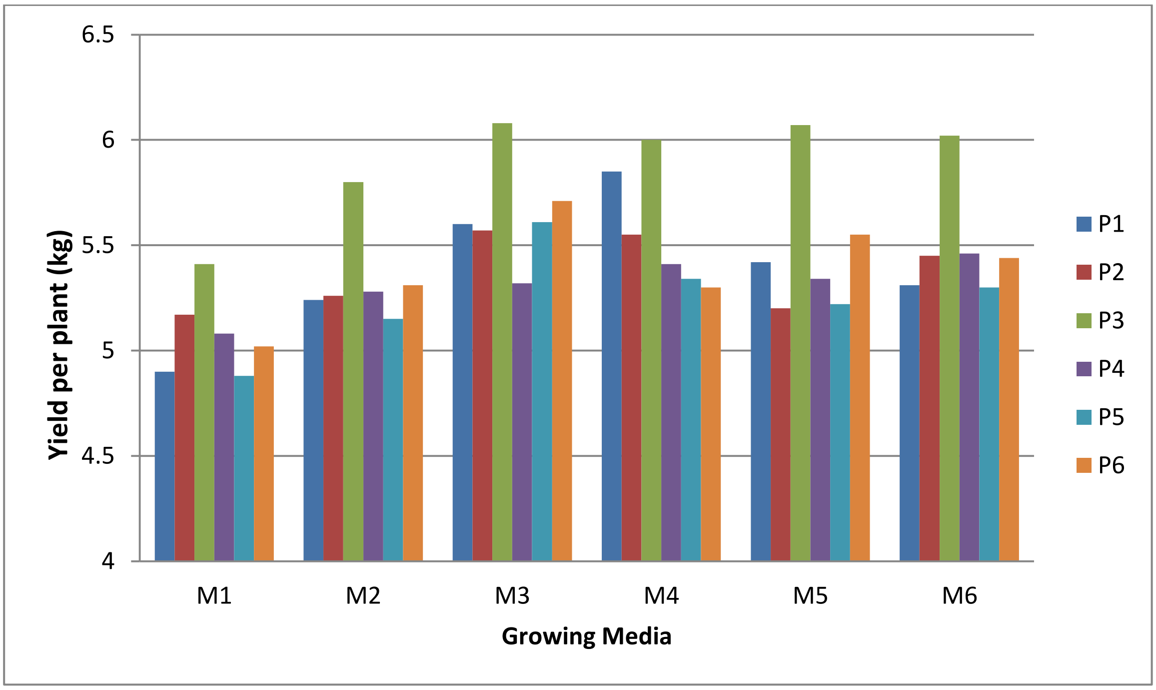

Fig 4.15 Effect of growing media on total yield /plant (Kg) of tomato cultivars

4.1.2.10 Total Yield (T/ Ha.)

It is evident from the data presented in Table 4.15 and Fig 4.16 shown that the different tomato cultivars significantly improved the total yield per hectare of tomato cultivars. The interaction between cultivars and growing media (P x M) was also significantly affected the total yield per hectare for tomato cultivars.

The data for the different growing media presented that the maximum 141 ton per hectare total yield was recorded under the media (M-3) cocopeat + vermicompost (2:1, v/v) as compared to control media which was statistically significant than all other treatments, whereas the minimum 127 ton per hectare total yield was recorded in the control media treatment (M-1). There was a substantial difference in total yield per hectare between different cultivar treatments. The maximum 147 ton per hectare total yield was recorded with cultivar NS-4266; however Punjab Sartaj (P-5) cultivar was recorded the minimum 131 ton per hectare total yield.

The data presenting interaction between cultivars and growing media (P x M) that the maximum 152.0 tonn per hectare total yield was recorded under NS-4266 cultivar with growing media cocopeat + vermicompost (2:1, v/v) with treatment (P-3, M-3) and cocopeat + vermiculite + perlite (3:1:1, v/v) with treatment (P-3, M-5) being statistically significant over all other treatments, while the treatment Punjab Sartaj grown with control media (P-5,M-1) was recorded the minimum 122.0 tonn per hectare total yield. Singh K. G and Singh A (2021), Spehia *et al*., (2020) and Sharma *et al*., (2009) all reported increased tomato yield per hectare in media enriched with vermicompost)

Table4.15 Effect of growing media on total yield/hectare (tonns)of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	123	131	140	146	136	133	135 ^{b}
P2 - US-2853	129	132	139	139	130	136	134 ^{bc}
P3 - NS-4266	135	145	**152**	150	**152**	151	147 ^{a}
P4 - Punjab Gaurav	127	132	133	135	134	136	133 ^{bc}
P5 - Punjab Sartaj	122	129	140	134	130	133	131 ^{c}
P6 - Punjab Swarna	125	133	143	133	139	136	135 ^{b}
P1- HeemShikhar	127 ^{d}	133 ^{c}	141 ^{a}	139 ^{ab}	137 ^{b}	137 ^{b}	
*At CD **(0.05),** Factor (P) = 3.236, Factor (M) = 3.236, Factor (P × M) = 1.6							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

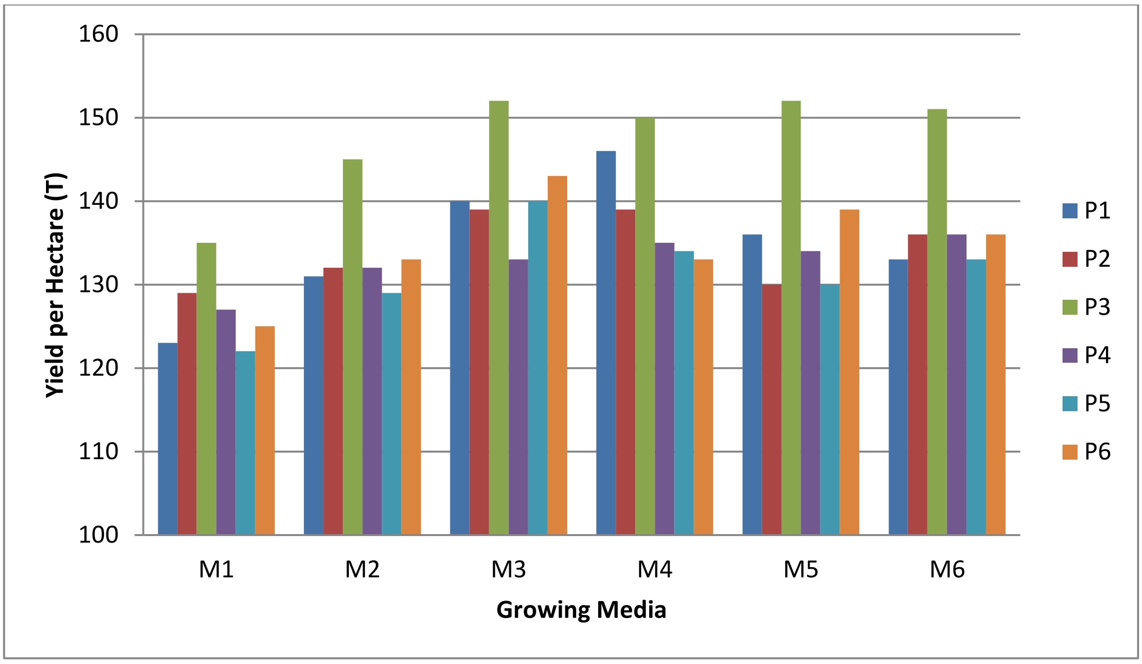

Fig 4.16 Effect of growing media on total yield per hectare of tomato cultivars

4.1.3 Effect of growing media on the fruit quality parameters

The observations regarding fruit quality parameters were recorded on each cultivar cultivated in each growing media as per the treatments with each replication on all five plants chosen at random. Under each replication, the average values were calculated as a treatment mean. Below are the details results and discussion as per the different quality parameters.

4.1.3.1 Total Soluble Solid (°Brix)

The data presented in Table 4.16 and Fig 4.17 revealed that the TSS significantly affected by the different cultivars and varied growing media in both years. However the interaction between cultivars and growing media (P x M) was not significantly affected the TSS of the tomato fruits.

The data for the different growing media presented that the maximum 4.8 ^{o}Brix TSS in tomato fruits was recorded under growing media (M-2) with cocopeat and (M-3) with cocopeat + vermicompost (2:1, v/v), whereas the minimum 4.6 ^{o}Brix TSS in tomato fruits was recorded in control media (M-1). The tomato cultivar NS-4266 (P-3) is best cultivars with fruit quality parameters, was recorded the maximum 5.5 ^{o}Brix TSS in fruits as compare to check cultivar, however the cultivar Punjab Swarna (P-5) was recorded the minimum 3.9 ^{o}Brix TSS in fruits.

The interaction between cultivars and growing media (P x M) was recorded the maximum TSS 5.6 °Brix with cultivar P-3 and growing media (M-3) under treatment with cocopeat + vermicompost (2:1, v/v) with combination treatments (P-3, M-3) as compare to all other treatments, however treatment with cultivar P-6 with control growing media M-1 having soil only (P-6, M-1) was recorded the minimum 3.8 °Brix TSS in the tomato fruits

Different growing media with the same nutritional composition had no significant effect on tomato fruit quality, according to Gul and Sevgican (1992). According to Ghehsareh *et al*., (2011a), medium containing a combination of cocopeat had greater TSS than cocopeat alone. High TSS concentration has also been recorded by Llaven *et al*., (2008) and Abduli *et al*., (2013) due to the addition of Vermicompost. Olle (2012), Lari *et al*., (2014), Gungor and Yildirim (2013) all reported similar findings.

Table 4.16 Effect of growing media on Total soluble Solids (°Brix) in tomato fruits

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	4.3	4.3	4.4	4.4	4.4	4.4	**4.4^{d}**
P2 - US-2853	3.9	4.4	4.5	4.4	4.3	4.4	**4.3^{d}**
P3 - NS-4266	5.4	5.5	**5.6**	5.4	5.5	5.4	**5.5^{a}**
P4 - Punjab Gaurav	4.5	5.0	4.7	4.6	4.9	4.7	**4.7^{c}**
P5 - Punjab Sartaj	5.3	5.4	5.3	5.3	5.3	5.3	**5.3^{b}**
P6 - Punjab Swarna	3.8	4.0	4.0	4.0	3.9	3.9	**3.9^{e}**
Mean M	**4.6^{b}**	**4.8^{a}**	**4.8^{a}**	**4.7^{ab}**	**4.7^{ab}**	**4.7^{ab}**	
*At CD **(0.05) -** Factor (P) = 0.117, Factor (M) = 0.117, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

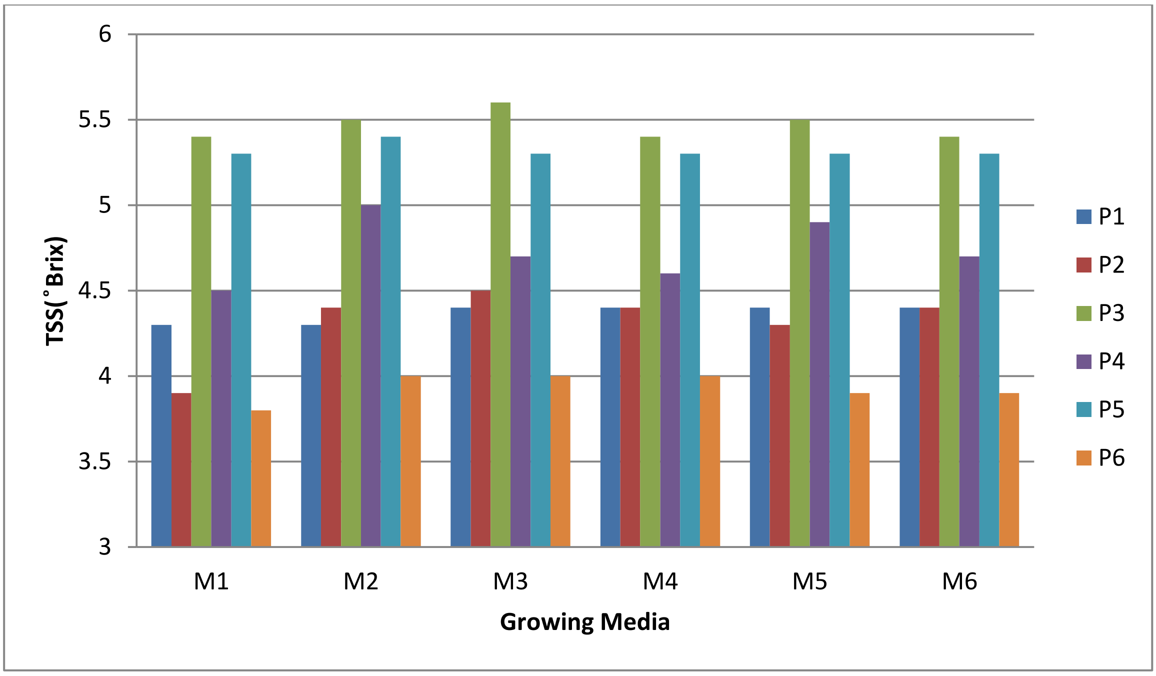

Fig 4.17 Effect of growing media on Total soluble Solids (°Brix) of tomato cultivar

4.1.3.2Titratable acidity in fruits (%)

There was significant effect of different tomato cultivars and different growing media on acidity in tomato fruits during both years as presented in Table 4.17 and Fig 4.18, However the interaction between cultivars and growing media (P x M) was not significantly affected the acidity of the tomato fruits.

The data for the different growing media presented that the maximum acidity 0.38 percent in tomato fruits were recorded under growing media (M-2) cocopeat only and (M-3) cocopeat + vermicompost (2:1, v/v), which was statistically significant when compared to all other treatments, However the minimum 0.36 percent acidity in fruits was recorded with control media treatment (M-1) soil only. The cultivar NS-4266 (P-3) was recorded the maximum 0.41 percent acidity in tomato fruits which was statistically significant over the check cultivar Heemshikar (P-1), whereas the minimum 0.33 percent acidity was recorded in cultivar Punjab Swarna (P-5).

The interaction between cultivars and growing media (P x M) with the maximum 0.43 percent acidity was recorded with treatment combination P-3,M-3 as compared to all other treatments, whereas treatment combination P-5, M-1 was recorded the minimum 0.31 percent acidity in fruits. Similar results recorded by Kowalczyk *et al*., (2011) and Mazur *et al*., (2012) that the titratable acidity of 'cherry' tomato fruits generated from coconut fiber and mineral wool, was 0.44-0.45 percent and 0.51-0.52 percent, respectively. Toor *et al*., (2006) discovered that the titratable acidity of 'Flavouriono' "cherry" tomato fruits was 0.45-0.55% and that of Tradiro fruits was 0.60-0.71 percent.

