OPTIMIZATION OF NUTRIENT CONCENTRATION AND GROW MEDIA FOR STEVIA CROP UNDER HYDROPONIC FARMING

By

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B.Tech (Agril. Engg.)

THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY IN
PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE AWARD OF THE DEGREE OF

MASTER OF TECHNOLOGY
IN
AGRICULTURAL ENGINEERING

(SOIL AND WATER CONSERVATION ENGINEERING)

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2023

DECLARATION

I, **Mr. S. JANAKI RAMUDU,** hereby declare that the thesis entitled **“OPTIMIZATION OF NUTRIENT CONCENTRATION AND GROW MEDIA FOR STEVIA CROP UNDER HYDROPONIC FARMING”** submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Technology in Agricultural Engineering** in the major field of **Soil and Water Conservation Engineering** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: **(S. JANAKI RAMUDU)**

Date: **I.D. No. BEM/20-06**

CERTIFICATE

Mr. **S. JANAKI RAMUDU** has satisfactorily prosecuted the course of research and that the thesis entitled "**OPTIMIZATION OF NUTRIENT CONCENTRATION AND GROW MEDIA FOR STEVIA CROP UNDER HYDROPONIC FARMING"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by him for a degree of any university.

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This is to certify that the thesis entitled "**OPTIMIZATION OF NUTRIENT CONCENTRATION AND GROW MEDIA FOR STEVIA CROP UNDER HYDROPONIC FARMING"** submitted in partial fulfillment of the requirements for the degree of **"Master of Technology in Agricultural Engineering"** in the major field of **"Soil and Water Conservation Engineering"** of the Acharya N. G. Ranga Agricultural University, Lam, Guntur is a record of the bonafide original research work carried out by **Mr. S. JANAKI RAMUDU** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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ACKNOWLEDGEMENTS

It is a matter of pleasure to glance back and recall the path of traverse during the days of hard work and perseverance.

I wish to express my whole hearted gratitude and indebtedness to my respected guide ***Dr. K. N. Raja Kumar****, Assistant Professor, Department of Soil and Water Conservation Engineering, O/o Dean Agril. Engg. & Technology, Administrative office, Lam, Guntur for his continuous encouragement and constructive suggestions from the beginning to the end of my research work. Without his thoughtful suggestions, generous help, co-operation, encouragement and meticulous guidance in every step of my research work and also writing thesis, this research work would not come in the present shape and form.*

I sincerely extend my deep sense of gratitude to ***Dr. R. Ganesh Babu,*** *Assistant Professor and Head, Department of Irrigation and Drainage Engineering****,*** *Dr N.T.R College of Agricultural Engineering, Bapatla and member of my Advisory committee for inspiring guidance and consistent support throughout the course of present investigation.*

I express my sincere thanks to **Dr. CH. Someswara Rao,** *Assistant Professor, Department of Processing and Food Engineering, Dr. NTR College of Food Science and Technology, Bapatla and member of my Advisory committee without his thoughtful suggestions, generous help, co-operation, encouragement and meticulous guidance in every step of my research work and also writing thesis, this research work would not come in the present shape and form.*

I am indebted and higher order sincere gratitude to ***Dr. D. D. Smith****, Associate Dean, Dr. N.T.R. College of Agricultural Engineering, Bapatla for his guidance, helpfulness and for providing necessary facilities during my research.*

I am extremely thankful to ***Dr. G. Rama Rao****, Dean of P.G Studies, Acharya N.G. Ranga Agricultural University, lam Guntur for fulfilling all requirements during the research program*

I would like to express my sincere thanks to ***Dr. G. Ravi Babu****, Professor & Head, Department of Soil and Water Conservation Engineering, Dr. NTR College of Agricultural Engineering, Bapatla,* ***Dr. K. Krupavathi,*** *Assistant Professor, Department of Irrigation and Drainage Engineering, Dr. NTR College of Agricultural Engineering, Bapatla for their cooperation and encouragement.*

It is my great pleasure to thank all the faculty members, Ph.D. Scholars and P.G. students of all the departments for their motivation and encouragement whenever required during the course of my study. My special heart full thanks to all my Friends and my Juniors for their motivation, special concern, love, support and encouragement during my research work.

My sincere thanks to ***Sri G. Chinna Nagayya and Sri Kelly Babu*** *in Department of Soil and Water conservation Engineering for their support and encouragement during my research work.*

I am in dearth of words to express my heart full gratitude and love to my beloved parents, ***Mr. S. Sreenivasulu*** *and* ***Mrs. S. Mallamma*** *for their unbounding love, support, care and dedicated efforts to educate me to this level.*

I am thankful to the university authorities for their encouragement and the financial help rendered by Acharya N.G. Ranga Agricultural University, Lam, Guntur in resource form is gratefully acknowledged.

Above all, I thank God for giving me the required strength and his ever-lasting blessings throughout my studies.

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LIST OF SYMBOLS AND ABBREVIATIONS

Unless otherwise stated, the abbreviations and symbols in the text shall have the following meaning

%	-	Per cent
˚C	-	Degree Celsius
ANOVA	-	Analysis of Variance
DAT	-	Days After Transplantation
DI	-	Deficit Irrigation
dS/m	-	desi Siemens per meter
DMRT	-	Duncan Multiple Range Test
EC	-	Electrical Conductivity
pH	-	Negative Logarithm of Hydrogen Ion
et al.	-	and other people
etc.	-	and so, on
Fig	-	Figure
g	-	Grams
hr	-	Hour
i.e.	-	that is
kg	-	Kilogram
km^2	-	Square kilometre
lph	-	Litre per hour
m	-	Meter
mm	-	Millimetre
NFT	-	Nutrient Film Technique
PVC	-	Polyvinyl chloride
Rh	-	Relative Humidity

ABSTRACT

Author	**:**	**SURAKATTULA JANAKIRAMUDU**
Title of Thesis	**:**	**“OPTIMIZATION OF NUTRIENT CONCENTRATON AND GROWING MEDIA FOR STEVIA CROP UNDER HYDROPONICS”**
Submitted for the Award of	**:**	**Master of Technology**
Faculty	**:**	**Agricultural Engineering and Technology**
Department	**:**	**Soil and Water conservation Engineering**
Major Advisor	**:**	**Dr. K. N. Raja Kumar**
University	**:**	**Acharya N. G. Ranga Agricultural University**
Year of Submission	**:**	**2023**

Soil is the essential medium for the growing of plants. It provides water, air and nutrients etc, for the successful growth of plant. However, soils do pose severe limitations for the plant growth some times. Disease causing organisms, nematodes, unfavourable soil compaction, unsuitable soil reaction, poor drainage and increase in salinity etc. will also affect the crop growth. Along with this, cultivation of crops in soil (open field agriculture) is difficult as it requires more space, labour and high quantity of water. In some places soil is not available for growing crops like metropolitan areas. Under such conditions, soil-less culture can be successfully introduced.

The soilless culture is mainly referred to the technique of Hydroponics. It means growing of plants in nutrient solution without use of soil. The plants are grown with their roots in the mineral nutrient solution only or in an inert medium, such as cocopeat, perlite and vermiculite, etc. In another side Stevia is a perennial herb belonging to the Asteraceae family. It is a natural sweetener tastes 200 to 300 times sweeter than table sugar and it is used for diabetic patients to lessen the sugar levels in the blood. This crop requires favourable media, nutrients and environmental conditions to achieve higher yields. This can be possible with hydroponic farming in controlled atmosphere by optimizing the nutrient concentration and growing media.

Keeping this in view, a field experiment was carried out for optimization of nutrient concentration and growing media for stevia crop under hydroponic farming at Dr. NTR College of Agricultural Engineering, Bapatla during the year 2022. The experiment was laid out in split plot design with main treatments as 4 levels of nutrient concentrations (C_1 = 0.75, C_2 = 1.0, C_3

= 1.25 and C_4 = 1.5ds/m) and four types of growing media (M_1 = rockwool, M_2 = perlite, M_3 = clay balls and M_4 = vermiculite) as subplots with three replications. Nutrient Film Technique (NFT) method of cultivating was adopted under hydroponic farming. Normal farmer practice was carried out in open field to compare the yield and cost of cultivation of stevia crop.

Climate parameters viz, temperature, relative humidity and CO_2 are the major factors for plant growth and they were recorded at 2 hours interval throughout the experiment in hydroponic farming. Biometric parameters like plant height, No. of branches, root length, no. of leaves, leaf length and stem diameter of stevia crop were observed in hydroponic farming and in open field condition. The obtained data was analysed in the SPSS software and DMRT was carried out to find the significant grouping between the treatments. The cost economics of stevia crop under hydroponic farming and in open field condition was carried by straight line method.

Under hydroponic farming in naturally ventilated polyhouse, the highest and lowest temperature recorded in the month of May (36.81 ˚C) and march (25.05 ˚C). The highest and lowest relative humidity were found in the month of march (78.79 %) and April (61.59 %). The highest and lowest CO_2 levels are found in the month of May (541.7 ppm) and March (405.27 ppm). Where as in open field conditions, the highest and lowest temperature recorded in the month of May (39.1 ˚C) and March (22.1 ˚C). The highest and lowest relative humidity are found month of march (82.7 %) and may (38.4 %).

In biometric parameters under hydroponic farming at 60 DAT, the highest plant height was recorded in C_4M_3 (45.8 cm) and the lowest height was recorded in C_1M_1 (28.1 cm). The highest No of branches was recorded in C_3M_3 (5 No's) and the lowest was recorded in C_1M_1 (3 No's). The highest root length was recorded in C_3M_3 (21 cm) and the lowest was recorded in C_1M_1 (11.1 cm). The highest No. of leaves was recorded in C_3M_3 (162 No's) and the lowest was recorded in C_1M_1 (65 No's). The highest leaf length was recorded in C_2M_4 (5.8 cm) and the lowest was recorded in C_1M_1 (5.2 cm). The highest girth diameter was recorded in C_3M_2 (3.2 mm) and the lowest was recorded in C_1M_1 (2.1 cm). The highest yield was recorded in C_3M_3 (228.8 g) and the lowest was recorded in C_1M_1 (184.5 g). Where as in open field conditions at 60 DAT, the average plant height was recorded (21.27 cm). the average No. of branches was recorded (4 No's) and the average no of leaves was recorded (50 No's). The average leaf length was observed (4.33 cm) and the average girth diameter was observed (1.67 mm). Statistical analysis showed that there is significant difference between in the plant height, no of branches, root length, no of leaves, leaf length and girth diameter within the treatments for stevia crop under hydroponic farming. The highest yield treatment of C_3M_3 considered to calculate the total yield of total yield of 250 m2 area of hydroponic farming in naturally ventilated polyhouse. Then the total yield of stevia crop was 410.4 kg. Net returns obtained in hydroponic farming for 30 A-frame structures in naturally ventilated polyhouse was Rs. 505160/- and the benefit cost ratio was 2.6. This gives rise to a payback period of approximately 3 years. Net returns obtained in the open field condition was Rs. 28600/-

Key words: Hydroponics, Nutrient Film Technique (NFT), Nutrient concentration, Growing media and Stevia crop

Chapter I

INTRODUCTION

Present world population is around 7.7 billion and it was estimated to reach 9.7 billion by 2050. To meet the food demand of growing population, production of food requires to be doubled. Throughout the world, 50% of the arable land is unsuitable for farming activities (United Nation, 2017). India's population is estimated at 1.37 billion (18% of the world population) having only 2.4% of the world's geographical area and 4% of world's fresh water out of which 80% is used for agricultural operations. Food insecurity is a problem in India and many countries of the world. The concern with this is seen in the productivity of existing agricultural and fresh water gathering facilities. Even with our energies, 1.0 billion people hurt from malnutrition modernly and 1.2 billion live in zones with water shortage (Bellona Foundation, 2009).

The major reason of the food crisis is climate change that causes droughts, frequent floods, poverty, soil erosion and land degradation. The poverty in many countries especially in southern Africa causes reduced food production because of reduced accessibility to irrigation and fertilizer. The degradation and soil erosion due to the traditional farming methods strips the soil to low vitamins and minerals. In view of the above reasons, the world requires to invent techniques to improve and increase the productivity of farming systems.

Soil is the essential medium for the growing of plants. It provides water, air and nutrients etc, for the successful growth of plant. However, soils do pose severe limitations for the plant growth sometimes disease causing organisms, nematodes, unfavourable soil compaction, unsuitable soil reaction, poor drainage and increase salinity etc. will also affect the crop growth. Along with this, conventional method of crop cultivation in soil (open field agriculture) is difficult as it requires more area, labour and high quantity of water. In some places soil is not available for growing crops like metropolitan areas. Another serious problem is the availability of labour for conventional open field agriculture. Under such conditions, soil-less culture can be successfully introduced.

The soilless culture is mainly referred to the technique of Hydroponics. It means growing of plants in nutrient solution without use of soil. The word hydroponics was coined by Professor William Gericke in the early 1930's describe about the growing of plants with their roots suspended in water containing mineral nutrients. The plants are grown with their roots in the mineral nutrient solution only or in an inert medium, such as cocopeat, perlite and vermiculite, etc. Plants grown in the hydroponic system can achieve 20-25% higher yields than a soil-based system with productivity 2-5 times higher (United Nation, 2017).

Hydroponics is the fastest growing sector of agriculture, and it could very well dominate the food production systems in the future. As population increases and arable land declines due to poor land management, new technologies like hydroponics farming create additional channel for intensive crop production. Hydroponic system provides all the nutrients without involving soil, additional labour, allowing farmers to benefit from efficiencies and to obtain high quality produce. The benefits of controlling and managing pH, CO_2, heat, nutrient supply, water requirement, temperature and lighting help farmers to boost production of crops in hydroponics system. It is not otherwise easy to handle such parameters in traditional farming. The efficiency of a hydroponic system can save upto 90% of water. With the help of hydroponics, one has several options of growing plants, which includes vertically there by drastically reduces the land requirements needed to grow the crops. Growing hydroponically, improves the quality and taste of produce, because the system utilizes quality of nutrients and clean water under controlled environment without pesticides or herbicides.

The revolutionary expansion of hydroponics in many countries of the world in the last three decades may be ascribed to the ability of soilless growing systems to be independent of the soil and hence of all problems related to it. The main problems arising from the soil are the presence of soil-borne pathogens at the start of the crop and the decline of soil structure and fertility due to its continual cultivation for the same or a related crop species. Hydroponics has proved to be an excellent alternative to soil sterilization. Achievement of high yields and good quality is possible with hydroponics even in saline or sodic soils, or non-arable soils with poor structure, which represent a major proportion of cultivable land throughout the world (Jensen *et.al.*, 2010). A further advantage of hydroponics is the precise application of nutrition. This is particularly true in crops grown either on inert substrates or in pure nutrient solution. However, even in soilless crops grown in chemically active growing media, the nutrition of the plants can be better controlled than in crops cultivated in the soil, due to the limited volume of substrate per plant and its standard, homogeneous constitution, which is well known to the grower.

One of the hydroponic techniques used is Nutrient Film Technique (NFT). In NFT technique, plant roots are placed in a layer of shallow water that circulates and contains nutrients. The advantage of NFT technique is that plant growth is easier to control. In the hydroponic plaqnts cultivation, some parameters need to be considered. Some of the most important parameters are Total dissolved solids/Electrical conductivity and pH of the nutrient solution. Each plants require a different balance of composition and amount of nutrients. The amount of nutrients supplied must be according to the plant's need. Giving too little or excessive amount of nutrients, can cause crop yields not optimal, or can even cause crop failure. Therefore, a system that is able to control nutrient solution is needed.

Clay balls, vermiculite, perlite, and rockwool are inert materials that are used to support plant roots in the nutrient film technique of the hydroponic system. Clay balls do not store water, but they do contain microscopic air pockets that allow for good drainage and root aeration, as well as supporting plant roots. Water and air are retained by perlite and rock wool, whereas only water is retained by vermiculite. The plant roots directly absorb nutrients from the fluid as it passes through these four mediums. The pH of perlite is 6.6 to 7.5, while that of rockwool is 8. A neutral pH is found in clay balls and vermiculite. Perlite, clay balls, vermiculite, and rockwool were utilised in the current study because of their advantages in growing plants. These are frequent medium in hydroponics system production, however research into their benefits and drawbacks is required.

On the other hand, Stevia crop is a perennial herb belonging to the Asteraceae family and it is medicinally important plant found in Brazil and Paraguay. It is an intensely sweet-tasting plant that has been used to sweeten beverages and make tea since the 16^{th} century. Stevia plant is a natural sweetener tastes 200 to 300 times sweeter than table sugar (Yadav *et al.*, 2011). It is used by the diabetic patients to lessen the sugar levels in the blood. Stevia is a short-day plant grown under tropical and sub-tropical conditions. Long day-length is helpful for higher leaf yield. Relative humidity of 60-80% is suitable for proper growth and development. An ideal temperature ranging between 25°C to 37°C can boost the commercial stevia leaves production. The major stevia growing states in India, are Maharashtra, Punjab, Karnataka, Chhattisgarh, Madhya Pradesh, and Andhra Pradesh. Gradually stevia farming is picking up in Uttar Pradesh as well. Use of stevia plant or leaves is also helpful in providing protection to gums and teeth. Currently, India has about 30 million diabetic patients, which is expected to increase to 80 million until 2025. In this way, the Indian farmers have also started to take stevia cultivation to the next level trailing the huge demand for the diabetic market here. It's a medicinal plant and important to note that, in order to be used in pharmaceuticals, plant material must be free of heavy metals, soil, soil microorganisms, herbicides, and pesticides. As a result, hydroponics may be a suitable growing system for high quality biomass production while allowing the regulation of secondary metabolism by managing the nutrient solution. The expectation of yield in hydroponics is higher than traditional farming system. Hence, developing a new farming technique is required especially in India to avoid food crisis issue in the future. By keeping in view of the above details, the present research study is proposed with the following objectives.

Objectives of the study

1. To optimize pH, Electrical Conductivity of the hydroponic nutrient solution for stevia crop.
2. To optimize growing media for stevia crop in nutrient film technique as hydroponic farming.
3. To study the biometric parameters of the stevia crop grown at different grow media and nutrient concentration under hydroponics.
4. To evaluate the cost economics of stevia crop under hydroponic system in naturally ventilated polyhouse.

Chapter II

REVIEW OF LITERATURE

The chapter deals with the review of literature related to the present study. A brief review pertaining research work on nutrient concentration, growing media, biometric parameters and cost economics of stevia crop grown in hydroponics and open field condition. Hydroponic culture is the most intensive method of crop production in today's agricultural industry. Utilizing an appropriate nutrient solution is one of the most important components of establishing and maintaining a hydroponic greenhouse stevia crop. Inadequate management of nutrient solution such as the use of too low or too high concentration of the nutrient solution, or an imbalanced ion composition could inhibit plant growth due to either toxicity or nutrient-induced deficiency. On the other hand, growing media is an important parameter in hydroponic system. The main function of a growing medium is to physically support plants and to supply adequate oxygen, water and nutrients to ensure optimal plant functions. The choice of soilless growing medium for plant nutrition, growth and support is crucial for improving the eco-sustainability of the production. However, study of biometric parameters is an important consideration in in the experiment. This study also concerned with calculating the cost of cultivation, returns and cost benefit ratio to identify economic viability and technical feasibility of stevia crop and also provide the information regarding the profitability of cultivation. The review of past research helps to achieve the above goal and give a better insight into the subject. Keeping in view of the objectives of the study, the comprehensive review is presented through the following sections.

2.1 Optimization of pH, Electrical Conductivity of the hydroponic nutrient solution for different crops

Nutrient management is a method of using crop nutrients as efficiently as possible to improve the productivity without harming the environment. In hydroponics, nutrient management is a very necessary step. Total dissolved solids, electrical conductivity, pH, and nutrient concentration ratio are four main characteristics to focus on nutrient management in soilless culture. Therefore, the earlier research results related to the above four characteristics are reviewed and presented below.

Sarmah *et al.* (2020) conducted an experiment on hydroponic marigold at Department of Horticulture Assam Agricultural University. The experiment was laid out using completely randomized design with two factor and three replications. In the experiment, marigold plants were grown in five different hydroponic systems (Nutrient film technique, Water Culture, Aggregate systems with Sand, Cocopeat and Sawdust as potting media) with three different levels of hydroponic nutrient solution (EC 1.0 ds/m, EC 1.5 ds/m and EC 2.0 ds/m). Experimental results showed that the system, nutrient solution and their interaction significantly affected the flower quality and production. Among the five systems, NFT was found significantly superior to all other systems in terms of quality flower production. Thus, from the floriculture perspective conclusion was drawn that treatment combination of NFT and EC 1.5 dS/m is optimum for quality flower production of marigold.

Sun *et al*. (2019) studied the effects of N rates on steviol glycosides production through hydroponic and plot experiments. The plot experiment was conducted at Institute of Botany, Jiangsu Province and Chinese 128 Academy of Sciences. The steviol glycosides yield was not significantly changed by N fertilization, but leaf steviol glycosides concentrations were significantly reduced due to the “dilution effect”. Additionally, N addition decreased leaf carbon C/N ratio and soluble sugar concentration, accompanied with the inhibited phosphoenol pyruvate carboxylase and L-phenylalanine ammonia lyase activities. A significant positive correlation between leaf SGs concentrations, C/N ratio and soluble sugar concentration was observed. Overall, suggested that N-driven Stevia growth negatively affects steviol glycosides concentrations. The leaf C/N ratio and soluble sugar changes indicated the occurrence of metabolic reprogramming.

Alshrouf (2017) observed that due to tremendous demand for water resources and subsequently food supply, many new developments in the farming innovative methods which include a complex hydroponic system have been evolved**.** Hydroponics is the art of soilless agriculture in which growth of plants in a soil less medium or aquatic based environment as aeroponics farming system. Several studies of commercial-scale development of hydroponic, aeroponics and aquaponics production showed the potential positive role for these new technologies in the sustainable food security. Such agricultural farming systems may provide a sustainable alternative for different types of production that it requires less water, less fertiliser and less space to improve yields per unit area.

Kaur (2016) conducted the field experiment in 2016 for the development of hydroponic system for greenhouse tomato in the Demonstration Farm of Department of Soil and Water Engineering, PAU, Ludhiana. The experiment was set up in a completely randomised manner with three Hoagland solution treatments (100%), (75%), and (50%). Under regulated conditions, the crop was cultivated in PVC pipes. The temperature and relative humidity in the greenhouse were kept between 24 and 32 degrees Celsius and 40 and 65 per cent, respectively. In the tank, the pH and EC of the Hoagland solution were kept at 5.5 to 6.5 and 1.5 to 2.5 ds/m, respectively. T1 (100%) yielded 72.57 tonnes per hectare, which was equivalent to T2 (75%) yield of 69.28 tonnes per hectare.

Askar (2015) studied the potential of nutrient film technique (NFT) hydroponic system for flowers and bulbs production of the Asiatic hybrid lily cv. "Blackout" using rainwater and nutrient solutions with rock wool cubes as medium with or without removal of flower buds and mother bulb scales in university of Baghdad. The nutrient film technique hydroponic system was an excellent method to produce lily flowers in 55 days. The rainwater contained some amounts of macro and micro elements in forms that plants can absorb. The rainwater *spinaciaoleracea* had a pH value 6.20 which was suitable for plant growth. The nutrient film technique hydroponic system was shown to be the most effective for bulblets and daughters production, but different solutions showed different results and the Hoagland solution and Morishige and Skoog solution gave the best results related to the production of these propagated storage organs.

Niu *et al.* (2015) conducted a study to evaluate the availability to cultivate eucalyptus seedlings in hydroponic system at University of Georgia, Athens. The experiment was completely random design with a factorial treatment structure (2 species × 6 P concentration) with 4 replications. Each replication had 8 plants/seedlings. ANOVA was the primary statistical test used. Phosphorus had direct effect on leaves area, plant height, and stem diameter. The phosphorus use efficiency (PUE) was highest at lower P concentration in nutrient solution. That was good for optimum production and good quality crops. This work make confirm to produce comfortably in high vigor woody plants cultivation in hydroponics.

Roosta and Hamidpur (2011) conducted a study about the consequence of foliar apply to the nutrients in water-based cultivation systems at Vali-e-Asr University of Rafsan-jan, Iran. Different 40 to 50 carp fish were stocked in the rearing tanks. This stocked water was source of nutrients for plants growing in aquaponic system. In case of iron deficiency, iron was added in solutions. In water loses case to balance this situation use tap water. Tap water was used for compensating water loses. Fishes diet plan present 46.3% protein nutrition. This nutrition helps to increase the growth rate of plant. Among all chemicals, only Iron and boron help to increase the growth of hydroponic plants, but in case of aquaponic system potassium, magnesium, iron and boron chemicals helped for growing crop. The effect of different chemicals were in order of B < Mg < Zn < Mn < Fe < K.

Aminifard *et al*. (2010) carried out a field trial during the last week of November 2002 and 2003 growth seasons to investigate the interactive effect of different plant densities and N fertiliser rates on yield and quality attributes on radish (*Raphanus sativus* L.) at the experimental station of national research center in Shalkan, Qalubia government, Egypt. Plants were spaced at 10 and 20 cm inter-row and 5 or 10 cm intra-row distances (plants thinned when leaves were 5-8 cm tall) and received N fertiliser (ammonium sulfat) at rates of 40, 60 and 80 kg. One-half of the N dose was applied before sowing while the remaining N was applied as a top-dressing 15 days after sowing. The roots were harvested at 35 days after sowing. Data are tabulated on yield, N content in leaves and roots. Yield, roots and dry matter content recorded the highest values with the highest rate of N application. Decreasing plant density significantly reduced the total yield but markedly enhanced root quality. It was concluded that the reduction in yield due to lower plant density can be compensated by the higher prices of high-quality roots.

Varlagas *et al.* (2010) conducted three experiments in a west east oriented glasshouse located in Athens, Greece during the period of 2007 to 2008 for simulation of uptake concentration of Na+ and Cl- in root zone area of crop. One was carried out to check the model with NaCl concentrations. The range of NaCl concentration lied between 0 to 14.7 mol/m^3. Other treatments ware investigated to calibrate the model in either low or high ranges. The low range of concentration lied between 0.5 to 2 mol/m^3 and high range of concentration lied between 1.2 to 12 mol/m^3. The concentration of Na+ chemical forecast easily but concentration of Cl- chemical was difficult. Cl- value not less than 10 mol/m3. The results shows that tomatoes genotypes high salt prohibition properties for maintain the sodium ion in root zones at optimum level in tomatoes hybrid.

Signore *et al*. (2008) observed the nutrient solutions must have a high electric conductivity (EC) in closed soilless systems. The experiment was carried out at the 'La Noria' Experimental Farm of the Institute of Sciences of Food Production of the National Research Council (NRC), Mola di Bari, Italy during the period of February-July using a hybrid cultivar of cherry tomato (Solanum lycopersicum L., cv. Naomi). A completely randomized design with three replications was used. Each experimental unit contained sixteen plants. Comparison was done by two different ways of increasing EC for tomatoes grown by Nutrient Film Technique (NFT). The initial EC of the nutrient solution was increased by doubling the concentration of macro nutrients or adding NaCl in order to maintain EC above 3.5 ds/m. It was concluded that the addition of NaCl allowed a meaningful reduction in the quantities of nutrients utilized with inclusive savings of 11 % for S and 20 % for P without any decrease in marketable yield.

Pinker and BöhmeHumboldt (2007) studied greenhouse conditions to evaluate their productivity potential. The Dutch cultivar 'Ritmo' (RZ) and the Asian clone '1507' were investigated from May to August 2006. In this experiment, two hydroponic systems the 'Substrate Culture' and Nutrient-Film-Technique (NFT) were compared. Plants were cultivated in containers filled with perlite, on peat slabs and in NFT with EC values 2 and 4 in the nutrient solution, In countries with limited sources of substrate components water culture can be an alternative for protected cultivation. The Nutrient film technique (NFT) was system with reduced needs of substrate (only rockwool cubes for plant propagation) and has a potential for economical use of water.

Lykas *et al*. (2006) studied that influence of nutrient solution first one is mixing rate, and another one time of use on pH and electrical conductivity (EC) of a recirculated nutrient solution used for the irrigation of a greenhouse soilless rose crop was studied during 2001 at the University of Thessaly, situated near Volos, (39◦44′, 22◦79′, 85 m) on the coastal area of eastern Greece. Measurements of microclimate variables, pH, and EC of nutrient solutions and crop transpiration was conducted. The measurements of pH and EC values of nutrient solutions mixed with different mixing rates and applied for crop fertigation were used to develop and calibrate a model for pH and EC prediction in relation to nutrient-solution mixing rate and time of use. Application of the calibrated model gave satisfactory results. It was found that nutrient solutions with high mixing rates or volume equal to or double that of the total water consumed by the canopy during the conservation period had the most stable EC evolution and minimal pH changes. The experimental design was a randomized complete block (3x4) with four replications.

Karimaei *et al.* (2001) carried out the experiment for comparison of Hoagland nutrient solution in one concentration level and two concentrations of Massantini solution. First is full 100% and second is 50% strength. Also, two Romain type (White Seed and Black Seed cultivars) were compared with two Crisphead cultivars (Martha and Olimpo). Closed hydroponic system (ebb and flow) with sand media was used. The experimental design was a randomized complete block (3x4) with four replications. Hoagland solution gave robust consequence followed by 50% Massantini solutions. The relation between growth rate, plant attributing characters and N, P and K concentrations were pessimistic. The pH value or electrical conductivity showed negative inter-relations with some plant attributing characters such as number of leaves, weight of dry leaves and concentration of Potassium. The maximum growth rate of lettuce was found at the lowest pH (5.83), which was determined for Hoagland solution. This pH is very close to proposed pH for lettuce cultivation since most growth parameters, N and P concentration levels and N:P and K:N ratios were highest in Hoagland solution, it may be concluded that Hoagland nutrient solution is more appropriate for hydroponic cultivation of lettuce than Massantini nutrient solution.

Maia *et al.* (2001) conducted study about the cultivation of Menthaarvensis L. Essential oil at the university of sao Paulo, in Piracicaba, Brazil, South America. Plants are transplanted into net pots. In this study11 types of nutrient solution were used. The main aim of this work is determining the main element required for nutrient solution for commercially cultivation, that causes increased the plant yield and oil present in high menthol composition. The plants were grown in solutions containing three concentrations of each nutrient. In the presence of Nitrogen increased the leaves weight, but decreased the oil with low menthol content. Magnesium increased in oil percentage in the plants. The effect of nitrogen and magnesium were more in oil present in the plant.

Paiva *et al.* (1998a) studied about cultivation in hydroponic under greenhouses in the Department of Phytotechny, Federal University of Viçosa, Viçosa, Minas Gérais, from January to April 1995. This study was used advance type Hoagland solution accommodated various calcium concentration (0.2, 2.5, 5.0, 10, 15, 20 mm/lit). A trial was conducted in a greenhouse These are representing in randomized design with three treatments. This work results were if fruit keep less relative humidity, the concentration of calcium will be more. That caused more water was loss from plant tissues lead blossom-end rot when low concentration of calcium was goes to the crop.

Paiva *et al.* (1998b) conducted the experiment in a greenhouse hydroponically using a modified Hoagland solution containing different Ca concentrations (0.2, 2.5, 5.0, 10.0, 15.0, and 20.0 mmol L^{-1}). A trial was conducted in a greenhouse in the Department of Phyto Techny, Federal University of Viçosa, Viçosa, Minas Gérais, from January to April 1995. The trial consisted of three replications per treatment in a fully randomized design. The fruits of the second and third replications were picked after full ripening and analysed for their Ca, magnesium (Mg), potassium (K), lycopene, and total carotene levels. The total lycopene and carotene levels decreased with increasing Ca concentration in the nutrient solution, possibly due to the reduction in K absorption with minimum levels of Ca concentration of nutrient solution.

Park *et al.* (1994) investigated the most appropriate nutrient rich solutions among Cooperˈs, Hoagland, Arnon and Yamazakis solutions in the polyethylene greenhouse of Korea university in Seoul. Two cultivars 'Averto' and 'Zorzi' were used in this experiment. In Yamazaki solutions gave best results in terms of root weight and crop yield. Second investigation was conducted with Yamazaki solution. It was treated with electric conductivity of 0.5, 1.5 and 2.0 mS/cm with different ionic strength and noticed change in mineral content or vitamin C content.

2.2 Optimization of growing media for different crops in hydroponic farming using nutrient film technique.

Growing media consist of mixtures of components that provide water, air, nutrients and support to plants. The media provide support to the plant, while the nutrients are provided by added fertilizers. Water and air are provided in the pore spaces in the media. The four main factors affect air and water status in containers are the media components and ratios, height of the media in the container, media handling and watering practices. Choosing an appropriate growing media is a really critical task. A perfect one will greatly impact plants' growth and the quality yield. Another role of the media is to allow plant's roots to have maximum exposure to the nutrient. Hydroponic system will moister the growing media with the nutrient solutions. And the wet media will transfer the nutrient to the root system. The below reviews of earlier research work helped to select the grow media information on present objective to meet the objectives of the study.

Chhetri *et al*. (2022) carried out an experiment for two months from Nov to Dec 2020 in the research house of Wind Power Nepal Pvt. Ltd, located at an altitude of 1310 meters above sea level. The experimental design used in this study was a factorial randomized block design (RBD) with two factors. The first factor was growing media; namely cocopeat, sponge, and perlite. The second factor was crop types namely lettuce and pakchoi that were harvested in 30 days. The data was subjected to the ANOVA technique in R-studio software version 4.0 and Fisher's protected least significant difference (LSD) test was used to separate the means. The highest plant yield (12.55 g) was obtained from plants grown in cocopeat in the NFT hydroponics system. The longest plant shoot height (9.69 cm) was obtained from plants grown in the sponge, while the lowest plant shoot height (8.85 cm) was observed in plants grown in perlite. The broadest plant leaf width (5.54 cm) was observed in plants grown in the cocopeat when compared to the sponge (4.93 cm) and perlite (4.32 cm) growing media. The results of this study showed that growing media cocopeat followed by sponge performed better as compared to perlite.

Krishan *et al*. (2020) carried out an experiment for fabrication and performance evaluation of a shaped frame hydroponic system under protected structures at the centre of excellence on protected cultivation and precision farming (coe-pcpf), college of agriculture, IGKV, Raipur, during the year 2017-18. The experiment was laid out with three treatments T1 (A-frame PVC pipe), T2 (A-frame UPVC pipe), T3 (A-frame CPVC pipe), of hydroponic system. The transplanting of seedlings of leafy garlic was done in perforated net pots with a media of coco-pit and vermiculite in 3:1 proportion and clay pellets. Irrigation was applied to the crop by ebb flow technique. The pH and EC of the hydroponic solution was maintained in the range of 5.5 to 6.5 and 1.5 to 2.5 dS/m respectively in the tank. Effects of material on the growth of plants, EC and pH level of nutrient solution have also been studied and it was found that material had a very little or no effect on the growth as well as EC and pH aspects of nutrient solution at least in the first year of cultivation which might be changed in later years.

Fadel *et al.* (2017) studied the effect of using various substrate materials on the development of seedlings for ornamental plants. Bermuda, *Petunia* and *Epipremnumaureum*, were cultivated in different substrates. Synthetic sponge (Polyurethane sponge), Rockwool and sterilized cotton were used as the substrate materials in each case where an experimental water-circulating apparatus was designed and installed to execute the test. Results showed that after 15 days, Bermuda grass in Rockwool reached a germination rate of 70% while it did not exceed 50% in sponge or in medically treated cotton. The highest germination rate after 20 days for *Petunia* was observed to be 30% when treated cotton was used, while it was 22% and 7% when Rockwool and sponge were utilized, respectively.

Renuka *et al*. (2015) conducted a experiment to study the effect of media on rooting of carnation cuttings of cv. BALTICO at commercial floriculture farm, Mudimyal, Rangareddy district, Telangana during September, 2011 to March, 2012 under naturally ventilated poly house. The experiment was conducted in Randomized Block Design. All the media treatments studied recorded superior rooting parameters over control. Among the media treatments studied red earth + coco peat recorded minimum number of days for root initiation, maximum percentage of rooting, cumulative root length, maximum fresh weight of roots and percentage of establishment of rooted cuttings followed by coco peat + vermicompost and vermicompost alone.

Media in combination recorded maximum rooting percentage, cumulative length of roots and fresh weight of roots over individual media treatments studied.

Joseph and Muthuchamy (2014) observed that there was a need for low cost, readily available, simple, attractive technologies which can utilize space and water efficiently to increase the productivity in agriculture. This study was an attempt to develop certain low-cost aggregate hydroponic techniques for tomato production under naturally ventilated polyhouse located in Precision Farming Development Centre, Tamil Nadu Agricultural University, India. The experiment was laid out in a factorial randomized block design replicated thrice. Three different hydroponic systems, i.e., tray, trough & pot and three different media combinations, i.e., cocopeat+gravel+silex stone, cocopeat+pebble+silex stone & cocopeat+perlite+silex stone, constituted the factors of the treatments. The maximum yield (4.9 kg/plant) was observed for the treatment trough with cocopeat+gravel+silex stone (T4) followed by trough with cocopeat+perlite+silex stone (T6) and trough with cocopeat+pebble+silex stone (T5) with values 4.2 and 3.9 kg/ plant respectively. The highest productivity obtained from the treatment T4 was 245.3 t/ha. The treatment T2 (tray with cocopeat+pebble+silex stone) yielded least (2.8kg/plant) with a productivity of 138.3 t/ha. The highest total soluble solids (12.5°brix) were recorded for the treatment T4 followed by T6 (10.9°brix) and T5 (10.5°brix) and the lowest (8.3°brix) was recorded for the treatment T1 (tray with cocopeat+gravel+silex stone.

Kameswari *et al.* (2014) conducted an experiment for growing chrysanthemum variety 'punjab anuradha' continuously for three years to study the suitability of different potting media. Growth and floral characters have shown significant differential response among the treatments. Maximum values for plant height, number of branches per plant, plant spread, flower weight, duration of flowering, number of flowers per plant and spray length was found in the media containing Coco peat: Sand: FYM: Vermicompost. Maximum flower diameter, however, was found in Soil: Sand: FYM: Vermicompost in ratio of 2:1:0.5:0.5, In this combination Soil was replaced with Coco peat. Soil: Sand: FYM: Vermicompost was found to be superior over Coco peat: Sand: FYM: Vermicompost in terms of nutrient content.

Albaho *et al.* (2013) investigated the suitability of some locally available materials, in Kuwait. The experiments were conducted in a polycarbonate greenhouse equipped with evaporative cooling system. Ambient temperatures ranged between 18 and 26°C during the crop period (January to May 2011). Four combinations of media were used as substrates *i.e.*, M_1- Peat moss + Perlite + Vermicompost (35:40:25

percent), M_2 - Peat moss + Perlite + Vermicompost + Coco peat (25:25:25:25 percent), M_3 - Coco peat (100 percent) and M_4 - Perlite + Peat moss (50:50 percent) as control. The experiments were carried out inside a cooled greenhouse. It was reported that growing media M_1 as well as M_2 are the best substrates for use in the Grow bag technique for cucumber cultivar 'Banan".

2.3 Biometric parameters of the different crops grown at different grow media and nutrient concentration under hydroponics.

Growth analysis is a mathematical expression of environmental effects on growth and development of crop plants. This is a useful tool in studying the complex interactions between the plant growth and the environment. The problem of accounting for variation in yield in terms of growth and development of the crop is very complex due to the effect of external environment on the plant physiological processes, the interrelation between different physiological processes, and the dependence of the above two on internal factors determined by the genetic constitution of the plant. The basic principle behind this concept of analysis is the estimation of crop growth at various stages and finally reasoning for yield variation. This would give an insight not only on the performance, of a particular genotype, but also on the impact of superimposed agronomic practices on the crop at any particular stage of growth as well as on the final yield. The below reviews of earlier research work will help to collect the information on present objective.

Agarwal *et al.* (2019) carried out an experiment at Defence Institute of Bio-Energy research (Defence Research and Development organization) Haldwani, Uttarakhand (India) to study the effect of three different growing conditions, *viz*, soil grown system, soil-less and hydroponics system on productivity and quality of lettuce. Soil-less cultivation is one such technique which offers better productivity of lettuce crop to the tune of 3-4 times higher than soil grown system with better quality produce. Lettuce crop under hydroponics system developed profuse root system with average root length of 31.0 cm and fresh weight of 1.12 kg whereas under soil grown system the average root length was the minimum (10.0 cm) with minimum fresh weight of roots (0.152 kg). Ascorbic acid was the highest in the hydroponically grown crop of lettuce (11.2 mg/100g). Crop grown under soil-less vertical system exhibited the highest phenol content. Flavonoid content was at par among the hydroponics and soil less system but was quite low in the soil grown lettuce.

Lokhande (2018) designed and developed a hydroponic structure with nutrient film technique. In his study he found out that the controlled atmosphere system temperature inside the green and white hydroponic structure has great influence on crop growth. Temperature inside the green and white colour hydroponic structure was found 5-10 ^{0}C less than the outside temperature which was favourable for the growth of fenugreek. Relative humidity inside green and white colour hydroponic structure was found 20-35% more as compare to open field. When comparison between green and white colour hydroponic structure relative humidity inside the green colour hydroponic structure was found 2-5 % more than white colour hydroponic structure. Light intensity inside green and white colour hydroponic structure was found 5-10% less than the open field. When comparison between green and white colour hydroponic structure light intensity inside the white colour hydroponic structure was found 1-3% more than green colour hydroponic structure. Biometric characteristics *i.e.*, height of plant, number of leaves, stem diameter, inside the green colour hydroponic and white colour hydroponic was found two to three times more than the open field condition. Quality parameters *i.e.*, moisture content, iron content, chlorophyll content was found maximum inside the green colour hydroponic structure. The Moisture content was found (94.877%), iron content (324.306 ppm) and chlorophyll content 36.794 mg/gm were found in green hydroponic structure. Yield of fenugreek was found greater in the green colour hydroponic structure in between (150-210 q/ha). Yield in the open field was found 2 times less as compare to the green and white hydroponic structure

Kumar *et al*. (2014) conducted field experiment during 2009 and 2010 at Institute of Himalayan Bioresource Technology, Council of Scientific Industrial Research (CSIR), Palampur, India, to assess the effect of pinching on growth, yield and quality of stevia. It consists of eight treatments of pinching; six treatments were executed at 20, 30 and 40 days after transplanting (DAT) at 10 and 20 cm height (main branches only), one at 40 DAT (main, secondary branches) at 20 cm height and one control (no pinching). The experiment was conducted using a randomized complete-block design with three replications. Pinching treatments significantly affected number of leaves, branches per plant, plant spread and leaf yield, as compared with the control. Stevia plants pinched at 40 DAT (main, secondary branches) at 20 cm height recorded significantly higher number of leaves plant-1 (213), fresh leaf weight (93.8 g plant-1) at first harvest and 27.7 % higher total leaf dry biomass as compared with control. They concluded that pinching enhances leaf biomass and profits in stevia.

Domingues *et al.* (2012) described one of the most commonly consumed leaf vegetable lettuce farming in hydroponic system where the growth depends on the composition of nutrient solution. The experiment was realized in greenhouse located in the Centre of Agricultural Sciences, State University of Londrina – UEL. Agronomic and chemical parameters were analysed for both crops, attesting the precocity in harvest (64 vs. 71 days) with less labour, better management and higher productivity, particularly in fresh and dry matter of aerial parts, presenting 267.56 and 13.33 g/plant respectively, using the developed system. Regarding the concentration of nutrients for the automated hydroponic system was identical to that obtained by the researchers referred, as follows: K > N > Ca > P > Mg > S > Fe > Zn >Mn> Cu. This similarity highlights the efficiency of regulating the conductivity and pH in the instrumental method applied to Hydroponics, offers the producer an effective and applicable alternative in the growth of lettuce.

Wahome *et al*. (2011) investigated the potential of growing gypsophila using different hydroponics systems in the greenhouse of the Horticulture Department, Faculty of Agriculture, Luyengo Campus of the University of Swaziland. The experiments were laid out in a split plot design. Three hydroponics systems were used as the main plots, i.e., elevated tray, ground lay bed and bag culture systems. The sub-plots were allocated to three different aggregate/medium components, i.e., sawdust, river sand and vermiculite. Throughout the production period, plants grown using river sand had the lowest plant height. The highest plant height (52.9 cm) was obtained from plants grown in vermiculite at 12 weeks after transplanting (WAT). Plant height of gypsophila plants grown using sawdust at 12 WAT was almost double that of those grown using sand. There was a significant ($P < 0.05$) reduction in amount of shoots/plant in gypsophila grown in sand medium in all three hydroponics systems. The highest number of shoots/plants was obtained from plants grown in sawdust in all hydroponics systems. The highest cut flower stem length (67.0 cm) was obtained from plants grown in sawdust in the bag culture hydroponics system, while the lowest cut flower stem length (25.0 cm) was observed in plants grown in sand in the elevated tray hydroponics system. The highest number of branches/plants was generally observed in plants grown in the bag culture hydroponics system when compared to the elevated tray and ground laid bed hydroponics systems.

2.4 Cost economics of different crops under hydroponic system in naturally ventilated polyhouse.

Cost economics of hydroponic production was measured in terms of gross return, gross margin, net return and benefit cost ratio. Variable and fixed costs were taken into deliberation to estimate the gross cost of production. Variable costs included human labour, seed, electricity, watering and other equipment and fixed cost included depreciation cost of equipment and shed. The present study has been formulated to study the cost of cultivation of stevia to encourage the farmers regarding cultivation of this plant and also provide information regarding profitability of cultivation. Stevia become a potential and renewable raw material in the food market because the increase in the number of diabetic and health-conscious individual boosts up the international market of high-quality stevia leaves which is a non-caloric natural sugar. Lack of information regarding the cost of cultivation of stevia specially in Indian context generate plenty of confusion with regard to cultivation of this plant and also about selection of the profitable propagating material. The present study thus concerned with calculating the cost of cultivation, return and cost benefit ratio to identify economic viability and technical feasibility of stevia cultivation. The below reviews of earlier research works helped to collect the information and to fulfill the present objective

Jain *et al.* (2021) studied the Comparative Analysis of the Economics of Crop Cultivation under the Poly House and Open Field Conditions in Rajasthan. The results revealed that the total cost incurred in the crop cultivation under polyhouse conditions was higher than open field conditions for all three crops. The share of the total variable cost was more than 65 percent for the three crops in each condition and was slightly higher under open field conditions, while the share of fixed costs was higher in the total cost of cultivation for the crops grown under polyhouse. On the other hand, returns obtained from polyhouse cultivation were observed more than the returns obtained from open field conditions. For all the crops, net returns were more than double when grown in polyhouses, which suggested a profitable situation for the crop's grower under polyhouse. Returns per rupee were again higher for the cucumber, tomato, and chilli grown under polyhouse conditions with values 2.17, 2.12, and 2.21 respectively, then in open field conditions amounting to 2.11, 1.96, and 1.82 correspondingly. To reap these benefits associated with polyhouse cultivation, marginal and small farmers can go for cooperative farming. Regular training and extension services are to be made available to the young entrepreneurs and farmers to impart information about the technical know-how of the growing crops under protective technologies.

Kammar *et al.* (2019) analysed the hydroponic technology which studied at baghalkot district, with 15 farmers selected purposively who have been practicing this technology since at least last two years. Majority of the farmers adopted a 72 trays model which produced on an average 4.5 fresh fodder from 500 g maize grains per tray where daily fresh fodder production was 45 kg per day/ unit. The economics of hydroponic fodder production and conventional practices were studied and found that per kg green fodder production require 2.84 and 0.5 Rs in hydroponic system and farmers field where the period of growing (8-9 Vs. 70-75 days), electricity cost (30/9days Vs.540 /72 days), cost of water (2-3 Vs 20-40 litres for per kg fodder production) and space (100 ft2 Vs.43560ft2) respectively. The results implied that, maize is the best source for producing fodder under hydroponics, the system of hydroponics can be prepared using low-cost material, no soil media is used and no nutrients are added to the water used for hydroponics production. But, in rural areas, where the timer facility is not used, it was difficult to get the uniform growth of fodder. There was an incidence of not getting proper germination where the grains were infested.

Rawahy and Mbaga (2019) investigated the economic effect of cooling nutrient solutions temperature technique on cucumber output. The experiments were conducted in a cooled greenhouse of dimension 30 m long x 9 m wide at the Directorate General of Agriculture and Livestock Research in Rumais, Barka during three periods of growing cucumber under hydroponics viz., summer temperature period (June-August), fall temperature period (September-November) and spring temperature period (February-May) for two years during 2016 or 2017and 2017 or 2018. Four nutrient solutions temperatures are investigated and a Cost Benefit Analysis is undertaken. Results indicate that all the four cooling nutrient temperature yields positive returns (benefits) above variable and total costs for the two years of this experiment. Cooling nutrient temperature (22ºC) yields higher returns than the other treatments followed by treatment (25ºC), (28ºC) and then the control treatment. Returns for the second year are higher than the first year. Therefore treatment (22ºC) was observed to be the best overall producing the highest return above variable and total costs. It is therefore considered the best alternative for cucumber growers.

Quagrainie *et al.* (2018) studied the economic analysis of aquaponics and hydroponics production in the U.S. Midwest. Three sources of data were considered to analyze the feasibility of aquaponics and hydroponics production. The data include production costs, selling prices, production, infrastructure, etc. The profitability of aquaponics in the Midwest of the United States was investigated in this study. For the study, three operating aquaponics farms, a university greenhouse experiment, and published research were used as sources of data. In the first analysis, the economics of aquaponics and hydroponics systems are compared under similar operating conditions. In comparison to the hydroponics system, the aquaponics system demands a larger initial investment and operational expense, but produces fewer vegetables. Aquaponics, on the other hand, becomes profitable if the vegetable production is managed as an organic production and the harvest is sold at a 20 per cent premium price. The second analysis created three distinct representative farm sizes for basil and tilapia aquaponics production—small, medium, and big. Basil cultivation yields higher financial returns than fish farming. When the basil price is over $10.00 per kg, any farm size is feasible. Because of cheaper production costs, the larger farm produces the best outcomes.

Tokunaga *et al.* (2015**)** studied economics of commercial aquaponics in Hawaii. The model case's system configuration is shown in the output. Because the size of the raceways and fish tanks on the farms analysed differed, the researchers developed estimates based on biological considerations and items collected from each farm. The combination of vegetable and fish production is one of the fundamental assumptions. 1.63 gal/sq. ft. is supposed to be the ratio between fish tank volume and vegetable grow bed surface area. To be prudent, this is slightly higher than the three farms' average of 1.47 gal/sq. ft. Each of the four aquaponic systems on the model farm has a 5,000-gallon fish tank, eight 384 square foot raceways, a bio filter, a 0.2 kW water pump, and a 0.4 kW air blower. The racetrack surface area of the farm is 12,288 square feet, and the fish tank volume is 20,000 gallons. Some farms employ an external bio filter, while others use a bio filter in the form of volcanic cinder growing material. Solid's removal devices are present on all farms. We put a bio filter in our system for the purpose of simplicity.

Sengar and Kothari (2008) conducted an experiment under greenhouse for economic analysis of rose crop. Raising of rose nursery is quite difficult due to low temperature in winter season. Looking to the importance and temperature requirement for nursery raising for proper growth in winter, rose (Rosachinensis) was selected for experiment under arch shape greenhouse. The total construction cost of 80 m^2 arch shape greenhouse was Rs.1,00,000/-. Out of total 80 m^2 floor area, 55 m^2 area is used for plant seedling and 25 m^2 areas is left for movement in the greenhouse carrying out agricultural operations. In 55 m^2 area of greenhouse, 9700 seedlings could be raised with 0.075 x 0.075 m spacing in 20 pits. Suitability of the economics of greenhouse, four economic indicators such as net present worth, internal rate of return, benefit cost ratio and payback period were calculated for rose nursery. Greenhouse is an effective solution to nursery grower who would be able to recover his investment on greenhouse within a period of 2.2 years. Minimum survival percentage found in rose nursery in greenhouse was 65%. NPW of investment made on greenhouse, the internal rate of return, the benefit cost ratio, when rose nursery grown inside the greenhouse were Rs.453221 /-, 53%, 4.5 respectively.

Chapter III

MATERIALS AND METHODS

Optimization of hydroponic nutrient concentration and grow media in the hydroponic farming are important issues of consideration for successful operation and management of crops under hydroponic farming. Experiment was carried out to standardize the nutrient concentration and grow media under hydroponic farming for stevia crop. It includes design and installation of Nutrient Film Technique (NFT) under hydroponic farming, study of environmental parameters, concentration of nutrient solution, grow media, biometric parameters and cost economics of stevia crop under hydroponic farming. In order to achieve the objectives of the present study, this chapter deals with the materials and methodology used in conducting the research work are described here in the following section.

3.1 LOCATION OF STUDY AREA

The experiment was conducted under hydroponic unit located in naturally ventilated poly-house and open field for comparison during the year 2021-22 at Dr. NTR College of Agricultural Engineering, Bapatla. Bapatla is situated in the Bapatla district of Andhra Pradesh, India at latitude 15°53’47" N and longitude 80°27"37" E which is 8 km away from Bay of Bengal and at an Altitude of 6 meters above the mean sea level. The location of the study area is shown in Fig 3.1.

3.2 AGRO CLIMATIC CONDITIONS OF THE STUDY AREA

Bapatla comes under humid sub-tropical area and is very close to the coast with very hot summer and cool winter. The maximum and minimum temperatures are 38.6°C during May month and 17.6°C during January month respectively with an average air temperature of 28.4°C. The mean relative humidity ranged from 62 to 80 % with an average of 75%. The average wind speed is equal to 8.68 Kmph, while the annual precipitation ranges from 666-1392 mm with normal rainfall of 1120 mm. The soils of the study area are Red loamy and sandy loamy. The predominant crops grown in the study area are paddy and maize. Also, some areas under cereals (like black gram, green gram and red gram), pulses (like cotton and chillies) and the commercial crops and vegetables including tomato crop. The weather parameters of the study area during crop period are shown in Table 3.1.

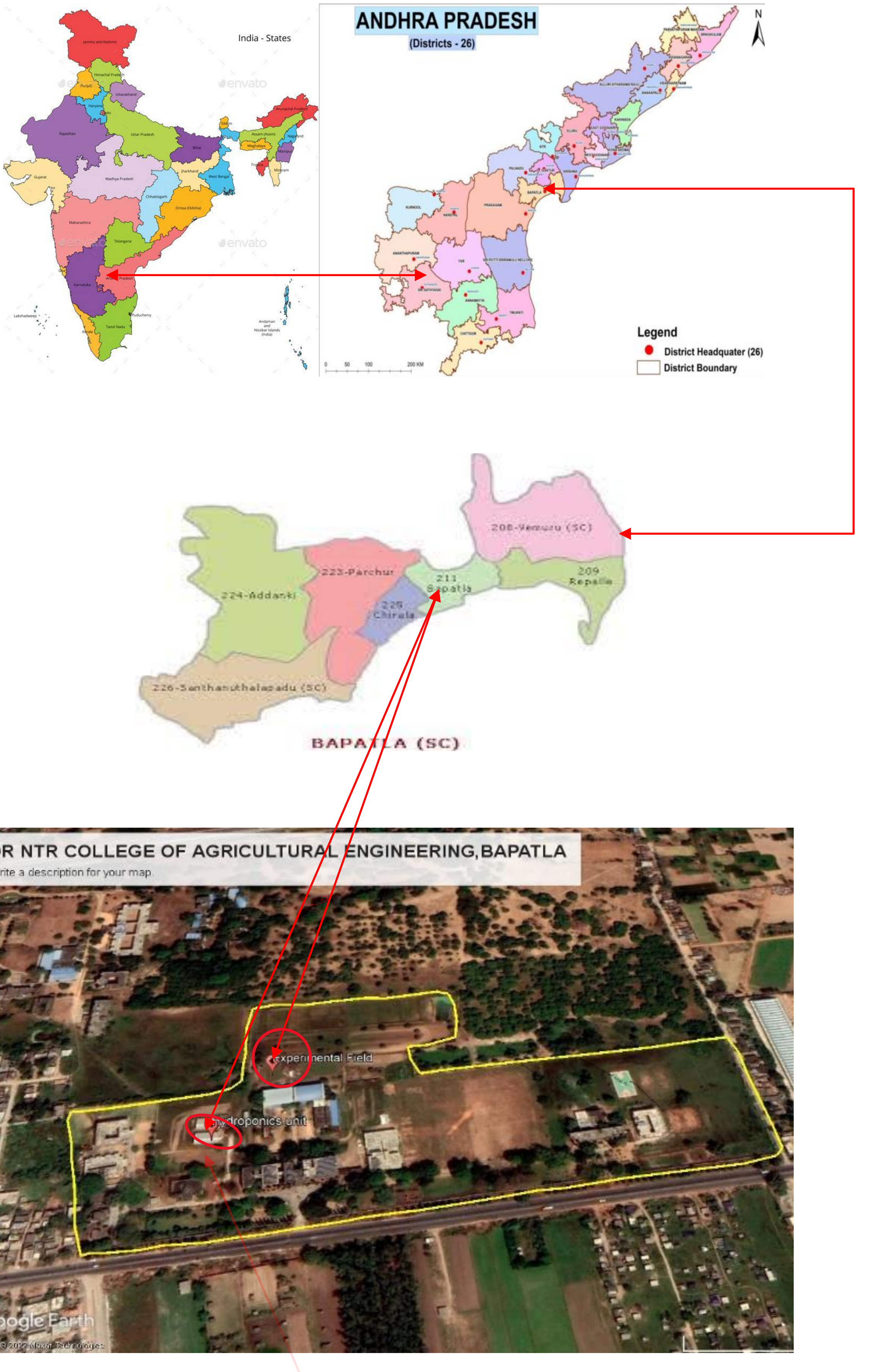

Fig 3.1 Experimentiial location of the study area

Table 3.1 Weather parameters recorded during the experimental period

Month &Year	Average daily temperature (^0C)		Average relative humidity (%)		Average CO_2 level (ppm)	
	Max	Min	Max	Min	Max	Min
March, 2022	35.49	25.05	78.79	61.92	526	405
April, 2022	35.51	26.41	77.74	61.46	538	424
May, 2022	36.81	27.19	73.51	61.59	541	444

3.3 INSTALLATION OF NUTRIENT FILM TECHNIQUE (NFT) OF HYDRIOPONIC FARMING

The main types of hydroponic farming systems are Aeroponics, Deepwater culture (DWC), Drip system, Ebb and flow, Nutrient film technique (NFT) and Wick system. Out of the available systems, Nutrient Film Technique (NFT) is the most popular hydroponic farming system. In this method, nutrient solution is pumped constantly through channels in which plants are placed. When the nutrient solution reaches the end of the channel, they are sent back to the beginning of the system. This makes it a recirculating system and plant roots are not completely submerged, which is the main reason for naming this method is NFT.

NFT requires the components like A- Frame structure, channels, pump, reservoir and accessories.

3. 3. 1 A-Frame Structure

The A-Frame structure maximizes the space within their garden or small-scale farm. It requires pipes and tubes in order to connect the various layers of the farm. The structure was made up of hollow galvanized Iron (GI) pipe. The specifications of the A-Frame structure was given in Table 3.2 and shown in Fig 3.2

Table 3.2 Specification of A-frame structure

S. No	Component	Size
1	GI Pipe	20.0 cm square
2	Height of A-frame	2.0 m
3	Bottom width of A- frame	1.2 m
4	Height from ground to first row	0.5 m
4	Length of the channel	3.2 m
6	Channel cross section	10.0 × 6.3 cm
7	Spacing between the two channels	25 cm

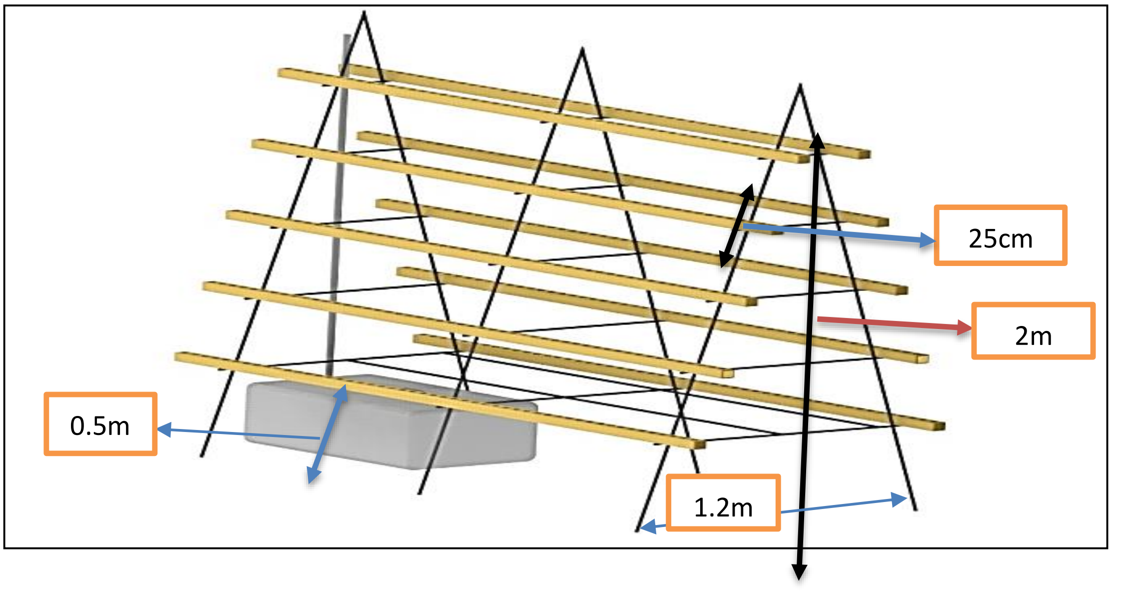

Fig 3.2 A frame structure nutrient film technique as the method of hydroponics

3.3.2 Channels or Tubes

The channels are made of water-tight unplasticized polyvinyl chloride (UPVC) food grade of cross section 10.0 cm × 6.3 cm with length 3.2 m was used as NFT channels for holding the plants and also for circulation of nutrient solution. On the UPVC pipe, 7-8 mm size holes are done to fit the net pots for seedlings. On each rectangular channel containing 20 holes at 16 cm distance. Each A-frame containing 5 of rectangular channels at each side as shown in Fig 3.2. Each A-frame structure has a plant population of 200 No's

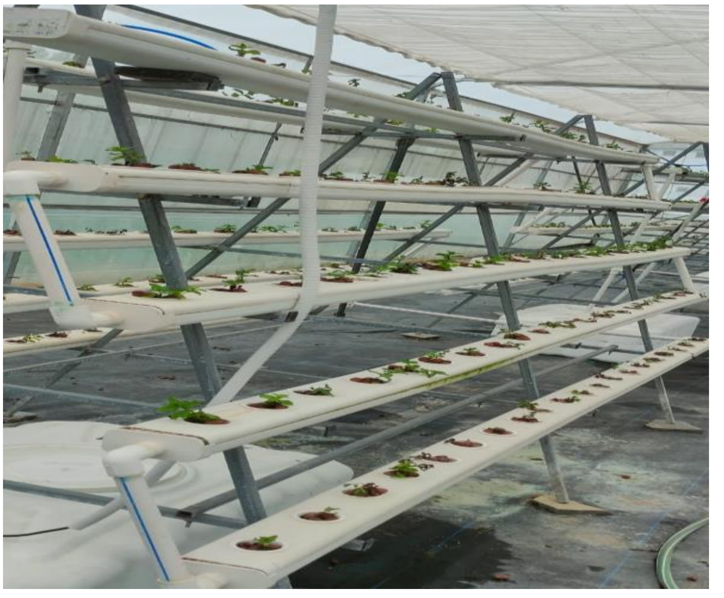

Plate 3.1 NFT channels of hydroponics

3.3.3 Pump for Recirculation of Nutrient Solution

Nutrient Film Technique of hydroponics required a reliable pump to recirculate the nutrient solution in the channels. In the present study 0.1hp submersible pumps were used for each A-Frame unit (Fig 3.2) and the pump specifications shown in Table 3.3.

Table 3.3 Technical specification of submersible pump

Model No.	Power Consumption	Outlet Nozzle Size	Maximum Head	Maximum Cooler Height Recommended
MSP 800	50W	1.905cm	2.743m	2.438m

Plate 3.2 Pump used in the nutrient film technique

3.3.4 Reservoir

The reservoir is used to contain the nutrient solution since the NFT system is a recirculating one. The reservoir size depends on the number of plants accommodated in one A- Frame structure. PVC made 200 litres capacity reservoir (Plate 3.3) was used at each A-Frame structure with a total of 8 No's in the present study. The reservoir joins the grow tray via a nutrient pump on the high end and the nutrient return pipe on the low end. Inside the reservoir, there is an air stone connected to an air pump outside to oxygenate the water.