Table 4.17 Effect of growing media on Acidity in fruits (%) of tomato cultivar

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	0.39	0.40	0.41	0.39	0.39	0.39	**0.40[b]**
P2 - US-2853	0.34	0.36	0.37	0.36	0.35	0.34	**0.35[c]**
P3 - NS-4266	0.39	0.41	0.43	0.42	0.40	0.39	**0.41[a]**
P4 - Punjab Gaurav	0.34	0.37	0.36	0.34	0.36	0.35	**0.35[c]**
P5 - Punjab Sartaj	0.31	0.34	0.33	0.32	0.34	0.33	**0.33[d]**
P6 - Punjab Swarna	0.39	0.42	0.40	0.39	0.41	0.40	**0.40[b]**
Mean M	**0.36[c]**	**0.38[a]**	**0.38[a]**	**0.37[b]**	**0.37[b]**	**0.37[b]**	
*At CD **(0.05) -** Factor (P) = 0.009 , Factor (M) = 0.009, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

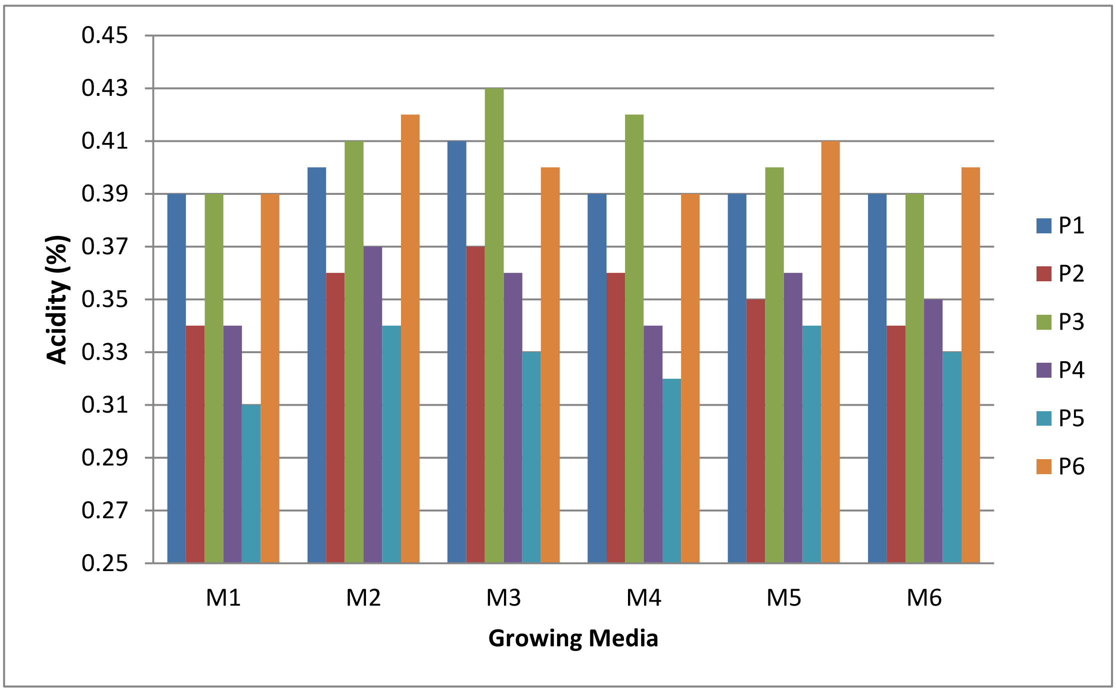

Fig 4.18 Effect of growing media on Acidity in fruits (%) of tomato cultivar

4.1.3.3 Lycopene content (mg/100g)

The data presented in Table 4.18 and Fig 4.19 revealed that the lycopene content significantly affected by the different cultivars and varied growing media in both years. The interaction between cultivars and growing media (P x M) was also significantly affected the lycopene of the tomato fruits.

The data for the different growing media presented that the maximum 4.18 mg/100g lycopene content in tomato fruits was recorded in growing media cocopeat + vermicompost (2:1, v/v) as compared to all other treatments, whereas the minimum 3.96 mg/100g lycopene content in fruits of tomato was recorded in control media (M-1). The cultivar NS-4266 (P-3) was recorded the maximum 5.01 mg/100g lycopene content in fruits as compared to all the treatments; however the minimum 1.31 mg/100g lycopene content in fruits was recorded in check cultivars (P-1).

The data for the interaction between tomato cultivars and growing media (P x M) presented that the maximum 5.04 mg/100g lycopene content was recorded with treatment P-3,M-3 and P-3,M-5 as compare to all other treatment, However the minimum 1.26 mg/100g lycopene content was recorded in Punjab Sartaj cultivar grown under control growing media with treatment combination (P-5,M-1). This could be attributed to increased nutrient availability, higher CEC, moisture retention, and a greater number of pore spaces, according to Helyes *et al*., (2012) and Olle *et al*., (2012). Alternative growing conditions with the same nutrient content showed no significant effect on the lycopene level of cherry tomatoes, according to Mazur *et al*., (2012).

Table 4.18 Effect of growing media on lycopene (mg/100g) in tomato fruits

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	4.51	4.55	4.55	4.51	4.52	4.50	**4.52^{c}**
P2 - US-2853	4.06	4.26	4.56	4.33	4.21	4.11	**4.25^{d}**
P3 - NS-4266	5.01	4.99	5.04	4.99	5.04	4.97	**5.01^{a}**
P4 - Punjab Gaurav	4.21	4.50	4.73	4.66	4.72	4.65	**4.58^{c}**
P5 - Punjab Sartaj	4.69	4.75	4.89	4.87	4.78	4.72	**4.78^{b}**
P6 - Punjab Swarna	1.26	1.32	1.31	1.31	1.32	1.31	**1.31^{e}**
Mean M	**3.96^{c}**	**4.06^{b}**	**4.18^{a}**	**4.11^{ab}**	**4.10^{b}**	**4.04**	
*At CD **(0.05) -** Factor (P) = 0.071, Factor (M) = 0.071, Factor (P × M) = 0.175							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

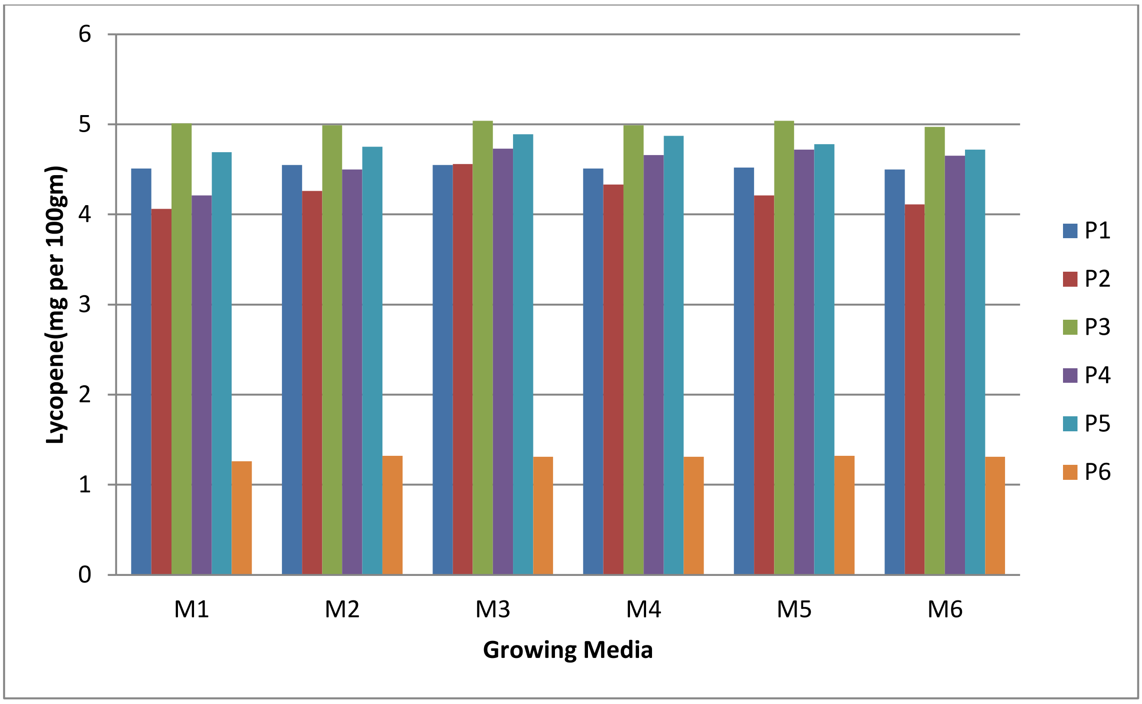

Fig 4.19 Effect of growing media on lycopene in fruits of tomato cultivars

4.1.3.4 Vitamin C (mg/ 100g)

The effects of different cultivars and growing media on vitamin C concentration were statistically significant during both years, as shown in Table 4.19 and Fig 4.20. However the interaction between cultivars and growing media (P x M) was not significantly affected the Vitamin C content of the tomato fruits.

The data for the different growing media presented that the maximum 24.6 mg/100g vitamin C content in fruits was recorded in growing media (M-3) cocopeat + vermicompost (2:1, v/v) and (M-5) cocopeat + vermicultite +Perlite (3:1:1, v/v), whereas the minimum 23.9 mg/100g vitamin C content in fruits was recorded in the control treatment (M-1) having soil only. The cultivar NS-4266 (P-3) was recorded the maximum 27.8 mg/100g vitamin C content in fruits, which was statistically significant as comparison to the check cultivar (P-1), however the minimum 18.5 mg/100g vitamin C content in fruits recorded in cultivar Punjab Swarna (P-6).

The interaction between cultivars and growing media (P x M) was recorded with maximum 28.7 mg/100g vitamin C content with treatment combination P-3,M-3 as compared to all other treatments, whereas the minimum 18.2 mg/100g vitamin C content was recorded with treatment combination (P-6, M-6). The findings are similar to those of Truong and Wang (2015) and Truong *et al.*, (2018) the vitamin C content of fruit juice increased as more vermicompost was added to the media. According to Ahmed *et al.*, (2014) and Vijitha and Mahendran (2010), observed that vitamin C content varied considerably with different irrigation treatments. Ghehsareh *et al.*, (2011a) also recorded that tomato grown in cocopeat-containing media contained less vitamin C than other media combinations.

Table 4.19 Effect of growing media on Vitamin C (mg/100g) in tomato fruits

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	26.4	27.0	27.8	27.1	27.8	27.5	27.3[a]
P2 - US-2853	26.4	27.6	27.7	27.7	27.5	27.2	27.4[a]
P3 - NS-4266	27.6	27.4	28.7	28.2	27.8	26.8	**27.8[a]**
P4 - Punjab Gaurav	20.2	21.7	20.8	21.1	22.9	22.7	21.6[c]
P5 - Punjab Sartaj	23.5	23.7	24.1	24.0	23.2	22.7	23.5[b]
P6 - Punjab Swarna	19.1	18.4	18.5	18.5	18.3	18.2	**18.5[d]**
Mean M	**23.9**	24.3	**24.6**	24.4	**24.6**	24.2	
*At CD **(0.05) -** Factor (P) = 0.966 , Factor (M) = NS, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

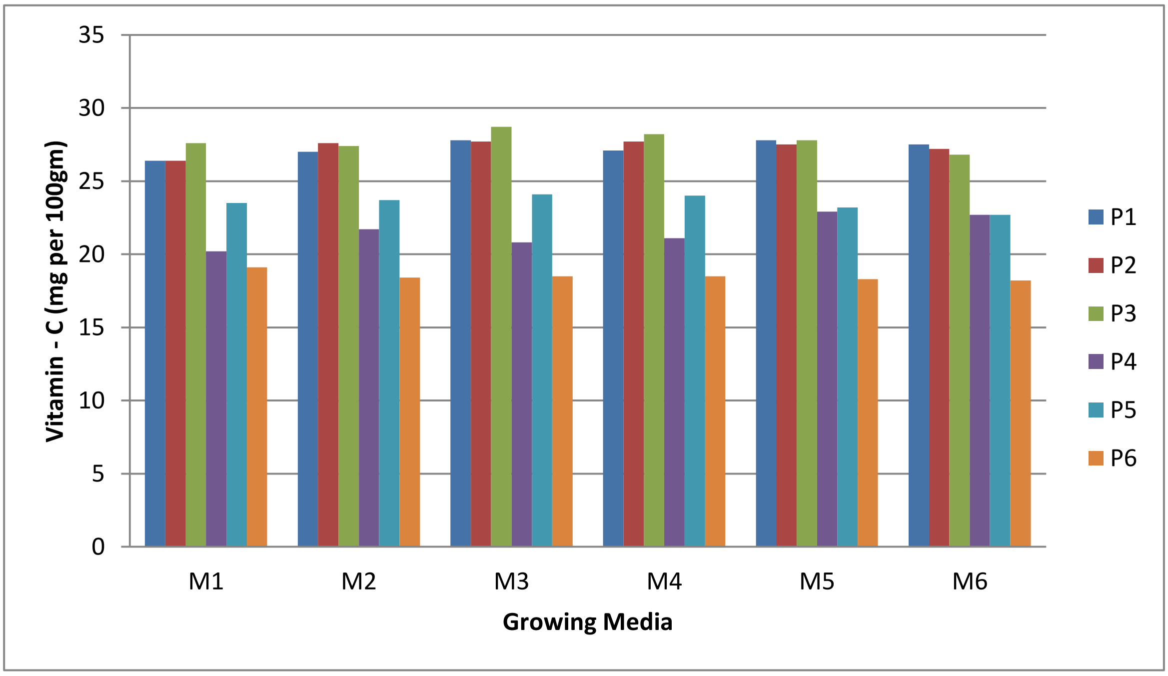

Fig 4.20 Effect of growing media on Vitamin C in fruits of tomato cultivars

4.3 Effect of growing media on economic analysis (B:C ratio) of tomato cultivars

Benefit-cost analysis of tomato production with different cultivars grown with different growing media under protected conditions was worked out to evaluate profitability and the economics was calculated at prevailing market rates as mentioned in Appendix II. The cost of the produce, the cost of cultivation, and the net return were calculated to determine the viability of growing tomatoes in a poly house with soilless medium.

It is evident from the data presented in Table 4.20 and Fig 4.21 demonstrated that the different tomato cultivar and varying growing media significantly impact the benefit cost ratio of tomato cultivars, however the interaction between cultivars and growing media (P x M) was not significantly affected the benefit cost ratio of tomato cultivars.

The treatment with the growing media (M-1) as control media of soil only was recorded the maximum 2.01 B:C ratio, followed by 1.97 B:C ratio under growing media (M-3) cocopeat + vermicompost (2:1, v/v). The treatment with the growing media (M-2) as cocopeat only was recorded with 1.85 B:C ratio, followed by growing media (M-6) cocopeat + vermiculite + perlite (6:1:1 v/v) was recorded with 1.79 B:C ratio, which was statistically significant over all other treatments of growing media. The minimum 1.74 B:C ratio was recorded under growing media M-5 with having treatment cocopeat + vermiculite + perlite (3:1:1 v/v). The tomato cultivar NS-4266 (P-3) was recorded with the maximum 2.05 B:C ratio, which was statistically significant over the check cultivar treatment (P-1) with having 1.87 B:C ratio, whoever the minimum 1.82 B:C ratio was recorded with tomato cultivar P-4 and P-5.

The interaction between tomato cultivars and growing media (P x M) was found to be non-significant, with the cultivar P-3 was recorded the maximum 2.21 B:C ratio under the soil only with control treatment M-1, followed by the growing media combination with cultivar (P-3 M-3) with media cocopeat + vermicompost (2:1, v/v) as ratio 2.12 and the treatment (P-5, M-5) was recorded the minimum (1.66).

Similar results were orbserved by Biwalkar and Jain (2014) and Saurabh *et al*., (2019), they found that growing vegetables in soilless media is a viable strategy for lowering the cost of growing vegetable crops under protected settings without sacrificing yield or fruit quality. Spehia *et al*., (2020), Subramani *et al*., (2020) and

Mehta *et al.*, (2022) found similar results that cocopeat and saw dust are both economically and environmentally sustainable media for soilless tomato cultivation because they are renewable, readily available, and easy to dispose of. The cocopeat with saw dust in a 1:1 ratio is cost-effective and yields more tomatoes than alternative media under protected conditions.