Plate 3.3 Reservoir/tank used in nutrient film technique

3.3.5 Net Cups

The liquid culture method net cups i.e., plastic material small size white colour cups were used for holding the plants in growing medium for the crop growth. The cups are having 5.0 cm diameter and 4.7 cm height (Plate 3.4). These cups were placed in the holes made on the channels.

Plate 3.4 Net cups used in the experiment

3.3.6 Foggers

Foggers were used to maintain the temperature and relative humidity inside the poly house. Each fogger has 4-way nozzle with a flow rate of 4 l/h at an operating pressure range of 3.12 to 4.21 kg/cm^2. The average droplet size of the fogger is fine fog of 65 microns and connected to 1HP motor. This created a favourable saturated humidity ideal during crop period. The foggers installed in polyhouse are shown in Plate 3.5.

Plate 3.5 Foggers used in the naturally ventilated polyhouse

3.4 CROP AND VARIETY

In the present study stevia crop (*Stevia rebaudiana bertoni*) was selected to grow in hydroponics and in open field condition. The details of the crop and variety are shown in Table 3.4.

Table 3.4 Details of stevia crop

S.No	Components	Details
1	Crop	Stevia
2	Scientific name	*Stevia rebaudiana bertoni*
3	Variety	Morita II
4	Date of sowing	10/03/2022
5	Date of First harvest	15/05/2022
6	Duration	60 days

3.5 DESIGN AND LAYOUT OF EXPERIMENT

Field experiment was conducted with Morita variety of stevia crop under nutrient film technic of hydroponic farming in split plot design consisting of four nutrient concentration levels as main treatment and four types of growing media as sub treatments with three replications during March 2022 at hydroponic unit and compared with open field condition at Dr. NTR College of Agricultural Engineering, Bapatla. Stevia seedlings were procured from farmer's field and placed in net pots on 10.03.2022. The layout of the experiment was shown in Plate 3.6.

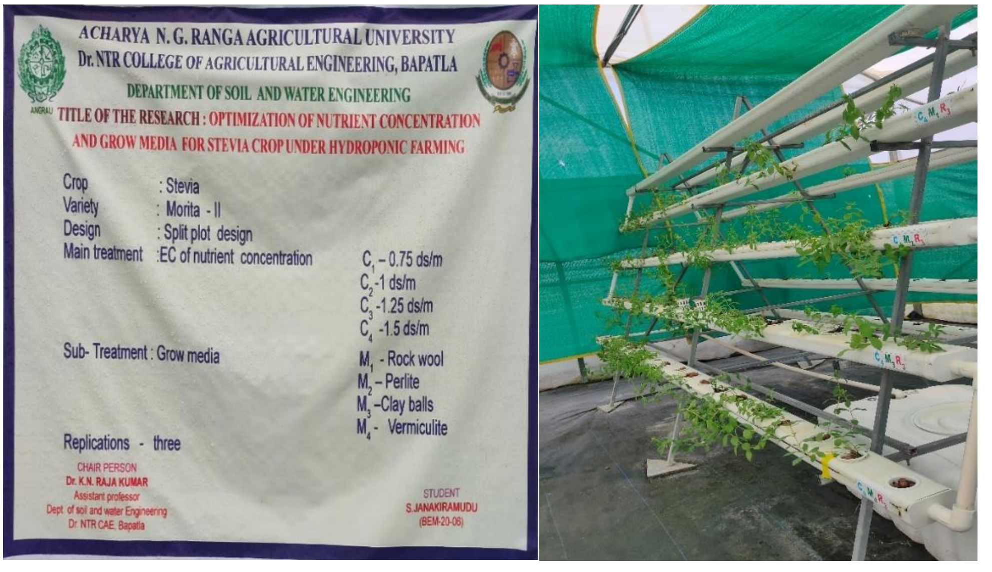

Plate 3.6 Design and layout of experiment

Treatments are as follows:

Main plots: Nutrient concentration (C)

C_1 = 0.75 dS/m concentration of nutrient solution

C_2 = 1.0 dS/m concentration of nutrient solution

C_3 = 1.25 dS/m concentration of nutrient solution

C_4 = 1.50 dS/m concentration of nutrient solution

Sub plots: Grow media (M)

M_1 = Rock wool

M_2= Perlite

M_3= Clay balls

M_4 = Vermiculate

3.6 IRRIGATION SOURCE

The source of irrigation water for open field cultivation and for preparing nutrient solution was from nearby bore well. The water was analysed for chemical properties like pH, EC, and TDS and are shown in Table 3.5.

Table 3.5 Quality parameters of irrigation water

S.No	Water quality parameters	contents
1	Electrical conductivity	0.50 dS/m
2	pH	7.50
3	Total dissolved solids	340 ppm

3.7 NUTRIENT SOLUTION PREPARATION

Hydroponic gardener uses minerals that are water soluble and ready to be taken up by the plant roots. A large number of hydroponic nutrient formulae have been developed and the success of each nutrient formula depends on the conditions and type of crops are being grown. These formulae contain the minerals and nutrients that a plant needs, in the correct proportions and are available in powder or liquid form.

Nutrient solution contains the macro nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur and micro nutrients such as iron, manganese, boron, zinc, copper, and chlorine.

In the present study, A and B named hydroponic nutrient solutions were used to provide nutrients to the plant and are shown in Plate 3.7

Plate 3.7 A and B nutrients used in experiment for stevia crop

The preparation of the nutrient solution comprises the steps of mixing into a volume of water. Firstly, 10 litters of water was taken in bucket, then 40 ml stock solution was “A” added in bucket and stirred well, later 40 ml stock solution “B” was added and stirred well. After 10-15 minutes the pH of solution was checked, it must be in between 5.5 to 6.5. If pH is at higher side, then add pH down solution drop wise till pH drops down in between 5.5 to 6.5.

3.7.1 Concentration of Nutrients Solution

Nutrient solution is the most important chemical of the hydroponic system. In the present study the nutrient solution was prepared by following the guideline of poly-house hydroponic system. The solution was prepared by mixing major fertilizers like Nitrogen, Potassium and Phosphorus and calcium nitrate, with bore well water. The pH of the water was 7.1 and 6.3 before and after mixing the chemical. The compositions of the chemicals in nutrients solution are shown in Table 3.6

Table 3.6: Quantity of different nutrient solution used in the study

Concentration	Macro nutrients (ml)	Micro nutrients (ml)	Nutrient solution in the tank(dS/m)
C_1	200-220	200-220	0.75
C_2	300-320	300-320	1.0
C_3	400-420	400-420	1.25
C_4	500-520	500-520	1.5

Plate 3.8 Addding the nutrient solution to the tank

3.7.2 pH down solution

The pH lowering in the hydroponic farming is done by using phosphoric acid (H_3PO_4) as shown Plate 3.9. Phosphoric acid contains phosphate (P). The solution was added to the nutrient reservoir drop by drop when nutrient pH is high in order to lower the pH until the required level of pH in the nutrient solution is needed.

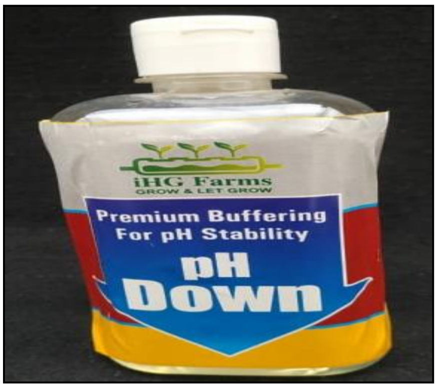

Plate 3.9 pH down solution used in the experiment

3.7.3 pH up solution

Potassium hydroxide was used for increasing the pH of the solution as shown in the Fig 3.3. In order to make a solution of KOH, 10g of KOH pellets were taken and 90ml of water was added. The solution was added to the nutrients reservoir when pH is too low in order to raise the pH to the proper level.

Fig 3.3 pH up pellets used in the experiment

3.8 PLANT SUPPORTING MEDIA

In a traditional garden, plant roots are in the soil. In hydroponics, often a growing medium is used in place of soil. The roots of a hydroponic plant do not work as hard as those of a plant grown in soil because their needs are readily met by the nutrient solution. Ideal mediums are chemically inert, porous, clean and able to drain freely. Many materials have been used as hydroponic growing mediums.

In the present study four types of plant supporting media were used and they are vermiculite, rock wool, perlite and expanded clay balls.

3.8.1 Clay balls

Clay balls were used as a growing media in the present study. Expanded clay balls are made by heating the clay to over 2000^{0}F. As the balls heat up, they fill with bubbles and form into small marble-sized units. Because of natural pH, clay pebbles provide a growing medium that is ideal for a wide variety of plant, and they are reusable as well. The pores make throughout each ball, the pellets make it easy to support a steady distribution of nutrients, oxygen and water around the root of the plants (Plate 3.10).

Plate 3.10 Clay balls media used in the experiment

3.8.2 Perlite

Perlite is mainly composed of minerals that are subjected to very high heat, which are then expanded like popcorn so it becomes very light weight, porous and absorbent. Perlite originates from a silicone mineral which forms in volcanoes and is very light in weight (Hussain *et al.,* 2014). Perlite has a neutral pH, excellent wicking action, and is very porous. It is produced in various grades, the size of perlite used was 0.5 to 2 mm and 1.5 to 3 mm in diameter (Plate 3.11). It has one of the best oxygen retention levels of all growing mediums and is usually white in colour. It provides good drainage, and holds air and it is very porous and has a strong capillary action and it can hold three to four times its weight of water.

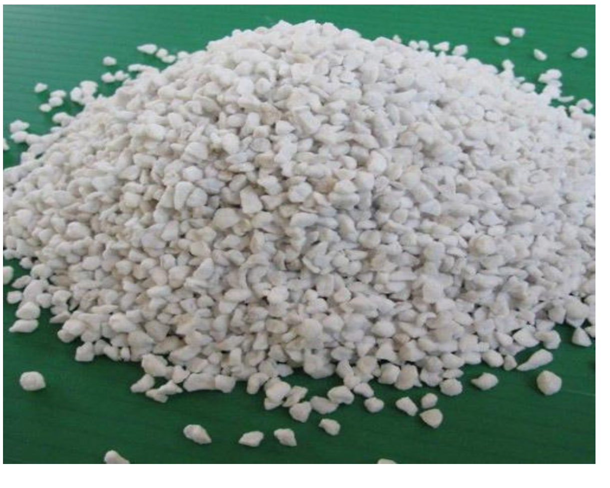

Plate 3.11 Perlite media used in the experiment.

3.8.3 Vermiculite

Vermiculite is a naturally occurring mineral that has been used for a long time as a growing medium in hydroponic gardens. This is lightweight, chemically inert, heat resistant and sterile substance having water holding capacity more than soil (Plate 3.12). This substance is heated in a furnace at 2000^0F and the product is used in culturing plants. It is considered as an excellent rooting medium. As a growing media, vermiculite is quite similar to perlite except that it has a relatively high cation-exchange capacity, meaning it can hold nutrients for later use.


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Plate 3.12: Vermiculite media used in the experiment

3.8.4 Rockwool

Rockwool cubes are the popular growing medium for hydroponic gardening. They are derived by melting rockwool with the basalt rock at a temperature of 3000^0F, which creates lava (Plate 3.13). This is then spun to create fibres that look like cotton candy. After the complete process of spinning, they are blended with the sticky agent and then compressed into mats. These mats are further cut into various cubes like structures, and they are sold to gardeners as a growing medium for hydroponic gardening. Rockwool is an extremely lightweight and versatile growing medium; it is able to hold both moisture and oxygen pretty well. It can hold up to 18% of oxygen, which makes it extremely crucial for the plant roots, and also, it puts a stop to overwatering.

Plate 3.13 Rockwool media used in this experiment

3.9 TRANSPLANTATION

3.9.1 Transplantation of Stevia Seedlings in Hydroponic Unit

One month old seedlings of stevia were transplanted in net pots which were placed on A frame hydroponic structure. Nursery placed in the pots and transplanted in the structure is shown in Plate 3.14 on 10-03-2022

Plate 3.14 Seedlings transferred to the Net pots

3.9.2 Transplantation of Stevia Crop in Open Field

The field was prepared with cultivator followed by rotavator for loosening the soil. Weeds and stones were removed prior to plantation of nursery. Drip irrigation system was used to irrigate the stevia crop and the spacing between the drip lines is 45 cm (Plate 3.15).

Stevia crop was cultivated in open field condition for comparison of yield with hydroponic farming.

Plate 3.15 Field preparation by rotovator **Plate 3.16 Drip layout in the field**

Transplanting was done on 10-03-2022. Plant to plant and row spacing of stevia was maintained as 30 cm × 45 cm (Plate 3.17).

Plate 3.17 Transplantation of stevia seedlings in to the field

Plate 3.18 After transplantation into the field

3.10 OBSERVATIONS OF THE STUDY

3.10.1 Measurement of Environmental Parameters

The environmental parameters like temperature, relative humidity and CO_2 level were measured in naturally ventilated polyhouse under hydroponic farming for stevia crop daily at two hours interval. The measured data was used to calculate the weekly average data, which was used for observing daily variation in microclimate during the experiment period.

The environmental parameters like temperature, relative humidity and CO_2 level are the important parameters influencing the growth of stevia crop in the hydroponic faming under naturally ventilated polyhouse. These parameters were recorded daily at 2 hours interval during the crop growing period using the Rotranic CP11 instrument. The specifications of Rotranic CP11 are given in the Table 3.7

Table 3.7 Specifications of Rotronic CP11 Instrument

Brand	Rotronic instruments	Measurement parameters	CO_2, Relative humidity, temperature
Data logger type	Temperature, humidity and CO_2	Sensor type	Thermistor
Interface type	USB	Maximum temperature measurement	$\pm$60˚C
Power source	Battery	Best temperature measurement accuracy	$\pm$0.3 K
IP Rating	IP30	Diplay type	Digital
Model number	CP11	Includes	ROTRONIC sw2.1
Battery life	2days	Maximum humidity measurement	99.95%RH
Battery type	AA	Alaram	Yes

Plate 3.19: Rotronic sensor

3.10.2 Measurement of pH and EC of the nutrient solution

In the hydroponic farming, plants receive nutrients through nutrient solution which is recirculating in the system. The pH value and required EC concentration as per the treatment should be maintained in the nutrient solution regularly. To maintain the EC and pH levels in the nutrient solution regularly, the pH and EC are measured regularly. The pH of the nutrient solution was measured by pH meter (Plate 3.20). The specifications of the pH meter are given in the Table 3.8. The EC level of the nutrient solution was measured regularly buy using EC or TDS meter (Plate 3.21). the specifications of the Eco or TDS meter are given in the Table 3.9

Plate 3.20 Aquasol Pen type pH meter used in the experiment

Table 3.8 Specification of AQUASOL DIGITAL Pen Type Digital pH Meter

Brand	AQUASOL DIGITAL
Model Number	Pen Type pH
Type	Digital pH Meter
Measuring Range	0-14
Accuracy	2%
Temperature range	0 -80 degrees C
Battery life	Enhance life
Power	3V × 2 lithium batteries LR44
Weight	55 g
Dimensions	35mm × 155mm

Plate 3.21 Aquasol Pen type EC/TDS meter

Table 3.9 Specification of AQUASOL DIGITAL Pen Type Digital EC/TDS Meter

Brand	AQUASOL DIGITAL
Model Number	Pen Type pH
Type	Digital pH Meter
Range	0 – 9990 ppm
Temperature range	0 -80 degrees C
Accuracy	2%
Battery life	Enhance life
Power	3V × 2 lithium batteries LR44
Weight	55 g
Dimensions	35mm × 155mm

3.10.3 Measurement of Biometric Parameters

The biometric parameters such as plant height, stem diameter, number of leaves per plant, root length, leaf length, and girth diameter were measured during the crop growing period in the hydroponic farming. Randomly four plants were chosen from each replication for recording the data.

3.10.3.1 Plant height

The height of randomly selected plants in hydroponic and in open field were measured after 10 days of transplanting at every 5 days interval. It was measured as vertical distance from the base of plant to the tip of the plant with the help of measuring scale (Plate 3.22).

Plate 3.22 Measuring the height of the stevia plant

3.10.3.2 Total Number of Leaves

The No. of leaves of randomly selected plants in hydroponic and in open field were measured after 10 days of transplanting at every 5 days interval.

3.10.3.3 Number of branches

The No. of branches of randomly selected plants in hydroponic and in open field were measured after 10 days of transplanting at every 5 days interval.

3.10.3.4 Length of plant roots

The length of plant roots of randomly selected plants in hydroponic farming were measured after 10 days of transplanting at every 5 days interval. In hydroponic system plant roots are visible. The visible root length outside of net pots (Plate 3.23) was measured

Plate 3.23 Measuring the root length of stevia plant

3.10.3.5 Girth diameter

The girth diameter of randomly selected plants in hydroponic and in open field were measured after 10 days of transplanting at every 5 days interval. It was measured at the base of the plant with the help of digital vernier calliper (Plate 3.24).

Plate 3.24 Measuring grith diameter of stevia plant.

3.10.3.6 Plant leaf length

The leaf length of randomly selected plants in hydroponic and in open field were measured after 10 days of transplanting at every 5 days interval. It was measured from the base of the plant with the help of digital vernier calliper. It was measured from the pointy part at one end of the leaf to the point where the leaf joints the stalk at the other end with the help of measuring scale (Plate 3.25).

Plate 3.25 Measuring the leaf length of stevia crop

3.11 YIELD PARAMETERS

The easiest harvesting technique of stevia crop was by cutting the branches off with pruning shears before stripping the leaves (Hossain *et al*, 2017). The yield of stevia crop was recorded as total fresh plant weight, fresh weight of leaves and dry weight of leaves.

Plate 3.26 Harvesting of stevia crop

3.11.1 Total Fresh Plant Weight (g)

The total fresh plant weight was calculated at the end of experiment by recording whole plant weight from each replication after harvesting with the help of an electronic balance as shown in Plate 3.27.

Plate 3.27 Weighing the total fresh weight of harvested stevia

3.11.2 Fresh Weight of Leaves (g)

The fresh leaves are removed after weighing the total fresh weight of the plant, the weight of collected leaves was recorded with the help of an electronic balance as shown in Plate 3.28.

Plate 3.28 Weighing the total fresh weight of leaves

3.13.3 Dry Weight of Leaves (g)

The dry weight of plant samples was noted at the end of experiment after natural drying for a period of 2 days (Plate 3.29).

Plate 3.29 Weighing of dried stevia leaves using electronic balance

3.12 EVALUATION OF COST ECONOMICS FOR STEVIA CROP UNDER HYDROPONIC FARMING AND OPEN FIELD CULTIVATION

The cost economics stevia crop under hydroponic farming and open field cultivation was worked out to compare the net returns and benefit cost ratio. The life period of naturally ventilated polyhouse was considered as 20 years. Standard market rates were considered for each item. Fixed cost, operating cost, net return and benefit cost ratio for each system was worked out. Economics of stevia production under polyhouse and open field condition was worked out in terms of total expenditure.

3.12.1 Fixed Cost

Fixed cost comprised of interest on initial cost and depreciation on the system. The interest calculated on the capital was at the rate of 10 percent per annum. The depreciation of the system was worked out by straight line method as follows.

3.12.2 Depreciation

Depreciation is a term that is defined as loss of value of an asset with use and time. Cost of depreciation of a hydroponic can be estimated by using the following equation given below

$$\text{Depreciation, D} = \frac{P-S}{L} \text{ ……………….. (3.1)}$$

Where,

D = Depreciation per annum

P= Initial cost of hydroponic system.

S = Salvage value @ 10%

L = Expected life period of the hydroponic system

Salvage value of hydroponics may be taken as 10 percent of the purchase price.

3.12.3 Interest

An annual charge of interest was calculated taking 10 percent of interest rate as basis. Cost for interest was calculated using the formula given below.

$$\text{Interest (\%)} = \frac{P+S}{2} \times \frac{i}{100} \text{ ……………………(3.2)}$$

Where, A = Interest cost per year

P = Purchase price of the hydroponics

S = Salvage value of the hydroponics

I = Interest rate, %

3.12.4 Variable Costs:

Total Variable Cost which included variable inputs such as seeds cost, electricity cost, nutrient solution cost, maintenance cost, labour cost, cost of pesticides and fungicides and miscellaneous.

3.12.5 Total Costs:

Total costs included total fixed costs as well as total variable costs.

Total costs = Total fixed costs + Total variable costs ………………… (3.3)

3.12.6 Gross Return:

Gross Return for stevia crop was the value of the main product at the selling price of the main product.

Gross return = Total quantity of stevia crop × price of the product ………… (3.5)

3.12.7 Net Return:

Net return was calculated by deducting the total costs from the gross returns.

Net return = Gross return – Total cost (Jain *et. al.*, 2021) …………. (3.6)

3.12.8 Benefit-Cost Ratio:

The benefit-cost ratio was calculated by using formula (Paudel and Adhikari, 2018)

$$\text{BC Ratio} = \frac{\text{Gross Return}}{\text{Total cost}} \text{ ………….. (3.7)}$$

The value of the return from hydroponics farming was calculated based on the total production of the stevia crop from hydroponics farming.

4.12.9 Payback Period: Payback period was calculated using Eq 3.8

$$\text{Payback period (PBP)} = \frac{\text{IC}}{\text{ANP}} \text{ ………………. (3.8)}$$

Where,

PBP = Payback period, year,

IC = Initial cost of hydroponics, and

ANP = Average net annual profit per year

3.15 STATISTICAL ANALYSIS

The statistical tool SPSS (V16.0) was used to find out the significant difference between the treatment means. One way ANOVA technique was used to compare the treatment means of plant growth parameters, yield parameters. The Duncan Multiple range test (DMRT) was performed to find the significant grouping between means of plant growth parameters and yield parameters **(Duncan 1955).**

Chapter IV

RESULTS AND DISCUSSION

Open field cultivation of high value crops is often affected by unfavourable weather conditions like high or low temperature, excess or deficit rainfall, extremes in light intensity, wind velocity etc., especially during sensitive stages of growth. An understanding of the influence of the microenvironment on the growth of crop would be much helpful in tapping the potential yield under protected cultivation. The use of soil alone as growing medium in protected cultivation has started to face serious limitations. Furthermore, soil borne pests and diseases limit productivity, particularly of the high value crops. In view of all these factors, substrates consisting of clay balls, perlite, vermiculite, rock wool acting as a growing media. Owing to their relatively cheaper cost and easy availability, these substrates could be effectively utilized in hydroponic farming. A suitable nutrient solution and soil less media for growing stevia crop in the hydroponic system is important to enhance the yield of stevia crop under unfavourable climate and soil conditions. Keeping these aspects in mind, a research work was undertaken to optimization of nutrient concentration and growing media for stevia crop under hydroponics farming. The environmental factors like temperature, relative humidity and light intensity were recorded under poly house. The effect of growing media and nutrient concentration on plant growth character, root character, yield parameters were observed. The results of the study were analysed and discussed in this chapter.

4.1 DISTRIBUTION OF ENVIRONMENTAL PARAMETERS UNDER NATURALLY VENTILATED POLYHOUSE

During the research work, it was found that the environmental parameters play an important role in growth, development and production of stevia crop under naturally ventilated polyhouse with nutrient film technique.

Environmental parameters such as rainfall, temperature, relative humidity, concentration of CO_2 and wind speed are the major factors for plant growth and they are recorded throughout the experiment. The observations during the crop period were recorded and discussed in this chapter**.**

4.1.1 Rainfall Distribution during Crop Growing Period of Study Area

Stevia crop was grown under hydroponic farming and in open field condition as the farming practise to compare the yield the hydroponic farming is under naturally ventilated polyhouse which has no effect on rainfall distribution.

Very low rainfall amount was recorded in the month of May (3.7 mm). whereas no rainfall was recorded in the month of March and April during the crop period. This condition led to increase the no of irrigations in open field cultivation. In case of hydroponic farming limited amount of water is required for mixing the nutrient solution instead of irrigation and it brings 90 % of water saving under hydroponic farming.

Table 4.1 Average rainfall of the study area during crop growing period

Month	Rainfall during crop growing period (mm)	Decennial rainfall (2012- 2022) (mm)
March	0	0.1
April	0	5.2
May	3.7	32.0
Total	3.7	37.3

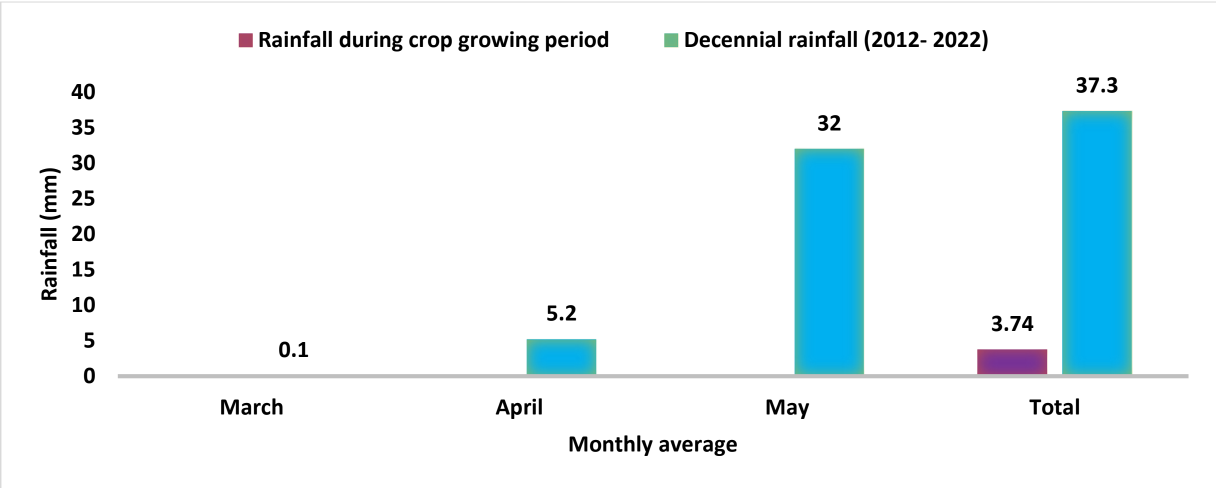

Fig 4.1 Rainfall (mm) during crop growing period

4.1.2 Temperature distribution during crop growing period of study area under naturally ventilated polyhouse

The temperature plays vital role in the vegetative growth *i.e.*, respiration, photosynthesis transpiration, nutrient uptake etc. Due to controlled atmosphere management in the naturally ventilated polyhouse hydroponic structure with nutrient film technique, temperature inside the structure was observed less than outside condition. This may be one of the reasons of getting maximum yield in hydroponic structure. The recommended temperature of stevia crop is in between 25 to 36 ^{0}C. Generally, the temperature was increased in the polyhouse, when compared to open field condition. Since the structure is a naturally ventilated polyhouse and the foggers were operated every one hour to maintain the optimum temperature for stevia crop in polyhouse. The temperature inside the naturally ventilated polyhouse was recorded at 2 hours interval from 20th march, 2022 to 10th may, 2022. During the crop growing period the highest temperature was found in the month of May (36.81^{0}C) and the lowest temperature was found in the month of march (25.05^{0}C). The average of monthly observations is shown in Table 4.2 and Fig 4.2. The daily temperature data are shown in Appendix A.

The amount of distribution of temperature during crop growing period and last 10 years mean temperatures (2012- 2022) are shown in Table 4.3 and depicted in Fig 4.3. during the crop growing period the highest temperature was recorded in the month of May (39.1 ^{0}C) fallowed by April and March (38.5 ^{0}C, 37.7 ^{0}C) and the lowest temperature was recorded in the month of March (22.1^{0}C) fallowed by April and May (25.9^{0}C, 26.6 ^{0}C). The highest temperature was occurred in May (39.4 ^{0}C) fallowed by April (38.9 ^{0}C) and the lowest temperature was recorded in the month of march (22.5 ^{0}C) during the last 10 years mean temperature. Due to the controlled atmosphere system, temperature inside the polyhouse hydroponic structure has great influence on crop growth. Temperature inside the polyhouse was found 5-6 ^{0}C less than the outside temperature. This difference was found due to the installation of floggers and exhaust fans, which helps in controlling the temperature and also green net shades used as a covering material in the naturally ventilated polyhouse. The results obtained during the research work are represented graphically as shown in Fig 4.1 and Fig 4.2. Similar results have been reported for temperature (Meena *et al.*, 2012) and (Meena *et al.*, 2014). green net shade used as covering material in hydroponic unit

Table 4.2 Average temperature during the crop growing period under naturally ventilated polyhouse

	Months		
Time (hr)	**March (^{0}C)**	**April (^{0}C)**	**May (^{0}C)**
0	25.05	26.41	27.19
2	25.12	26.07	27.91
4	25.12	25.72	27.70
6	25.08	26.86	29.56
8	27.11	30.31	31.82
10	32.59	33.12	35.24
12	35.49	35.51	36.81
14	33.88	34.37	35.55
16	30.51	31.64	31.67
18	28.02	28.43	30.63
20	26.86	27.02	29.07
22	26.45	26.70	28.42

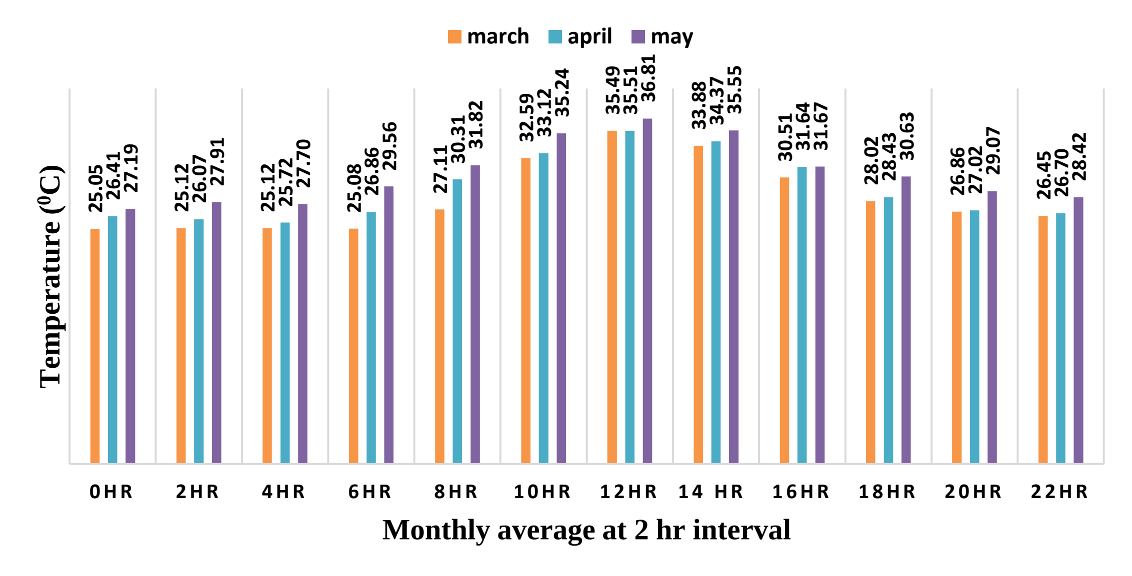

Fig 4.2 Average temperature at 2hr interval during the crop growing period

Table 4.3 Temperature distribution during crop growing period under open field condition

Month	Temperature during crop growing period (2022) (^{0}C)		Decennial temperature (2012- 2022) (^{0}C)	
	Max	**Min**	**Max**	**Min**
March	37.7	22.1	38.8	22.4
April	38.5	25.9	38.9	26.0
May	39.1	26.6	39.4	27.8

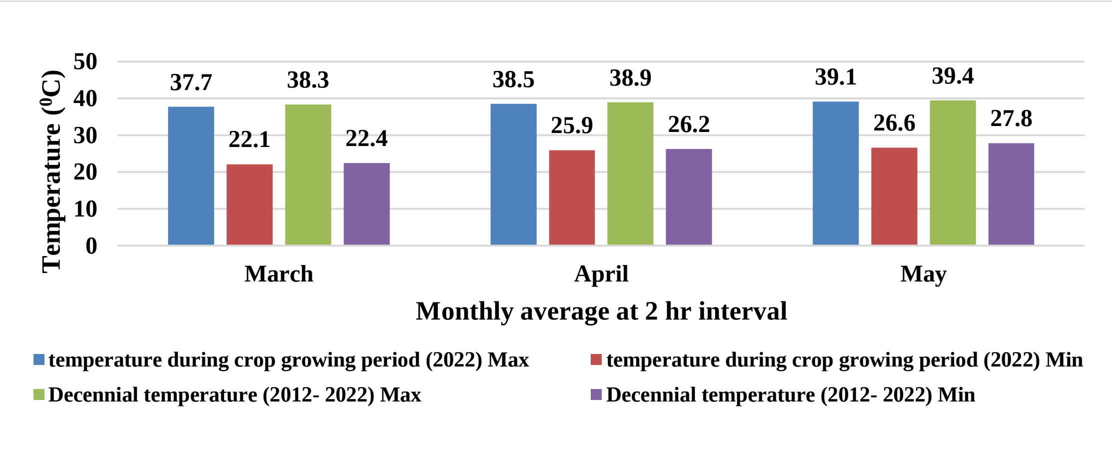

Fig 4.3 Temperature during the crop growing period under open field condition

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4.1.3 Relative humidity distribution during crop growing period under naturally ventilated polyhouse

Relative humidity plays an important role for plant growth, respiration, transpiration and water uptake by the plant during the crop growth. Relative humidity in the atmosphere has its own importance as it governs most of the metabolic and photosynthesis activities of the plants. It has been observed that a relative humidity between 60 and 80 per cent is ideal for stevia plant growth. Very high relative humidity provides better environment for pathogenic organism making the plant susceptible to diseases. Low relative humidity is also harmful for plants since, it increases the evaporation rate and enhances the water requirement at the same time. During the crop period, the relative humidity was recorded at 2 hours interval in the hydroponic unit. The highest relative humidity was found in the month of march (78.79 %) and the lowest relative humidity was found in the month of April (61.46 %). The average relative humidity during crop growing period under naturally ventilated polyhouse condition. The amount and distribution of relative humidity during the crop growing period and last 10 years mean relative humidity (2012- 2022) are shown in Table 4.5 and depicted in Fig 4.5. During the crop growing period the highest relative humidity was recorded in the month of march (82.7 %) fallowed by April and May (79.8 %, 73.8 %) and the lowest relative humidity was recorded in the month of May (38.4 %) fallowed by April and march (40.6 %, 43.7 %). The highest relative humidity was occurred in March (83.1 %) fallowed by April (80.8 %) during the last 10 years mean relative humidity.

The relative humidity inside the naturally ventilated polyethylene for hydroponic structures was found to have great influenced on crop growth. In open field relative humidity was found maximum as compare to hydroponic structures during the growth stages of crop, due the installation of foggers and dehumidifiers in the polyhouse. The average variation of relative humidity during the crop growing period of the study area under naturally ventilated polyhouse is shown in Table.4.4. This difference was observed due to the controlled atmosphere management inside the hydroponic structure and open field conditions. Results obtained during the research work are shown graphically as shown in Fig 4.4. Similar results have been reported for relative humidity (Meena *et al.*, 2012).

Table 4.4 Average relative humidity during crop growing period under naturally ventilated polyhouse.

	Monthly average relative humidity (%)		
Time (hr)	March	April	May
0	78.79	77.14	73.51
2	78.58	77.26	74.01
4	75.96	73.98	68.85
6	71.31	68.30	66.62
8	67.97	66.92	65.80
10	63.70	63.89	63.18
12	61.92	61.61	61.59
14	68.22	67.00	64.84
16	72.54	71.04	69.79
18	77.05	73.15	69.19
20	78.25	75.00	74.28
22	78.65	77.65	76.80

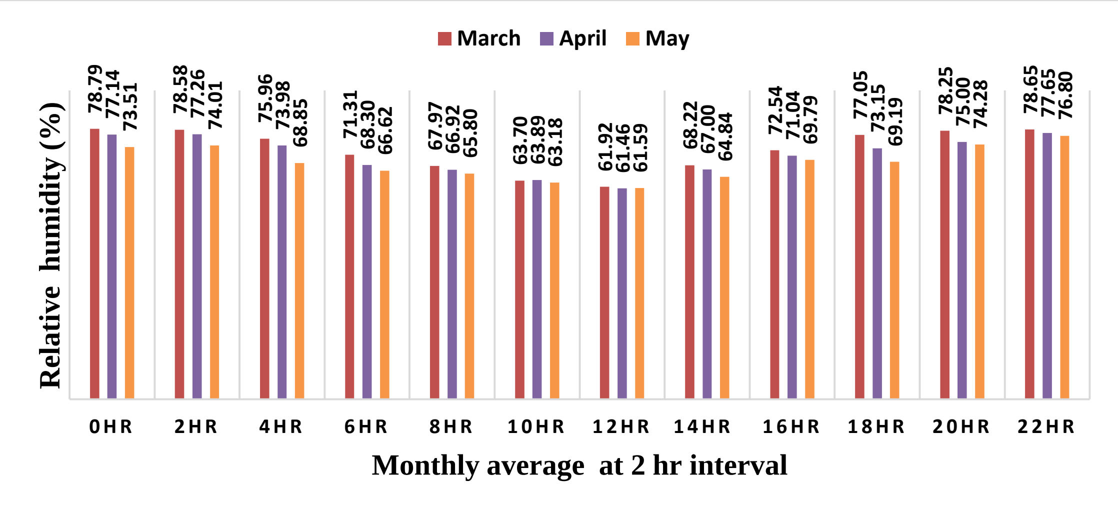

Fig 4.4 Variation of relative humidity at 2hr interval during crop growing period under naturally ventilated polyhouse

Table 4.5 Average relative humidity during crop growing period of field condition

Month	Relative humidity during crop growing period (%)		Decennial relative humidity (2012- 2022) (%)	
	Max	Min	Max	Min
March	82.7	43.7	83.1	44.3
April	79.8	40.6	80.8	42.6
May	73.8	38.4	76.1	39.3

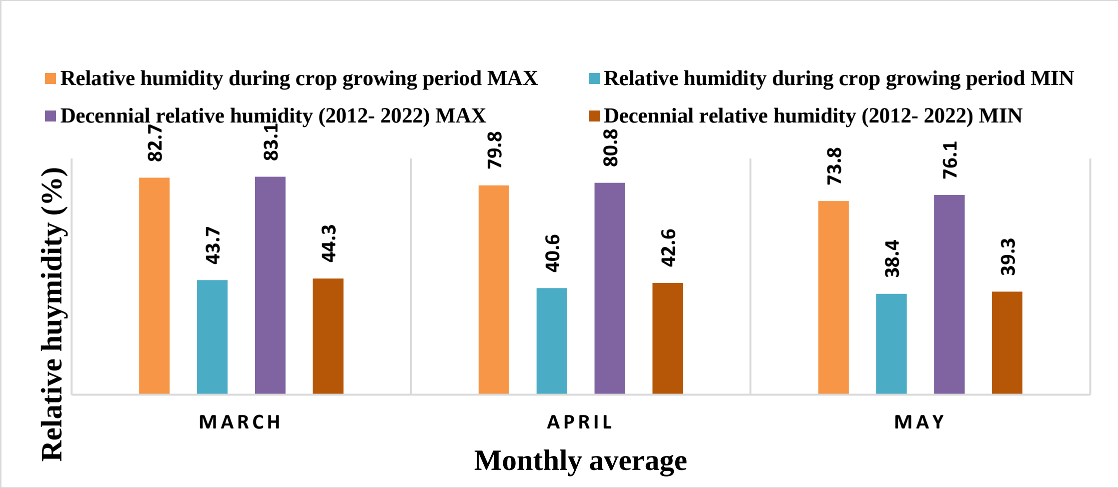

Fig 4.5 Variation of relative humidity (%) during crop growing period under open field condition

4.1.4 Carbon Dioxide Concentration During the Crop Growing Period Under Naturally Ventilated Polyhouse

The amount of CO_2 present in the plant environment affects the plant growth considerably, because it is essential for photosynthesis. Carbon dioxide (CO_2) exists as a gas in atmosphere slightly above 0.03 per cent or 345 ppm. During the day, when photosynthesis occurs under natural light, the plants in a greenhouse draw down level of CO_2 to below 200 ppm. Under these circumstances, infiltration or ventilation increases CO_2 levels, if the level of CO_2 is less than ambient levels, CO_2 may retard the plant growth. The carbon dioxide (CO_2) inside the naturally ventilated polyhouse hydroponic structure has been recorded 2 intervals using rotranic sensor. The observation was recorded and shown in Table 4.13. The daily average variation of CO_2 concentration in the polyhouse was observed from March to May. The highest CO_2 concentration value is 549.1 ppm in the month of May and the lowest value is 405.27 ppm in the month of March. Table 4.6 shows that CO_2 concentration during the crop growing period of the study area under naturally ventilated polyhouse. Results obtained during the research work are shown graphically as shown in Fig 4.6. Similar results have been reported for CO_2 concentration (Meena *et al.*, 2012)

Table 4.6 CO_2 concentration of the during the crop growing period of the study area under naturally ventilated polyhouse condition.

	Monthly average CO_2 concentration (ppm)		
Time (hr)	**March**	**April**	**May**
0	405.27	424.30	444.80
2	419.45	431.60	449.60
4	433.82	437.63	456.90
6	443.36	446.07	460.50
8	465.91	471.80	475.80
10	492.20	515.80	516.40
12	526.36	538.03	541.70
14	511.82	517.40	530.50
16	490.64	495.23	499.40
18	447.36	472.67	481.40
20	439.91	455.30	460.60
22	435.18	446.17	447.40

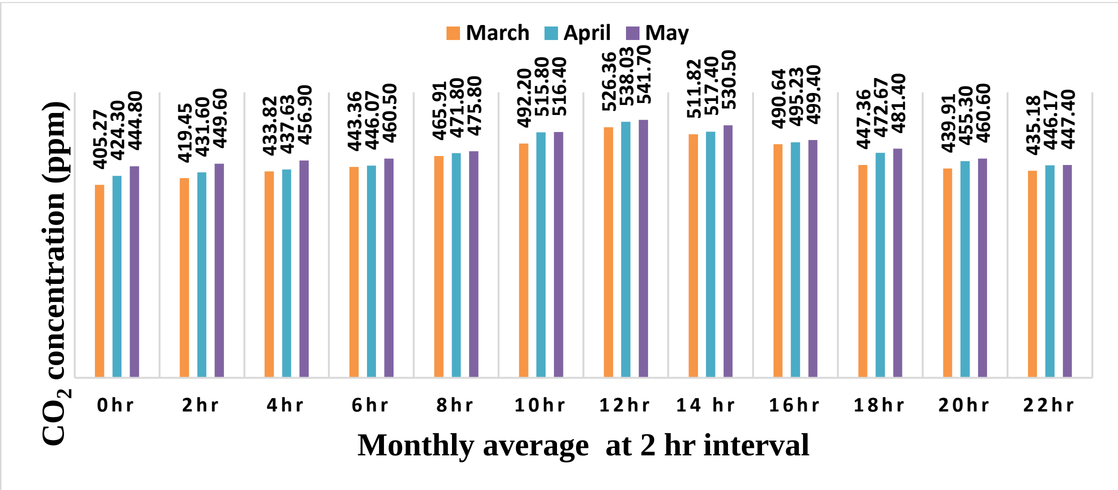

Fig 4.6 Variation of CO_2 concentration during the crop growing period at 2 hr interval under naturally ventilated polyhouse.

4.1.5 Wind Speed During the Crop Growing Period

The amount and distribution of wind speed during the crop growing period of 2022, and last 10 years mean wind speed (2012- 2022) are shown in Table 4.7 and depicted in Fig 4.7. during the crop growing period the highest wind speed was recorded in the month of May (6 km/hr) fallowed by April (5 km/hr) and the lowest wind speed was recorded in the month of march (3 km/hr). The average highest wind speed was occurred in May (7.5 km/hr) fallowed by April (7. Km/hr during the last 10 years mean wind speed.

Table 4.7 Wind speed during the crop growing period

Month	Wind speed during crop growing period (km/hr)	Decennial wind speed (2012- 2022) (km/hr)
March	3	5.3
April	5	7.5
May	6	7.5

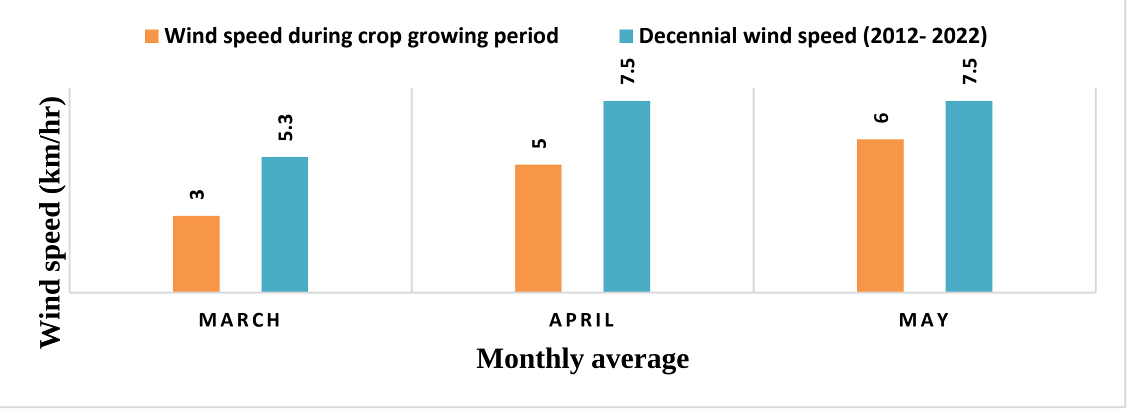

Fig 4.7 Variation of wind speed during the crop growing period under open field condition

4.2 ELECTRICAL CONDUCTIVITY AND pH VARIATION IN THE NUTRIENT SOLUTION

The two most important parameters in nutrient solution of hydroponic systems are electrical conductivity and pH. Maintenance of electrical conductivity of the hydroponic solution is imperative to the proper growth and development of the plants growing in the hydroponic systems. A normal EC level in the root zone is needed by the plant to absorb more water and retain it for a longer time. Electrical conductivity not only is a measure of the amount of nutrients given to the plants but also is a climate control mechanism relating to water absorption. Therefore, EC management is extremely central in terms of water absorption and retention. Maintenance of pH of the nutrient solution is equally important. If the pH of the nutrient solution is not maintained in the optimum range, then the plants will lose their ability to absorb some of the nutrients which are needed for their healthy growth and development. For the proper growth and development of crop, the pH and EC of nutrient solution in the hydroponic systems are to be monitored and maintained.

4.2.1 Electrical Conductivity Variation in Nutrient Solution of Hydroponic Unit

The electrical conductivity, which is used as an indicator of the strength of the nutrient solution was monitored and adjusted frequently in the NFT during the entire crop growing period. The graphical representation of the EC values of the nutrient solution throughout the crop growing period in hydroponic system shown in Fig 4.8. The values of EC of nutrient concentration such as 0.75, 1.0, 1.25, 1.5 dS/m was introduced into the growing systems and plants were placed in contact with the nutrient solution, plants started taking up nutrients due to which there was a decrease in the EC value of the nutrient solution. The EC values of the nutrient solution were not allowed to fall below the recommended level. The changing interval of nutrient solution 4-5 days. Adding the 50 to 100 ml of A and B nutrient solutions at every 4-5 days interval. When the EC reached below the recommended value, solution was replaced and fresh solution was introduced into the growing systems which is evident from the sharp peaks in the fig 4.8. Results showed that at the starting of the crop growing period EC variation is slightly less and from the middle to end of the crop growing period EC variation is slightly more in the nutrient solution. Table 4.8 shows that daily observed data at 8.30 AM in the different nutrient concentration in the hydroponics.

Table 4.8 Daily observed data of EC of the nutrient solution

EC				
DATE	**C1**	**C2**	**C3**	**C4**
20-03-2022	0.75	1.01	1.26	1.51
21-03-2022	0.73	0.99	1.24	1.49
22-03-2022	0.71	0.97	1.22	1.47
23-03-2022	0.70	0.96	1.21	1.45
24-03-2022	0.76	1.01	1.26	1.51
25-03-2022	0.75	0.99	1.25	1.49
26-03-2022	0.73	0.97	1.22	1.47
27-03-2022	0.70	0.95	1.20	1.46
28-03-2022	0.76	1.01	1.27	1.51
29-03-2022	0.75	1.00	1.24	1.49
30-03-2022	0.72	0.98	1.22	1.47
31-03-2022	0.68	0.95	1.20	1.45
01-04-2022	0.76	1.01	1.26	1.51
02-04-2022	0.75	0.99	1.24	1.49
03-04-2022	0.72	0.97	1.22	1.47
04-04-2022	0.70	0.95	1.20	1.45
05-04-2022	0.76	1.01	1.26	1.50
06-04-2022	0.73	0.99	1.24	1.49
07-04-2022	0.71	0.97	1.22	1.47
08-04-2022	0.69	0.95	1.20	1.45
09-04-2022	0.76	1.01	1.25	1.51
10-04-2022	0.74	0.99	1.24	1.49
11-04-2022	0.71	0.97	1.21	1.47
12-04-2022	0.69	0.95	1.18	1.44
13-04-2022	0.76	1.01	1.26	1.51
14-04-2022	0.74	0.99	1.24	1.48
15-04-2022	0.71	0.97	1.22	1.46
16-04-2022	0.69	0.95	1.19	1.43
17-04-2022	0.77	1.01	1.26	1.51
18-04-2022	0.74	0.99	1.24	1.49
19-04-2022	0.72	0.96	1.21	1.46
20-04-2022	0.69	0.94	1.19	1.43
21-04-2022	0.76	1.01	1.26	1.51
22-04-2022	0.73	0.99	1.24	1.48
23-04-2022	0.70	0.96	1.21	1.44
24-04-2022	0.77	1.02	1.26	1.52
25-04-2022	0.75	1.00	1.24	1.50
26-04-2022	0.72	0.96	1.21	1.46
27-04-2022	0.69	0.94	1.18	1.43
28-04-2022	0.76	1.02	1.26	1.51
29-04-2022	0.74	0.99	1.24	1.48
30-04-2022	0.72	0.96	1.21	1.46
01-05-2022	0.69	0.94	1.18	1.43
02-05-2022	0.78	1.02	1.27	1.52
03-05-2022	0.75	1.00	1.24	1.49
04-05-2022	0.72	0.97	1.21	1.46
05-05-2022	0.69	0.95	1.18	1.43

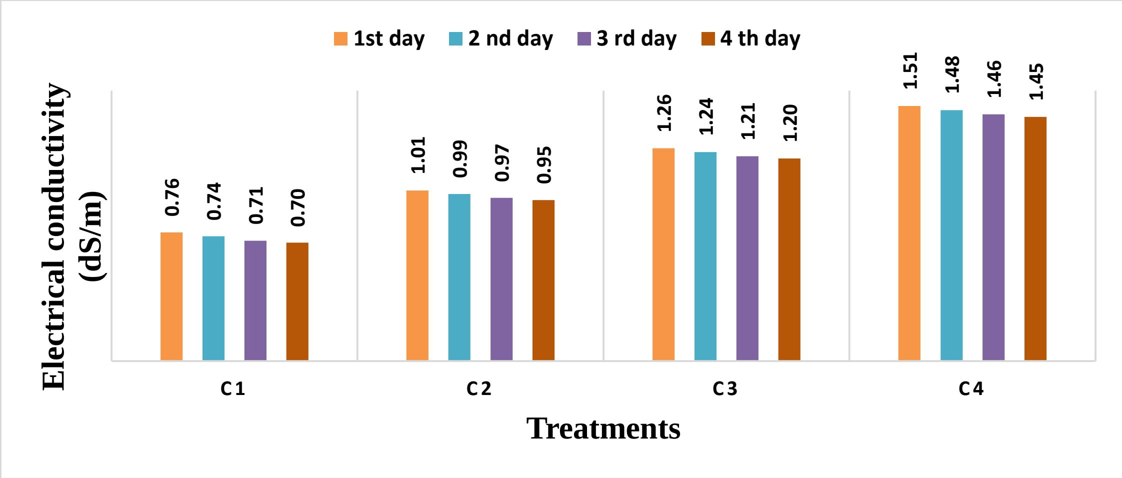

Fig 4.8 Daily average EC variation during the crop growing period in different levels of nutrient solution

4.2.2 pH Variation in the Nutrient Solution

During the experiment, the pH levels of the nutrient solutions were kept within the range where plants are not negatively influenced by the pH. For this, the pH of the nutrient solution was checked periodically and adjusted if necessary. The graphical representation of the pH values in the nutrient solution during the crop growing period for the hydroponic system are shown in Fig 4.9. The pH of the nutrient concentration was slightly lowered while adding the A and B nutrient solution in the reservoir because it was added to the nutrient solution reservoir every 4-5 days to optimise, raising the nutrient concentration back to the needed concentration. However, the ideal pH range for stevia crops is between 6.0 and 6.5. The pH up and down solutions were added to change the pH value of the nutrition solution. The pH of the solution was brought down using phosphoric acid by adding 5 to 10 drops at every 4 to 5 days interval. Results showed that at the starting of the crop growing period. pH variation is slightly less and from the middle to end of the crop growing period slightly more in the nutrient solution. It was observed that the pH of the nutrient solution has a tendency to go up as the plants utilized nutrients and the electrical conductivity of the solution decreased. The daily observed data of the pH at 8.30 AM in the different nutrient concentration in the hydroponics are shown in Table 4.9.

The pH of the nutrient solution was maintained in the required range of 6.0-6.5 during the experiment by adding pH up and down solution.

Table 4.9 Daily observed data of pH of nutrient solution

DATE	C_1	C_2	C_3	C_4
20-03-2022	6.04	6.02	6.05	6.07
21-03-2022	6.07	6.05	6.09	6.1
22-03-2022	6.1	6.08	6.12	6.14
23-03-2022	6.12	6.12	6.15	6.18
24-03-2022	6.15	6.14	6.19	6.21
25-03-2022	6.1	6.08	6.05	6.08
26-03-2022	6.12	6.11	6.09	6.12
27-03-2022	6.15	6.14	6.12	6.15
28-03-2022	6.18	6.17	6.15	6.17
29-03-2022	6.14	6.11	6.1	6.12
30-03-2022	6.16	6.15	6.14	6.16
31-03-2022	6.2	6.18	6.18	6.19
01-04-2022	6.14	6.1	6.07	6.09
02-04-2022	6.17	6.13	6.12	6.14
03-04-2022	6.21	6.17	6.16	6.18
04-04-2022	6.24	6.21	6.19	6.22
05-04-2022	6.19	6.17	6.16	6.13
06-04-2022	6.22	6.21	6.2	6.18
07-04-2022	6.24	6.25	6.25	6.22
08-04-2022	6.26	6.29	6.3	6.26
09-04-2022	6.21	6.18	6.15	6.17
10-04-2022	6.24	6.22	6.19	6.2
11-04-2022	6.27	6.27	6.24	6.25
12-04-2022	6.3	6.31	6.29	6.3
13-04-2022	6.24	6.2	6.17	6.18
14-04-2022	6.27	6.25	6.23	6.21
15-04-2022	6.3	6.29	6.29	6.25
16-04-2022	6.32	6.33	6.31	6.3
17-04-2022	6.2	6.19	6.16	6.18
18-04-2022	6.24	6.23	6.2	6.22
19-04-2022	6.27	6.28	6.25	6.27
20-04-2022	6.29	6.31	6.29	6.3
21-04-2022	6.15	6.1	6.12	6.15
22-04-2022	6.19	6.15	6.17	6.19
23-04-2022	6.23	6.2	6.22	6.24
24-04-2022	6.13	6.12	6.1	6.11
25-04-2022	6.18	6.17	6.15	6.16
26-04-2022	6.22	6.21	6.19	6.2
27-04-2022	6.26	6.27	6.23	6.24
28-04-2022	6.13	6.1	6.13	6.1
29-04-2022	6.18	6.15	6.18	6.15
30-04-2022	6.23	6.19	6.21	6.2
01-05-2022	6.27	6.23	6.24	6.24
02-05-2022	6.08	6.05	6.08	6.1
03-05-2022	6.12	6.09	6.11	6.14
04-05-2022	6.17	6.14	6.14	6.18
05-05-2022	6.19	6.19	6.19	6.22

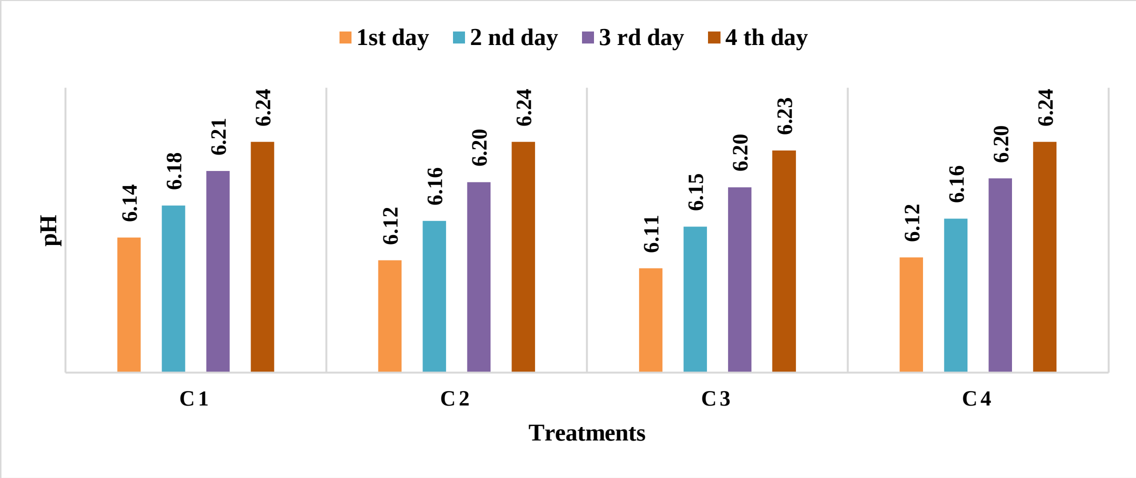

Fig 4.9 Average daily pH variation of nutrient solution during the crop growing period

4.3 GROWTH PARAMETERS OF STEVIA CROP GROWN UNDER HYDROPONIC FARMING

Stevia crop growth in terms of plant height, number of branches, root length, number of leaves, leaf length and girth diameter showed significant variation due to different levels of EC of nutrient concentration and different types of growing media during the crop period of 10-03-2022 to 10-04-2022. The data biometric observations recorded at every 5 days interval after transplantation, but the data of 20 DAT, 40 DAT and 60 DAT was analysed and are presented below.

4.3.1 Plant Height (cm) During the Crop Growing Period under Hydroponic Farming

During the Crop growing period, nutrient concentration as well as growing media has significantly affected the plant height of stevia crop growth. Among all the concentration at 20 DAT the highest plant height was recorded in C_4, C_3, C_2 (16.16, 15.28, 15.19 cm) and the lowest plant height recorded in C_1 (12.11 cm). Similarly at 40 DAT the highest plant height recorded in C_4, C_3, C_2 (30.75, 26.97, 26.76 cm) and the lowest value recorded in C_1 (20.05 cm). At 60 DAT the highest value recorded C_4, C_2, C_3 (45.8, 38.8, 38.9 cm) and the lowest value in C_1 (28.1 cm). The results of the height of the plant by the influence of nutrient concentration and growing media are shown in Table 4.10 and depicted in Fig 4.10. The analysis of variance to compare the means of plant height (Table 4.11) showed there is a significant difference between the EC of nutrient concentration levels at 20, 40, 60 DAT (P = 0.000, 0.000, 0.000). The Duncan test for comparing treatment means for main plots (nutrient concentration levels) of plant height at 20 DAT showed that C_1 and C_4 treatment has significant difference, where C_2 and C_3 has on par effect (Appendices). At 40 DAT C_1 and C_4 treatment has significant difference on plant height, where C_2 and C_3 has on par effect. At 60 DAT C_1 and C_4 treatment has significant difference, where C_2 and C_3 has on par effect.

The height of stevia crop at all stages showed a marked difference among different types of media. At all stages of observation, clay balls (M_3) showed the tallest plant height followed by M_4, M_2 and M_1. Inden and Torres (2004) reported that utilization of vermiculite and perlite in hydroponics culture results in higher yields as compared to other inert materials. Analysis of variance to compare the means of sub plots for plant height showed that there is significant difference between the sub plots at 20DAT. 40DAT and 60 DAT (P = 0.000, 0.000, 0.000). the Duncan test for comparing the treatment means for sub plots (growing media) of plant height at 20DAT. 40DAT and 60 DAT showed M_1

and M_3 treatments showed significant difference, where M_2 and M_4 has on par effect (Appendices E).

The interaction effect between EC of nutrient concentration and growing media did not influence the plant height significantly (P = 0.126, 0.095 and 0.093) at all the growth stages of stevia crop.

Table 4.10 Plant height (cm) at 20 DAT, 40 DAT and 60 DAT under Hydroponic Farming

Nutrient Concentration	Growing media	20 DAT	40 DAT	60 DAT
C_1	M_1	12.11	20.05	28.1
	M_2	12.53	20.93	29.7
	M_3	14.19	24.09	34.4
	M_4	13.68	22.84	32.4
C_2	M_1	13.64	23.99	34.6
	M_2	14.03	25.35	37.3
	M_3	15.19	26.76	38.9
	M_4	13.11	22.39	32.2
C_3	M_1	12.87	21.60	30.8
	M_2	14.51	24.92	36.1
	M_3	15.28	26.97	38.8
	M_4	13.91	24.12	34.6
C_4	M_1	13.72	24.03	34.9
	M_2	14.53	25.93	38.0
	M_3	16.16	30.75	45.8
	M_4	15.99	29.83	44.1

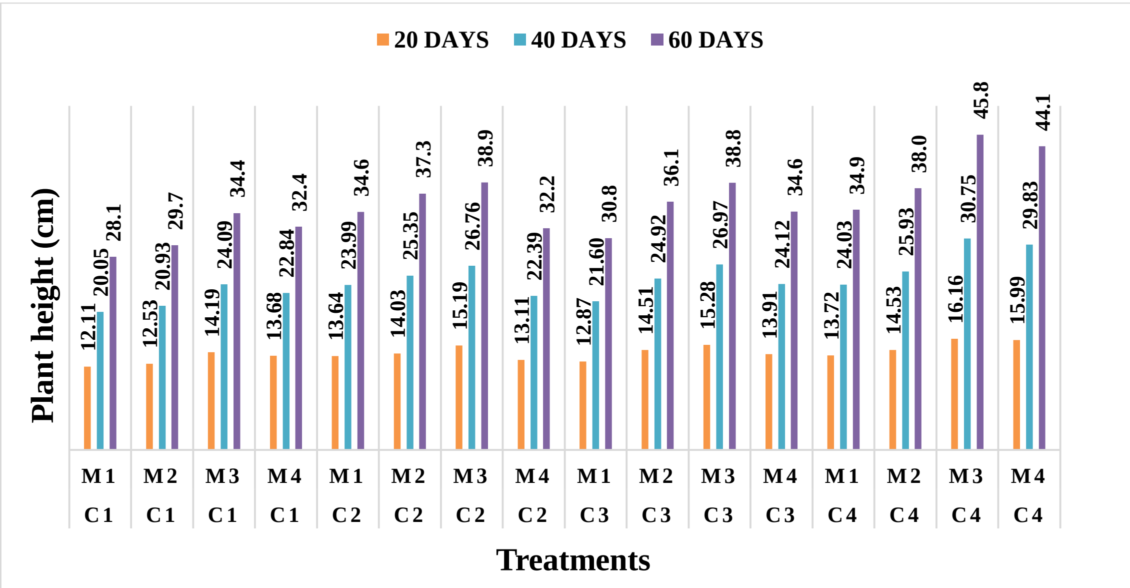

Fig 4.10 Plant height (cm) during crop growing period at 20 DAT, 40 DAT and 60 DAT under hydroponics

Table 4.11 Univariate analysis of variance to compare the means of plant height for stevia crop at 20, 40 and 60 DAT

Plant height at 20 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	71.163[a]	23	3.094	5.024	0.000
Intercept	9528.785	1	9528.785	15471.249	0.000
Rep	2.390	2	1.195	1.941	0.166
Main	23.392	3	7.797	12.660	0.000
Main*replication	7.655	6	1.276	2.071	0.095
Sub	27.891	3	9.297	15.095	0.000
Main * Sub	9.835	9	1.093	1.774	0.126
Error	14.782	24	0.616		
Total	9614.730	48			
Corrected Total	85.945	47			
a. R Squared = 0.828 (Adjusted R Squared = 0.663)					
Plant height at 40 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	467.542[a]	23	20.328	5.841	0.000
Intercept	29205.333	1	29205.333	8391.835	0.000
Rep	22.643	2	11.321	3.253	0.056
Main	192.942	3	64.314	18.480	0.000
Main*replication	54.652	6	9.109	2.617	0.043
Sub	136.682	3	45.561	13.091	0.000
Main * Sub	60.623	9	6.736	1.935	0.095
Error	83.525	24	3.480		
Total	29756.400	48			
Corrected Total	551.067	47			
a. R Squared = 0.848 (Adjusted R Squared = 0.703)					
Plant height at 60 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	1240.905[a]	23	53.952	6.062	0.000
Intercept	61097.005	1	61097.005	6864.832	0.000
Rep	61.330	2	30.665	3.446	0.048
Main	554.172	3	184.724	20.756	0.000
Main*replication	138.370	6	23.062	2.591	0.044
Sub	331.174	3	110.391	12.404	0.000
Main * Sub	155.859	9	17.318	1.946	0.093
Error	213.600	24	8.900		
Total	62551.510	48			
Corrected Total	1454.505	47			
a. R Squared = 0.853 (Adjusted R Squared = 0.712)					

4.3.2 Plant Height (cm) During the Crop Growing Period under open Field Condition

The results of the plant height in open field cultivation are shown in Table 4.12 and are depicted in Fig 4.11. It was observed that, the lowest plant height was recorded when compared to hydroponic farming at 20, 40, 60 DAT (5.2, 11.63, 21.27). This might be due to the unfavourable condition at open field condition.