Table 4.20 Effect of growing media on Benefit: Cost ratio of tomato cultivars

Cultivar/Media	M1	M2	M3	M4	M5	M6	Mean P
P1- HeemShikhar	1.94	1.82	1.95	2.01	1.72	1.75	**1.87 [b]**
P2- US-2853	1.98	1.82	1.94	1.91	1.65	1.77	**1.85 [b]**
P3- NS-4266	2.21	2.01	2.12	2.06	1.93	1.98	**2.05 [a]**
P4- Punjab Gaurav	2.03	1.83	1.86	1.81	1.69	1.73	**1.82 [b]**
P5- Punjab Sartaj	1.93	1.78	1.96	1.84	1.66	1.73	**1.82 [b]**
P6- Punjab Swarna	1.97	1.84	1.99	1.82	1.76	1.79	**1.86 [b]**
Mean M	**2.01 [a]**	**1.85 [d]**	**1.97 [b]**	**1.91 [c]**	**1.74 [f]**	**1.79 [e]**	
*At CD **(0.05) -** Factor (P) = 0.044 , Factor (M) = 0.044, Factor (P × M) = NS							
M1= Soil only (Control), M2= Coco-peat, M3 = Coco-peat +Vermicompost (2:1), M4 = Coco-peat +Vermicompost (3:1), M5 = Cocopeat + Vermiculite + Perlite (3:1:1), M6= Coco-peat + Vermiculite + Perlite (6:1:1).							

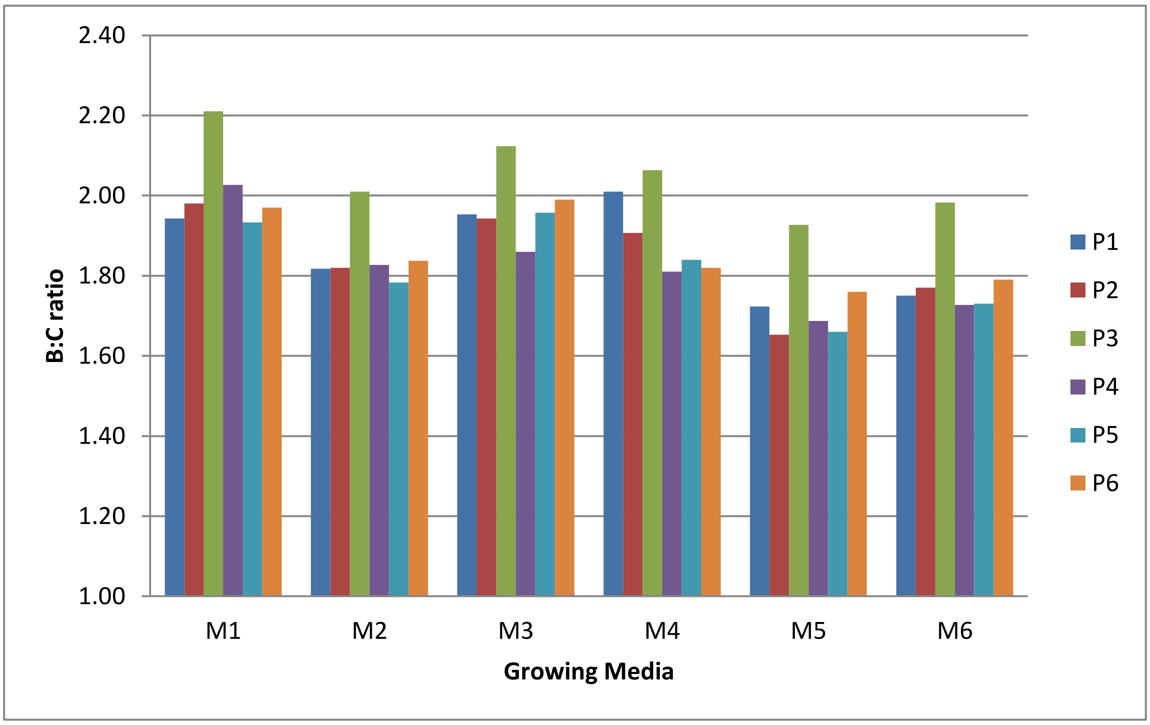

Fig 4.21 Effect of growing media on Benefit: Cost ratio of tomato cultivars

4.3 Effect of growing media on different parameters before start of experiment.

The chemical properties of media before harvesting in UV stabilised polybags in a polyhouse were examined for two years, from 2018-19 to 2019-20. Before starting the experiments, samples of the different growing media used in the experiment, such as soil as control media, cocopeat, cocopeat+Vermicompost (2:1), cocopeat+Vermicompost (3:1), cocopeat+Vermiculite+Perlite (3:1:1), and cocopeat+Vermiculite+Perlite (6:1:1), were collected from the grow bags and subjected to standard analysis for their properties, including mineral status (EC, PH and NPK). The data results in the table 4.21 presented the availability of major nutritional status under different media were analyzed as follows:

4.3.1 Effect of growing media on pH of substrate

The information on the effect of different combination growing media on pH represented in the Table 4.2 and Fig 4.22. The maximum7.5 pH was recorded with the control media M-1, which consisted of soils, followed by 7.03 pH with the media M-3, which consisted of cocopeat + vermicompost (2:1, v/v as compare to other treatments, and the minimum 6.25pH was recorded with the media M-2, which consisted only of cocopeat. Nutrient availability can be affected by high pH, making nutrients unavailable to the plant. The pH values remained around neutral in the present investigation. Voogt (2011) and Gislerod *et al.*, (1996) observed similar results in other cut flower crops, where elevated pH caused a drop in various growth and yield parameters.The pH of substrates improved with addition of compost,as it was one of the components, which was found to be near neutral. Such circumstances are usually favourable for nutrition absorption and utilisation.

4.3.2 Effect of growing media on EC of substrate

The data represents in Table 4.2 and Fig 4.23 on the effect of various combinations growth media on EC of the substate. The growing media M-1 which contains only soil was recorded the maximum0.71dS/m EC, which was considerably greater than the all other media, whereas the media M-5containing cocopeat + Vermiculite + Perlite (3:1:1) wasrecorded the minimum 0.44 dS/m EC. Nutrient availability can be affected by high EC, making nutrients unavailable to the plant. Putranta *et al*., (2019) found similar results in tomato crops, where high EC caused a decrease in various growth and yield parameters. According to standards and requirements, the EC of growing media should be less than 1 m mhos/cm for good plant growth.Such conditions are usually favourable for nutrition absorption and utilisation. Mokhtari et al. found similar results (2013).

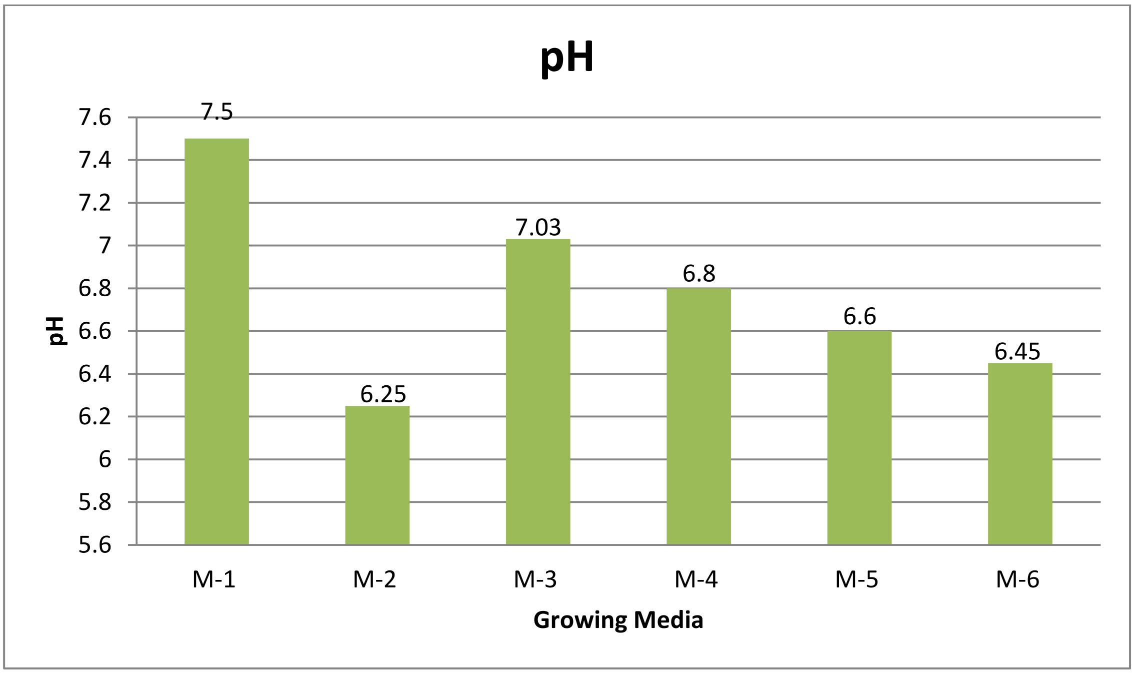

Fig 4.22 Effect of growing media on pH of substrate

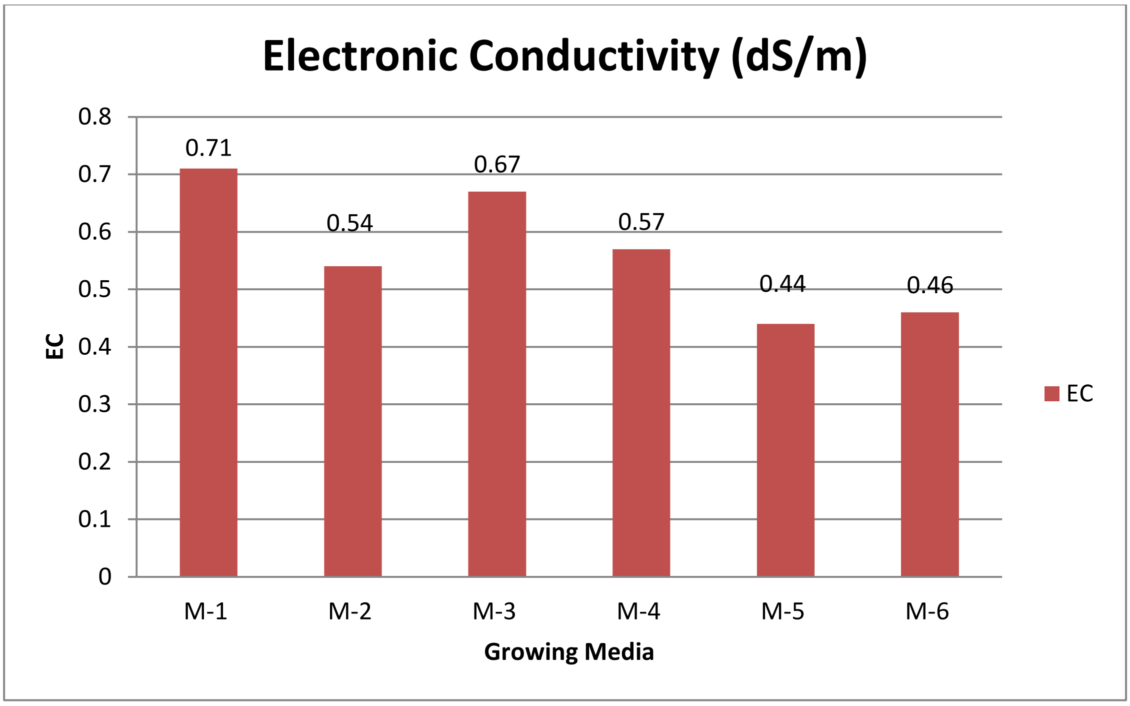

Fig 4.23 Effect of growing media on EC of substrate

Table 4.21 Ec, pH and Nutrient content of growing Medias before trial

Growing Media	M1	M2	M3	M4	M5	M6
Media Properties	**Soil as (Control)**	**Coco-peat**	**Cocopeat + Vermi-compost (2:1)**	**Cocopeat + Vermi-compost (3:1)**	**Cocopeat + Vermiculite + Perlite (3:1:1)**	**Cocopeat + Vermiculite + Perlite (6:1:1)**
pH	7.5	6.25	7.03	6.80	6.6	6.45
EC	0.67	0.54	0.71	0.57	0.44	0.46
Nitrogen (g/kg)	1.15	0.45	1.44	1.36	0.91	1.15
Phosphorus(g/kg)	0.95	0.76	1.11	0.87	0.58	0.95
Potassium(g/kg)	1.23	1.16	1.08	1.11	0.99	1.23

4.3.3 Effect of growing media on Nitrogen content of substrate

The impact of different combination growth media on nitrogen content availability was clearly evident in Table 4.2 and Fig 4.24. The media M-3 containing cocopeat + vermicompost (2:1, v/v) wasrecorded the maximum 1.44 g/kg nitrogen contentas compare to the other treatments, whereas the media M-2 containing only cocopeat wasrecorded the minimum 0.45 g/kg nitrogen content. The treatment (M-4) cocopeat + vermicompost (3:1, v/v) was recorded 1.36 g/kg nitrogen content and while the treatment (M-6) cocopeat + vermiculite + perlite (6:1:1, v/v) was recorded 0.87 g/kg nitrogen content.

4.3.4 Effect of growing media on Phosphorus content of substrate

The impact of varied combination growing media on phosphorus content availability was shown by observing the data in Table 4.2 and Fig 4.24 The media M-3, which consisted of cocopeat + vermicompost (2:1, v/v) wasrecorded the maximum 1.11 g/kg phosphorus content, which was substantially greater than all other treatments, followed bycontrol media M-1 treatment of growing media, which consisted of soil only was recorded 0.95 g/kg phosphorus content. However, the growing media M-4 cocopeat + vermicompost (3:1, v/v) treatment was recorded with 0.87 g/kg phosphorus content, which was significantly higher than all other soilless substrate treatments, whereas the minimum 0.46 g/kg phosphorus content was recorded in the media(M-6) cocopeat + vermiculite + perlite (6:1:1, v/v) treatment.

4.3.5 Effect of growing media on Potassium content of substrate

The Table 4.2 and Fig 4.24 shows that potassium concentrations in different media were measured before the start of experiment in both years. A review of the data revealed that different combinations of growth material have different effects on potassium availability. The control media M-1, which only contained soils, was recorded the maximum 1.23 g/kg potassium content, which was significantly higher than all other treatments, followed by the media M-2, which only contained cocopeat, recorded 1.16 g/kgpotassium content. However,the treatment (M-4) cocopeat + vermicompost (3:1, v/v) was recorded1.11g/kgphosphorus content, which was significantly higher than all other soilless substrate treatments, whereas the minimum 0.89 g/kg phosphorus content was recorded in the treatment (M-6) cocopeat + vermiculite + perlite (6:1:1, v/v).

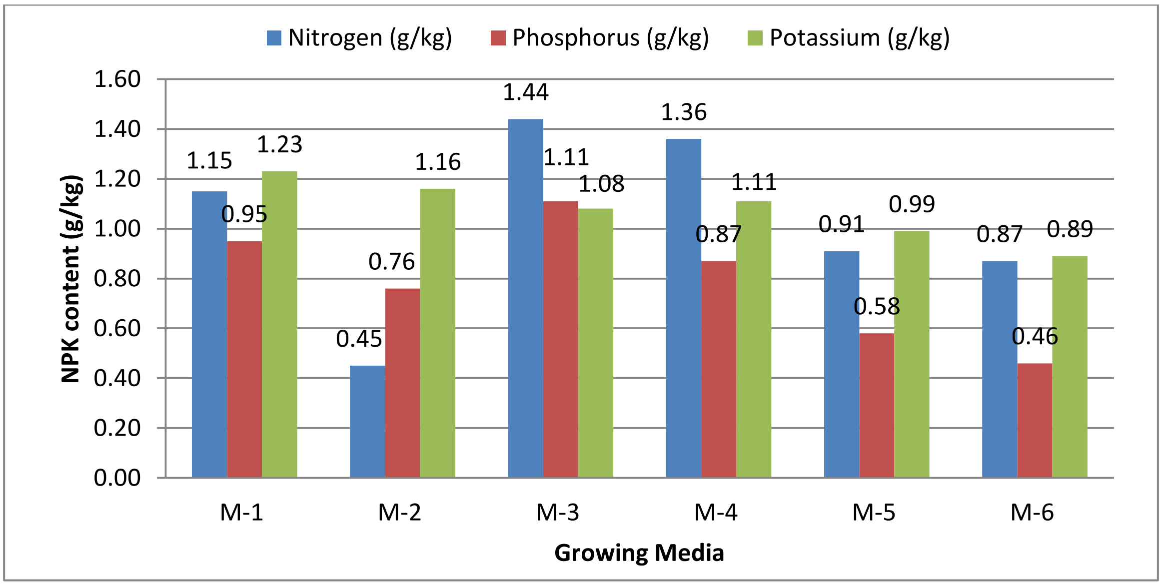

Fig 4.24 Effect of growing media on NPK of substrate

Putranta *et al*., (2019) found comparable results in tomato crops grown on a variety of medium. According to the researchers, plants grown on cocopeat + compost followed by soilrite + compost was recorded the maximum leaf nitrogen content, whereas plants cultivated on cocopeat + compost followed by cocopeat + soilrite had the highest phosphorus content. Similar findings observed by Hicklenton (1983) and Carlino *et al*., (1998) that plants cultivated in soilrite + compost + rice husk had the highest potassium levels, followed by soilrite + compost. Increased uptake of nitrogen by plant in the substrate can results in increased the suitable growing conditions, can contribute to improved shoot growth and leaf nutrient content. Similarly, increased phosphate and potassium intake can result in increased root mass development and enhanced vase life.

4.4 Effect of growing media on leaf elemental content of tomato cultivars

For two years, the effect of tomato cultivar and growing media on the nutrient content of tomato leaves in UV stabilised polybags under protected conditions was studied. The leaf is an essential element of the plant that performs photosynthesis and transports nutrients to numerous sinks in order to support activities. As a result, a plant's growth and fruitfulness can be used as an indicator of the leaf's nutrient condition. As a result, medium alteration to maintain optimal nutritional status will go a long way toward ensuring high productivity. With the addition of vermicompost to cocopeat, the availability of macro nutrients in tomato leaves rose. This could be owing to the media's improved physical condition, which allows it to retain more moisture and hence absorb more water and nutrients.

4.4.1 Nitrogen Content of the Leaf (percent)

The data presented in Table 4.22 showed a significant effect in both years, the results on leaf nitrogen content of a promising cultivar as influenced by varied growing conditions also presented in Fig 4.26 The maximum 3.64 percent leaf nitrogen content was recorded in growing media (M-3) cocopeat + vermicompost (2:1, v/v) treatment as compared to all other treatments, whereas the minimum 2.59 percent leaf nitrogen content was recorded in growing media with cocopeat only (M-2).

4.4.2 Phosphorus Content in Leaves (percent)

The data Table 4.22 and Fig 4.26 reveals that different growing media had a significant impact on leaf phosphorus content over both years. The maximum 1.36 percent leaf phasphorus content was recorded in growing media (M-3) with cocopeat + vermicompost (2:1, v/v) treatment as compared to all other treatments, whereas the minimum 1.21 percent leaf phosphorus content was recorded in growing media with cocopeat only (M-2).

4.4.3 Potassium content in leaves (percent)

Different growing conditions had a significant impact on the leaf Potasium content during both years, as indicated in Table 4.22 and Fig 4.26. The maximum 4.15 percent leaf potassium content was recorded in the growing media (M-3) cocopeat + vermicompost (2:1, v/v) treatmentas compared to all other treatments, whereas the minimum 2.51 percent leaf potassium content was recorded in growing media with cocopeat only (M-2).

4.4.4 Sulfur Content in Leaves (percent)

Different growing mediums had a significant impact on leaf sulphur content during both years, as indicated in Table 4.22 and Fig 4.26. The maximum 0.68% leaf sulphur content was recorded in growing media (M-3) with cocopeat + vermicompost (2:1, v/v)as compared to all other treatments, whereas the minimum0.32 percent leaf sulphur content was recorded in growing media with cocopeat only (M-2).

4.4.5 Calcium Content in Leaf (percent)

The leaf Calcium content was considerably influenced by the growing media over both years, as shown in Table 4.22 and Fig 4.26. The (M-3) cocopeat + vermicompost (2:1, v/v) treatment wasrecorded the maximum 2.73 percent leaf calcium content as compared to all other treatments, whereas the minimum 2:23 percent leaf calcium content was recorded in growing media with cocopeat only (M-2).

4.4.6 Magnesium content in leaves (percent)

The leaf magnesium content was considerably influenced by the growing media over both years, as shown in Table 4.22 and Fig 4.26. The maximum 0.61 percent leaf magnesium content was recorded in growing media (M-3) with cocopeat + vermicompost (2:1, v/v) as compared to all other treatments, whereas the minimum0.44percent leaf magnesium content was recorded in growing media with cocopeat only (M-2).

These findings are in line with those of Sayed *et al*., (2015), as well as Nurzynski *et al*., (2001 and 2012), who discovered that using an optimal soilless growing substrate promotes plant NPK uptake. Our findings support those of Truong *et al*., (2017), who discovered that the nitrogen and phosphorus content of leaves increased with the quantity of vermicompost increased in growing media. The enhanced mineral nitrogen and phosphorus content of the medium may have contributed to the leaf's increased total nitrogen and phosphorus concentrations.The level of potassium in the media increases as the vermicompost ratio increases in the media.This could be owing to the high humus content in vermicompost, which promotes root development and potassium absorption. Similar findings from Xiong *et al*., (2017) suggested that cocopeat coir is a better growing medium for tomatoes than rockwool and peat vermiculite.

Table 4.22 Detail of leaf elemental content of tomato after 3rdharvesting stage

Growing Media Treatment	Nitrogen %	Phosphorus %	Potassium %	Sulphur %	Calcium %	Magnesium %
M-1	3.22	1.25	3.24	0.65	2.47	0.48
M-2	2.59	1.21	2.51	0.32	2.23	0.44
M-3	**3.64**	**1.36**	**4.15**	**0.68**	**2.73**	**0.61**
M-4	2.73	1.32	3.36	0.42	2.27	0.55
M-5	2.98	1.48	2.71	0.68	2.37	0.57
M-6	2.82	1.43	2.65	0.65	2.58	0.54

Fig. 4.25Performance of tomato cultivar NS-4266 in soilless substrate

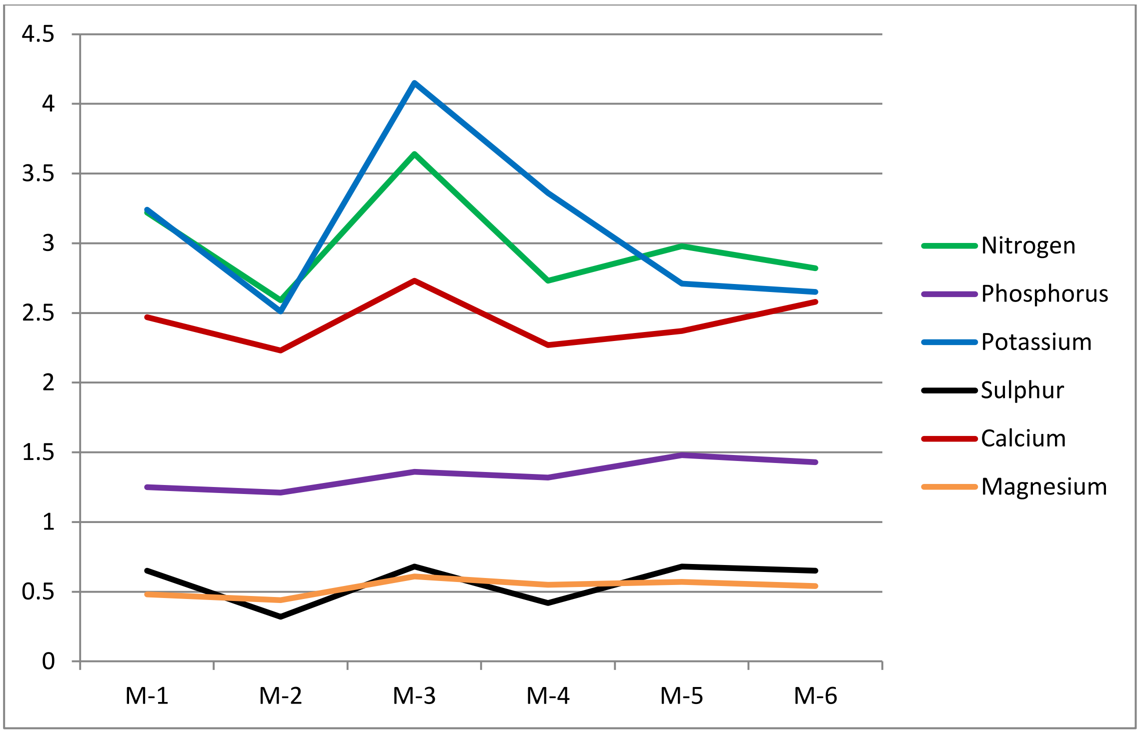

Fig 4.26 Detail of leaf elemental content of tomato leaf after 3rdharvesting stage

4.6.7 Leaf Micronutrient Content- (Zinc, Iron, Manganese, Copper, Boron)

During both years, the leaf Micronutrient content was considerably impacted by different growing conditions, as shown in Table 4.23 and Fig 4.27. The maximum leaf micronutrient content with Zinc (83ppm), Fe (102ppm), Mn (96ppm), Copper (32ppm), Boron (60ppm), and Molybdenum (2ppm) was recorded under growing media (M-3) cocopeat + vermicompost (2:1, v/v) as compare to all other media,whereasthe minimum leaf micronutrient content with Zinc (53pp), Fe (91ppm), Mn (69ppm), Copper (17ppm), Boron (52ppm), and Molybdenum (1ppm) was recorded under growing media cocopeat (M-2).

Despite all the fact that the lowest uncredited nutrient content (showing greater plant absorption) is normally preferred, two Vermicompost treatments showed improved nutritional credit due to the availability of a percentage of nutrients in Vermicompost. These findings are similar to those reported by Xiong *et al*., (2017) and Truong *et al*., (2017) in their research.

Table 4.23 Detail of leaf elemental content of tomato after 3rdharvesting stage:

Growing Media Treatment	Zinc(PPM)	Ferrous / Iron (PPM)	Manganese (PPM)	Copper (PPM)	Boron PPM	Molybednum (PPM)
M-1	70	96	92	28	58	2
M-2	53	91	69	17	52	1
M-3	**83**	**102**	**96**	**32**	**60**	**2**
M-4	66	94	87	21	59	1
M-5	73	99	92	26	58	2
M-6	68	93	81	18	53	1

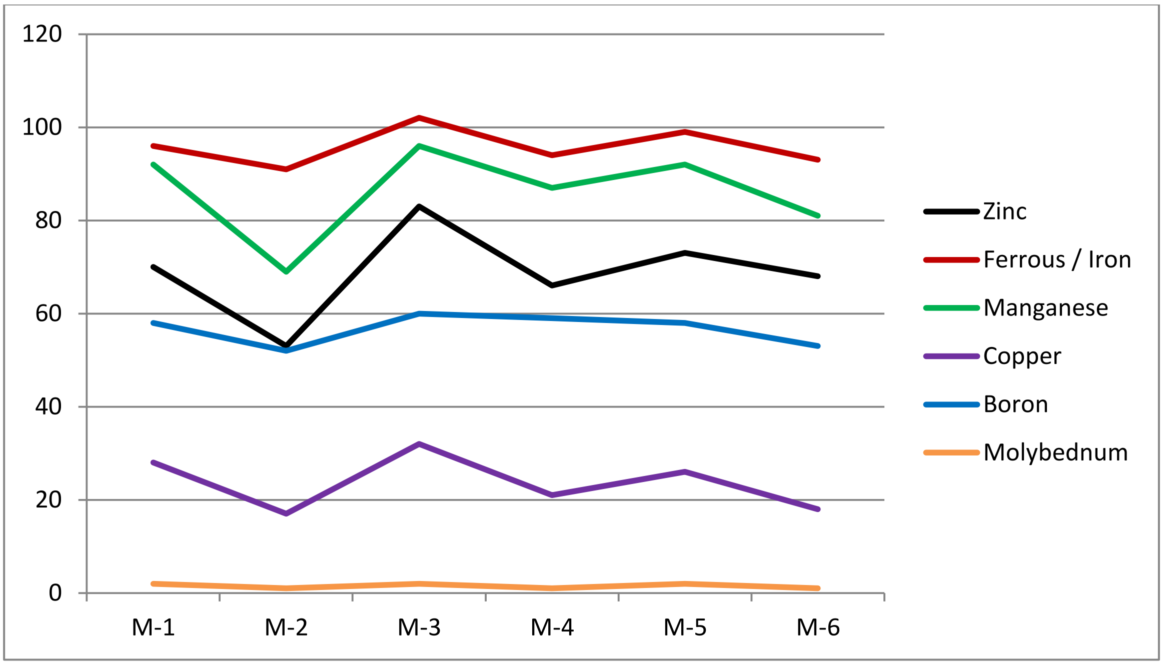

Fig 4.27 Detail of leaf elemental content of tomato after 3rd harvesting stage

CHAPTER V

SUMMARY AND CONCLUSION

Protected cultivation has great potential in northern India, where the extreme temperature, unpredictable heavy rainfall, soil born insect pest problems and problematic soil conditions have affected the year around availability of tomato crop cultivated under open field conditions in the different agro climatic zones of the region. By overcoming the limitations of the soil production system like soil-borne pests like nematodes, termites, root rot and collar rot, the growing media without soil can be an important component for enhanced crop productivity under protected conditions. The present research work entitled "Performance of tomato cultivar (*Solanum lycopersicum* L.) in different soilless culture substrate under protected conditions" was carried out at Hi-Tech Vegetable Centre, village - Bir Charik, district Moga, Punjab during the years 2018 to 2020. To assess the profitability of tomato cultivation with different cultivars produced in different growing media under protected conditions; the present studies were carried out with the objectives as under:

1. To find out the best tomato cultivars for protected cultivation by evaluating the growth, yield and quality parameters.
2. To find out the best growing media for the growth and development of tomato cultivars for getting higher yield.
3. To find out the best economical growing media for tomato cultivation under protected conditions.

The results of the experiments have been summarized under the various headings and sub headings as below:

5.1 Effect of tomato cultivars on growth, production and fruit quality parameters

5.1.1 Effect of tomato cultivars on growth parameters

The plant survival percentages have not much impact on the tomato cultivars from P-1 to P-6, the maximum 98.2 % plant survival recorded in cultivar US-2833 (P-2), however the minimum 96.8 plant survival recorded P-5 cultivars. The cultivar NS-4266 (P-3) had recorded the maximum 374.8 cm plant height as compare to check cultivar HeemShikhar (P-1), whereas, the check cultivar recorded the minimum 345.3 cm plant height. The cultivar Punjab Gaurav (P-4) had under taken the maximum 86.6 days to flower initiation, whereas the minimum 58.3 days taken by check cultivar (P-1). The fifty percent of flowering was recorded maximum at 97.3 days in Punjab Gaurav cultivar, whereas the minimum 69.4 days recorded in cultivar US-2853 (P-2). The cultivar treatments P4, P-5 and P-6 deviate significantly from check cultivar in terms of days to 50% flowering, while cultivar P-2 and P-3 are comparable to check cultivar P-1.