Table 4.12 Plant height (cm) during crop growing period at 20 DAT, 40 DAT and 60 DAT under open field condition

Plant height (cm)	20 DAT	40 DAT	60 DAT
Plant 1	5.4	11.4	20.6
Plant 2	5.6	12.6	23.2
Plant 3	4.7	10.6	19.5
Plant 4	4.9	11.4	21.3
Plant 5	5.5	12.2	22.4
Plant 6	5.9	13.2	24.2
Plant 7	5.3	11.3	20.4
Plant 8	4.6	10.6	19.7
Plant 9	4.8	10.7	19.6
Plant 10	5.3	11.9	21.8
Average	**5.2**	**11.6**	**21.27**

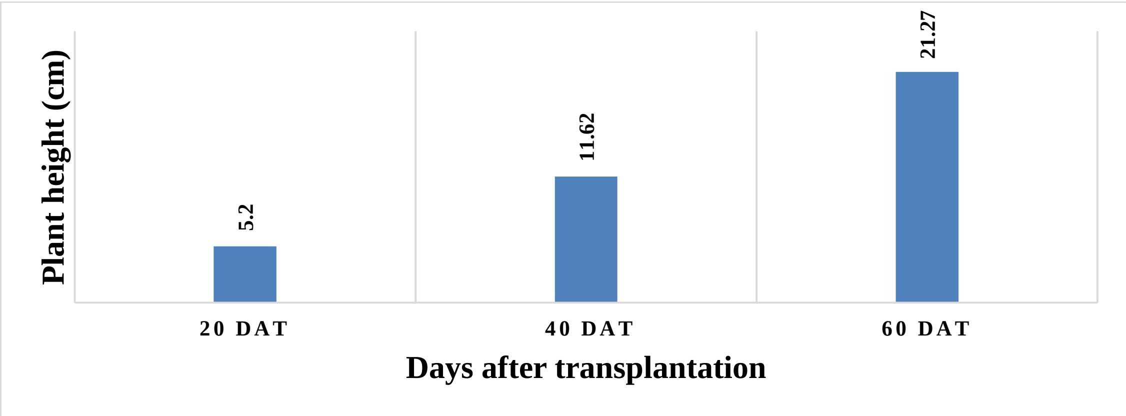

Fig 4.11 Average plant height (cm) during crop growing period at 20 DAT, 40 DAT and 60 DAT under open field conditions

4.3.3 No of Branches During the Crop Growing Period under Hydroponic Farming

During the Crop growing period, nutrient concentration as well as growing media has significantly affected the No. of branches of stevia crop growth. Among all the concentration at 20 DAT the highest No. of branches was recorded in C_1, C_2, C_3 (4, 4, 4) and the lowest No. of branches recorded in C_4 (3). Similarly at 40 DAT the highest No. of branches recorded in C_1, C_2, C_3 (5, 5, 5) and the lowest value recorded in C_4 (4). At 60

DAT the highest value recorded C_1, C_2, C_3 (5, 5, 5) and the lowest value in C_4 (4). The results of the No. of branches by the influence of nutrient concentration and growing media are shown in Table 4.13 and depicted in Fig 4.12. The analysis of variance to compare the means of No. of branches (Table 4.14) showed there is a significant difference between the EC of nutrient concentration levels at 20, 40, 60 DAT (P = 0.000, 0.000, 0.000). The Duncan test for comparing treatment means for main plots (nutrient concentration levels) of no of branches at 20DAT 40DAT and 60 DAT showed that C_3 and C_4 treatment has significant difference, where C_1 and C_2 has on par effect (Appendices C).

The No. of branches of stevia crop at all stages showed a marked difference among different types of media. At all stages of observation, clay balls(M_3) showed the more no of branches followed by M_2, M_4 and M_1. Wahome *et al*., (2011) reported that high number of branches/flowers of gypsophila grown using sawdust, perlite and vermiculite could probably be due to higher water holding and nutrient holding capacities of the medium as compared to sand. Analysis of variance to compare the means of sub plots for No. of branches showed that there is significant difference between the sub plots at 20 DAT, 40 DAT and 60 DAT (P = 0.000, 0.000, 0.000). The Duncan test for comparing the treatment means for sub plots (growing media) of No. of branches at 20DAT, showed that M_2 and M_3 treatment has significant difference, whereas M_1 and M_4 has on par effect. At 40 DAT and 60 DAT showed M_1 and M_3 treatments showed significant difference, where M_2 and M_4 has on par effect (Appendices E).

The interaction effect between EC of nutrient concentration and growing media did not influence the No. of branches significantly (P = 0.294, 0.160, 0.160) at all the growth stages of stevia crop

Table 4.13 No. of branches at 20 DAT, 40 DAT and 60 DAT under hydroponic farming

Nutrient concentration	Growing media	20 DAYS	40 DAYS	60 DAYS
C_1	M_1	2	3	3
	M_2	3	4	4
	M_3	4	5	5
	M_4	3	4	4
C_2	M_1	3	4	4
	M_2	3	4	4
	M_3	4	5	5
	M_4	3	4	4
C_3	M_1	3	4	4
	M_2	4	5	5
	M_3	4	5	5
	M_4	3	4	4
C_4	M_1	3	3	3
	M_2	3	3	3
	M_3	3	4	4
	M_4	2	3	3

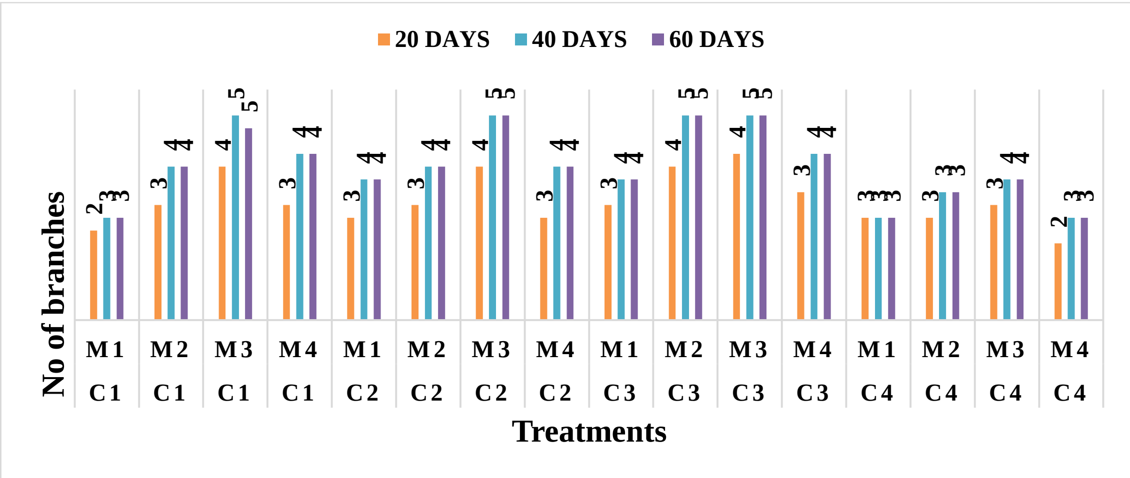

Fig 4.12 No. of branches during crop growing period at 20 DAT, 40 DAT and 60 DAT under hydroponics

Table 4.14 Univariate analysis of variance to compare the means of No. of branches for stevia crop at 20, 40 and 60 DAT

No. of branches at 20 DAT					
Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	26.833[a]	23	1.167	5.793	0.000
Intercept	456.333	1	456.333	2265.931	0.000
Rep	5.042	2	2.521	12.517	0.000
Main	7.167	3	2.389	11.862	0.000
Main*replication	3.458	6	0.576	2.862	0.030
Sub	8.833	3	2.944	14.621	0.000
Main * Sub	2.333	9	0.259	1.287	0.294
Error	4.833	24	0.201		
Total	488.000	48			
Corrected Total	31.667	47			
a. R Squared = .847 (Adjusted R Squared = .701)					
No. of branches at 40 DAT					
Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	54.812[a]	23	2.383	7.004	0.000
Intercept	776.021	1	776.021	2280.551	0.000
Rep	8.667	2	4.333	12.735	0.000
Main	16.229	3	5.410	15.898	0.000
Main*replication	5.833	6	0.972	2.857	0.030
Sub	19.063	3	6.354	18.673	0.000
Main * Sub	5.021	9	0.558	1.639	0.160
Error	8.167	24	0.340		
Total	839.000	48			
Corrected Total	62.979	47			
a. R Squared = 0.847 (Adjusted R Squared = 0.701)					
No. of branches at 60 DAT					
Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	54.812[a]	23	2.383	7.004	0.000
Intercept	776.021	1	776.021	2280.551	0.000
Rep	8.667	2	4.333	12.735	0.000
Main	16.229	3	5.410	15.898	0.000
Main*replication	5.833	6	0.972	2.857	0.030
Sub	19.063	3	6.354	18.673	0.000
Main * Sub	5.021	9	0.558	1.639	0.160
Error	8.167	24	0.340		
Total	839.000	48			
Corrected Total	62.979	47			
a. R Squared = 0.870 (Adjusted R Squared = 0.746)					

4.3.4 No. of Branches During the Crop Growing Period under Open Field Condition

The results of the No. of branches in open field cultivation are shown in Table 4.15 and are depicted in Fig 4.13. It was observed that, the lowest No. of branches was recorded when compared to hydroponic farming at 20, 40, 60 DAT (2, 3, 4 No's). This might be due to the unfavourable condition at open field condition.

Table 4.15 No of branches at 20 DAT, 40 DAT and 60 DAT under open field conditions

No of branches	20 DAT	40 DAT	60 DAT
Plant 1	2	4	4
Plant 2	3	4	5
Plant 3	2	4	4
Plant 4	1	3	3
Plant 5	2	4	4
Plant 6	2	3	3
Plant 7	2	3	3
Plant 8	1	3	3
Plant 9	2	3	3
Plant 10	2	4	4

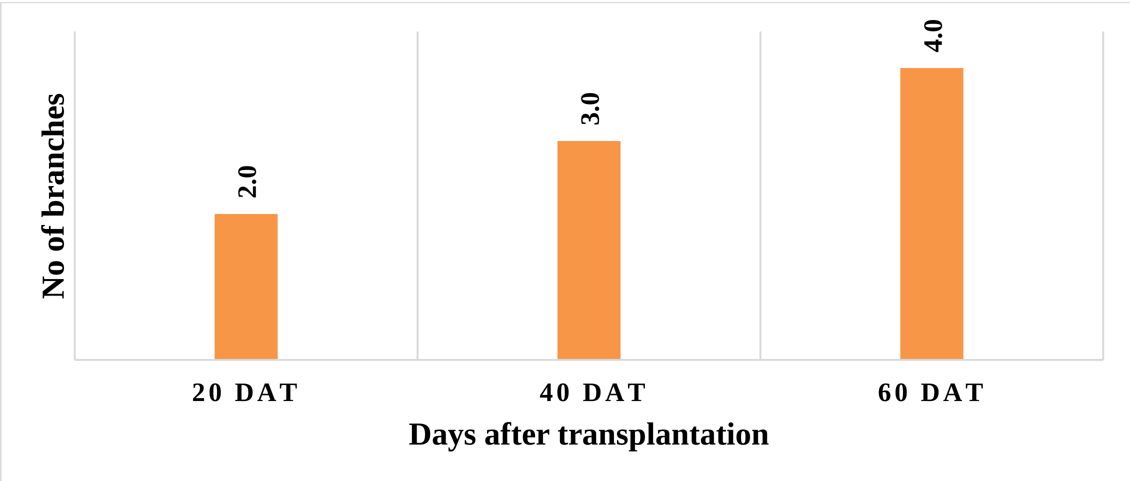

Fig 4.13 Average no of branches during crop growing period at 20 DAT, 40 DAT and 60 DAT under open field conditions

4.3.5 Root Length (cm) During the Crop Growing Period under Hydroponic Farming

During the Crop growing period, nutrient concentration as well as growing media has significantly affected the root length of stevia crop growth. Among all the concentration at 20 DAT the highest root length was recorded in C_3, C_2, C_1 (8.72, 7.72, 7.64 cm) and the lowest root length recorded in C_4 (6.15 cm). Similarly at 40 DAT the highest root length recorded in C_3, C_1, C_2 (14.69, 11.65, 11.37 cm) and the lowest value recorded in C_4 (8.24 cm). At 60 DAT the highest value recorded C_3, $C_{2,}$ C_1 (21.0, 16.4, 16.2 cm) and the lowest value in C_4 (10.6 cm). The results of the root length by the influence of nutrient concentration and growing media are shown in Table 4.16 and depicted in Fig 4.14. The analysis of variance to compare the means of root length (table 4.17) showed there is a significant difference between the EC of nutrient concentration levels at 20, 40, 60 days (P = 0.000, 0.000, 0.000). the Duncan test for comparing treatment means for main plots (nutrient concentration levels) of root length at 20 DAT showed that C_3 treatment has significant difference, where C_4, C_1 and C_2 has on par effect. At 40 DAT and 60 DAT C_1 and C_3 treatment has significant difference on root length, where C_2 and C_1 has on par effect (Appendices E).

The root length of stevia crop at all stages showed a marked difference among different types of media. At all stages of observation, clay balls(M_3) showed the highest root length followed by M_4, M_2 and M_1. Analysis of variance to compare the means of sub plots for root length showed that there is significant difference between the sub plots at 20DAT (P = 0.017). But there no significant difference between the 40DAT and 60 DAT (P = 0.120, 0.182). the Duncan test for comparing the treatment means for sub plots (growing media) of root length at 20DAT showed M_3 treatments showed significant difference, where M_2, M_1 and M_4 has on par effect (Appendices C).

The interaction effect between EC of nutrient concentration and growing media did not influence the root length significantly (P = 0.079, 0.104, 0.075) at all the growth stages of stevia crop.

Table 4.16 Root length (cm) at 20 DAT, 40 DAT and 60 DAT under hydroponics

Nutrient concentration	**Growing media**	**20 DAT**	**40 DAT**	**60 DAT**
C_1	**M_1**	6.75	10.04	13.6
	M_2	6.93	11.13	15.7
	M_3	7.64	11.65	16.2
	M_4	6.51	9.59	13.3
C_2	M_1	6.96	10.15	13.7
	M_2	6.17	8.92	11.9
	M_3	7.72	11.36	15.5
	M_4	7.08	11.37	16.4
C_3	M_1	7.15	11.57	16.3
	M_2	7.63	12.15	16.9
	M_3	8.72	14.69	21.0
	M_4	7.75	12.37	17.5
C_4	M_1	6.67	9.00	11.6
	M_2	6.55	9.77	13.9
	M_3	6.15	8.24	10.6
	M_4	6.65	8.83	11.2

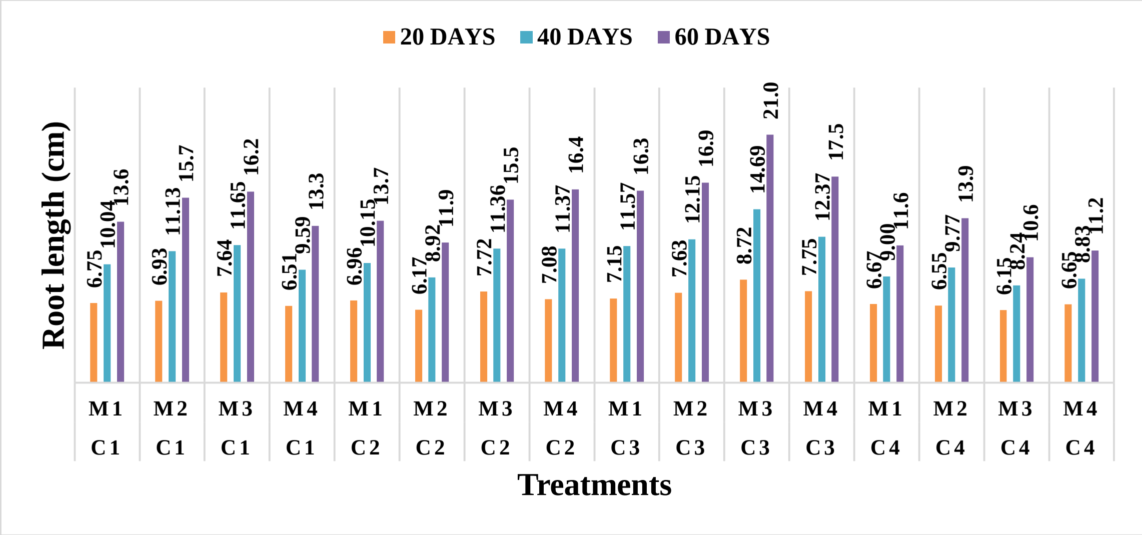

Fig 4.14 Root length (cm) during the crop growing period at 20 DAT, 40 DAT and 60 DAT under hydroponics

Table 4.17 Univariate analysis of variance to compare the means of root length for stevia crop at 20, 40 and 60 DAT

Root length at 20 DAT					
Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	24.506[a]	23	1.065	3.222	0.003
Intercept	2398.427	1	2398.427	7252.698	0.000
Rep	1.715	2	0.857	2.593	0.096
Main	10.529	3	3.510	10.613	0.000
Main*replication	2.062	6	.344	1.039	0.425
Sub	4.124	3	1.375	4.157	0.017
Main * Sub	6.077	9	0.675	2.042	0.079
Error	7.937	24	0.331		
Total	2430.870	48			
Corrected Total	32.443	47			
a. R Squared = 0.755 (Adjusted R Squared = 0.521)					
Root length at 40 DAT					
Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	142.460[a]	23	6.194	3.506	0.002
Intercept	5467.735	1	5467.735	3095.3	0.000
Rep	8.638	2	4.319	2.445	0.108
Main	84.887	3	28.296	16.018	0.000
Main*replication	7.627	6	1.271	0.720	0.638
Sub	11.396	3	3.799	2.150	0.120
Main * Sub	29.912	9	3.324	1.881	0.104
Error	42.395	24	1.766		
Total	5652.590	48			
Corrected Total	184.855	47			
a. R Squared = 0.771 (Adjusted R Squared = 0.551)					
Root length at 60 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	382.897[a]	23	16.648	3.502	0.002
Intercept	10384.083	1	10384.083	2184.207	0.000
Rep	23.760	2	11.880	2.499	0.103
Main	222.963	3	74.321	15.633	0.000
Main*replication	22.453	6	3.742	0.787	0.589
Sub	25.057	3	8.352	1.757	0.182
Main * Sub	88.663	9	9.851	2.072	0.075
Error	114.100	24	4.754		
Total	10881.080	48			
Corrected Total	496.997	47			
a. R Squared = 0.770 (Adjusted R Squared =0 .550)					

4.3.6 No. of Leaves During the Crop Growing Period under Hydroponic Farming

During the Crop growing period, nutrient concentration as well as growing media has significantly affected the No. of leaves of stevia crop growth. Among all the concentration at 20 DAT the highest No. of leaves was recorded in C_3, C_2, C_4 (53, 49, 45 no's) and the lowest No. of leaves recorded in C_1 (28 no's). Similarly at 40 DAT the highest No. of leaves recorded in C_3, C_2, C_4 (108, 91, 86 no's) and the lowest value recorded in C_1 (46 no's). At 60 DAT the highest value recorded C_3, C_2, C_4 (162, 132, 127 no's) and the lowest value in C_1 (65 no's). The results of the No. of leaves by the influence of nutrient concentration and growing media are shown in Table 4.18 and depicted in Fig 4.15. The analysis of variance to compare the means of No. of leaves (Table 4.19) showed there is a significant difference between the EC of nutrient concentration levels at 20, 40, 60 days (P = 0.002, 0.000, 0.000). The Duncan test for comparing treatment means for main plots (nutrient concentration levels) of No. of leaves at 20 DAT showed that $C_1$and C_4, C_4 and C_2 and also C_2 and C_3 has on par effect. At 40 DAT and 60 DAT showed that C_1 and C_3 treatment has significant difference, where C_4 and C_2 has on par effect (Appendices E).

The no of leaves of stevia crop at all stages showed a marked difference among different types of media. At all stages of observation, clay balls(M_3) showed the more no of leaves followed by M_2, M_4 and M_1. Analysis of variance to compare the means of sub plots for no of leaves showed that there is significant difference between the sub plots at 20DAT. 40DAT and 60 DAT (P = 0.000, 0.000, 0.000). the Duncan test for comparing the treatment means for sub plots (growing media) of no of leaves at 20DAT, 40DAT and 60 DAT showed that M_1 and M_3 treatment has significant difference, whereas M_4 and M_2 has on par effect (Appendices C).

The interaction effect between EC of nutrient concentration and growing media did not influence the no of leaves significantly (P = 0.086, 0.110, 0.136) at all the growth stages of stevia crop.

Table 4.18 No. of leaves at 20 DAT, 40 DAT and 60 DAT interval under hydroponics

Nutrient concentration	Growing media	20 DAYS	40 DAYS	60 DAYS
C_1	M_1	28	46	65
	M_2	34	59	85
	M_3	46	76	108
	M_4	36	64	92
C_2	M_1	38	71	105
	M_2	39	73	108
	M_3	49	91	132
	M_4	34	65	96
C_3	M_1	33	63	92
	M_2	44	87	130
	M_3	53	108	162
	M_4	38	76	115
C_4	M_1	32	60	88
	M_2	38	73	108
	M_3	45	86	127
	M_4	39	73	108

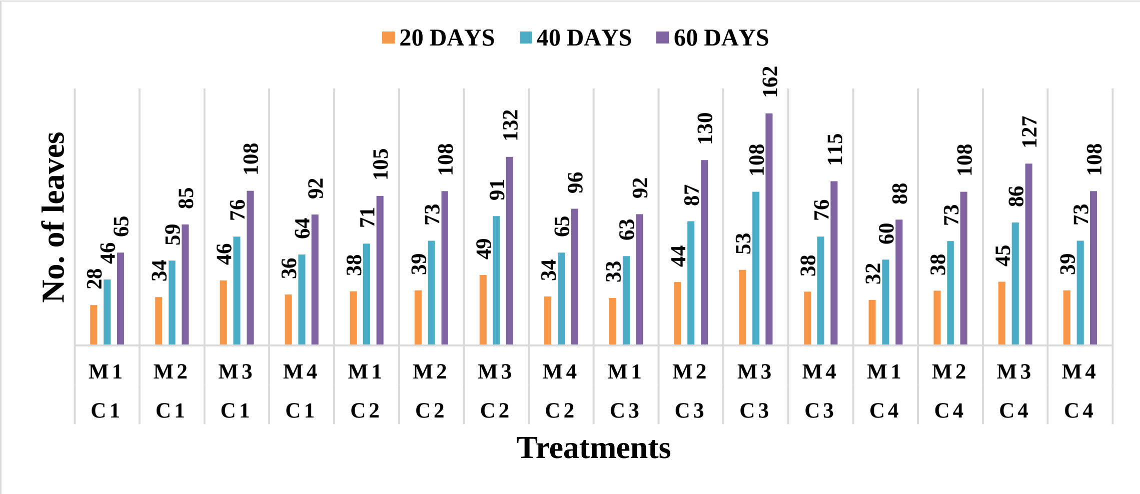

Fig 4.15 No. of leaves during the crop growing period at 20 DAT, 40 DAT and 60 DAT under hydroponics

Table 4.19 Univariate analysis of variance to compare the means of No. of leaves for stevia crop at 20, 40 and 60 DAT

No. of leaves at 20 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	2427.417[a]	23	105.540	8.448	0.000
Intercept	73476.750	1	73476.750	5881.407	0.000
Rep	227.625	2	113.812	9.110	0.001
Main	245.583	3	81.861	6.553	0.002
Main*replication	208.542	6	34.757	2.782	0.034
Sub	1522.083	3	507.361	40.611	0.000
Main * Sub	223.583	9	24.843	1.989	0.086
Error	299.833	24	12.493		
Total	76204.000	48			
Corrected Total	2727.250	47			
a. R Squared = 0.890 (Adjusted R Squared = 0.785)					
No. of leaves at 40 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	12287.833[a]	23	534.254	8.519	0.000
Intercept	257547.000	1	257547.000	4106.607	0.000
Rep	1448.375	2	724.187	11.547	0.000
Main	2961.333	3	987.111	15.740	0.000
Main*replication	1155.792	6	192.632	3.072	0.022
Sub	5675.833	3	1891.944	30.167	0.000
Main * Sub	1046.500	9	116.278	1.854	0.110
Error	1505.167	24	62.715		
Total	271340.000	48			
Corrected Total	13793.000	47			
a. R Squared = .891 (Adjusted R Squared = .786)					
No. of leaves at 60 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	30296.833[a]	23	1317.254	8.001	0.000
Intercept	554700.000	1	554700.000	3369.334	0.000
Rep	3821.375	2	1910.687	11.606	0.000
Main	8491.667	3	2830.556	17.193	0.000
Main*replication	2787.458	6	464.576	2.822	0.032
Sub	12630.167	3	4210.056	25.573	0.000
Main * Sub	2566.167	9	285.130	1.732	0.136
Error	3951.167	24	164.632		
Total	588948.000	48			
Corrected Total	34248.000	47			
a. R Squared = 0.885 (Adjusted R Squared = 0.774)					

4.3.7 No of Leaves During the Crop Growing Period under open field condition

The results of the No. of leaves in open field cultivation are shown in Table 4.20 and are depicted in Fig 4.16. It was observed that, the lowest No. of leaves was recorded when compared to hydroponic farming at 20, 40, 60 DAT (12, 27, 50 no's). This might be due to the unfavourable condition at open field condition.

Table 4.20 No. of leaves at 20 DAT, 40 DAT and 60 DAT under open field condition

	20 DAT	40 DAT	60 DAT
Plant 1	12	28	53
Plant 2	16	34	61
Plant 3	11	27	52
Plant 4	12	26	47
Plant 5	12	29	54
Plant 6	14	26	43
Plant 7	12	24	41
plant 8	10	23	43
Plant 9	11	22	38
Plant 10	14	34	65
Average	**12**	**27**	**50**

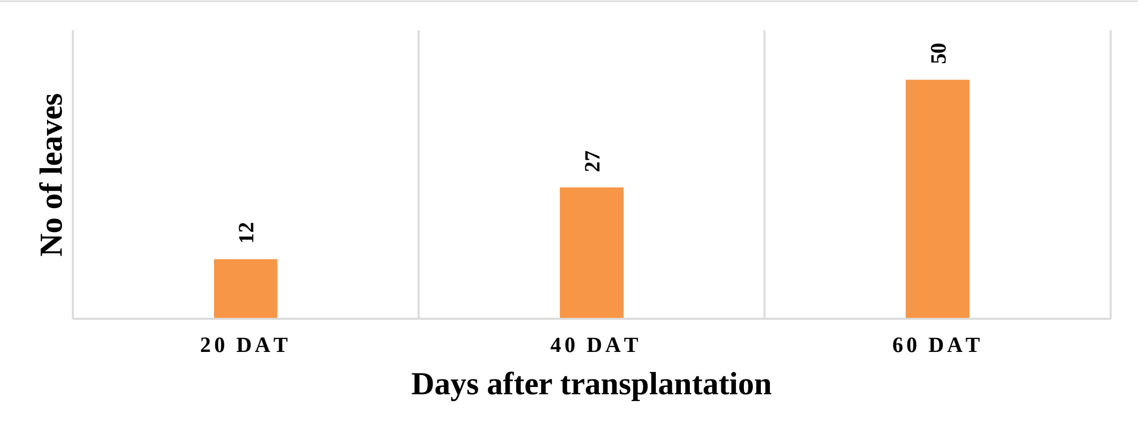

Fig 4.16 No. of leaves during the crop growing period at 20 DAT, 40 DAT and 60 DAT under open field condition

4.3.8 Leaf Length (cm) During the Crop Growing Period under Hydroponic Farming

During the Crop growing period, nutrient concentration as well as growing media has significantly affected the leaf length of stevia crop growth. Among all the concentration at 20 DAT the highest leaf length was recorded in C_4, C_3, C_2 (2.6, 2.6, 2.6 cm) and the lowest leaf length recorded in C_1 (2.4 cm). Similarly at 40 DAT the highest leaf length recorded in C_4, C_2, C_3 (4.2, 4.2, 4.1 cm) and the lowest value recorded in C_1 (3.8 cm). At 60 DAT the highest value recorded C_4, C_2, C_3 (5.8, 5.7, 5.6 cm) and the lowest value in C_2 (5.2 cm). The results of the leaf length by the influence of nutrient concentration and growing media are shown in Table 4.21 and depicted in Fig 4.17. The analysis of variance to compare the means of leaf length **(**Table 4.22**)** showed there is no significant difference between the EC of nutrient concentration levels at 20, 40, 60 days (P = 0.402, 0.372, 0.400).

The leaf length of stevia crop at all stages showed a marked difference among different types of media. At all stages of observation, vermiculite(M_4) showed the more leaf length followed by M_3, M_2 and M_1. Analysis of variance to compare the means of sub plots for leaf length showed that there is significant difference between the sub plots at 20 DAT, 40 DAT and 60 DAT (P = 0.026, 0.000, 0.000). The Duncan test for comparing the treatment means for sub plots (growing media) of leaf length at 20 DAT showed that M_3 treatment has significant difference, whereas M_1, M_4 and M_3 has on par effect. At 40 DAT and 60 DAT showed M_1 and M_3 treatments showed significant difference, where M_2 and M_4 has on par effect (Appendices E).

The interaction effect between EC of nutrient concentration and growing media did not influence the leaf length significantly (P = 0.647, 0.057, 0.112) at all the growth stages of stevia crop.