5.1.2 Effect of tomato cultivars on production parameters

The Punjab Swarna cultivar had taken the maximum 93.4 days to first fruit set, whereas cultivar US- 2853 took the minimum 65.3 days to first fruit set. The maximum 6.8 fruit set per cluster were recorded in NS-4266 and Punjab Swarna, whereas the minimum 6.4 fruits per cluster in cultivar Punjab Sartaj. The US-2853 cultivar had the maximum 11.5 clusters per plant, while NS-4266 cultivar is at par with the check cultivar. The maximum 117days taken to first harvest was recorded in cultivars treatment P-4 to P-6, whereas the cultivars P-3 and P-2 took minimum 90.2 and 89.2 days to first harvest, respectively as compare to check. The cultivars treatment P-4 to P-6 took the maximum 209 days to last harvest, whereas the minimum 201.6 and 202.3 days to last harvest recorded in cultivars P-2 and P-3 respectively. The maximum 86.6 fruits per plant were recorded in NS-4266 cultivar which is at par with US-2833, whereas the minimum 68.7 fruits per plant recorded cultivar Punjab Sartaj. The NS-4266 cultivar had recorded the maximum 61.9g average fruit weight, whereas Punjab Gourav cultivar recorded the minimum 58.1 average fruit weight. The fruits of cultivar Punjab Swarna had the maximum 3.3 locules per fruit, whereas fruits of cultivar US- 2853 recorded the minimum 2.4 locules per fruit as comparison to check cultivars. The maximum 7.4 cm fruit diameter had recorded under Punjab Swarna cultivar, however, the minimum 6.5 cm fruit diameter recorded in Punjab Gaurav as compare to the check cultivar. The NS-4266 cultivar had recorded the maximum 5.9 kg per plant total yield; however cultivar Punjab Sartaj recorded the minimum 5.25 kg per plant total yield. Similarly, the maximum 147 ton per hectare total yield had recorded with cultivar NS-4266, however Punjab Sartaj (P-5) cultivar recorded the minimum 131 ton per hectare total yield.

5.1.3 Effect of tomato cultivars on fruit quality parameters

The cultivar NS-4266 (P-3) is best cultivars with fruit quality parameters, had recorded the maximum 5.5 ^{o}Brix TSS in fruits, the maximum 0.41 percent acidity in tomato fruits, the maximum 5.01 mg/100g lycopene content in fruits and the maximum 27.8 mg/100g vitamin-C content in fruits as compared to the check Heemshikhar, whereas the cultivar Punjab Swarna had recorded the minimum 3.9 ^{o}Brix TSS in fruits and the minimum 0.33 percent acidity recorded in cultivar Punjab Sartaj. The Punjab Swarna cultivar had recorded the minimum 1.31 mg/100g lycopene content in fruits and the minimum 18.5 mg/100g vitamin-C content in fruits as compare to check cultivar.

5.2 Effect of growing media on growth, production and quality parameter of tomato

5.2.1 Effect of growing media on growth parameter of tomato cultivars

The plant survival had been recorded the maximum 100% under growing media M-3 to M-6, whereas the minimum 88.4 % plant survival recorded in control media M-1. The maximum 373.4 cm plant height of tomato cultivars recorded under growing media (M3) cocopeat + vermicompost (2:1, v/v) treatment, whereas the minimum 359.2 cm plant height recorded under growing media cocopeat (M-2). The maximum 74 days had been taken to flowering initiation under control media (M-1), however the minimum 70.6 days taken under the media M-5 cocopeat, vermiculite, and perlite (3:1:1, v/v). In control media (M-1), the tomato cultivars had taken the maximum 84.7 days to reach 50% flowering, whereas the minimum 81.7 days taken to reach 50% flowering under media M-5 with cocopeat, vermiculite, and perlite (3:1:1, v/v). The maximum 80.6 days taken to first fruit set recorded under M-1 control media, whereas the minimum 78.2 days taken to first fruit set recorded in M-5 media with cocopeat + vermicompost (3:1, v/v).

5.2.2 Effect of growing media on production parameter of tomato cultivars

The maximum 6.9 fruits per cluster had recorded in M-6 media, which included cocopeat, vermiculite, and perlite (6:1:1, v/v) as compare to control media (M-1), which had taken the minimum 6.2 fruits per cluster. The M-3 media having cocopeat + vermicompost (2:1, v/v) had recorded the maximum 11.3 clusters per plant, whereas the minimum 10.7 clusters per plant recorded under control media (M-1). The maximum 104.6 days taken to first harvest under M-2 media with cocopeat, whereas the minimum 101.8 days taken to first harvest in M-5 media. The maximum 206.7 days taken to last harvest recorded in control media, whereas the minimum 204.3 days taken to last harvest recorded in M-5 media. The cultivars had produced the maximum 79.6 fruits per plant in M-6 media, whereas the minimum 76.2 fruits per plant recorded in control media (M-1). The maximum 61g average fruit weight had recorded in the (M-5), whereas the minimum 58.2g average fruit weight recorded in control media (M-1). The maximum 2.9 locules per fruits had been recorded in case of growing media M-3 and M-5 media as, however the minimum 2.8 locules per fruits in case control media M-1 and other growing media M-2 and M-4. The maximum 7.0 cm fruit diameter had recorded under growing media (M-3) and (M-4), whereas the minimum 6.2 cm fruit diameter recorded in control media (M-1). In the growing media (M-3) and (M-4) had recorded the maximum 5.65 kg yield per plant, whereas the control media (M-1) had recorded the minimum 5.08 kg yield per plant. The maximum 141 tonn total yield per hectare recorded in the growing media (M-3), whereas the minimum 127 tonn total yield per hectare in control media (M-1).

5.2.3 Effect of growing media on fruit quality parameter of tomato cultivars

The maximum 4.8 ^{o}Brix TSS in tomato fruits had been recorded in growing media (M-2) and (M-3), whereas the minimum 4.6 ^{o}Brix TSS in tomato fruits recorded under control media (M-1). The maximum 0.38 percent acidity in tomato fruits had recorded under growing media (M-2) and (M-3), whereas the minimum 0.36 percent acidity recorded under control media (M-1). The cultivars grown in M-3 growing media had recorded the maximum 4.18 mg/100g lycopene content, however the minimum 3.96 mg/100g lycopene content recorded in control media (M-1). The maximum 24.6 mg/100g vitamin-C content in fruits had been recorded in the growing media M-3 and M-5, whereas the minimum 23.9 mg/100g vitamin-C content recorded in the control growing media M-1.

5.3 Economic Analysis (B:C ratio) of growing media with tomato production under protected conditions

The tomato cultivar NS-4266 had recorded the maximum 2.05 B:C ratio, which was statistically significant over the check cultivar Heemshikar with ratio 1.87

and the minimum 1.82 B:C ratio recorded in tomato cultivar P-4 and P-5. The media treatment with the control media M-1 had the maximum 2.01 B:C ratio, followed by 1.97 B:C ratio under media combination M-3, whereas the growing media M-5 had recorded the minimum 1.74 B:C ratio. The results had shown that NS-4266 had recorded the maximum BC ratio under the growing media M-3.

5.4 Effect of growing media on media parameters

The control media M-1 had recorded with maximum 7.5 pH and the maximum 0.71 EC as compare to other growing media treatments, however the minimum 6.25 pH recorded with the growing media M-2 and the minimum 0.44 EC had recorded in media M-5. Nutrient availability can be affected by high EC, making nutrients unavailable to the plant. The media M-3 containing cocopeat + vermicompost (2:1, v/v) had the maximum 1.44 g/kg nitrogen content, the maximum 1.11 g/kg phosphorus level, whereas the growing media M-2 and M-6 had the minimum 0.45 g/kg and 0.87 g/kg nitrogen content respectively and the minimum 0.46 g/kg phosphorus content recorded in M-6 media. The control media M-1 had the maximum potassium content (1.23 g/kg) as compare to the other treatments and the minimum 0.89 g/kg potassium content had recorded in media M-6.

The optimum EC and pH affected the nutrient uptake, as well as suitable growing conditions for plants in the media, whereas nitrogen content in growing media can contribute to improved shoot growth and leaf nutrition. Similarly, the increased phosphate and potassium intake can result in increased root mass development and enhanced roots health.

5.5 Effect of growing media on Leaf elemental content

5.5.1 Effect of growing media on leaf macro-nutrients content

The (M-3) cocopeat + vermicompost (2:1, v/v) treatment had the maximum 3.64 percent leaf nitrogen content, the maximum 1.36 percent leaf phosphorus content, maximum 4.15 percent leaf potassium content, the maximum 0.68 percent leaf Sulphur content, had the maximum 2.73 percent leaf Calcium content and the maxium leaf 0.61 percent Magnesium content as compared to control treatment and all other treatments.

5.5.2 Effect of growing media on leaf micro-nutrients content

During the study the tomato cultivars grown with the different combination of growing media having cocopeat, vermicompost, vermiculite and perlite, the tomato cultivar NS-4266 leaf samples grown with media (M-3), as the growing media treatment had recorded the maximum leaf micronutrient content with Zinc (53ppm), Fe (102ppm), Mn (96ppm), Copper (32ppm), Boron (60ppm), and Molybdenum (2ppm), which was statistically significant over all other treatments.

5.6 Conclusion:

From the present investigation, it can be concluded that the cultivar selection and best economical growing media is very important to get the best quality of tomato fruits production with an open grow bag under protected structures. So the results of the present study was concluded as below

- The Tomato cultivar NS-4266 has the best growth and yield contributing attributes as compare to all the cultivars treatments.
- The soil is the best and most cost-effective growing media for tomato cultivation in Punjab.
- But in the case of problematic soil conditions (salinity), insect-pest problems (nematodes, termites) and soil-born diseases like damping off, sclerotinia), the soilless growing media with a combination of cocopeat and vermicompost (2:1, v/v) produces the most economical yield among all the soilless growing media.
- Whereas (M-6) Cocopeat + Vermiculite + Perlite (6:1:1, v/v) is the second best growing media combination, which can also be employed as a cost-effective soilless growing medium when compared to other commercial growing media.

The study's findings may be beneficial to tomato growers who produce tomatoes in problematic soils under protected conditions. The evaluating tomato cultivars for higher quality yields will give farmers with better economic returns of tomato cultivation in Punjab.

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Annexure – I

Benefit: Cost analysis of growing media- Polyhouse Area of 4000 Sq. m.(1-Acre)

S. No	Particulars	Quantity	Rate/unit(Rs.)	Total(Rs.)
	Variable cost			
1	Seed (10g per packet)	6 Pkt.	650 / Pkt.	**3900**
2	White UV Stabilized Bags used for 10 years	5000 bags	15 / bags	**7500**
3	Fertilizer	800 kg	100 /kg	**80000**
4	Fungicide	8 Pkt	500 / Pkt	**4000**
5	Labour (man-days)	800 days	275 / day	**220000**
A.	**Total Variable Cost**			
6	Polyhouse (NVPH) with drip system for 10 years	$4000m^2$	$935/m^2$	187000*
B. Media cost				
M-1	Soil (4.0 kg/bag) Used for 10 years for Polyhouse	20000 kg	5 /kg	**10000**
M-2	Cocopeat Moist (3.0 kg/ bag) Used for 3 years	15000	15 /kg	**75000**
M-3	Cocopeat Moist (2.0 kg/ bag) Vermicompost -Fresh Moist (1.25 Kg/Bag) All media are mixed (2:1) & used for 3 years	10000 kg 6250 kg	15 /kg 10 / kg	**50000** **20833**
M-4	Cocopeat Moist (2.5 kg/ bag) Vermicompost-Fresh Moist (1.00 Kg/Bag) All media are mixed (3:1) & used for 3 years	12500 kg 5000 kg	15 /kg 10 / kg	**62500** **16667**
M-5	Cocopeat Moist (2.0 kg/ bag) Vermiculite (0.75 kg/Bag) Perlite (0.25 kg/Bag) All media are mixed (3:1:1) & used for 3 years	10000 kg 3750 kg 1250 kg	15 / kg 35 / kg 80 / kg	**50000** **43750** **33333**
M-6	Cocopeat Moist (2.5 kg/ bag) Vermiculite (0.5 kg/bag) Perlite (0.1kg/bag) All media are mixed (6:1:1) & used for 3 years	12500 kg 2500 kg 500 kg	15 / kg 35 / kg 80 / kg	**62500** **29167** **13333**
C. Income after selling crop				
8	Gross income (Yield per acre x Price) X kg per plant × 10000 plants per acre	10000X kg	Rs.20 per kg	200000X

	Growing media	M1	M2	M3	M4	M5	M6
9	**Cost of cultivation (Y)**	512400	577400	573233	581567	629483	607400
10	**Net return (8-9) (Z)**	200000X -512400	200000X -577400	200000X -573233	200000X -581567	200000X -629483	200000X - 607400
11	**B:C ratio (10/9)**	Z/Y	Z/Y	Z/Y	Z/Y	Z/Y	Z/Y

* * Total cost of 4000 Sq. m Polyhouse to be borne by the farmer with subsidy of 50% divided by life expectancy of 10 years.

(Total cost of polyhouse= Rs. 3740000 and with 50 % farmers share =1870000); Average life span of polyhouse= 10 years, therefore, per year cost of polyhouse= Rs.187000).

Annexure II: Pooled data for Plant Survival, Plant height & Days to Flower initiation.

Sr. No	Tomato cultivars	Media Treat-ments	Plant Survival %			Plant height (up to last Harvest)			Days taken to Flower initiation		
			2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled
T-1	P-1	M1	92	86	89	347	333	340	65	54	60
T-2	P-1	M2	92	97	94	335	345	340	65	53	59
T-3	P-1	M3	100	100	100	357	362	360	64	52	58
T-4	P-1	M4	100	100	100	339	355	347	65	51	58
T-5	P-1	M5	100	100	100	341	352	347	63	51	57
T-6	P-1	M6	100	100	100	335	342	339	63	52	58
T-7	P-2	M1	89	94	92	350	357	354	67	57	62
T-8	P-2	M2	92	103	97	374	381	378	65	50	58
T-9	P-2	M3	100	100	100	372	383	378	64	52	58
T-10	P-2	M4	100	100	100	373	380	377	65	54	59
T-11	P-2	M5	100	100	100	366	382	374	63	50	57
T-12	P-2	M6	100	100	100	365	384	374	64	48	56
T-13	P-3	M1	92	81	86	369	376	373	66	54	60
T-14	P-3	M2	92	103	97	381	364	372	64	52	58
T-15	P-3	M3	100	100	100	372	383	378	65	53	59
T-16	P-3	M4	100	100	100	369	383	376	66	54	60
T-17	P-3	M5	100	100	100	387	369	378	64	51	57
T-18	P-3	M6	100	100	100	364	381	372	64	54	59
T-19	P-4	M1	89	89	89	363	371	367	93	81	87
T-20	P-4	M2	92	103	97	370	379	374	94	83	88
T-21	P-4	M3	100	100	100	382	392	387	93	82	88
T-22	P-4	M4	100	100	100	364	370	367	92	81	87
T-23	P-4	M5	100	100	100	357	365	361	90	78	84
T-24	P-4	M6	100	100	100	374	382	378	91	80	85
T-25	P-5	M1	89	94	92	361	365	363	93	83	88
T-26	P-5	M2	94	100	97	359	352	356	93	81	87
T-27	P-5	M3	100	100	100	367	385	376	91	79	85
T-28	P-5	M4	100	100	100	371	361	366	92	80	86
T-29	P-5	M5	100	100	100	361	370	365	90	79	85
T-30	P-5	M6	100	100	100	357	362	360	90	78	84
T-31	P-6	M1	86	81	83	353	366	360	93	81	87
T-32	P-6	M2	94	100	97	337	344	340	94	82	88
T-33	P-6	M3	100	100	100	369	356	363	92	81	86
T-34	P-6	M4	100	100	100	348	354	351	93	81	87
T-35	P-6	M5	100	100	100	349	360	355	90	78	84
T-36	P-6	M6	100	100	100	340	345	342	91	80	86

Annexure III: Pooled data for Days to 50 % flowering, days to fruit set & No. of fruits /cluster

Sr. No	Tomato cultivars	Media Treat-ments	Days taken to 50 % flowering			Days to initiation of fruit set			No. of fruits /cluster		
			2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled
T-1	P-1	M1	74	68	71	71	62	66	6.54	5.51	6.03
T-2	P-1	M2	74	67	71	71	62	67	6.85	6.09	6.47
T-3	P-1	M3	73	67	70	70	61	65	6.98	6.21	6.60
T-4	P-1	M4	75	66	70	70	62	66	7.10	6.34	6.72
T-5	P-1	M5	70	66	68	70	63	67	7.23	6.46	6.85
T-6	P-1	M6	72	67	69	69	60	65	7.35	6.59	6.97
T-7	P-2	M1	73	69	71	71	62	67	6.54	6.44	6.49
T-8	P-2	M2	73	67	70	70	62	66	6.82	6.06	6.44
T-9	P-2	M3	73	66	69	69	60	65	6.96	6.20	6.58
T-10	P-2	M4	73	67	70	70	62	66	7.03	6.26	6.64
T-11	P-2	M5	71	63	67	68	60	64	7.16	6.39	6.77
T-12	P-2	M6	71	66	68	68	61	65	7.23	6.46	6.84
T-13	P-3	M1	75	67	71	71	63	67	6.67	5.90	6.28
T-14	P-3	M2	74	68	71	71	62	66	6.98	6.21	6.60
T-15	P-3	M3	73	67	70	70	60	65	7.10	6.34	6.72
T-16	P-3	M4	74	68	71	71	61	66	7.23	6.46	6.85
T-17	P-3	M5	72	66	69	69	61	65	7.35	6.59	6.97
T-18	P-3	M6	73	67	70	70	62	66	7.48	6.71	7.10
T-19	P-4	M1	101	95	98	98	90	94	6.42	5.65	6.03
T-20	P-4	M2	102	96	99	99	91	95	6.73	5.96	6.35
T-21	P-4	M3	100	95	97	97	90	94	6.85	6.09	6.47
T-22	P-4	M4	101	96	98	98	89	93	6.98	6.21	6.60
T-23	P-4	M5	99	92	96	95	87	91	7.10	6.34	6.72
T-24	P-4	M6	99	92	96	96	88	92	7.23	6.46	6.85
T-25	P-5	M1	101	95	98	98	90	94	6.35	5.59	5.97
T-26	P-5	M2	102	95	98	98	90	94	6.67	5.90	6.28
T-27	P-5	M3	99	93	96	96	88	92	6.79	6.03	6.41
T-28	P-5	M4	100	94	97	97	89	93	6.92	6.15	6.53
T-29	P-5	M5	98	91	95	95	86	90	7.04	6.28	6.66
T-30	P-5	M6	98	92	95	95	87	91	7.17	6.40	6.78
T-31	P-6	M1	102	96	99	99	91	95	6.92	6.15	6.53
T-32	P-6	M2	99	97	98	100	92	96	7.76	5.99	6.88
T-33	P-6	M3	100	94	97	97	89	93	7.89	5.56	6.73
T-34	P-6	M4	101	95	98	98	89	94	8.01	5.91	6.96
T-35	P-6	M5	99	91	95	95	87	91	8.14	5.78	6.96
T-36	P-6	M6	100	91	95	96	89	92	8.26	5.56	6.91

Annexure IV: Pooled data for No. of Clusters / plant, Days to first Harvest & Days to last Harvest

Sr. No	Tomato cultivars	Media Treat-ments	No. of Clusters per plant			Days Taken to first Harvest			Days Taken to last Harvest		
			2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled
T-1	P-1	M1	11.59	10.69	11.14	95	86	90	205	201	203
T-2	P-1	M2	12.18	11.28	11.73	95	86	91	205	199	202
T-3	P-1	M3	12.38	11.48	11.93	94	84	89	202	198	200
T-4	P-1	M4	12.03	11.13	11.58	94	85	90	204	201	202
T-5	P-1	M5	11.88	10.98	11.43	94	84	89	204	202	203
T-6	P-1	M6	11.85	10.95	11.40	93	85	89	203	199	201
T-7	P-2	M1	11.74	10.84	11.29	95	86	90	205	201	203
T-8	P-2	M2	12.22	11.32	11.77	94	85	90	204	200	202
T-9	P-2	M3	12.34	11.44	11.89	93	85	89	202	199	200
T-10	P-2	M4	12.04	11.14	11.59	94	85	90	204	201	202
T-11	P-2	M5	11.82	10.92	11.37	92	83	87	202	199	200
T-12	P-2	M6	11.97	11.07	11.52	92	84	88	202	200	201
T-13	P-3	M1	11.59	10.69	11.14	95	87	91	205	201	203
T-14	P-3	M2	11.80	10.90	11.35	95	86	90	205	201	203
T-15	P-3	M3	11.88	10.98	11.43	94	86	90	204	197	201
T-16	P-3	M4	11.73	10.83	11.28	95	87	91	205	201	203
T-17	P-3	M5	12.41	11.51	11.96	93	84	89	203	199	201
T-18	P-3	M6	12.03	11.13	11.58	94	85	89	204	200	202
T-19	P-4	M1	11.73	8.83	10.28	122	114	118	212	209	210
T-20	P-4	M2	12.33	9.43	10.88	123	115	119	213	209	211
T-21	P-4	M3	12.18	9.28	10.73	121	113	117	211	205	208
T-22	P-4	M4	12.03	9.13	10.58	122	113	117	212	208	210
T-23	P-4	M5	11.88	8.98	10.43	119	110	115	209	205	207
T-24	P-4	M6	12.74	9.84	11.29	120	111	116	210	205	207
T-25	P-5	M1	11.80	8.90	10.35	122	113	118	212	208	210
T-26	P-5	M2	12.41	9.51	10.96	122	114	118	212	209	210
T-27	P-5	M3	12.83	9.93	11.38	120	112	116	210	207	208
T-28	P-5	M4	12.26	9.36	10.81	121	112	117	211	207	209
T-29	P-5	M5	12.10	9.20	10.65	119	110	115	209	205	207
T-30	P-5	M6	11.95	9.05	10.50	119	111	115	209	206	208
T-31	P-6	M1	10.28	9.38	9.83	123	114	118	213	209	211
T-32	P-6	M2	10.71	9.81	10.26	123	115	119	213	206	210
T-33	P-6	M3	11.84	8.94	10.39	121	112	117	211	208	209
T-34	P-6	M4	10.60	9.73	10.17	122	113	117	212	204	208
T-35	P-6	M5	10.49	9.56	10.03	119	110	115	209	205	207
T-36	P-6	M6	10.38	9.46	9.92	120	111	116	210	207	209

Annexure V: Pooled data for average fruits per plant, average fruit weight and locules/fruits.

Sr. No	Tomato cultivars	Media Treat-ments	Average No. of fruits per plant			Average Fruit Weight (g)			No. of Locules per fruits		
			2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled
T-1	P-1	M1	78	86	82	65	53.3	59.1	3.0	2.4	2.73
T-2	P-1	M2	82	85	83	65	53.7	59.6	3.0	2.5	2.77
T-3	P-1	M3	83	93	88	68	55.9	61.7	3.2	2.6	2.88
T-4	P-1	M4	82	88	85	67	54.9	60.8	3.1	2.5	2.80
T-5	P-1	M5	82	95	88	68	56.8	62.6	3.1	2.5	2.82
T-6	P-1	M6	77	88	82	66	54.8	60.6	3.1	2.3	2.68
T-7	P-2	M1	83	94	88	65	53.8	59.6	2.6	2.0	2.31
T-8	P-2	M2	86	83	84	65	53.8	59.7	2.6	2.2	2.37
T-9	P-2	M3	81	98	89	68	56.0	61.8	2.6	2.4	2.47
T-10	P-2	M4	77	88	83	65	53.8	59.6	2.6	2.1	2.34
T-11	P-2	M5	79	89	84	67	55.5	61.4	2.6	2.5	2.56
T-12	P-2	M6	84	91	87	66	54.5	60.3	2.6	2.5	2.53
T-13	P-3	M1	81	87	84	66	54.1	60.0	3.3	2.5	2.90
T-14	P-3	M2	79	94	86	66	54.4	60.2	3.2	2.4	2.82
T-15	P-3	M3	87	92	89	69	57.5	63.3	3.2	2.6	2.89
T-16	P-3	M4	82	92	87	69	57.1	62.9	3.2	2.6	2.90
T-17	P-3	M5	80	94	87	68	56.5	62.3	3.2	2.6	2.90
T-18	P-3	M6	83	86	84	69	56.9	62.8	3.2	2.5	2.88
T-19	P-4	M1	64	55	69	63	51.3	57.2	2.8	2.2	2.49
T-20	P-4	M2	65	54	69	64	52.5	58.3	2.8	2.1	2.45
T-21	P-4	M3	67	56	70	65	53.0	58.8	2.8	2.4	2.61
T-22	P-4	M4	67	55	70	64	52.8	58.6	2.8	2.1	2.45
T-23	P-4	M5	66	55	69	65	53.2	59.1	2.8	2.2	2.53
T-24	P-4	M6	66	54	69	63	51.0	56.8	2.8	2.1	2.47
T-25	P-5	M1	64	53	67	63	51.1	56.9	3.5	2.9	3.22
T-26	P-5	M2	65	53	68	65	53.2	59.0	3.7	2.7	3.20
T-27	P-5	M3	65	55	69	66	51.5	58.9	3.6	3.2	3.39
T-28	P-5	M4	67	56	70	66	52.8	59.5	3.6	3.1	3.35
T-29	P-5	M5	66	54	69	65	55.6	60.5	3.5	3.2	3.37
T-30	P-5	M6	64	54	68	65	56.0	60.4	3.5	2.9	3.19
T-31	P-6	M1	64	52	66	62	50.7	56.5	3.2	2.7	2.93
T-32	P-6	M2	65	54	69	64	52.8	58.6	3.2	2.8	3.03
T-33	P-6	M3	67	56	71	66	53.1	59.4	3.2	2.6	2.88
T-34	P-6	M4	67	55	70	65	55.2	60.3	3.3	2.6	2.92
T-35	P-6	M5	66	55	69	66	53.8	59.9	3.3	2.6	2.95
T-36	P-6	M6	68	53	68	65	53.9	59.6	3.3	2.7	2.97

Annexure VI: Pooled data for fruits diameter, fruit yield per plant and total yield t/ha.

Sr. No	Tomato cultivars	Media Treat-ments	fruits Diameter (cm)			Fruit Yield per plant (Kg)			Total Yield (Tonn per ha.)		
			2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled
T-1	P-1	M1	6.5	5.7	6.1	5.2	4.8	5.0	129	120	125
T-2	P-1	M2	6.9	6.0	6.4	5.5	5.0	5.2	137	125	131
T-3	P-1	M3	7.4	6.4	6.9	5.9	5.3	5.6	147	133	140
T-4	P-1	M4	7.1	6.3	6.7	5.8	5.9	5.8	145	148	146
T-5	P-1	M5	7.2	6.4	6.8	5.7	5.2	5.4	142	129	136
T-6	P-1	M6	7.0	6.1	6.6	5.6	5.0	5.3	140	126	133
T-7	P-2	M1	6.5	5.7	6.1	5.2	4.9	5.1	131	123	127
T-8	P-2	M2	6.8	6.0	6.4	5.5	5.1	5.3	137	126	132
T-9	P-2	M3	7.2	6.3	6.7	5.8	5.4	5.6	145	134	139
T-10	P-2	M4	7.2	6.4	6.8	5.7	5.4	5.5	143	134	139
T-11	P-2	M5	7.0	6.1	6.5	5.6	4.8	5.2	141	120	130
T-12	P-2	M6	7.0	6.2	6.6	5.6	5.2	5.4	139	130	135
T-13	P-3	M1	6.7	5.8	6.3	5.3	6.0	5.7	133	150	142
T-14	P-3	M2	7.0	6.1	6.6	5.6	6.0	5.8	140	151	145
T-15	P-3	M3	7.5	6.6	7.1	6.0	6.2	6.1	150	154	152
T-16	P-3	M4	7.4	6.5	6.9	5.8	6.2	6.0	145	156	150
T-17	P-3	M5	7.2	6.4	6.8	5.9	6.2	6.1	148	155	152
T-18	P-3	M6	7.1	6.3	6.7	5.9	6.2	6.0	147	154	151
T-19	P-4	M1	6.4	5.6	6.0	5.1	5.3	5.2	128	131	130
T-20	P-4	M2	6.7	5.9	6.3	5.4	5.2	5.3	135	129	132
T-21	P-4	M3	7.1	6.3	6.7	5.8	4.9	5.3	145	122	133
T-22	P-4	M4	7.2	6.4	6.8	5.7	4.9	5.3	142	122	132
T-23	P-4	M5	6.9	6.0	6.4	5.5	5.1	5.3	137	128	133
T-24	P-4	M6	7.0	6.1	6.6	5.6	4.9	5.2	140	123	131
T-25	P-5	M1	6.9	6.0	6.5	5.1	4.8	5.0	127	121	124
T-26	P-5	M2	7.8	6.9	7.3	5.3	5.0	5.2	133	124	129
T-27	P-5	M3	8.3	7.4	7.8	5.7	5.5	5.6	143	137	140
T-28	P-5	M4	8.1	7.3	7.7	5.6	5.0	5.3	141	126	134
T-29	P-5	M5	7.9	7.1	7.5	5.4	5.0	5.2	136	125	130
T-30	P-5	M6	8.0	7.2	7.6	5.5	5.0	5.3	138	124	131
T-31	P-6	M1	6.5	5.7	6.1	5.2	4.9	5.1	129	124	126
T-32	P-6	M2	6.8	6.0	6.4	5.4	5.2	5.3	135	130	133
T-33	P-6	M3	7.2	6.3	6.7	5.8	5.6	5.7	145	140	143
T-34	P-6	M4	7.2	6.4	6.8	5.7	4.9	5.3	143	122	133
T-35	P-6	M5	7.0	6.0	6.5	5.6	5.5	5.6	140	137	139
T-36	P-6	M6	7.0	6.0	6.5	5.5	5.4	5.4	138	134	136

Annexure VII: Pooled data for different Lab parameters TSS – Brix, Acidity and Lycopene