Table 4.21 Leaf length (cm) at 20 DAT, 40 DAT and 60 DAT under hydroponics

Nutrient concentration	Growing media	20 DAYS	40 DAYS	60 DAYS
C_1	M_1	2.4	3.8	5.3
	M_2	2.5	4.0	5.4
	M_3	2.6	4.1	5.6
	M_4	2.4	3.8	5.3
C_2	M_1	2.4	3.8	5.2
	M_2	2.4	3.9	5.3
	M_3	2.6	4.2	5.7
	M_4	2.5	4.1	5.6
C_3	M_1	2.5	3.9	5.4
	M_2	2.6	4.0	5.4
	M_3	2.6	4.1	5.6
	M_4	2.6	4.1	5.6
C_4	M_1	2.5	3.9	5.3
	M_2	2.4	3.9	5.3
	M_3	2.6	4.1	5.6
	M_4	2.5	4.2	5.8

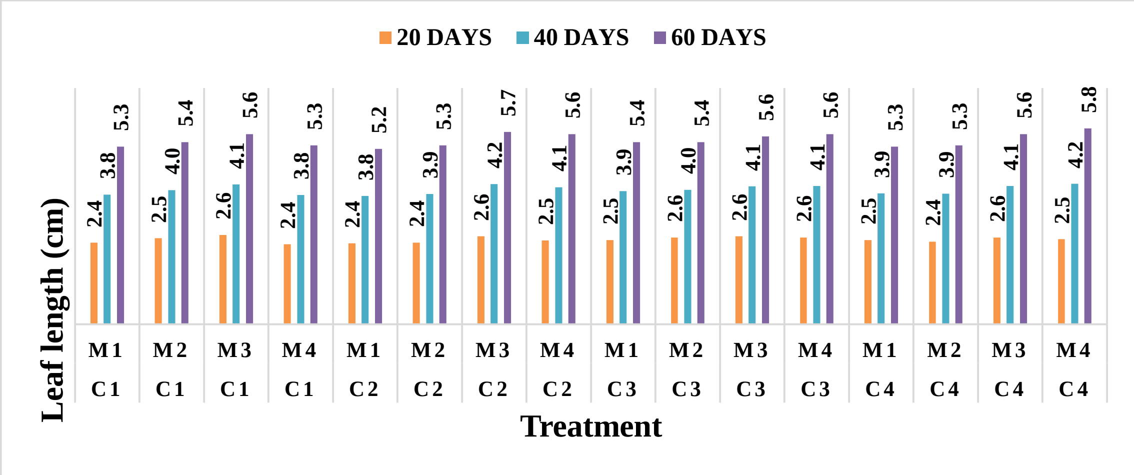

Fig 4.17 Leaf length (cm) at 20 DAT, 40 DAT and 60 DAT under hydroponics

Table 4.22 Univariate analysis of variance to compare the means of leaf length for stevia crop at 20, 40 and 60 DAT

Leaf length at 20 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	0.722[a]	23	0.031	2.107	0.038
Intercept	302.304	1	302.304	20296.4	0.000
Rep	0.203	2	0.101	6.808	0.005
Main	0.045	3	0.015	1.018	0.402
Main*replication	0.206	6	0.034	2.300	0.068
Sub	0.165	3	0.055	3.692	0.026
Main * Sub	0.103	9	0.011	0.767	0.647
Error	0.357	24	0.015		
Total	303.384	48			
Corrected Total	1.079	47			
a. R Squared = 0.669 (Adjusted R Squared = 0.351)					
Leaf length at 40 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	1.395[a]	23	0.061	4.695	0.000
Intercept	764.005	1	764.005	59148.79	0.000
Rep	0.203	2	0.101	7.855	0.002
Main	0.042	3	0.014	1.091	0.372
Main*replication	0.407	6	0.068	5.253	0.001
Sub	0.484	3	0.161	12.489	0.000
Main * Sub	0.259	9	0.029	2.224	0.057
Error	0.310	24	0.013		
Total	765.710	48			
Corrected Total	1.705	47			
a. R Squared = 0.818 (Adjusted R Squared = 0.644					
Leaf length at 60 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	2.680[a]	23	0.117	4.439	0.000
Intercept	1433.360	1	1433.360	54604.198	0.000
Rep	0.200	2	0.100	3.817	0.036
Main	0.081	3	0.027	1.024	0.400
Main*replication	0.876	6	0.146	5.563	0.001
Sub	1.087	3	0.362	13.807	0.000
Main * Sub	0.435	9	0.048	1.842	0.112
Error	0.630	24	0.026		
Total	1436.670	48			
Corrected Total	3.310	47			
a. R Squared = 0.810 (Adjusted R Squared = 0.627)					

4.3.9 Leaf Length (cm) During the Crop Growing Period under Open Field Condition

The results of the leaf length in open field cultivation are shown in table 4.23 and are depicted in fig 4.18. It was observed that, the lowest leaf length was recorded when compared to hydroponic farming at 20, 40, 60 DAT (1.25, 2.48, 4.33 cm). This might be due to the unfavourable condition at open field condition.

Table 4.23 Leaf length (cm) at 20 DAT, 40 DAT and 60 DAT under open field condition

	20 DAT	40 DAT	60 DAT
Plant 1	1.3	2.5	4.3
Plant 2	1.2	2.52	4.5
Plant 3	1.3	2.5	4.3
Plant 4	1.2	2.36	4.1
Plant 5	1.4	2.6	4.4
Plant 6	1.4	2.76	4.8
Plant 7	1.1	2.34	4.2
Plant 8	1.1	2.38	4.3
Plant 9	1.2	2.36	4.1
Plant 10	1.3	2.5	4.3
Average	**1.25**	**2.48**	**4.33**

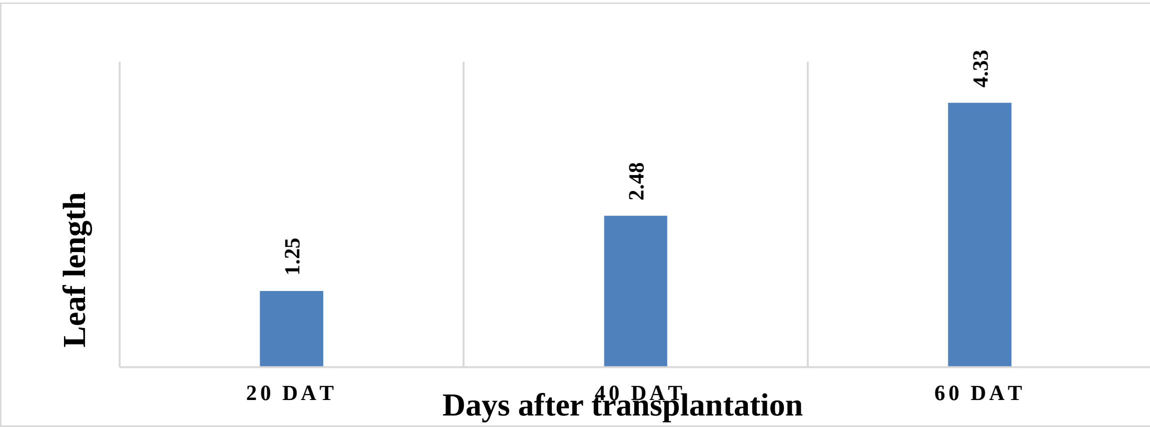

Fig 4.18 Leaf length (cm) at 20 DAT, 40 DAT and 60 DAT under open field condition

4.3.10 Girth Diameter (mm) During the Crop Growing Period under Hydroponic Farming

During the Crop growing period, nutrient concentration as well as growing media has significantly affected the girth diameter of stevia crop growth. Among all the concentration at 20 DAT the highest girth diameter was recorded in C_4, C_3, C_2 (1.03, 1.0, 0.95 mm) and the lowest leaf length recorded in C_1 (0.76 mm). Similarly at 40 DAT the highest leaf length recorded in C_4, C_3, C_2 (2.09, 1.98, 1.86 mm) and the lowest value recorded in C_1 (1.42 mm). At 60 DAT the highest value recorded C_4, C_3, C_2 (3.2, 3.0, 2.8 mm) and the lowest value in C_2 (2.1 mm). The results of the girth diameter by the influence of nutrient concentration and growing media are shown in table 4.24 and depicted in Fig 4.19. The analysis of variance to compare the means of girth diameter (Table 4.25) showed there is a significant difference between the EC of nutrient concentration levels at 20, 40, 60 days (P = 0.000, 0.000, 0.000). The Duncan test for comparing treatment means for main plots (nutrient concentration levels) of girth diameter at 20 DAT, 40 DAT and 60 DAT showed that C_1, C_2, $C_3$and C_4 treatments has significant difference on girth diameter.

The girth diameter of stevia crop at all stages showed a marked difference among different types of media. At all stages of observation, perlite (M_2) showed the highest girth diameter followed by M_3, M_4 and M_1. Analysis of variance to compare the means of sub plots for girth diameter showed that there is significant difference between the sub plots at 20DAT. 40DAT and 60 DAT (P = 0.004, 0.013, 0.021). The Duncan test for comparing the treatment means for sub plots (growing media) of girth diameter at 20DAT, 40DAT and 60 DAT showed M_3 treatment showed significant difference, where M_1, M_4 and M_2 has on par effect (Appendices E).

The interaction effect between EC of nutrient concentration and growing media did not influence the girth diameter significantly (P = 0.823, 0.900 and 0.912) at all the growth stages of stevia crop.

Table 4.24 Girth diameter (mm) at 20 DAT, 40 DAT and 60 DAT under hydroponics

Nutrient concentration	Growing media	20 DAYS	40 DAYS	60 DAYS
C_1	M_1	0.76	1.42	2.1
	M_2	0.80	1.53	2.2
	M_3	0.84	1.66	2.5
	M_4	0.77	1.47	2.2
C_2	M_1	0.83	1.57	2.3
	M_2	0.84	1.60	2.4
	M_3	0.95	1.86	2.8
	M_4	0.87	1.68	2.5
C_3	M_1	0.93	1.82	2.7
	M_2	0.93	1.86	2.8
	M_3	1.00	1.98	3.0
	M_4	0.90	1.72	2.6
C_4	M_1	0.96	1.95	2.9
	M_2	1.03	2.09	3.2
	M_3	1.02	2.07	3.1
	M_4	0.98	1.98	3.0

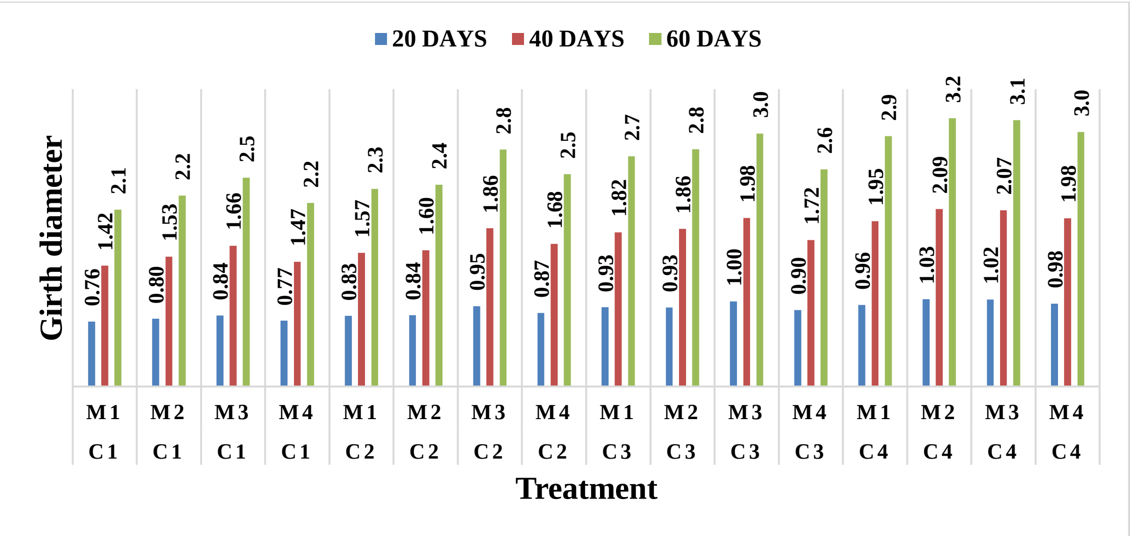

Fig 4.19 Girth diameter (mm) at 20 DAT, 40 DAT and 60 DAT under hydroponics

Table 4.25 Univariate analysis of variance to compare the means of girth diameter for stevia crop at 20, 40 and 60 dat

Girth diameter at 20 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	0.382[a]	23	.017	5.866	0.000
Intercept	38.934	1	38.934	13741.418	0.000
Rep	0.031	2	0.016	5.539	0.011
Main	0.268	3	0.089	31.567	0.000
Main*replication	0.019	6	0.003	1.091	0.396
Sub	0.050	3	0.017	5.879	0.004
Main * Sub	0.014	9	0.002	0.551	0.823
Error	0.068	24	0.003		
Total	39.384	48			
Corrected Total	0.450	47			
a. R Squared = 0.849 (Adjusted R Squared = 0.704)					
Girth diameter at 40 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	2.335[a]	23	0.102	4.368	0.000
Intercept	149.778	1	149.778	6443.989	0.000
Rep	.162	2	0.081	3.493	0.047
Main	1.696	3	0.565	24.321	0.000
Main*replication	.077	6	0.013	.554	0.762
Sub	.308	3	0.103	4.410	0.013
Main * Sub	.092	9	0.010	.439	0.900
Error	.558	24	0.023		
Total	152.671	48			
Corrected Total	2.893	47			
a. R Squared = 0.807 (Adjusted R Squared = 0.622)					
Girth diameter at 60 DAT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	6.149[a]	23	0.267	4.147	0.000
Intercept	334.224	1	334.224	5184.504	0.000
Rep	0.465	2	0.233	3.610	0.043
Main	4.482	3	1.494	23.178	0.000
Main*replication	0.201	6	0.033	0.519	0.788
Sub	0.757	3	0.252	3.913	0.021
Main * Sub	0.243	9	0.027	0.419	0.912
Error	1.547	24	0.064		
Total	341.920	48			
Corrected Total	7.696	47			
a. R Squared = 0.799 (Adjusted R Squared = 0.606)					

4.3.11 Girth Diameter (mm) During the Crop Growing Period under Open Field condition

The results of the girth diameter in open field cultivation are shown in table 4.26 and are depicted in fig 4.20. It was observed that, the lowest girth diameter was recorded when compared to hydroponic farming at 20, 40, 60 DAT (0.28, 0.8, 1.67 mm). This might be due to the unfavourable condition at open field condition.

Table 4.26 Girth diameter (mm) at 20 DAT, 40 DAT and 60 DAT under open field condition

Girth diameter (mm)	**20 DAT**	**40 DAT**	**60 DAT**
Plant 1	0.21	0.73	1.53
Plant 2	0.24	0.89	1.87
Plant 3	0.22	0.79	1.65
Plant 4	0.23	0.88	1.87
Plant 5	0.2	0.74	1.56
Plant 6	0.22	0.90	1.94
Plant 7	0.23	0.84	1.76
Plant 8	0.19	0.68	1.43
Plant 9	0.21	0.61	1.23
Plant 10	0.22	0.84	1.78
Average	**0.21**	**0.79**	**1.66**

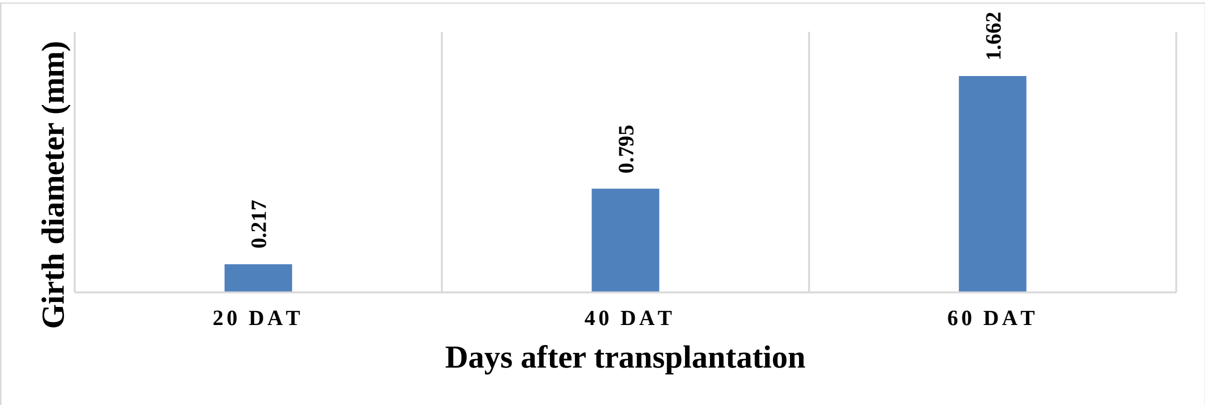

Fig 4.20 Girth diameter (mm) at 20 DAT, 40 DAT and 60 DAT under open field condition

4.4 YIELD OF STEVIA CROP (g)

The observations recorded on the dry weight of stevia leaves after drying the leaves in a natural ventilated polyhouse shown in table 4.27**.** The dry weight of stevia leaves was found to be significantly influenced by both EC of nutrient concentration levels and growing media. The results shown that highest value of dry weight of stevia leaves was found in C_3 (1.25dS/m) treatment (228.8g) followed by C_4 (1.5 dS/m), C_2 (1.0 ds/m) and C_1 (0.75 dS/m) treatments (225.8, 208.9 and 184.5). The analysis of variance to compare the means of dry weight of stevia leaves (Table 4.28) showed that there is significant difference between the EC of nutrient concentration levels (P = 0.000). The Duncan test for comparing the treatment means for main plots EC of nutrient concentration levels) of dry weight of stevia leaves showed that C_1, C_2, C_3 and C_4 has significant difference (appendices).

In case of growing media dry weight of stevia leaves (228.8 g) was produced by M_3 (clay balls) treatment fallowed by M_2, M_4 and M_1. The analysis of variance to compare the means of dry weight of stevia leaves (Table 4.28) showed that there is a significant difference between the growing media (P = 0.000). the Duncan for comparing the treatments means for sub plots of dry weight of stevia leaves showed that M_1 and M_3 treatment have significant difference, whereas M_2 and M_4 had on par effect.

The interaction effect between EC of nutrient concentration and growing media did not influence the yield significantly (P = 0.093) of stevia crop.

Table 4.27 Effect of nutrient concentration levels and growing media on dry weight (g) stevia leaves under hydroponics

Nutrient concentration	Grow media	Total fresh weight of plant (g)	Wet weight of leaves (g)	Dry weight of leaves (g)
C_1	M_1	965.1	434.3	178.1
	M_2	974.2	438.4	179.7
	M_3	999.6	449.8	184.4
	M_4	988.8	445.0	182.4
C_2	M_1	1108.9	499.0	204.6
	M_2	1123.4	505.5	207.3
	M_3	1132.1	509.4	208.9
	M_4	1095.9	493.2	202.2
C_3	M_1	1196.7	538.5	220.8
	M_2	1225.3	551.4	226.1
	M_3	1240.3	558.1	228.8
	M_4	1217.5	547.9	224.6
C_4	M_1	1164.8	524.1	214.9
	M_2	1181.8	531.8	218.0
	M_3	1224.0	550.8	225.8
	M_4	1214.8	546.7	224.1

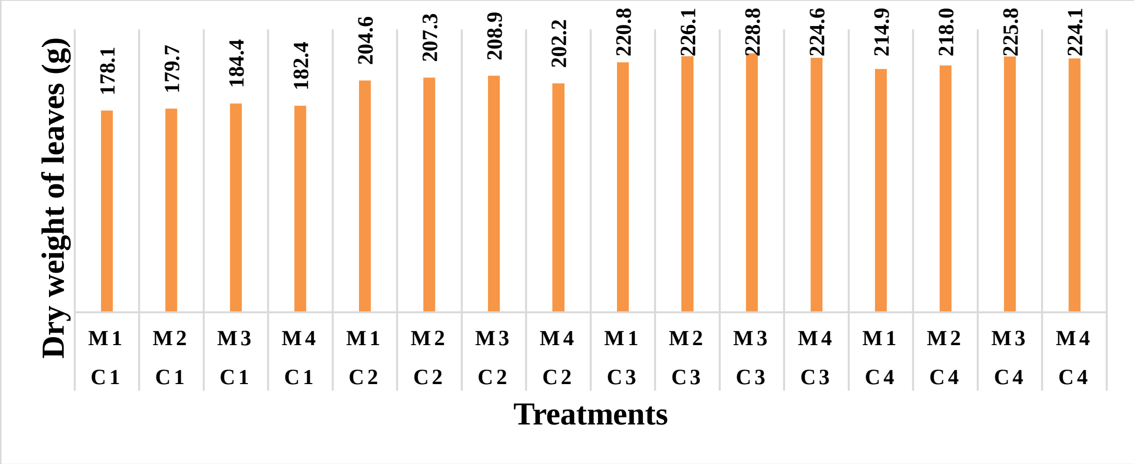

Fig 4.21 Dry weight (g) of stevia leaves grown under hydroponics

Table 4.28 Univariate analysis of variance to compare the means of yield for stevia crop under hydroponics

YIELD					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	14832.405[a]	23	644.887	72.459	0.000
Intercept	2080209.505	1	2080209.505	233731.405	0.000
Rep	61.330	2	30.665	3.446	0.048
Main	14145.672	3	4715.224	529.800	0.000
Main*replication	138.370	6	23.062	2.591	0.044
Sub	331.174	3	110.391	12.404	0.000
Main * Sub	155.859	9	17.318	1.946	0.093
Error	213.600	24	8.900		
Total	2095255.510	48			
Corrected Total	15046.005	47			

a. R Squared = 0.986 (Adjusted R Squared = 0.972)

4.3.8 Dry Weight (g) of Stevia Leaves Grown Under open Field Condition

Stevia crop grown in 216 square meters in open field condition and it is harvested at 90 days interval. The total dry weight of stevia leaves was obtained in first harvest was 7kg. Correa *et al*. (2008) higher yield was observed in hydroponic system as compared to the soil-based system.

4.5 COST OF CULTIVATION FOR STEVIA CROP GROWN UNDER HYDROPONICS AND OPEN FIELD CONDITION

The comparative analysis of cultivation costs was done for the stevia crop grown under hydroponic farming in naturally ventilated polyhouse and in open field condition. The details of the cost involved in the cultivation of the stevia crop under hydroponic farming is given in the Table 4.29 and the crop grown in open field is given in Table 4.31. Straight line method was used to calculate the cost of cultivation under hydroponic farming. The cost of material was calculated by ascertaining the raw material price in the market and the estimated unit cost of the hydroponic system. Polyhouse construction and its depreciation and interest forms a major component under fixed cost, its share was comparatively greater for stevia crop grown under hydroponic farming than in open field condition. In the fixed cost the depreciation and interest are calculated by using Eq 3.1 and Eq 3.2 and variable cost includes the sum the prices of all inputs given to the growing of stevia crop. The total cost which includes sum of the fixed cost and variable cost. The gross return, net return and benefit cost ratio was calculated by using Eq 3.5, Eq 3.6 and Eq 3.7 respectively.

To calculate cost of cultivation, the highest treatment yield i.e., C_3 M_3 (228.8 g/one channel). Each A-frame have 10 channels, so C_3 M_3 treatment yield was converted to all the treatments and it was 109.4 kg in a total of 8 A-frame structures. In a 250 m^2 polyhouse a total of 30 no of A-frames can be accommodated. Then the best treatment yield (C_3 M_3) was converted to 250 m^2 area (30 A frames) to calculate the cost of cultivation and then benefit cost ratio of hydroponic farming.

The cost of cultivation of stevia crop under 250 m^2 polyhouse hydroponic farming, the yield of stevia crop was 410.4 kg. The total cost of naturally ventilated polyhouse and 30 A-frame structures was Rs. 17,50,000/-. In the fixed cost, the depreciation and interest were observed that Rs. 78,750/- and Rs. 96,250/- and the total fixed cost was Rs. 1,75,000/- respectively. The total variable cost for stevia production under hydroponic farming for 30 A frame structures is Rs. 1,40,640/- and the total cost of stevia production under hydroponics includes total fixed cost and total variable cost, it was observed that Rs. 3,48,640/-. The gross return, net return and benefit cost ratio was incurred Rs. 8,20,800/-, Rs. 5,05,160 and 2.60 respectively and shown in table 4.30. The results were in consonance with the results reported by Kumar, *et al* (2014).

whereas in open field conditions average yield of stevia crop was about 28 kg per year in 216 m^2 area. The total cost was observed Rs. 27,400/- and the gross return, net return and benefit cost ratio incurred was Rs. 56,000/-, Rs. 28,600/- are shown in Table 4.31.

A significant difference in the prices received in the crop grown under different conditions was observed. Hydroponic farming cultivation could fetch higher prices by making supply during the off-season, which may the reason for the above difference.

Table 4.29 Cost of cultivation for the stevia crop under hydroponic farming (250 m^2 polyhouse)

S. No	Particulars	Number	Quantity	Amounts
	Cost of polyhouse	1		Rs. 5,25,000/-
	Cost of hydroponic unit with 30 no's of A-frames, channels, reservoirs, foggers, shade nets etc.			Rs.12,25,000/-
	Total initial cost	1		Rs. 17,50,000/-
A	**Fixed cost**			
	Depreciation	**1**		Rs. 78,750-
	Interest			Rs. 96,250/-
	Total			Rs. 1,75,000/-
B	**Variable cost**			
	seedlings	1600	3*6,000 Rs/-	Rs. 18,000/-
	Electricity		12*500 Rs/-	Rs. 6,000/-
	Nutrient solution (A+B)	A+B	6*5,400 Rs/-	Rs. 30,000/-
	Clay balls	30kg	1kg=108 Rs/- 30*108 Rs/-	Rs. 3,240/-
	Labour chargers		365*200=	Rs. 73,000/-
	pH up and down solution		1 lit	Rs. 2,000
	Total			Rs. 1,34,640/-
C	**Repair and maintenance**			
	Pumping motors		6	Rs.6,000/-
D	**Total cost (A+B+C)**		1,75,000+1,34,640+6,000	Rs. 3,15,640/-

Table 4.30 Benefit cost ratio of stevia crop under hydroponic farming

S. No	Particular	Unit	Amount
1	Fixed cost	INR	Rs. 1,75,000/-
2	Variable cost	INR	Rs. 1,40,640/-
	Total cost		Rs. 3,15,640/-
3	Yield	kg/year	68.4*6=410.4 kg
4	Sale price	Rs/kg	Rs. 2,000/-
5	Gross return	INR	Rs. 8,20,800/-
6	Net return	INR	Rs. 5,05,160/-
7	BCR		2.60
8	Pay Back Period		3.4 years

Table 4.31 Cost of cultivation of stevia crop under open field condition (216 m^2 area)

S. No	Particular	Quantity	Amount
1	Seed bed preparation	Rs.1,000/-	Rs.1,000/-
2	seedlings	1,600 no’s	Rs. 4,800/-
3	Labour charges	10*300=3000 Rs/- 3000*4	Rs. 12,000/-
4	N: P: K	2000*4	Rs. 8,000/-
5	Electricity for pumping	400*4	Rs.1,600/-
	Total		Rs. 27,400/-
	Gross return	2000*7kg/ harvest 28kg*2000	Rs. 56,000/-
	Net return		Rs. 28,600/-

Chapter V

SUMMARY AND CONCLUSIONS

Hydroponics proved to be a promising technique that produced higher yields and nutritionally superior quality of produce as compared to the conventional soil-based cultivation system. The experiment entitled "Optimization of nutrient concentration and growing media for stevia crop under hydroponics" was carried out at Department of Soil and Water Conservation Engineering, Dr. NTR College of Agricultural Engineering, Bapatla, Andhra Pradesh, during the period 10-03-2022 to 10-05-2022. The performance of stevia crop under hydroponic farming naturally ventilated polyhouse was compared with crop grown in open field condition. The experiment was conducted in split plot design with four main treatments of nutrient concentration ((C_1 = 0.75, C_2 = 1.0, C_3 = 1.25 and C_4 = 1.5ds/m) and four sub treatments of growing media (M_1 = rockwool, M_2 = perlite, M_3 = clay balls and M_4 = vermiculite) with three replications.

Environmental parameters viz, temperature, relative humidity and CO_2 are the major factors for plant growth were observed at 2 hours interval using rotranic CP11 instrument during the crop growing period in hydroponic farming under naturally ventilated polyhouse. Two important parameters in nutrient solution of hydroponic farming are electrical conductivity and pH was measured daily at 9:30 AM using EC and pH meter to optimize the nutrient solution and pH for stevia crop.

Biometric parameters like plant height, number of branches, root length, no. of leaves, leaf length and stem diameter of stevia crop were observed at 10 days after transplanting and then at every 5 days interval in hydroponic farming and in open field condition. The obtained data was analysed with statistical tool SPSS (V16.0) to find the significant difference between the treatment means. One way ANOVA technique was used to compare the treatment means of plant growth parameters, yield parameters. The Duncan Multiple range test (DMRT) was performed to find the significant grouping between means of plant growth parameters and yield parameters.

By using straight line method, the cost economics of stevia crop under hydroponic farming and in open field condition was calculated by considering certain assumptions when necessary. Cost economics divided into two categories viz., fixed costs and operating, these were calculated. Benefit Cost ratio and Pay Back Period for the stevia crop grown under hydroponics was calculated

The results of the stevia crop are the highest temperature was found in the month of May in naturally ventilated polyhouse and in open field condition (36.81 ˚C and 39.1˚C). the lowest temperature was found in the month of March in polyhouse and open field condition (25.05˚C and 22.1˚C). The highest relative humidity was found in the month of March in naturally ventilated polyhouse and in open field condition (78.79 % and 82.7 %). the lowest relative humidity was found in the month of April and May in polyhouse and open field condition (61.59 % and 38.4 %). The highest and lowest CO2 levels are found in the month of May (541.7 ppm) and March (405.27 ppm).

The plant height at 20 DAT the highest plant height was recorded in C_4, C_3, C_2 (16.16, 15.28, 15.19 cm) and the lowest plant height recorded in C_1 (12.11 cm). Similarly at 40 DAT the highest recorded in C_4, C_3, C_2 (30.75, 26.97, 26.76 cm) and the lowest value recorded in C_1 (20.05 cm). At 60 DAT the highest value was recorded in C_4, C_2, C_3 (45.8, 38.8, 38.9 cm) and the lowest was in C_1 (28.1 cm). In open field condition was observed that, the average plant height was recorded at 20, 40, 60 DAT are 5.2, 11.63, 21.27 cm.

The highest no of branches was recorded in C_1, C_2, C_3 (4, 4, 4) and the lowest no of branches recorded in C_4 (3) at 20 DAT. Similarly at 40 DAT the highest no of branches recorded in C_1, C_2, C_3 (5, 5, 5) and the lowest value recorded in C_4 (4). At 60 DAT the highest value recorded C_1, C_2, C_3 (5, 5, 5) and the lowest value in C_4 (4). In the open field condition was observed that, the average no of branches was recorded at 20, 40, 60 DAT (2, 3, 4).

The highest root length was recorded in C_3, C_2, C_1 (8.72, 7.72, 7.64 cm) and the lowest root length recorded in C_4 (6.15 cm) at 20 DAT. Similarly at 40 DAT the highest root length recorded in C_3, C_1, C_2 (14.69, 11.65, 11.37 cm) and the lowest value recorded in C_4 (8.24 cm). At 60 DAT the highest value recorded C_3, C_2, C_1 (21.0, 16.4, 16.2 cm) and the lowest value in C_4 (10.6 cm).

The highest no of leaves was recorded in C_3, C_2, C_4 (53, 49, 45 no’s) and the lowest no of branches recorded in C_1 (28 no’s) at 20 DAT. Similarly at 40 DAT the highest no of leaves recorded in C_3, C_2, C_4 (108, 91, 86 no’s) and the lowest value recorded in C_1 (46 no’s). At 60 DAT the highest value recorded C_3, C_2, C_4 (162, 132, 127 no’s) and the lowest value in C_1 (65 no’s). In the open field condition was observed that, the average no of leaves was recorded at 20, 40, 60 DAT (12, 27, 50 no’s).

The highest leaf length was recorded in C_4, C_3, C_2 (2.6, 2.6, 2.6 cm) and the lowest leaf length recorded in C_1 (2.4 cm) at 20 DAT. Similarly at 40 DAT the highest leaf length recorded in C_4, C_2, C_3 (4.2, 4.2, 4.1 cm) and the lowest value recorded in C_1 (3.8 cm). At 60 DAT the highest value recorded C_4, $C_{2,}$ C_3 (5.8, 5.7, 5.6 cm) and the lowest value in C_2 (5.2 cm). In the open field condition was observed that, the average leaf length was recorded at 20, 40, 60 DAT (1.25, 2.48, 4.33 cm).

The highest girth diameter was recorded in C_4, C_3, C_2 (1.03, 1.0, 0.95 mm) and the lowest girth diameter recorded in C_1 (0.76 mm) at 20 DAT. Similarly at 40 DAT the highest girth diameter recorded in C_4, C_3, C_2 (2.09, 1.98, 1.86 mm) and the lowest value recorded in C_1 (1.42 mm). At 60 DAT the highest value recorded C_4, C_3, C_2 (3.2, 3.0, 2.8 mm) and the lowest value in C_2 (2.1 mm). In the open field condition was observed that, the average girth diameter was recorded at 20, 40, 60 DAT (0.28, 0.8, 1.67 mm).

The highest yield of stevia crop was obtained in C_3M_3 treatment (228.8 g) fallowed by C_3M_2 (226.1 g). The least yield of stevia crop obtained in C_1M_1 (178.1 g)

The analysis of variance to compare the means of plant height showed that there is a significant difference between the EC of nutrient concentration levels at 20, 40, 60 DAT (P = 0.000, 0.000, 0.000). The analysis of variance to compare the means of no of branches showed that there is a significant difference between the EC of nutrient concentration levels at 20, 40, 60 DAT (P = 0.000, 0.000, 0.000). The analysis of variance to compare the means of root length showed there is a significant difference between the EC of nutrient concentration levels at 20, 40, 60 days (P = 0.000, 0.000, 0.000). The analysis of variance to compare the means of no of leaves showed there is a significant difference between the EC of nutrient concentration levels at 20, 40, 60 days (P = 0.002, 0.000, 0.000). The analysis of variance to compare the means of leaf length showed there is no significant difference between the EC of nutrient concentration levels at 20, 40, 60 days (P = 0.402, 0.372, 0.400). The analysis of variance to compare the means of grith diameter showed there is a significant difference between the EC of nutrient concentration levels at 20, 40, 60 days (P = 0.000, 0.000, 0.000). The analysis of variance to compare the means of yield showed that there is significant difference between the EC of nutrient concentration levels (P = 0.000).