Sr. No	Tomato cultivars	Media Treat-ments	TSS (°Brix)			Acidity (mg / 100ml juice)			Lycopene (mg / 100ml fw)		
			2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled
T-1	P-1	M1	4.42	4.26	4.34	0.41	0.36	0.39	4.52	4.49	4.51
T-2	P-1	M2	4.46	4.23	4.34	0.44	0.39	0.41	4.51	4.59	4.55
T-3	P-1	M3	4.55	4.31	4.43	0.43	0.38	0.40	4.56	4.53	4.55
T-4	P-1	M4	4.49	4.28	4.38	0.42	0.37	0.39	4.52	4.49	4.51
T-5	P-1	M5	4.52	4.36	4.44	0.46	0.41	0.43	4.53	4.50	4.52
T-6	P-1	M6	4.43	4.33	4.38	0.45	0.40	0.42	4.51	4.49	4.50
T-7	P-2	M1	4.02	3.83	3.92	0.37	0.31	0.34	4.07	4.04	4.06
T-8	P-2	M2	4.46	4.28	4.37	0.39	0.33	0.36	4.27	4.24	4.26
T-9	P-2	M3	4.53	4.37	4.45	0.40	0.34	0.37	4.57	4.54	4.56
T-10	P-2	M4	4.47	4.29	4.38	0.39	0.33	0.36	4.34	4.31	4.33
T-11	P-2	M5	4.43	4.26	4.34	0.38	0.32	0.35	4.22	4.19	4.21
T-12	P-2	M6	4.33	4.37	4.35	0.37	0.31	0.34	4.12	4.09	4.11
T-13	P-3	M1	5.30	5.40	5.35	0.41	0.36	0.39	5.16	4.86	5.01
T-14	P-3	M2	5.49	5.32	5.40	0.43	0.38	0.40	5.14	4.84	4.99
T-15	P-3	M3	5.43	5.26	5.34	0.44	0.39	0.41	5.19	4.89	5.04
T-16	P-3	M4	5.37	5.21	5.29	0.42	0.37	0.39	5.14	4.84	4.99
T-17	P-3	M5	5.40	5.23	5.31	0.41	0.36	0.39	5.19	4.89	5.04
T-18	P-3	M6	5.39	5.22	5.30	0.41	0.36	0.39	5.12	4.82	4.97
T-19	P-4	M1	5.45	5.42	5.43	0.36	0.31	0.34	4.22	4.19	4.21
T-20	P-4	M2	5.63	5.46	5.54	0.40	0.34	0.37	4.51	4.49	4.50
T-21	P-4	M3	5.68	5.48	5.58	0.39	0.33	0.36	4.74	4.71	4.73
T-22	P-4	M4	5.55	5.32	5.43	0.37	0.31	0.34	4.67	4.64	4.66
T-23	P-4	M5	5.63	5.46	5.54	0.39	0.33	0.36	4.73	4.70	4.72
T-24	P-4	M6	5.52	5.29	5.40	0.38	0.32	0.35	4.66	4.64	4.65
T-25	P-5	M1	4.71	4.38	4.55	0.35	0.29	0.32	4.84	4.54	4.69
T-26	P-5	M2	5.11	4.84	4.97	0.37	0.31	0.34	4.90	4.60	4.75
T-27	P-5	M3	4.83	4.65	4.74	0.36	0.30	0.33	5.04	4.74	4.89
T-28	P-5	M4	4.78	4.46	4.62	0.34	0.28	0.31	5.02	4.72	4.87
T-29	P-5	M5	5.03	4.73	4.88	0.37	0.31	0.34	4.93	4.63	4.78
T-30	P-5	M6	4.91	4.48	4.69	0.36	0.30	0.33	4.87	4.57	4.72
T-31	P-6	M1	4.04	3.53	3.79	0.42	0.36	0.39	1.31	1.21	1.26
T-32	P-6	M2	4.09	4.01	4.05	0.45	0.39	0.42	1.37	1.27	1.32
T-33	P-6	M3	4.11	3.93	4.02	0.43	0.37	0.40	1.39	1.23	1.31
T-34	P-6	M4	4.04	3.74	3.89	0.42	0.36	0.39	1.36	1.26	1.31
T-35	P-6	M5	4.05	3.82	3.93	0.44	0.38	0.41	1.40	1.23	1.32
T-36	P-6	M6	4.03	3.66	3.84	0.43	0.37	0.40	1.36	1.26	1.31

Annexure VIII: Pooled data for Vitamin C and B: C Ratio

Sr. No	Tomato cultivars	Media Treatments	Vitamin C mg 100 /ml juice			B : C Ration		
			2018 - 2019	2019 - 2020	Pooled	2018 - 2019	2019 - 2020	Pooled
T-1	P-1	M1	26.42	26.40	26.41	2.02	1.87	1.94
T-2	P-1	M2	26.92	27.02	26.97	1.90	1.73	1.82
T-3	P-1	M3	27.76	27.86	27.81	2.05	1.86	1.95
T-4	P-1	M4	27.06	27.20	27.13	1.99	2.03	2.01
T-5	P-1	M5	27.74	27.84	27.79	1.81	1.64	1.72
T-6	P-1	M6	27.46	27.56	27.51	1.84	1.66	1.75
T-7	P-2	M1	27.76	27.52	27.64	2.04	1.92	1.98
T-8	P-2	M2	27.54	27.30	27.42	1.89	1.75	1.82
T-9	P-2	M3	28.86	28.62	28.74	2.02	1.87	1.94
T-10	P-2	M4	28.33	28.09	28.21	1.97	1.84	1.91
T-11	P-2	M5	27.88	27.65	27.76	1.79	1.52	1.65
T-12	P-2	M6	26.93	26.69	26.81	1.83	1.71	1.77
T-13	P-3	M1	26.32	26.42	26.37	2.08	2.34	2.21
T-14	P-3	M2	27.57	27.67	27.62	1.93	2.09	2.01
T-15	P-3	M3	27.68	27.78	27.73	2.10	2.15	2.12
T-16	P-3	M4	27.63	27.73	27.68	1.99	2.14	2.06
T-17	P-3	M5	27.50	27.60	27.55	1.88	1.97	1.93
T-18	P-3	M6	27.19	27.29	27.24	1.94	2.03	1.98
T-19	P-4	M1	20.30	20.20	20.25	2.00	2.05	2.03
T-20	P-4	M2	21.80	21.70	21.75	1.86	1.79	1.83
T-21	P-4	M3	20.87	20.77	20.82	2.02	1.70	1.86
T-22	P-4	M4	21.48	20.71	21.09	1.95	1.67	1.81
T-23	P-4	M5	23.30	22.53	22.91	1.74	1.63	1.69
T-24	P-4	M6	22.61	22.71	22.66	1.84	1.61	1.73
T-25	P-5	M1	26.85	20.15	23.50	1.98	1.89	1.93
T-26	P-5	M2	27.06	20.36	23.71	1.85	1.72	1.78
T-27	P-5	M3	27.75	20.38	24.06	2.00	1.91	1.96
T-28	P-5	M4	27.36	20.66	24.01	1.94	1.74	1.84
T-29	P-5	M5	26.25	20.22	23.24	1.73	1.59	1.66
T-30	P-5	M6	25.37	20.01	22.69	1.82	1.64	1.73
T-31	P-6	M1	18.36	19.79	19.07	2.01	1.93	1.97
T-32	P-6	M2	18.40	18.50	18.45	1.87	1.80	1.84
T-33	P-6	M3	18.42	18.52	18.47	2.03	1.95	1.99
T-34	P-6	M4	18.41	18.51	18.46	1.96	1.68	1.82
T-35	P-6	M5	18.23	18.33	18.28	1.78	1.74	1.76
T-36	P-6	M6	18.15	18.25	18.20	1.81	1.77	1.79

Annexure IX : Maximum temperature of central zone of Punjab in 2019-20

Date	January	Febuary	March	April	May	June	July	August	September	October	November	December
1	19.6	18.0	20.6	32.0	39.2	44.0	40.5	31.0	32.6	30.0	29.6	21.6
2	21.2	20.2	18.4	32.8	32.6	43.4	40.0	29.6	33.6	31.2	26.0	21.8
3	16.6	22.0	20.2	33.4	36.6	41.0	39.2	32.8	34.4	31.8	28.0	22.0
4	18.4	21.4	21.0	35.0	36.6	40.6	36.0	33.6	35.0	28.0	28.8	22.2
5	17.0	23.0	22.2	35.4	39.2	44.6	37.5	35.0	33.6	30.2	29.6	23.6
6	16.5	22.0	23.4	35.6	39.2	40.6	35.3	33.6	35.0	30.0	29.2	23.0
7	18.0	17.0	23.6	36.0	40.6	41.0	38.4	36.4	35.0	30.4	26.0	24.0
8	18.6	16.4	19.8	32.2	40.6	43.2	37.0	36.4	34.6	30.2	28.0	22.4
9	19.0	18.6	23.2	34.2	41.0	43.6	34.5	31.0	35.6	31.2	28.0	19.6
10	19.6	19.0	25.4	36.6	40.6	45.2	33.6	34.4	35.2	31.0	27.0	19.4
11	21.2	19.6	21.4	35.6	36.5	44.8	33.2	35.8	35.6	31.2	24.0	20.6
12	20.0	21.0	25.0	34.0	37.8	41.4	32.0	35.4	36.0	31.2	25.2	15.2
13	19.0	23.4	22.2	31.2	39.0	39.4	31.0	30.2	34.0	31.4	24.6	13.8
14	21.4	20.0	20.6	35.8	35.2	41.6	26.8	34.6	34.0	32.2	23.4	15.6
15	17.0	20.0	24.4	37.6	34.2	42.2	29.6	33.6	33.8	33.0	26.6	16.2
16	18.6	19.6	26.0	30.4	35.0	37.2	28.2	32.2	34.0	32.2	24.8	12.4
17	19.4	18.4	26.2	22.6	27.4	40.4	31.6	30.2	35.4	31.0	25.4	14.2
18	20.4	16.6	27.6	27.6	33.3	32.2	33.2	31.0	32.6	27.2	25.8	14.4
19	21.4	22.0	29.6	31.6	37.4	38.2	31.6	33.0	30.6	31.0	25.6	13.5
20	22.2	20.2	28.4	33.6	38.8	37.4	34.8	32.6	33.0	29.6	25.2	15.2
21	16.2	23.6	28.4	35.4	40.0	37.0	34.6	34.6	33.0	29.2	24.0	15.2
22	14.8	20.0	27.2	38.0	40.6	39.8	36.0	35.4	32.4	31.0	21.0	10.2
23	19.0	20.0	27.0	40.5	35.4	39.0	36.6	35.4	32.6	30.6	25.8	12.6
24	17.0	20.2	25.0	40.4	34.0	37.0	37.2	35.4	32.0	30.4	26.4	10.6
25	18.6	21.6	23.0	36.6	35.6	37.2	29.6	33.0	32.6	31.0	25.6	9.0
26	16.6	22.2	28.6	39.0	38.4	39.4	31.2	35.0	31.6	30.0	23.4	9.8
27	16.4	18.6	30.2	39.0	39.6	38.2	31.4	35.4	30.8	30.4	24.4	8.8
28	18.2	19.0	30.6	39.8	41.6	40.2	33.4	36.4	30.0	30.4	21.0	10.2
29	18.4		32.6	40.0	42.4	41.2	34.6	36.0	26.5	30.0	22.6	10.4
30	16.2		32.6	40.2	43.6	40.4	34.6	35.0	28.6	30.0	22.2	10.2
31	17.2		31.0		45.0		30.2	35.2		30.6		13.8

Annexure – X Minimum temperature of central zone of Punjab in 2019-20

Date	January	Febuary	March	April	May	June	July	August	September	October	November	December
1	4.0	8.6	6.4	13.8	25.2	28.2	28.6	26.0	28.6	22.8	15.5	8.8
2	9.0	5.2	11.8	14.4	21.8	28.6	28.4	23.2	24.5	21.6	15.6	8.2
3	5.4	6.4	11.6	15.8	18.8	29.6	30.0	26.4	27.2	22.2	16.8	6.8
4	5.6	5.6	11.2	18.4	18.8	27.0	32.0	27.5	28.4	19.0	14.6	6.8
5	8.2	9.6	9.0	19.2	18.5	27.6	27.8	28.6	23.2	18.4	13.6	6.8
6	10.2	10.8	10.0	20.6	21.8	28.6	28.0	28.6	27.4	19.2	14.6	7.4
7	4.5	11.4	9.0	18.0	18.6	26.0	28.8	27.2	27.6	20.6	18.8	7.6
8	7.6	7.0	11.2	21.6	21.2	24.8	27.4	28.6	27.6	18.6	14.6	7.2
9	5.2	5.6	9.6	18.2	20.0	25.8	25.0	25.6	26.6	19.4	12.2	7.6
10	4.0	5.8	9.0	21.6	25.2	26.4	26.4	27.4	28.0	17.6	11.0	6.0
11	8.0	8.6	12.0	19.0	24.6	27.6	22.0	27.8	28.2	19.2	10.4	6.0
12	6.6	10.2	8.4	21.8	21.0	28.6	24.6	28.8	28.0	19.4	11.0	12.8
13	7.8	9.4	11.4	19.0	22.8	20.2	21.4	24.4	25.5	19.6	11.8	12.6
14	3.0	11.6	11.6	19.4	21.2	24.4	23.6	26.6	27.4	20.4	15.0	10.8
15	4.4	13.4	9.2	20.2	23.4	25.0	24.0	26.0	26.8	20.5	15.6	8.0
16	4.4	11.0	10.0	18.6	21.2	26.2	23.8	27.2	24.4	20.6	17.0	9.4
17	4.0	9.0	13.6	18.2	22.6	27.6	24.4	26.6	25.6	21.2	12.6	10.2
18	3.6	9.8	11.0	15.8	20.4	22.4	26.4	21.2	25.6	20.0	12.0	8.0
19	7.4	10.2	12.2	16.4	22.2	25.5	26.6	25.8	26.0	16.6	10.6	7.4
20	8.5	13.0	14.6	17.6	23.5	27.8	27.4	25.0	25.0	16.2	10.0	8.8
21	11.0	14.4	13.2	19.4	22.8	23.6	26.6	25.6	24.2	14.2	10.4	8.4
22	11.0	12.6	12.6	21.0	22.6	25.6	28.2	27.8	22.6	14.8	13.4	6.6
23	7.4	7.4	10.8	21.2	26.0	28.8	29.2	27.4	24.0	15.0	15.0	7.6
24	6.0	7.5	13.4	26.0	21.4	28.6	29.6	27.8	23.8	16.6	12.4	8.0
25	6.2	7.2	13.4	23.0	20.6	26.2	26.6	26.4	24.0	17.0	9.6	5.4
26	3.8	9.0	11.6	23.8	20.6	27.5	26.4	26.6	25.4	17.0	12.6	6.4
27	4.0	10.4	13.4	20.6	22.6	28.2	25.2	27.0	22.0	14.8	15.0	5.6
28	3.0	6.6	15.4	19.6	20.6	27.6	25.6	28.0	24.4	15.5	14.4	5.6
29	2.8		16.8	18.8	25.2	30.0	28.0	28.4	21.8	16.4	13.4	4.6
30	6.8		17.2	24.2	24.2	28.8	29.4	27.4	21.6	18.4	11.4	3.6
31	8.4		14.6		26.0		25.6	27.6		16.4		4.5

Annexure – XI Relative Humidity (RH) of central zone of Punjab in 2019-20 (%)