The cost of cultivation of stevia crop under 250 m^2 polyhouse hydroponic farming, the yield of stevia crop was 410.4 kg. The total cost of naturally ventilated polyhouse and 30 A-frame structures was Rs. 17,50,000/-. In the fixed cost, the depreciation and interest were observed that Rs. 78,750/- and Rs. 96,250/- and the total fixed cost was Rs. 1,75,000/- respectively. The total variable cost for stevia production under hydroponic farming for 30 A frame structures is Rs. 1,40,640/- and the total cost of stevia production under hydroponics includes total fixed cost and total variable cost, it was observed that Rs. 3,48,640/-. The gross return, net return and benefit cost ratio was incurred to Rs. 8,20,800/-, Rs. 5,05,160/- and 2.60

whereas in open field conditions average yield of stevia crop was about 28 kg per year in 216 m^2 area. The total cost was observed Rs. 27,400/- and the gross return, net return and benefit cost ratio incurred was Rs. 56,000/- and Rs. 28,600/- respectively

From the above study the following conclusions were drawn

- The recommended temperature of 25 to 37^0C for stevia crop can be maintained under hydroponic farming in naturally ventilated polyhouse to obtain maximum production.
- The recommended relative humidity of 60 to 80 % for stevia crop can be maintained under hydroponic farming in naturally ventilated polyhouse to obtain maximum production.
- The recommended CO_2 level of 400 to 550 ppm for stevia crop can be maintained under hydroponic farming in naturally ventilated polyhouse to obtain maximum production.
- The best yield can be obtained at the nutrient concentration of 1.25 dS/m.
- Clay balls are recommended as the growing media for stevia crop to achieve higher yields under hydroponic farming.
- Stevia crop can be grown in the treatment of C_3M_3 to achieve maximum production under hydroponic farming in naturally ventilated polyhouse,
- Stevia crop under hydroponic farming in naturally ventilated polyhouse of 250 m^2 area can be accommodated 30 A-frame structures
- For a 250 m^2 area of hydroponic farming of stevia crop having benefit cost ratio of 2.6. This gives to a payback period of approximately 3 years

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Appendix-A

Daily temperature during crop growing period

DATE	0hr	2hr	4hr	6hr	8hr	10hr	12hr	14 hr	16hr	18hr	20hr	22hr
20-03-22	23.89	24.61	24.56	24.39	27.17	31.56	34.83	35.44	28.25	26.44	26.33	25.44
21-03- 22	23.72	24.11	24.44	24.19	25.11	30.5	33.62	32.54	28.13	27.11	25.72	25.28
22-03-22	23.94	24.56	25.56	23.28	24.72	32.11	36.44	33.17	30.33	28	25.67	25.5
23-03-22	23.28	24.03	24.61	25.39	26.89	30.83	34.89	34.34	30.83	27.56	25.67	25.78
24-03- 22	25.9	23.89	23.56	24.39	25.5	32.03	35.33	34.38	30.89	27.83	25.83	25.5
25-03-22	26.5	25.78	25.25	26.17	28.44	34.44	38.25	34.94	29.89	27.78	27.56	26.11
26-03-22	25.25	25.61	25.03	23.17	25.56	32.17	35.94	33.44	29.83	28.67	26.83	26.39
27-03- 22	25.5	25.83	25.78	26.17	28.89	33.33	36.06	36.33	32.89	28.89	27.89	27.33
28-03-22	25.28	25.22	25.01	26.39	28.78	33.06	34.28	32.72	30.89	29	27.23	27.01
29-03-22	26.28	26.61	25.22	26.17	27.5	33.31	35.12	32.78	34.39	28.17	28.17	28.06
30-03- 22	26.06	26.11	27.28	26.17	29.67	35.17	35.61	32.61	29.33	28.78	28.61	28.5
01-04-22	27.17	26	25.72	25.67	26.83	27.11	28.44	27.39	27	27.61	26.33	26.33
02-04-22	26.06	25.61	25.56	25.17	31.17	32.28	34.67	33.11	31.44	28.89	27.44	27.61
03-04-22	25	24.33	24.39	25.17	23.17	27	31.61	30.33	31	27.5	26.56	26.22
04-04-22	25.72	26.5	25.56	25.39	32.33	34.67	36.23	32.33	32.94	28.44	27.11	26.89
05-04-22	26.39	26.5	26.06	27.7	35.22	34.72	32.5	34.61	33.03	27.33	26.44	26
06-04-22	25.33	24.17	23.5	23.17	29.72	32.61	36.78	34.42	31.28	29.28	27.94	27.89
07-04-22	27.61	27.33	27.28	28.67	28.5	32.61	36.17	34.67	30.78	27.17	26.17	26.25
08-04-22	26.25	25.03	24.39	25.39	31.94	33.83	35.89	32.77	30.03	27.33	26.44	26
09-04-22	25.33	24.17	23.5	23.17	29.72	36.61	38.78	37	32.78	27.28	27.06	26.94
10-04-22	25.17	25.39	25.5	27.56	30.28	35.11	36.28	34.83	29.67	29.67	29.06	28.72
11-04-22	28.44	28.56	28.5	30.11	29.72	33.33	36.17	36.28	31.89	31.11	30.78	25.78
12-04-22	25.89	26.56	25.89	27.32	27.89	31.56	35.61	34.72	32.6	27.44	26.11	25.89
13-04-22	26.17	25.11	26.33	25.72	27.61	30.89	35.56	37.11	33.33	29.44	25.94	26.83
14-04-22	27.22	27	26.94	27.32	27.83	31.28	33.44	36.89	35.03	29.83	26.61	26.5
15-04-22	26	25.78	26.17	27	29.33	33.25	36.33	34.67	33.11	27.67	25.78	25.11
16-04-22	25.28	25.61	25.22	26.12	29.25	32.67	35.67	33.39	31.61	28.39	27.17	27.06
17-04-22	27.06	27.11	26.28	27	28.28	32	34.13	34.94	31.11	28	27.11	26.17
18-04-22	25.25	25.03	24.78	27.39	30	33.19	36	35.83	31.39	28.78	27.61	27.5
19-04-22	27.17	26	25.72	25.67	30.28	34.61	37.83	35.17	34.78	31.03	27.17	27.06
20-04-22	27.06	27.11	26.28	29	32.17	33.44	35.11	33.89	29.03	28.78	27.61	27.5
21-04-22	27.17	26	25.72	25.67	29.39	30.17	37.5	36.67	31.39	28.39	27.17	27.06
22-04-22	27.06	27.11	26.28	27	29.78	33.72	35.44	35.83	32	30.11	27.17	27.06
23-04-22	28.11	28.03	27.03	28.83	34.94	34.72	35.39	33.61	29.72	29.39	28.5	28.61
24-04-22	27.06	27.11	26.28	25.94	30.98	33.34	36.39	33.25	31.03	24.89	25.17	25
25-04-22	25.22	24.67	24.5	26.61	32	36.28	37	37.94	34.25	29.72	27.17	27.06
26-04-22	27.06	27.11	26.28	26.61	31.87	34.12	36.61	33.17	31.67	28.89	26.56	26.22
27-04-22	25.72	25.39	25.39	27.44	30.72	34	36.03	34.03	31.25	28.39	27.17	27.06
28-04-22	27.06	27.11	26.28	29.94	34.17	35.83	36.39	34	31.28	28.78	27.61	27.5
29-04-22	27.17	26	25.72	29.67	31.5	31.78	36.44	34.28	31.11	24.89	25.17	25
30-04-22	25.22	24.67	24.5	28.25	32.61	36.83	35.03	34	31.67	28.39	26.56	26.22
01-05-22	25.72	25.39	25.39	28.11	32.39	31.89	37.78	34.67	29.61	29.67	29.06	28.72
02-05-22	28.44	28.56	28.5	30.11	31.89	35.11	36.83	35.39	30.78	29.61	29.11	28.44
03-05-22	29	28.83	29	29.61	32.28	35.56	36.83	37	32	33.78	29.11	28.61
04-05-22	27.72	28.39	28.33	28.56	30.78	36	36.83	34.33	30.72	29.61	28.83	28.61
05-05-22	28.67	28.44	28.44	31.56	29.56	36.44	38	35.67	31.67	29.61	29.11	28.44
06-05-22	29	28.83	29	29.61	32.28	35.03	36.28	33.72	33.17	30.06	29.67	26.72
07-05-22	25.22	26.06	25.61	27.67	33.33	36.33	37.56	37.78	33.17	29.61	29	28.89
08-05-22	25.72	28.67	28.17	31	28.78	32.17	36.39	37.17	33.5	35.25	29.44	28.67
09-05-22	26.11	28.03	27.03	28.83	34.94	36.72	37.39	35.61	29.72	29.39	28.5	28.61
10-05-22	26.33	27.89	27.5	30.5	31.94	37.11	34.17	34.11	32.39	29.67	28.89	28.5

APPENDIX-B

Daily relative humidity during crop duration

DATE	0hr	2hr	4hr	6hr	8hr	10hr	12hr	14 hr	16hr	18hr	20hr	22hr
20-03-22	78.1	79.3	77.5	64.1	61.3	60.7	60.4	67.8	76.2	78.8	76.2	79.7
21-03- 22	80.5	80.4	76.4	72.9	69.4	69.2	65.5	61.2	69	86.1	76.3	76.3
22-03-22	81.1	78.8	74.8	67.9	68.3	67.6	64.6	64.4	67.5	83.6	79.4	78.5
23-03-22	75.3	80.6	77.1	74.2	66.6	60.3	56.2	65.34	77.2	74.8	77.5	76.7
24-03- 22	76.1	75.5	75.5	71.9	69.2	68.8	60.3	65	67.9	69.9	81.8	80.4
25-03-22	79.6	76.3	72.3	71.9	69.1	61.9	60	64.78	69.6	70.1	78.9	84.6
26-03-22	75.1	76.8	75.8	72.3	70.7	68.2	61.1	77.8	74.1	81.9	79.3	81.9
27-03- 22	80.4	79	78.1	73.9	67.6	60.6	64.4	75.7	72.8	78.6	80	79.4
28-03-22	77.3	81.1	77.7	70.2	67.5	59.1	68.6	72.2	74.4	69.7	74.3	76.4
29-03-22	83.6	77.1	72.6	73.8	68.3	61.7	61.1	68.7	75.8	70.2	76.6	78.1
30-03- 22	79.6	79.5	77.8	71.3	69.7	62.6	58.9	67.5	73.4	83.8	80.4	73.1
01-04-22	76.3	79.2	77.2	73.5	72.6	68.1	61.9	69.5	74.3	70.6	71.2	78.6
02-04-22	75.3	76.8	73.4	69.3	65.2	66.0	63.2	69.3	66.5	63.4	66.5	74.3
03-04-22	75.2	76.2	76.6	81.3	67.3	65.0	62.7	70.4	76.0	71.9	74.4	78.5
04-04-22	80.1	75.3	77.9	73.7	62.0	69.0	61.3	71.8	73.9	72.1	71.6	74.7
05-04-22	77.0	76.8	77.4	61.0	58.9	67.1	68.3	76.4	64.9	77.5	76.0	80.4
06-04-22	81.8	75.8	72.4	71.3	70.0	55.5	60.6	71.6	77.6	75.7	74.4	84.0
07-04-22	74.9	76.1	73.2	65.1	70.6	61.2	56.0	69.9	77.0	74.7	79.9	81.9
08-04-22	77.3	79.8	82.1	73.6	67.1	52.8	55.3	65.2	64.9	67.5	76.0	79.4
09-04-22	81.8	85.8	73.4	71.3	70.0	55.5	60.6	71.7	64.2	75.0	75.0	74.4
10-04-22	66.6	70.5	75.5	66.5	66.1	59.7	56.6	62.9	68.9	67.0	70.2	82.0
11-04-22	76.3	72.5	68.4	60.1	73.1	55.3	62.6	65.4	69.2	70.2	62.9	73.1
12-04-22	69.3	66.0	71.0	67.5	62.0	61.0	59.3	56.3	60.6	64.7	77.8	77.9
13-04-22	78.3	82.9	69.9	70.6	71.5	68.3	64.1	62.5	64.6	66.4	74.7	75.2
14-04-22	78.5	74.8	74.6	66.4	67.9	66.2	65.9	68.0	66.9	68.7	76.2	79.7
15-04-22	72.3	75.7	72.7	68.7	66.2	61.7	57.7	68.2	62.8	76.0	80.9	79.8
16-04-22	81.6	81.5	79.8	66.7	63.8	60.8	56.6	60.8	70.6	73.8	77.4	76.5
17-04-22	78.7	78.2	70.5	68.7	65.0	60.1	57.1	66.6	70.8	73.1	68.3	83.8
18-04-22	83.1	81.3	68.5	69.7	67.5	61.7	59.7	63.6	68.8	75.8	74.8	79.5
19-04-22	76.3	79.2	77.2	70.5	71.8	72.5	63.3	66.1	69.7	74.1	77.4	76.5
20-04-22	78.7	78.2	70.5	65.4	65.7	66.8	60.7	72.4	84.7	75.8	74.8	76.7
21-04-22	76.3	79.2	77.2	73.5	73.0	67.6	61.0	65.6	72.1	73.8	77.4	74.4
22-04-22	78.7	78.2	70.5	68.7	70.0	58.3	64.2	62.5	71.5	69.9	77.4	76.5
23-04-22	69.0	67.4	72.2	62.7	58.4	66.7	65.9	70.8	82.0	78.9	69.6	75.5
24-04-22	77.7	78.2	70.5	65.8	72.1	65.6	54.7	68.6	74.2	80.5	80.4	68.9
25-04-22	79.7	77.7	74.5	71.2	69.3	65.7	65.3	70.7	67.7	73.2	77.4	77.7
26-04-22	78.7	78.2	70.5	71.2	67.3	67.0	64.3	69.2	69.6	73.3	77.4	73.0
27-04-22	80.1	81.3	79.5	65.2	72.5	69.4	64.0	64.3	73.8	73.8	77.4	78.3
28-04-22	78.7	78.2	70.5	60.5	59.1	64.1	65.2	61.4	77.6	75.8	74.8	74.5
29-04-22	76.3	79.2	77.2	65.1	60.6	69.7	66.7.5	62.9	74.0	87.5	80.4	78.9
30-04-22	79.7	77.7	74.5	64.2	65.1	68.2	64.4	65.4	71.7	73.8	77.4	85.0
01-05-22	78.1	79.3	77.5	68.1	69.3	69.2	60.4	67.8	72.2	73.8	76.2	79
02-05-22	74.3	76.5	66.4	69.1	67.4	62.9	60.1	69.9	71.6	70.6	76	76.2
03-05-22	76.1	73.4	63.6	66	69.7	60.5	59.1	61.6	71	72.4	77.1	80.3
04-05-22	72.8	75.9	69.1	63.9	64.3	61.1	61.8	65.1	71.8	74.8	79	81
05-05-22	74.34	76.2	66.9	64.5	62	64	60.6	66.4	71.4	71.1	76	76.2
06-05-22	71.1	73.4	63.6	66	59.7	64.3	68.6	68.4	67.7	70.6	70.7	80.4
07-05-22	76.9	73.6	72.7	64.2	64.5	55.3	61.5	56.7	67.9	63.7	71.2	77.1
08-05-22	73.42	70.3	71.4	67.3	66.2	68.3	59	61.7	60.6	64.1	66.3	70.2
09-05-22	67.76	73.4	70.2	69.7	67.4	63.2	60.9	65.8	72	63.9	75.6	72.5
10-05-22	70.32	68.1	67.1	67.4	67.5	63	63.9	65	71.7	66.9	74.7	75.1

APPENDIX-C

CO_2 level during crop duration

DATE	0hr	2hr	4hr	6hr	8hr	10hr	12hr	14 hr	16hr	18hr	20hr	22hr
20-03-22	392	435	435	446	473	488	551	529	498	426	444	432
21-03- 22	440	444	456	447	466	478	532	517	492	458	443	437
22-03-22	340	435	435	465	472	494	534	525	501	472	443	437
23-03-22	448	380	458	447	448	501	508	497	475	447	447	449
24-03- 22	340	435	435	439	463	507	528	509	497	422	424	431
25-03-22	429	424	429	435	465	511	522	515	488	460	443	437
26-03-22	389	375	391	428	471	501	530	508	486	472	437	432
27-03- 22	397	454	452	447	481	474	525	507	507	458	443	437
28-03-22	440	387	396	430	466	494	530	510	487	426	444	432
29-03-22	445	444	456	437	457	481	513	507	484	422	427	431
30-03- 22	398	401	429	456	463	494	517	506	482	458	444	432
01-04-22	422	406	409	421	448	480	516	544	473	444	433	430
02-04-22	411	411	411	416	449	477	495	540	394	443	442	428
03-04-22	404	411	415	425	431	541	499	520	394	452	442	427
04-04-22	418	426	426	429	437	477	514	536	482	451	446	438
05-04-22	416	421	427	481	435	484	508	469	460	570	457	409
06-04-22	425	431	436	441	521	575	558	505	528	485	482	484
07-04-22	347	471	457	477	458	483	511	497	647	503	498	484
08-04-22	369	371	457	477	458	543	511	546	647	503	378	484
09-04-22	441	456	450	457	460	480	495	485	595	446	442	444
10-04-22	443	457	455	461	458	472	508	536	475	461	450	441
11-04-22	438	355	450	456	473	542	499	540	473	435	426	415
12-04-22	441	446	467	458	456	461	502	523	519	456	452	447
13-04-22	375	393	450	457	525	475	496	487	459	476	443	447
14-04-22	437	452	459	459	477	524	530	458	504	480	446	436
15-04-22	444	454	447	453	458	500	513	493	524	476	464	471
16-04-22	440	463	448	454	461	525	522	584	511	478	447	443
17-04-22	437	450	451	457	460	480	495	435	524	478	484	464
18-04-22	432	447	450	455	491	581	632	520	475	477	479	456
19-04-22	468	477	467	469	468	480	516	444	489	510	447	443
20-04-22	443	440	446	450	525	564	579	528	554	480	457	447
21-04-22	432	447	442	441	486	525	569	536	554	475	440	452
22-04-22	433	435	354	443	510	554	589	557	454	487	452	456
23-04-22	441	462	479	438	488	543	587	537	534	465	467	425
24-04-22	425	431	438	441	521	579	563	555	554	515	523	494
25-04-22	428	449	445	448	526	550	634	533	394	479	501	446
26-04-22	432	447	450	455	491	561	632	520	575	477	489	436
27-04-22	462	403	408	412	497	539	620	532	394	438	435	419
28-04-22	409	415	409	413	425	464	501	513	483	444	448	432
29-04-22	410	415	419	421	439	535	522	514	394	450	447	443
30-04-22	406	406	407	417	422	480	495	535	394	446	442	444
01-05-22	436	454	454	443	456	487	514	462	487	453	441	431
02-05-22	461	446	499	524	488	503	537	537	505	487	475	438
03-05-22	445	445	448	524	521	539	535	503	494	488	435	441
04-05-22	448	463	445	364	526	510	533	574	486	461	449	448
05-05-22	452	441	460	445	491	541	556	522	496	489	467	455
06-05-22	436	452	469	445	444	492	568	540	505	483	474	448
07-05-22	440	464	451	474	451	555	563	555	512	505	486	473
08-05-22	454	452	452	449	481	472	523	505	501	477	455	450
09-05-22	448	448	447	481	452	518	510	558	511	503	467	445
10-05-22	428	431	444	456	448	547	578	549	497	468	457	445

Appendix-D

Biometric data of 5 days interval during crop growing period

DATE 20-03-2022	PLANT HIGHT	NO OF BRANCHES	ROOT LENGTH	NO OF LEAVES	LEAF LENGTH	GRITH DIAMETER
C1R1						
M1	8.4	3	4.5	21	1.8	0.46
M2	8.7	2	5.2	19	1.9	0.48
M3	9.2	3	6.1	29	1.9	0.51
M4	8.9	2	4.8	22	1.7	0.49
C1 R2						
M1	8.1	2	5.1	18	1.5	0.49
M2	8.8	3	4.6	23	1.7	0.52
M3	9.1	4	5.8	33	1.8	0.53
M4	9.2	3	5.2	20	1.6	0.48
C1 R3						
M1	7.9	2	5.7	20	1.8	0.47
M2	7.5	3	4.7	22	1.9	0.48
M3	9.4	3	5	29	2	0.47
M4	9.2	2	4.9	23	1.6	0.46
C2 R1						
M1	8.4	3	5.2	24	2	0.52
M2	8.7	2	4.7	20	1.9	0.49
M3	9.9	3	5.7	28	1.9	0.49
M4	8.9	2	5.1	18	1.8	0.51
C2 R2						
M1	8.6	2	5.6	19	1.6	0.46
M2	9.1	2	5.1	21	1.6	0.49
M3	9.4	3	6.3	29	1.8	0.53
M4	7.9	2	4.8	17	1.7	0.46
C2 R3						
M1	8.4	2	5.3	21	1.5	0.49
M2	7.3	3	4.6	23	1.6	0.48
M3	8.9	4	5.7	29	1.8	0.53
M4	8.6	2	4.9	22	1.6	0.50
C3 R1						
M1	8.1	2	5.3	18	1.8	0.53
M2	9.4	4	6.1	26	2.1	0.49
M3	9.6	4	6.5	27	2.3	0.56
M4	8.9	3	5.8	22	1.8	0.52
C3 R2						
M1	8.3	3	4.6	20	1.6	0.54
M2	9.2	2	4.9	19	1.7	0.48
M3	9.5	3	5	22	1.6	0.53
M4	8.6	2	5.3	17	1.9	0.52
C3 R3						
M1	9.1	2	4.9	18	1.9	0.49
M2	9.3	3	5.1	24	1.8	0.52
M3	9.2	4	5.7	28	1.7	0.52
M4	8.9	2	5.2	16	1.7	0.51
C4R1						
M1	8.8	2	5.7	16	1.7	0.48
M2	8.9	3	4.6	21	1.8	0.49
M3	9.1	3	5.5	26	1.8	0.52
M4	9.2	2	4.9	22	1.6	0.51
C4 R2						
M1	8.5	2	5.5	18	1.6	0.48
M2	8.7	2	5.4	19	1.7	0.53
M3	8.8	2	4.7	21	1.9	0.52
M4	8.9	2	5.7	25	1.9	0.49
C4 R3						
M1	8.4	3	5.3	20	2.1	0.52
M2	8.9	3	4.8	23	1.7	0.56
M3	8.7	3	5.1	25	1.7	0.54
M4	9.1	2	6.1	17	1.6	0.51
DATE 25-03-2022	**PLANT HIGHT**	**NO OF BRANCHES**	**ROOT LENGTH**	**NO OF LEAVES**	**LEAF LENGTH**	**GRITH DIAMETER**
C1R1						

M1	10.1	3	5.5	25	2.16	0.51
M2	10.8	2	6.3	25	2.27	0.56
M3	11.5	3	7.4	37	2.28	0.62
M4	10.9	2	5.8	29	2.05	0.60
C1 R2						
M1	10.3	2	5.8	23	1.86	0.61
M2	10.6	3	5.8	29	2.05	0.68
M3	11.6	4	6.8	40	2.16	0.74
M4	11.4	3	6.0	27	1.97	0.66
C1 R3						
M1	10.0	2	6.5	24	2.15	0.65
M2	9.9	3	5.5	29	2.25	0.67
M3	12.1	3	5.7	37	2.38	0.67
M4	11.9	2	5.4	30	1.98	0.63
C2 R1						
M1	11.3	3	5.9	34	2.34	0.67
M2	11.7	2	5.5	29	2.26	0.70
M3	13.2	3	6.6	39	2.28	0.71
M4	11.6	2	6.0	28	2.2	0.70
C2 R2						
M1	10.9	2	6.3	26	1.97	0.66
M2	12.0	2	5.6	28	1.98	0.64
M3	11.9	3	7.5	36	2.23	0.76
M4	9.8	2	6.0	23	2.1	0.68
C2 R3						
M1	11.0	2	6.3	29	1.84	0.70
M2	9.9	3	5.3	33	1.94	0.70
M3	11.8	4	6.3	42	2.15	0.77
M4	10.9	2	6.0	29	1.98	0.70
C3 R1						
M1	10.4	2	6.2	25	2.17	0.77
M2	12.2	4	7.3	40	2.43	0.71
M3	12.7	4	8.1	43	2.62	0.82
M4	11.2	3	7.1	34	2.18	0.68
C3 R2						
M1	10.3	3	6.0	27	1.99	0.73
M2	11.6	2	6.0	26	2.07	0.69
M3	12.5	3	6.8	34	2.03	0.73
M4	11.4	2	6.1	25	2.28	0.76
C3 R3						
M1	11.4	2	5.9	26	2.23	0.73
M2	12.0	3	6.2	35	2.16	0.79
M3	11.9	4	6.8	41	2.06	0.80
M4	11.4	2	6.6	25	2.09	0.73
C4R1						
M1	11.6	2	6.4	23	2.08	0.72
M2	11.8	3	5.5	31	2.16	0.73
M3	12.6	3	6.1	36	2.22	0.78
M4	12.1	2	5.6	29	2	0.78
C4 R2						
M1	10.7	2	6.1	25	1.95	0.74
M2	10.9	2	6.2	26	2.04	0.79
M3	12.6	2	5.2	31	2.24	0.77
M4	12.1	2	6.0	33	2.28	0.75
C4 R3						
M1	11.2	3	5.8	27	2.41	0.77
M2	12.3	3	5.5	32	2.07	0.86
M3	12.3	3	5.6	36	2.09	0.82
M4	13.4	2	6.7	28	2.05	0.74
DATE 30-03-2022	**PLANT HIGHT**	**NO OF BRANCHES**	**ROOT LENGTH**	**NO OF LEAVES**	**LEAF LENGTH**	**GRITH DIAMETER**
C1R1						
M1	11.7	3	6.4	29	2.52	0.70
M2	13.0	3	7.4	31	2.64	0.74
M3	13.8	4	8.7	45	2.66	0.77
M4	12.9	3	6.8	36	2.4	0.74
C1 R2						
M1	12.5	2	6.5	28	2.22	0.79
M2	12.4	3	7.1	35	2.4	0.82

M3	14.1	4	7.8	47	2.52	0.91
M4	13.6	3	6.8	34	2.34	0.82
C1 R3						
M1	12.1	2	7.4	28	2.5	0.81
M2	12.2	3	6.4	36	2.6	0.83
M3	14.7	4	6.4	45	2.76	0.83
M4	14.6	3	5.9	37	2.36	0.76
C2 R1						
M1	14.1	3	6.6	44	2.68	0.78
M2	14.8	3	6.4	38	2.62	0.87
M3	16.5	4	7.6	50	2.66	0.90
M4	14.3	3	6.9	38	2.6	0.86
C2 R2						
M1	13.3	2	7.1	33	2.34	0.82
M2	14.9	2	6.1	35	2.36	0.75
M3	14.3	3	8.6	43	2.66	0.95
M4	11.7	2	7.2	29	2.5	0.87
C2 R3						
M1	13.5	3	7.2	37	2.18	0.89
M2	12.4	4	6.1	43	2.28	0.89
M3	14.7	5	7.0	55	2.5	0.99
M4	13.3	3	7.1	36	2.36	0.87
C3 R1						
M1	12.7	3	7.0	32	2.54	0.97
M2	14.9	5	8.5	54	2.76	0.89
M3	15.9	5	9.6	59	2.94	1.04
M4	13.5	4	8.4	46	2.56	0.82
C3 R2						
M1	12.2	3	7.5	34	2.38	0.89
M2	14.0	3	7.1	33	2.44	0.87
M3	15.4	3	8.6	46	2.46	0.90
M4	14.3	3	6.8	33	2.66	0.97
C3 R3						
M1	13.7	3	6.9	34	2.56	0.94
M2	14.6	4	7.3	46	2.52	1.03
M3	14.6	5	8.0	54	2.42	1.05
M4	13.9	3	8.0	34	2.48	0.91
C4R1						
M1	14.4	3	7.2	30	2.46	0.93
M2	14.7	3	6.5	41	2.52	0.93
M3	16.1	3	6.6	46	2.64	1.01
M4	15.0	2	6.3	36	2.4	1.01
C4 R2						
M1	12.8	2	6.6	32	2.3	0.96
M2	13.2	2	6.9	33	2.38	1.03
M3	16.4	3	5.8	41	2.58	0.99
M4	15.3	2	6.4	41	2.66	0.98
C4 R3						
M1	13.9	3	6.2	34	2.72	0.99
M2	15.7	3	6.2	41	2.44	1.12
M3	16.0	3	6.1	47	2.48	1.07
M4	17.7	2	7.3	39	2.5	0.93

DATE 04-04-2022	**PLANT HIGHT**	**NO OF BRANCHES**	**ROOT LENGTH**	**NO OF LEAVES**	**LEAF LENGTH**	**GRITH DIAMETER**
C1R1						
M1	13.4	3	7.4	33	2.88	0.90
M2	15.1	3	8.4	37	3.01	1.03
M3	16.0	4	10.0	53	3.04	1.06
M4	14.9	3	7.9	43	2.75	0.97
C1 R2						
M1	14.7	2	7.2	33	2.58	0.97
M2	14.3	3	8.3	41	2.75	1.00
M3	16.6	4	8.9	54	2.88	1.17
M4	15.7	3	7.5	41	2.71	1.03
C1 R3						
M1	14.2	2	8.2	32	2.85	1.02
M2	14.6	3	7.2	43	2.95	1.05
M3	17.4	4	7.1	53	3.14	1.06

M4	17.2	3	6.4	44	2.74	0.96
C2 R1						
M1	17.0	3	7.2	54	3.02	0.96
M2	17.8	3	7.2	47	2.98	1.11
M3	19.8	4	8.5	61	3.04	1.14
M4	17.0	3	7.8	48	3	1.09
C2 R2						
M1	15.6	2	7.8	40	2.71	1.05
M2	17.8	2	6.6	42	2.74	0.93
M3	16.8	3	9.8	50	3.09	1.21
M4	13.6	2	8.5	35	2.9	1.12
C2 R3						
M1	16.1	3	8.2	45	2.52	1.13
M2	15.0	4	6.8	53	2.62	1.14
M3	17.6	5	7.6	68	2.85	1.26
M4	15.6	3	8.2	43	2.74	1.09
C3 R1						
M1	15.0	3	7.9	39	2.91	1.24
M2	17.7	5	9.7	68	3.09	1.14
M3	19.0	5	11.2	75	3.26	1.33
M4	15.8	4	9.8	58	2.94	1.01
C3 R2						
M1	14.2	3	8.9	41	2.77	1.11
M2	16.3	3	8.2	40	2.81	1.10
M3	18.4	3	10.4	58	2.89	1.13
M4	17.1	3	7.6	41	3.04	1.24
C3 R3						
M1	16.0	3	7.9	42	2.89	1.20
M2	17.3	4	8.4	57	2.88	1.33
M3	17.2	5	9.1	67	2.78	1.37
M4	16.4	3	9.3	43	2.87	1.16
C4R1						
M1	17.3	3	7.9	37	2.84	1.19
M2	17.6	3	7.4	51	2.88	1.20
M3	19.6	3	7.2	56	3.06	1.30
M4	17.8	2	7.0	43	2.8	1.31
C4 R2						
M1	15.0	2	7.2	39	2.65	1.25
M2	15.4	2	7.7	40	2.72	1.32
M3	20.3	3	6.3	51	2.92	1.27
M4	18.5	2	6.7	49	3.04	1.28
C4 R3						
M1	16.7	3	6.7	41	3.03	1.27
M2	19.1	3	7.0	50	2.81	1.45
M3	19.6	3	6.6	58	2.87	1.37
M4	22.0	2	7.9	50	2.95	1.19
DATE 09-04-2022	**PLANT HIGHT**	**NO OF BRANCHES**	**ROOT LENGTH**	**NO OF LEAVES**	**LEAF LENGTH**	**GRITH DIAMETER**
C1R1						
M1	15.0	3.0	8.3	37.0	3.2	1.02
M2	17.2	4.0	9.5	43.0	3.4	1.19
M3	18.3	6.0	11.3	61.0	3.4	1.22
M4	16.9	5.0	8.9	50.0	3.1	1.11
C1 R2						
M1	16.9	3.0	7.9	38.0	2.9	1.11
M2	16.1	4.0	9.6	47.0	3.1	1.14
M3	19.1	5.0	9.9	61.0	3.2	1.37
M4	17.9	4.0	8.3	48.0	3.1	1.19
C1 R3						
M1	16.3	2.0	9.0	36.0	3.2	1.19

M2	16.9	4.0	8.0	50.0	3.3	1.22
M3	20.0	5.0	7.8	61.0	3.5	1.23
M4	19.9	4.0	6.9	51.0	3.1	1.11
C2 R1						
M1	19.8	4.0	7.9	64.0	3.4	1.08
M2	20.8	4.0	8.0	56.0	3.3	1.30
M3	23.1	5.0	9.4	72.0	3.4	1.34
M4	19.7	5.0	8.7	58.0	3.4	1.26
C2 R2						
M1	18.0	3.0	8.6	47.0	3.1	1.23
M2	20.7	3.0	7.1	49.0	3.1	1.06
M3	19.2	4.0	11.0	57.0	3.5	1.41
M4	15.5	3.0	9.7	41.0	3.3	1.32
C2 R3						
M1	18.6	4.0	9.2	53.0	2.9	1.33
M2	17.6	5.0	7.6	63.0	3.0	1.34
M3	20.5	7.0	8.2	81.0	3.2	1.49
M4	18.0	4.0	9.3	50.0	3.1	1.27
C3 R1						
M1	17.3	4.0	8.8	46.0	3.3	1.45
M2	20.4	7.0	10.9	82.0	3.4	1.33
M3	22.2	6.0	12.7	91.0	3.6	1.56
M4	18.1	5.0	11.1	70.0	3.3	1.15
C3 R2						
M1	16.2	3.0	10.4	48.0	3.2	1.28
M2	18.7	4.0	9.3	47.0	3.2	1.29
M3	21.3	4.0	12.2	70.0	3.3	1.31
M4	20.0	4.0	8.4	49.0	3.4	1.46
C3 R3						
M1	18.3	4.0	8.9	50.0	3.2	1.42
M2	20.0	5.0	9.5	68.0	3.2	1.58
M3	19.9	6.0	10.2	80.0	3.1	1.63
M4	18.9	4.0	10.7	52.0	3.3	1.35
C4R1						
M1	20.1	3.0	8.6	44.0	3.2	1.41
M2	20.5	4.0	8.4	61.0	3.2	1.41
M3	23.1	3.0	7.7	66.0	3.5	1.54
M4	20.7	3.0	7.7	50.0	3.2	1.55
C4 R2						
M1	17.1	2.0	7.7	46.0	3.0	1.48
M2	17.6	3.0	8.4	47.0	3.1	1.57
M3	24.1	4.0	6.8	61.0	3.3	1.50
M4	21.7	2.0	7.0	57.0	3.4	1.52
C4 R3						
M1	19.4	3.0	7.2	48.0	3.3	1.50
M2	22.5	3.0	7.7	59.0	3.2	1.73
M3	23.2	4.0	7.1	69.0	3.3	1.63
M4	26.3	3.0	8.5	61.0	3.4	1.40
DATE 14-04-2022	**PLANT HIGHT**	**NO OF BRANCHES**	**ROOT LENGTH**	**NO OF LEAVES**	**LEAF LENGTH**	**GRITH DIAMETER**
C1R1						
M1	16.7	3.0	9.3	41	3.6	1.19
M2	19.4	4.0	10.6	49	3.8	1.40
M3	20.6	6.0	12.6	69	3.8	1.43
M4	19.0	5.0	9.9	57	3.5	1.30
C1 R2						
M1	19.1	3.0	8.6	43	3.3	1.29
M2	17.9	4.0	10.8	53	3.5	1.32
M3	21.6	5.0	10.9	68	3.6	1.60

M4	20.1	4.0	9.1	55	3.5	1.40
C1 R3						
M1	18.5	2.0	9.9	40	3.6	1.39
M2	19.3	4.0	8.9	57	3.7	1.43
M3	22.7	5.0	8.5	69	3.9	1.45
M4	22.6	4.0	7.5	58	3.5	1.30
C2 R1						
M1	22.7	4.0	8.6	74	3.7	1.25
M2	23.9	4.0	8.9	65	3.7	1.53
M3	26.5	5.0	10.4	83	3.8	1.58
M4	22.5	5.0	9.6	68	3.8	1.47
C2 R2						
M1	20.3	3.0	9.3	54	3.5	1.45
M2	23.6	3.0	7.6	56	3.5	1.23
M3	21.7	4.0	12.2	64	4.0	1.66
M4	17.5	3.0	10.9	47	3.7	1.56
C2 R3						
M1	21.2	4.0	10.2	61	3.2	1.56
M2	20.2	5.0	8.3	73	3.3	1.58
M3	23.5	7.0	8.9	94	3.6	1.75
M4	20.3	4.0	10.5	57	3.5	1.49
C3 R1						
M1	19.6	4.0	9.7	53	3.7	1.71
M2	23.2	7.0	12.1	96	3.8	1.57
M3	25.3	6.0	14.3	107	3.9	1.84
M4	20.5	5.0	12.4	82	3.7	1.34
C3 R2						
M1	18.2	3.0	11.8	55	3.6	1.49
M2	21.1	4.0	10.5	54	3.6	1.52
M3	24.3	4.0	14.0	82	3.8	1.54
M4	22.8	4.0	9.2	57	3.8	1.72
C3 R3						
M1	20.6	4.0	10.0	58	3.6	1.68
M2	22.7	5.0	10.6	79	3.6	1.88
M3	22.6	6.0	11.4	93	3.5	1.93
M4	21.5	4.0	12.1	61	3.7	1.59
C4R1						
M1	22.9	3.0	9.4	51	3.6	1.67
M2	23.5	4.0	9.3	71	3.6	1.67
M3	26.6	3.0	8.3	76	3.9	1.82
M4	23.6	3.0	8.5	57	3.6	1.84
C4 R2						
M1	19.3	2.0	8.3	53	3.4	1.76
M2	19.9	3.0	9.2	54	3.4	1.85
M3	27.9	4.0	7.4	71	3.6	1.78
M4	25.0	2.0	7.4	65	3.8	1.80
C4 R3						
M1	22.2	3.0	7.7	55	3.7	1.77
M2	26.0	3.0	8.4	68	3.6	2.05
M3	26.9	4.0	7.6	80	3.7	1.93
M4	30.6	3.0	9.1	72	3.9	1.65
DATE 19-04-2022	**PLANT HIGHT**	**NO OF BRANCHES**	**ROOT LENGTH**	**NO OF LEAVES**	**LEAF LENGTH**	**GRITH DIAMETER**
C1R1						
M1	18.4	3.0	10.2	47	4.0	1.30
M2	21.5	4.0	11.7	55	4.1	1.55
M3	22.9	6.0	13.8	77	4.2	1.58
M4	21.0	5.0	10.9	64	3.8	1.43

C1 R2						
M1	21.2	3.0	9.2	48	3.7	1.42
M2	19.7	4.0	12.0	59	3.8	1.45
M3	24.0	5.0	11.9	75	4.0	1.78
M4	22.3	4.0	9.9	62	3.8	1.55
C1 R3						
M1	20.6	2.0	10.7	44	3.9	1.54
M2	21.6	4.0	9.7	64	4.0	1.58
M3	25.4	5.0	9.2	77	4.3	1.61
M4	25.3	4.0	8.0	65	3.9	1.43
C2 R1						
M1	25.6	4.0	9.3	84	4.0	1.37
M2	26.9	4.0	9.7	74	4.1	1.70
M3	29.8	5.0	11.3	94	4.2	1.77
M4	25.2	5.0	10.4	78	4.2	1.63
C2 R2						
M1	22.6	3.0	10.0	61	3.8	1.61
M2	26.4	3.0	8.0	63	3.9	1.34
M3	24.2	4.0	13.3	71	4.4	1.86
M4	19.4	3.0	12.1	53	4.1	1.74
C2 R3						
M1	23.8	4.0	11.1	69	3.5	1.74
M2	22.7	5.0	9.0	83	3.6	1.76
M3	26.4	7.0	9.5	107	3.9	1.96
M4	22.6	4.0	11.6	64	3.9	1.66
C3 R1						
M1	21.8	4.0	10.5	60	4.0	1.92
M2	26.0	7.0	13.2	110	4.1	1.76
M3	28.4	6.0	15.8	123	4.2	2.07
M4	22.8	5.0	13.7	94	4.1	1.47
C3 R2						
M1	20.1	3.0	13.2	62	3.9	1.64
M2	23.5	4.0	11.6	61	3.9	1.70
M3	27.2	4.0	15.8	94	4.2	1.71
M4	25.6	4.0	9.9	65	4.2	1.92
C3 R3						
M1	22.8	4.0	11.0	66	3.9	1.89
M2	25.3	5.0	11.6	90	4.0	2.12
M3	25.3	6.0	12.5	106	3.9	2.18
M4	24.0	4.0	13.5	70	4.0	1.78
C4R1						
M1	25.7	3.0	10.1	58	4.0	1.88
M2	26.4	4.0	10.2	81	4.0	1.87
M3	30.0	3.0	8.8	86	4.3	2.05
M4	26.5	3.0	9.2	64	4.0	2.07
C4 R2						
M1	21.4	2.0	8.8	60	3.7	1.98
M2	22.1	3.0	10.0	61	3.7	2.08
M3	31.7	4.0	7.9	81	3.9	2.00
M4	28.2	2.0	7.7	73	4.2	2.03
C4 R3						
M1	25.0	3.0	8.1	62	4.0	1.98
M2	29.4	3.0	9.1	77	3.9	2.31
M3	30.5	4.0	8.0	91	4.0	2.18
M4	34.8	3.0	9.6	83	4.3	1.84
DATE 24-04-2022	**PLANT HIGHT**	**NO OF BRANCHES**	**ROOT LENGTH**	**NO OF LEAVES**	**LEAF LENGTH**	**GRITH DIAMETER**
C1R1						
M1	20.4	3.0	11.2	52	4.3	1.48

M2	23.6	4.0	12.8	61	4.5	1.76
M3	25.2	6.0	15.1	86	4.6	1.79
M4	23.0	5.0	12.0	71	4.2	1.62
C1 R2						
M1	23.2	3.0	9.9	53	4.0	1.61
M2	21.5	4.0	13.3	65	4.2	1.64
M3	26.5	5.0	12.9	82	4.3	2.03
M4	24.5	4.0	10.7	69	4.2	1.76
C1 R3						
M1	22.7	2.0	11.5	48	4.3	1.76
M2	24.0	4.0	10.5	71	4.4	1.80
M3	28.0	5.0	9.9	85	4.7	1.84
M4	28.0	4.0	8.5	72	4.3	1.63
C2 R1						
M1	28.4	4.0	10.0	94	4.4	1.54
M2	29.9	4.0	10.5	83	4.4	1.94
M3	33.1	5.0	12.2	105	4.6	2.02
M4	27.9	5.0	11.3	88	4.6	1.85
C2 R2						
M1	25.0	3.0	10.8	68	4.2	1.84
M2	29.3	3.0	8.5	70	4.3	1.52
M3	26.6	4.0	14.5	78	4.8	2.11
M4	21.3	3.0	13.3	59	4.5	1.99
C2 R3						
M1	26.3	4.0	12.1	77	3.9	1.99
M2	25.3	5.0	9.8	93	4.0	2.01
M3	29.3	7.0	10.1	120	4.3	2.24
M4	25.0	4.0	12.7	71	4.3	1.89
C3 R1						
M1	24.1	4.0	11.4	67	4.4	2.18
M2	28.7	7.0	14.4	124	4.4	2.00
M3	31.6	6.0	17.4	139	4.5	2.35
M4	25.1	5.0	15.0	106	4.5	1.66
C3 R2						
M1	22.1	3.0	14.7	69	4.3	1.86
M2	25.9	4.0	12.7	68	4.3	1.94
M3	30.2	4.0	17.6	106	4.6	1.94
M4	28.5	4.0	10.7	73	4.6	2.19
C3 R3						
M1	25.1	4.0	12.0	74	4.2	2.16
M2	28.0	5.0	12.7	101	4.3	2.42
M3	28.0	6.0	13.6	119	4.2	2.49
M4	26.5	4.0	14.9	79	4.4	2.02
C4R1						
M1	28.5	3.0	10.8	65	4.4	2.15
M2	29.3	4.0	11.2	91	4.3	2.14
M3	33.5	3.0	9.4	96	4.7	2.34
M4	29.4	3.0	9.9	71	4.4	2.37
C4 R2						
M1	23.6	2.0	9.4	67	4.1	2.27
M2	24.3	3.0	10.7	68	4.1	2.38
M3	35.5	4.0	8.4	91	4.3	2.28
M4	31.4	2.0	8.0	81	4.6	2.32
C4 R3						
M1	27.7	3.0	8.6	69	4.3	2.26
M2	32.8	3.0	9.8	86	4.3	2.64
M3	34.1	4.0	8.5	102	4.4	2.49
M4	39.1	3.0	10.2	94	4.8	2.10

DATE 29-04-2022	PLANT HIGHT	NO OF BRANCHES	ROOT LENGTH	NO OF LEAVES	LEAF LENGTH	GRITH DIAMETER
C1R1						
M1	22.0	3.0	12.1	57	4.7	1.61
M2	25.7	4.0	13.8	67	4.9	1.93
M3	27.4	6.0	16.4	95	4.9	1.96
M4	25.0	5.0	13.1	78	4.5	1.76
C1 R2						
M1	25.1	3.0	10.6	58	4.4	1.76
M2	23.4	4.0	14.5	71	4.5	1.79
M3	29.0	5.0	14.0	89	4.7	2.23
M4	26.6	4.0	11.4	76	4.6	1.93
C1 R3						
M1	24.8	2.0	12.3	52	4.6	1.93
M2	26.3	4.0	11.3	78	4.7	1.98
M3	30.7	5.0	10.6	93	5.0	2.02
M4	30.6	4.0	9.0	79	4.6	1.78
C2 R1						
M1	31.3	4.0	10.6	104	4.7	1.67
M2	32.9	4.0	11.3	92	4.8	2.13
M3	36.4	5.0	13.1	116	4.9	2.22
M4	30.6	5.0	12.2	98	5.0	2.03
C2 R2						
M1	27.3	3.0	11.5	75	4.6	2.02
M2	32.2	3.0	9.0	77	4.6	1.65
M3	29.1	4.0	15.7	85	5.2	2.32
M4	23.2	3.0	14.6	65	4.9	2.20
C2 R3						
M1	28.9	4.0	13.1	85	4.2	2.19
M2	27.9	5.0	10.5	103	4.3	2.22
M3	32.2	7.0	10.7	133	4.6	2.47
M4	27.3	4.0	13.8	78	4.6	2.07
C3 R1						
M1	26.4	4.0	12.3	74	4.8	2.40
M2	31.5	7.0	15.6	138	4.7	2.20
M3	34.7	6.0	18.9	155	4.9	2.59
M4	27.4	5.0	16.4	118	4.8	1.81
C3 R2						
M1	24.1	3.0	16.1	76	4.7	2.04
M2	28.2	4.0	13.8	75	4.7	2.13
M3	33.1	4.0	19.4	118	5.0	2.12
M4	31.3	4.0	11.5	81	4.9	2.42
C3 R3						
M1	27.4	4.0	13.0	82	4.5	2.38
M2	30.7	5.0	13.8	112	4.7	2.67
M3	30.6	6.0	14.7	132	4.6	2.76
M4	29.0	4.0	16.2	88	4.8	2.22
C4R1						
M1	31.4	3.0	11.5	72	4.7	2.37
M2	32.2	4.0	12.1	101	4.7	2.36
M3	37.0	3.0	9.9	106	5.2	2.59
M4	32.2	3.0	10.6	78	4.8	2.62
C4 R2						
M1	25.7	2.0	9.9	74	4.4	2.51
M2	26.5	3.0	11.5	75	4.4	2.63
M3	39.4	4.0	8.9	101	4.6	2.51
M4	34.6	2.0	8.3	89	4.9	2.57
C4 R3						
M1	30.5	3.0	9.1	76	4.6	2.50

M2	36.2	3.0	10.6	95	4.7	2.92
M3	37.7	4.0	9.0	113	4.8	2.75
M4	43.4	3.0	10.8	105	5.2	2.31

DATE 04-05-2022	**PLANT HIGHT**	**NO OF BRANCHES**	**ROOT LENGTH**	**NO OF LEAVES**	**LEAF LENGTH**	**GRITH DIAMETER**
C1R1	23.6	3.0	13.1	62	5.0	1.75
M1	27.9	4.0	14.9	73	5.2	2.11
M2	29.7	6.0	17.7	104	5.3	2.14
M3	27.0	5.0	14.2	85	4.9	1.92
M4						
C1 R2	27.0	3.0	11.3	63	4.7	1.91
M1	25.2	4.0	15.8	77	4.9	1.94
M2	31.5	5.0	15.0	96	5.0	2.44
M3	28.8	4.0	12.2	83	4.9	2.11
M4						
C1 R3	26.9	2.0	13.2	56	5.0	2.11
M1	28.7	4.0	12.2	85	5.1	2.16
M2	33.3	5.0	11.3	101	5.4	2.21
M3	33.3	4.0	9.5	86	5.0	1.95
M4						
C2 R1	34.1	4.0	11.3	114	5.1	1.82
M1	36.0	4.0	12.2	101	5.1	2.34
M2	39.7	5.0	14.1	127	5.3	2.44
M3	33.3	5.0	13.1	108	5.4	2.22
M4						
C2 R2	29.7	3.0	12.3	82	4.9	2.22
M1	35.1	3.0	9.5	84	5.0	1.80
M2	31.5	4.0	16.8	92	5.7	2.55
M3	25.1	3.0	15.8	71	5.3	2.41
M4						
C2 R3	31.4	4.0	14.0	93	4.6	2.40
M1	30.4	5.0	11.3	113	4.7	2.43
M2	35.1	7.0	11.4	146	5.0	2.71
M3	29.7	4.0	14.9	85	5.0	2.27
M4						
C3 R1	28.7	4.0	13.1	81	5.1	2.64
M1	34.2	7.0	16.8	152	5.1	2.42
M2	37.9	6.0	20.5	171	5.2	2.85
M3	29.7	5.0	17.7	130	5.2	1.97
M4						
C3 R2	26.0	3.0	17.6	83	5.1	2.22
M1	30.6	4.0	14.9	82	5.0	2.34
M2	36.1	4.0	21.2	130	5.5	2.32
M3	34.2	4.0	12.2	89	5.3	2.65
M4						
C3 R3	29.7	4.0	14.0	90	4.9	2.62
M1	33.3	5.0	14.9	123	5.0	2.94
M2	33.3	6.0	15.9	145	4.9	3.04
M3	31.5	4.0	17.6	97	5.2	2.44
M4						
C4R1	34.2	3.0	12.3	79	5.1	2.61
M1	35.1	4.0	13.1	111	5.0	2.59
M2	40.5	3.0	10.5	116	5.6	2.84
M3	35.1	3.0	11.3	85	5.2	2.88
M4						
C4 R2	27.9	2.0	10.5	81	4.8	2.76
M1	28.8	3.0	12.2	82	4.8	2.89
M2	43.2	4.0	9.5	111	5.0	2.76

M3	37.8	2.0	8.7	97	5.3	2.83
M4						
C4 R3	33.2	3.0	9.5	83	4.9	2.74
M1	39.6	3.0	11.3	104	5.0	3.22
M2	41.4	4.0	9.5	124	5.2	3.03
M3	47.7	3.0	11.4	116	5.7	2.54
M4	23.6	3.0	13.1	62	5.0	1.75
DATE 09-05-2022	**PLANT HIGHT**	**NO OF BRANCHES**	**ROOT LENGTH**	**NO OF LEAVES**	**LEAF LENGTH**	**GRITH DIAMETER**
C1R1						
M1	25.1	3.0	14.4	67	5.4	1.89
M2	30.2	4.0	16.3	79	5.6	2.29
M3	32.4	6.0	19.5	113	5.7	2.32
M4	29.6	5.0	15.8	92	5.2	2.08
C1 R2						
M1	29.8	3.0	12.3	68	5.1	2.07
M2	27.5	4.0	17.2	83	5.2	2.1
M3	34.7	5.0	16.4	103	5.4	2.65
M4	31.1	4.0	13.8	90	5.3	2.29
C1 R3						
M1	29.3	2.0	14.2	60	5.3	2.29
M2	31.5	4.0	13.5	92	5.4	2.35
M3	36.2	5.0	12.7	109	5.8	2.4
M4	36.6	4.0	10.3	93	5.4	2.11
C2 R1						
M1	37.6	4.0	12.5	124	5.4	1.96
M2	39.3	4.0	13.3	110	5.5	2.54
M3	43.4	5.0	15.6	138	5.7	2.65
M4	36.3	5.0	14.8	118	5.8	2.41
C2 R2						
M1	32.1	3.0	13.5	89	5.3	2.41
M2	38.9	3.0	10.3	91	5.4	1.94
M3	34.7	4.0	18.7	99	6.1	2.77
M4	27.8	3.0	17.5	77	5.7	2.63
C2 R3						
M1	34.1	4.0	15.2	101	4.9	2.61
M2	33.6	5.0	12.0	123	5.0	2.65
M3	38.5	7.0	12.2	159	5.3	2.95
M4	32.5	4.0	16.8	92	5.4	2.46
C3 R1						
M1	31.7	4.0	14.2	88	5.5	2.87
M2	37.8	7.0	18.0	166	5.4	2.63
M3	41.2	6.0	22.3	187	5.5	3.1
M4	32.3	5.0	19.3	142	5.6	2.13
C3 R2						
M1	28.3	3.0	19.6	90	5.5	2.41
M2	33.7	4.0	16.5	89	5.4	2.54
M3	39.2	4.0	23.2	142	5.9	2.52
M4	37.1	4.0	13.5	97	5.7	2.89
C3 R3						
M1	32.4	4.0	15.0	98	5.2	2.85
M2	36.7	5.0	16.3	134	5.4	3.21
M3	36.1	6.0	17.5	158	5.3	3.32
M4	34.5	4.0	19.6	106	5.6	2.65
C4R1						
M1	37.6	3.0	13.5	86	5.5	2.84
M2	38.5	4.0	15.6	121	5.4	2.82
M3	44.8	3.0	11.4	126	6.0	3.1
M4	38.7	3.0	12.0	92	5.6	3.14

C4 R2						
M1	30.8	2.0	11.0	88	5.1	3.01
M2	31.8	3.0	13.6	89	5.1	3.15
M3	47.4	4.0	10.2	121	5.3	3.01
M4	41.5	2.0	9.2	105	5.7	3.09
C4 R3						
M1	36.3	3.0	10.4	90	5.2	2.99
M2	43.8	3.0	12.6	113	5.4	3.51
M3	45.3	4.0	10.3	135	5.6	3.3
M4	52.2	3.0	12.4	127	6.1	2.76

Appendix-E

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of plant height 20 DAT

	Main plot	N	1	2	3
Duncan[a,b]	C_1	12	13.1333		
	C_2	12		13.9833	
	C_3	12		14.1417	
	C_4	12			15.1000
	Sig.		1.000	.626	1.000

Based on observed means.
The error term is Mean Square (Error) = 0.616.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of plant height 20 DAT

	Sub plot	N	1	2	3
Duncan[a,b]	M_1	12	13.0750		
	M_2	12		13.9000	
	M_4	12		14.1750	
	M_3	12			15.2083
	Sig.		1.000	.399	1.000

Based on observed means.
The error term is Mean Square (Error) = 0.616.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of plant height 40 DAT

	Main plot	N	1	2	3
Duncan[a,b]	C_1	12	21.9917		
	C_3	12		24.4000	
	C_2	12		24.6333	
	C_4	12			27.6417
	Sig.		1.000	.762	1.000

Based on observed means.
The error term is Mean Square (Error) = 3.480.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of plant height 40 DAT

	Sub plot	N	1	2	3
Duncan[a,b]	M_1	12	22.4167		
	M_2	12		24.2917	
	M_4	12		24.8083	
	M_3	12			27.1500
	Sig.		1.000	.504	1.000

Based on observed means.
The error term is Mean Square (Error) = 3.480.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of plant height 60 DAT

	Main plot	N	1	2	3
Duncan[a,b]	C_1	12	31.1667		
	C_3	12		35.0833	
	C_2	12		35.7333	
	C_4	12			40.7250
	Sig.		1.000	.598	1.000

Based on observed means.
The error term is Mean Square (Error) = 8.900.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of plant height 60 DAT

	Sub plot	N	1	2	3
Duncan[a,b]	M_1	12	32.0917		
	M_2	12		35.2750	
	M_4	12		35.8500	
	M_3	12			39.4917
	Sig.		1.000	.641	1.000

Based on observed means.
The error term is Mean Square(Error) = 8.900.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of no of branches at 20 DAT

	Main plot	N	1	2	3
Duncan[a,b]	C_4	12	2.5833		
	C_1	12		3.0000	
	C_2	12		3.0833	
	C_3	12			3.6667
	Sig.		1.000	.653	1.000

Based on observed means.
The error term is Mean Square (Error) = 0.201.
a.Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of no of branches at 20 DAT

	Sub plot	N	1	2	3
Duncan[a, b]	M_1	12	2.6667		
	M_4	12	2.7500		
	M_2	12		3.1667	
	M_3	12			3.7500
	Sig.		.653	1.000	1.000

Based on observed means.
The error term is Mean Square (Error) = 0.201.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of no of branches at 40 DAT

	Main plot	N	1	2	3
Duncan[a,b]	C_4	12	3.0833		
	C_1	12		4.0833	
	C_2	12		4.2500	4.2500
	C_3	12			4.6667
	Sig.		1.000	.491	.093

Based on observed means.
The error term is Mean Square (Error) = 0.340.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of no of branches at 40 DAT

	Sub plot	N	1	2	3
Duncan[a, b]	M_1	12	3.1667		
	M_4	12		3.8333	
	M_2	12		4.1667	
	M_3	12			4.9167
	Sig.		1.000	.174	1.000

Based on observed means.
The error term is Mean Square (Error) = 0.340.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of no of branches at 60 DAT

	Main plot	N	1	2	3
Duncan[a,b]	C_4	12	3.0833		
	C_1	12		4.0833	
	C_2	12		4.2500	4.2500
	C_3	12			4.6667
	Sig.		1.000	.491	.093

Based on observed means.
The error term is Mean Square (Error) = 0.340
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of no of branches at 60 DAT

	Sub plot	N	1	2	3
Duncan[a, b]	M_1	12	3.1667		
	M_4	12		3.8333	
	M_2	12		4.1667	
	M_3	12			4.9167
	Sig.		1.000	.174	1.000

Based on observed means.
The error term is Mean Square (Error) = 0.340.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of root length at 20 DAT

	Main plot	N	1	2
Duncan[a,b]	C_4	12	6.5083	
	C_2	12	6.9667	
	C_1	12	6.9917	
	C_3	12		7.8083
	Sig.		.062	1.000

Based on observed means.
The error term is Mean Square(Error) = 0.331
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of root length at 20 DAT

	Sub plot	N	1	2
Duncan[a,b]	M_2	12	6.8333	
	M_1	12	6.8833	
	M_4	12	6.9917	
	M	12		7.5667
	Sig.		.531	1.000

Based on observed means.
The error term is Mean Square(Error) = 0.331
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of root length at 40 DAT

	Main plot	N	1	2	3
Duncan[a,b]	C_4	12	8.9583		
	C_2	12		10.4417	
	C_1	12		10.6000	
	C_3	12			12.6917
	Sig.		1.000	.773	1.000

Based on observed means.
The error term is Mean Square (Error) = 1.776.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of root length at 60 DAT

	Main plot	N	1	2	3
Duncan[a,b]	C_4	12	11.8500		
	C_2	12		14.3667	
	C_1	12		14.7000	
	C_3	12			17.9167
	Sig.		1.000	.711	1.000

Based on observed means.
The error term is Mean Square (Error) = 4.754.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of no of leaves at 20 DAT

	Main plot	N	1	2	3
Duncan[a,b]	C_1	12	35.9167		
	C_4	12	38.4167	38.4167	
	C_2	12		40.0833	40.0833
	C_3	12			42.0833
	Sig.		.096	.259	.178

Based on observed means.
The error term is Mean Square (Error) = 12.493
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of no of leaves at 20 DAT

	Sub plot	N	1	2	3
Duncan[a,b]	M_1	12	32.9167		
	M_4	12		36.5833	
	M_2	12		38.8333	
	M_3	12			48.1667
	Sig.		1.000	.132	1.000

Based on observed means.
The error term is Mean Square(Error) = 12.493.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of no of leaves at 40 DAT

	Main plot	N	1	2	3
Duncan[a,b]	C_1	12	61.4167		
	C_4	12		73.0833	
	C_2	12		75.0833	
	C_3	12			83.4167
	Sig.		1.000	.542	1.000

Based on observed means.
The error term is Mean Square (Error) = 62.715.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of no of leaves at 40 DAT

	Sub plot	N	1	2	3
Duncan[a,b]	M_1	12	60.0833		
	M_4	12		69.5833	
	M_2	12		73.1667	
	M_3	12			90.1667
	Sig.		1.000	.279	1.000

Based on observed means.
The error term is Mean Square (Error) = 62.715.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of no of leaves at 60 DAT

	Main plot	N	1	2	3
Duncan[a,b]	C_1	12	87.4167		
	C_4	12		107.7500	
	C_2	12		110.0833	
	C_3	12			124.7500
	Sig.		1.000	.660	1.000

Based on observed means.
The error term is Mean Square (Error) = 164.632
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of no of leaves at 60 DAT

	Sub plot	N	1	2	3
Duncan[a,b]	M_1	12	87.4167		
	M_4	12		102.5833	
	M_2	12		107.5000	
	M_3	12			132.5000
	Sig.		1.000	.357	1.000

Based on observed means.
The error term is Mean Square (Error) = 164.632
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of leaf length at 20 DAT

	Sub plot	N	1	2
Duncan[a,b]	M_1	12	2.4500	
	M_4	12	2.4850	
	M_2	12	2.4967	
	M_3	12		2.6067
	Sig.		.386	1.000

Based on observed means.
The error term is Mean Square (Error) = 0.015.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of leaf length at 40 DAT

	Sub plot	N	1	2
Duncan[a,b]	M_1	12	3.8667	
	M_2	12	3.9250	
	M_4	12		4.0417
	M_3	12		4.1250
	Sig.		.221	.085

Based on observed means.
The error term is Mean Square(Error) = 0.013.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of leaf length at 60 DAT

	Sub plot	N	1	2
Duncan[a,b]	M_1	12	5.2833	
	M_2	12	5.3500	
	M_4	12		5.5917
	M_3	12		5.6333
	Sig.		.324	.535

Based on observed means.
The error term is Mean Square(Error) = 0.26
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of grith diameter at 20 DAT

	Main plot	N	1	2	3	4
Duncan[a,b]	C_1	12	.7967			
	C_2	12		.8700		
	C_3	12			.9400	
	C_4	12				.9958
	Sig.		1.000	1.000	1.000	1.000

Based on observed means.
The error term is Mean Square(Error) = 0.003.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of grith diameter at 20 DAT

	Sub plot	N	1	2
Duncan[a, b]	M_1	12	.8725	
	M_4	12	.8783	
	M_2	12	.8975	
	M_3	12		.9542
	Sig.		.288	1.000

Based on observed means.
The error term is Mean Square (Error) = 0.003
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of grith diameter at 40 DAT

	Main plot	N	1	2	3	4
Duncan[a,b]	C_1	12	1.5183			
	C_2	12		1.6783		
	C_3	12			1.8467	
	C_4	12				2.0225
	Sig.		1.000	1.000	1.000	1.000

Based on observed means.
The error term is Mean Square (Error) = 0.023.
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of grith diameter at 40 DAT

	Sub plot	N	1	2
Duncan[a, b]	M_1	12	1.6892	
	M_4	12	1.7125	
	M_2	12	1.7683	1.7683
	M_3	12		1.8958
	Sig.		.241	.052

Based on observed means.
The error term is Mean Square (Error) = 0.023
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of grith diameter at 60 DAT

	Main plot	N	1	2	3	4
Duncan[a,b]	C_1	12	2.2367			
	C_2	12		2.4983		
	C_3	12			2.7600	
	C_4	12				3.0600
	Sig.		1.000	1.000	1.000	1.000

Based on observed means.
The error term is Mean Square (Error) = 164.632
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Duncan test for comparing treatment means for sub plots (growing media) of grith diameter at 60 DAT

	Sub plot	**N**	**1**	**2**
Duncan[a, b]	M_1	12	2.5167	
	M_4	12	2.5533	
	M_2	12	2.6442	2.6442
	M_3	12		2.8408
	Sig.		.257	.070

Based on observed means.
The error term is Mean Square (Error) = 0.26

a. Uses Harmonic Mean Sample Size = 12.000.

b. Alpha = 0.05