Date	January	Febuary	March	April	May	June	July	August	September	October	November	December
1	70.5	78.0	71.0	54.5	23.0	35.5	52.0	86.0	93.0	79.5	66.5	71.5
2	62.5	73.0	69.0	56.0	31.0	42.5	41.0	88.5	81.5	73.5	78.5	68.5
3	79.5	72.0	79.0	58.0	35.0	41.5	53.0	78.0	78.5	75.0	73.0	65.0
4	70.5	74.5	77.0	61.5	30.0	40.5	58.0	77.5	78.0	71.0	66.0	70.5
5	79.0	69.5	73.0	58.0	31.0	38.0	57.5	77.0	81.0	72.5	62.0	73.5
6	73.5	75.5	68.0	64.5	29.0	33.0	63.5	81.5	74.5	73.5	54.5	65.5
7	74.0	84.0	68.0	53.5	26.0	38.0	57.5	70.5	75.5	65.0	57.0	66.5
8	67.0	76.5	78.0	57.5	25.0	30.5	78.0	69.5	76.5	71.5	55.5	65.0
9	65.5	76.0	68.0	58.0	29.0	35.0	66.0	79.0	74.5	69.0	62.0	72.0
10	63.0	73.0	63.0	45.5	25.0	35.0	77.0	69.5	73.0	66.5	63.0	72.5
11	68.0	72.5	65.0	49.5	37.0	22.5	70.5	65.5	76.0	71.5	65.5	71.5
12	72.0	71.5	65.0	51.0	35.0	26.5	84.0	78.5	73.5	70.0	70.0	84.0
13	71.5	69.5	67.0	60.0	34.0	41.0	79.5	94.5	72.5	71.0	70.0	95.5
14	66.5	72.5	74.0	47.0	55.0	29.0	92.5	72.0	79.0	69.0	75.5	83.5
15	65.0	80.5	71.0	42.5	55.0	34.5	82.0	87.0	76.5	68.0	64.0	83.0
16	64.5	85.0	71.0	54.5	54.0	46.0	86.0	76.0	62.5	71.5	73.5	85.5
17	70.0	72.5	63.0	79.0	69.0	49.0	76.5	75.5	70.0	68.5	70.0	73.0
18	67.0	85.0	64.0	63.5	61.0	60.0	72.0	80.5	74.5	65.5	68.5	81.5
19	68.5	79.0	63.0	57.5	41.0	51.0	76.0	79.5	74.0	60.5	66.0	82.0
20	72.0	81.5	66.0	53.0	29.0	43.0	58.5	78.0	68.0	64.0	66.0	84.0
21	79.5	68.5	54.0	49.5	34.0	64.5	76.0	72.0	70.0	64.0	68.0	89.5
22	93.0	78.0	58.0	43.0	33.0	45.5	65.0	69.0	79.0	59.5	74.5	93.5
23	70.0	72.5	59.0	44.0	41.0	50.0	66.5	66.5	68.5	67.5	63.0	84.0
24	74.5	71.5	70.0	35.0	59.0	63.0	74.0	74.0	91.5	57.5	66.0	81.5
25	64.5	71.5	84.0	50.5	45.0	54.5	86.0	75.5	91.0	60.5	65.0	88.5
26	69.0	67.5	68.0	40.0	40.0	44.0	81.5	73.5	76.0	72.0	90.0	77.0
27	70.0	67.5	64.0	36.5	29.0	41.5	90.0	69.5	69.0	65.0	67.5	81.5
28	71.5	72.0	68.0	33.5	25.0	46.5	77.5	70.5	90.5	67.0	79.5	81.0
29	63.5		68.0	31.0	29.0	44.5	66.5	72.5	78.5	69.5	76.5	89.0
30	73.5		65.0	21.0	33.0	42.0	71.0	74.0	86.0	67.0	69.5	88.0
31	72.0		55.0		24.0		79.5	75.0		69.5		71.5

Annexure – XII Sunshine Hours of central zone of Punjab in 2019-20

Date	January	Febuary	March	April	May	June	July	August	September	October	November	December
1	1.1	2.4	5.2	3.6	4.1	6.6	6.3	6.8	2.3	1.6	0.5	1.5
2	1.5	1.5	3.4	2.2	5.9	8.0	4.8	2.8	1.7	0.8	0.7	1.8
3	2.6	1.3	2.4	2.3	3.5	16.4	5.2	3.9	1.8	4.2	1.6	1.9
4	2.1	1.7	3.8	1.8	4.5	6.9	9.8	1.6	5.6	4.3	3.9	0.2
5	3.6	1.3	3.0	1.7	3.5	2.9	6.3	2.0	3.9	2.9	3.1	0.7
6	1.3	8.9	3.0	3.3	3.6	6.1	7.5	6.9	1.4	3.1	8.9	1.8
7	2.0	8.8	2.7	2.2	3.0	3.5	4.3	1.5	4.0	4.8	10.5	0.8
8	3.2	3.4	1.0	4.5	3.0	3.6	6.4	1.9	1.3	1.8	2.7	1.0
9	3.3	3.3	3.6	4.2	6.2	3.5	9.8	6.1	1.9	1.3	2.1	0.8
10	1.3	1.6	3.4	3.1	6.9	3.2	4.1	6.9	1.5	1.3	0.9	0.9
11	1.2	2.4	5.2	4.1	4.6	9.6	6.1	2.6	2.9	1.2	0.9	1.0
12	2.5	1.6	2.9	4.5	4.0	12.5	5.1	3.0	5.3	1.2	2.8	6.6
13	4.4	1.2	0.9	5.6	5.5	3.0	3.4	4.0	2.8	1.7	2.6	2.2
14	4.1	7.7	2.0	4.1	2.6	5.9	8.8	2.5	4.5	1.3	2.4	1.0
15	2.6	2.3	3.2	9.3	6.9	9.3	6.0	1.9	4.6	1.2	3.8	5.3
16	1.5	1.8	4.2	8.8	3.5	4.6	6.6	4.3	2.1	1.3	5.7	5.5
17	1.9	3.3	2.8	6.3	5.2	10.9	3.6	8.1	2.4	2.5	4.6	5.3
18	2.6	4.7	2.7	1.6	3.5	2.7	5.4	6.4	7.9	6.5	2.4	1.6
19	1.5	1.9	3.1	2.3	4.8	4.0	4.7	3.0	5.8	2.0	1.5	1.1
20	1.8	8.5	4.9	1.6	4.7	3.5	3.9	3.5	2.1	2.6	1.0	2.2
21	7.9	3.5	3.2	2.6	3.1	2.3	4.4	2.2	1.9	2.9	1.0	2.9
22	5.2	5.0	3.9	3.1	3.7	7.4	2.6	2.1	6.2	2.9	3.4	6.7
23	1.0	4.2	5.0	5.3	7.2	8.0	1.7	1.9	0.2	1.7	3.7	1.6
24	2.4	2.2	4.8	5.8	7.1	7.1	4.4	5.4	1.0	1.9	1.2	5.1
25	1.1	2.7	1.0	3.3	5.7	2.6	5.7	5.6	1.5	1.6	0.6	5.6
26	3.3	4.9	2.0	2.9	4.1	7.1	6.0	1.8	2.3	0.9	2.8	3.5
27	3.1	2.1	1.7	4.3	6.1	5.3	6.7	1.7	2.9	1.8	5.2	3.5
28	2.8	2.5	1.9	5.1	4.8	4.7	6.5	1.9	5.6	1.1	1.3	2.2
29	2.5		1.8	4.3	4.2	4.8	5.3	3.6	6.9	1.1	0.7	2.3
30	2.3		3.3	8.0	3.3	5.2	8.2	1.7	3.9	0.7	2.0	2.7
31	4.2		4.1		4.8		6.7	1.5		1.5		3.1

Annexure – XIII Wind Speed of central zone of Punjab in 2019-20

Date	January	Febuary	March	April	May	June	July	August	September	October	November	December
1	0.0	0.0	8.3	11.8	8.4	9.0	10.3	0.0	0.0	5.4	0.9	8.0
2	0.2	9.4	0.0	11.0	1.3	11.8	10.0	3.6	8.8	5.5	0.0	8.2
3	4.6	8.8	3.6	9.8	12.1	10.2	3.4	8.1	9.8	8.5	0.0	8.8
4	3.3	5.5	7.4	9.8	12.7	8.9	2.6	4.0	6.9	5.6	6.9	1.4
5	0.0	3.7	10.8	10.2	11.2	11.2	6.8	7.3	6.9	10.0	7.1	5.2
6	0.0	0.0	10.6	9.7	12.4	8.7	0.0	2.8	7.3	5.3	2.4	8.6
7	7.6	0.0	10.6	8.2	12.0	12.5	10.0	6.2	5.0	10.1	5.7	8.9
8	5.0	9.7	0.0	7.4	12.0	12.5	5.5	7.4	4.6	10.2	9.1	8.7
9	8.7	9.4	11.0	9.3	11.4	12.5	5.9	4.1	10.6	9.2	8.8	1.5
10	5.5	2.9	10.8	5.9	7.8	12.6	0.0	3.9	6.2	10.0	8.0	4.7
11	0.0	7.2	3.4	7.6	5.7	11.8	4.0	11.8	7.2	9.0	0.0	3.8
12	0.5	4.0	10.7	6.4	11.7	7.1	0.0	8.1	7.5	8.0	4.1	0.0
13	7.0	3.3	1.2	3.1	5.7	11.8	5.0	0.8	7.0	7.8	0.3	0.0
14	8.5	1.0	4.7	6.9	10.3	12.8	0.0	11.1	3.1	8.9	0.0	1.0
15	6.6	1.3	10.5	10.6	4.9	11.4	0.6	3.1	3.0	8.2	2.8	6.5
16	0.8	5.3	8.5	1.5	7.7	8.3	1.5	1.8	8.3	4.1	4.8	0.1
17	7.4	2.1	9.5	0.9	1.7	9.9	8.4	0.0	10.3	0.0	8.3	3.1
18	8.2	0.0	7.1	10.8	9.4	2.0	6.2	10.2	7.1	0.6	8.7	2.1
19	5.2	7.3	9.6	12.0	12.1	11.8	3.9	8.1	5.0	10.3	5.8	0.0
20	0.0	0.0	8.6	12.7	8.6	5.8	3.6	12.4	8.7	6.2	5.4	0.7
21	0.0	4.1	10.9	12.4	13.0	8.3	6.1	11.7	10.4	9.4	1.1	2.4
22	0.0	8.4	10.7	12.2	8.9	12.5	5.7	10.4	8.0	8.9	0.0	0.0
23	8.8	10.8	8.7	12.0	4.2	11.4	0.7	10.2	7.6	8.1	6.6	0.0
24	9.0	10.2	1.9	8.8	8.0	7.1	5.6	8.5	3.7	8.4	9.2	0.0
25	8.6	6.7	1.9	4.7	12.8	8.0	0.0	2.5	6.5	7.0	7.9	0.0
26	9.4	9.1	10.3	11.5	13.6	12.1	0.2	6.2	3.6	0.7	0.0	0.0
27	8.2	8.6	8.2	12.0	13.1	11.6	0.0	10.8	3.5	6.7	5.4	0.0
28	9.5	9.6	8.2	11.8	13.1	12.4	6.9	10.9	1.1	4.6	1.5	0.6
29	9.3		9.4	12.0	12.4	11.5	12.2	5.2	1.5	0.0	4.0	1.7
30	0.0		10.7	10.9	12.4	7.9	4.7	1.9	4.8	0.0	8.0	0.0
31	0.0		11.5		11.7		0.0	7.3		0.9		6.1

Annexure – XIV Rainfall of central zone of Punjab in 2019-20 (Units in mm)

Date	January	Febuary	March	April	May	June	July	August	September	October	November	December
1	0	0	0.1	0	0	4.8	0.1	4.9	0.4	0	0	0.2
2	0	13.5	1.3	0	0	2.2	27.2	5.5	4.3	15.8	0	0.8
3	0.2	34.3	2.6	0	0	2.7	7.7	105.1	9.2	0	0	0
4	6.9	0	0.1	0	12.3	3.4	1.5	13	0	0	0	0
5	19	0.1	1.2	0	0	1.7	0	0	0	0	0	0
6	0	0	4.1	0	0	0	0.2	3.3	0	0	0	0
7	0	0	0.1	0	0	0	0	0	0.1	0	0	0
8	40.3	1.9	0	0	0	0	1.4	0	0	0	0	0
9	0	0	0	0	0	0	1.2	0	0.4	0	0	0
10	0	0	0	0	0	46.7	0	0	5.6	0	0	0
11	0	0	0	0	0	15.5	0.4	0	24.8	0	0	0
12	0.3	0	0	0	0	3	76.9	0	0	0	0	0
13	0	0	0	0	0	31.9	2	0	0	0	0	0
14	0	0	0	7.5	0	0	0.6	0	0.9	0	0	0
15	0	0	0	0	0	13.8	1.6	0	0	0	0	0
16	0.4	0	0	0	1.5	3.7	0	0	0.4	0.2	0	0
17	2.7	0	0	0	0	4	0	0	2.1	5.7	0	0
18	0	0	0	0	0	0	49.1	0	0	2.6	0	0
19	4.1	0	0	0	0	0	21.5	0	0	0	0	0
20	0	0	0	0	0.7	0.2	141.3	0.2	0	0	0	0
21	2.4	0	0	5.1	0	0.2	5.4	3.9	10.7	0	0	0
22	28.3	0	0	0	17.2	0.1	0	21.4	3.3	0	0	0.3
23	3.3	0	0	0	25.4	0	0	1.1	52.3	43	0	0.4
24	0	0	0	0	0	0.7	0.2	0	0	28.4	0	0
25	0	0	0	0	0	61.4	0.5	0	0	0	0	0
26	0	5.5	0	0	0	5.7	11.9	0	0	0	0	3.1
27	0	0	0	0	0	1.2	98	0	0	0	0	0
28	0	0.1	0	0	9.2	0	25.3	0	4.4	0	0	0
29	0		0	0	0	0.3	12.5	0.7	1	0	0	0
30	0		0	0	0	0	4	0	3	0	0	0
31	0		0		0		2.6	0		0		0

CERTIFICATE OF PUBLICATION OF PAPERS FOR PH.D.

This is to certify that Mr./Ms. Nikhil Ambish Mehta pursuing Ph.D. (**Part Time**) programme in Department of Horticulture with Registration Number 41700289 under the Guidance of Dr. Ramesh Kumar Sadawarti has the following Publications / Letter of Acceptance in the Referred Journals / Conferences mentioned thereby fulfilling the minimum programme requirements as per the UGC.

List of Publications

Sno.	Title of paper with author names	Name of journal / conference	Published date	Issn no/ vol no, issue no	Indexing in Scopus/ Web of Science/UGC-CARE list (*please mention*)
1.	Economic analysis of Tomato cultivar (*Solanum Lycopersicum)* in different soilless substrate under protected conditions by N. A. Mehta, Savita and Monisha Rawat	**Research on Crops** By AGRICULTURAL RESEARCH INFORMATION CENTRE (Gaurav Publications, Regd.) C/o Systematic Printers, Udaypurian Street, Video Market Hisar-125 001, Haryana (India)	Accepted With Ref. No. GP-2022/ROC/11040/940 Dated: 13.02.2022	*Research on Crops Vol. 23, No. 2 (June) 2022.*	1.Scopus Q3: Sci Mago Journal Ranking (SJR) 2020: **0.25** 2.ResearchGate journal Impact 2019/2020: **0.17** 3. NAAS, New Delhi rating/scoring for 2021: **4.56** 4. Impact Factor (Cite Factor) 2018: **1.30**

Reg. No 41700289 , ambish24@gmail.com

Signature of Candidate with Date, Registration No, Email ID

List of Conferences and Workshops

1. Oral Presentation in International Conference on "Global initiatives in research, innovation and sustainable development of agriculture and allied agriculture sciences (GIRISDA-2022) on 6^{th} to 8^{th} June 2022 organized by Guru Kashi University, Bathinda.

2. Oral Presenation in the International Conference on " Food Security, nutrition and sustainable agriculture- emerging technology" in 2019 organized by Baba Farid group of institute, Bathinda.

3. Got first position in Poster Presentation in International Conference on "Sustainability- Life on Earth (ICS-LOE-2021)" organized by LPU Phagwara.

4. Got second position in the Poster Presentation in National Conference on Recent adnavnces in science & technologies for sustainable development" organized by DAV College Bathinda.

5. Presented in the workshop entitled "Entrepreneurship Development in Horticulture" held n 17^{th} -18^{th} September 2019 at Department of Agriculture, Sri Guru Granth Sahib World University, Fatehgarh Sahib, Punjab.

6. Participated in the National Symposium on Smart and Sustainable Agriculture (AGRICON-2019) held on 23^{rd} November 2019 organized by People Foundation and LPU, Phagwara Punjab.

7. Participated in the 106^{th} Indian Science Congress held at LPU, Phagwara from 3^{rd} to 7^{th} January 2019

8. Participated in Training program on" Monitoring of Environment Support Program, organized by Punjab Remote Sensing Centre, Ludhiana from 13^{th} -26^{th} July 2022.