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S Janakiramudu
Department of Soil and Water Engineering, Dr NTR College of Agricultural Engineering and Technology, ANGRAU, Bapatla, Andhra Pradesh, India

KN Raja Kumar
Department of Soil and Water Engineering, Dr NTR College of Agricultural Engineering and Technology, ANGRAU, Bapatla, Andhra Pradesh, India

R Ganesh Babu
Department of Soil and Water Engineering, Dr NTR College of Agricultural Engineering and Technology, ANGRAU, Bapatla, Andhra Pradesh, India

CH Someswara Rao
Department of Processing and Food Engineering, Dr NTR College of Food Science and Technology, ANGRAU, Bapatla, Andhra Pradesh, India

Corresponding Author:
S Janakiramudu
Department of Soil and Water Engineering, Dr NTR College of Agricultural Engineering and Technology, ANGRAU, Bapatla, Andhra Pradesh, India

Optimization of nutrient concentration and grow media for stevia crop under hydroponic farming

S Janakiramudu, KN Raja Kumar, R Ganesh Babu and CH Someswara Rao

Abstract

The purpose of this study was to determine the optimum nutrient concentration and suitable growing media for stevia crop grown under hydroponics. This research was carried out for two months (10-Mar to 10-May, 2022) in a naturally ventilated polyhouse, located at an altitude of 6m above the mean sea level. 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 = 1.5 ds/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. The yield of stevia crop was recorded as total fresh plant weight, fresh weight of leaves and dry weight of leaves were observed in hydroponic farming. The obtained data was analysed in the SPSS software and DMRT was carried out to find the significant grouping between the treatments. 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 results of this study showed that best yield can be obtained at the nutrient concentration of 1.25 dS/m and it is optimum quantity for production of stevia crop. Clay balls are recommended as the growing media for stevia crop to achieve higher yields under hydroponic farming.

Keywords: Hydroponics, nutrient film technique (NFT), nutrient concentration, growing media and stevia crop

Introduction

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 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) [17]. 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. 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. 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.

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 16th century. Stevia plant is a natural sweetener tastes 200 to 300 times sweeter than table sugar (Yadav *et al.*, 2011) [18]. It is used by the diabetic patients to lessen the sugar levels in the blood. 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. On the other hand 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. 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.

2 Materials and Methods

2.1 Experimental site

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.

2.2 Experimental design

The experiment was conducted under hydroponic unit located in naturally ventilated poly-house 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. 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.

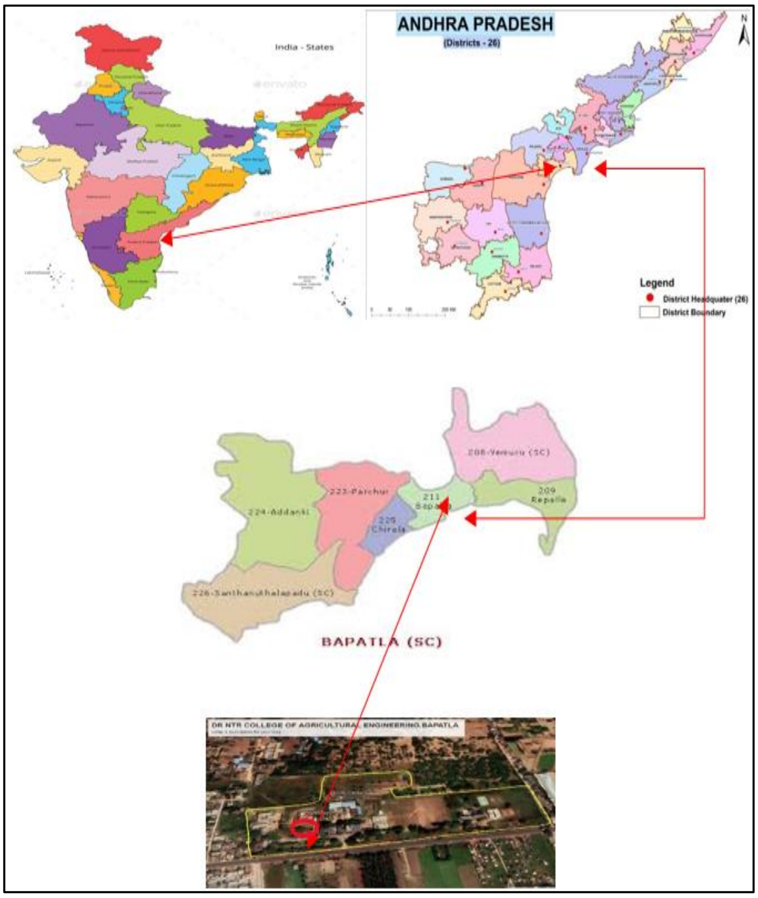

Fig 1: Experimential location of the study area

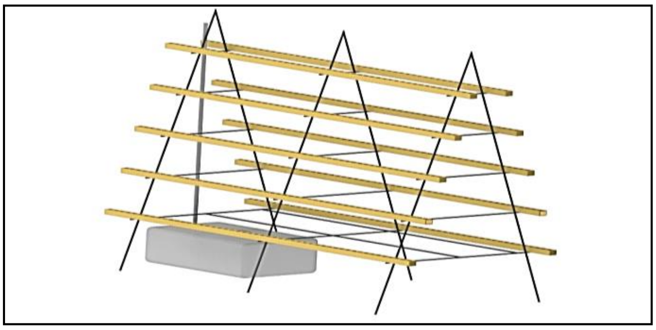

Fig 2: A frame structure nutrient film technique as the method of hydroponics

Fig 3: Seedlings transferred to the net pots

2.3 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 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

One month old seedlings of stevia were transplanted in net pots which were placed on A frame hydroponic structure. 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. The preparation of the nutrient solution comprises the steps of mixing into a volume of water. Firstly, 10 litters of water were 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. 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. 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. 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. The EC level of the nutrient solution was measured regularly buy using EC or TDS meter as shown in figure 4

2.4 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) [5]. The yield of stevia crop was recorded as total fresh plant weight, fresh weight of leaves and dry weight of leaves. 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. 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. The dry weight of plant samples was noted at the end of experiment after natural drying for a period of 2 days as shown in the figure 5

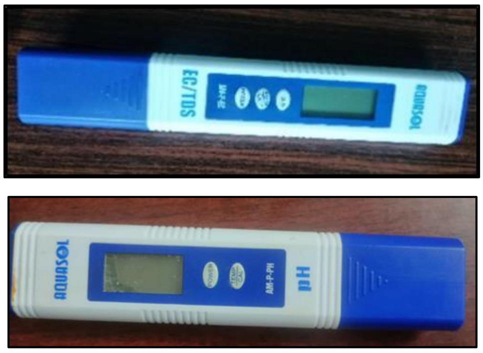

Fig 4: Aquasol Pen type EC/TDS and pH meter used in the experiment

Fig 5: Measurement of plant yield

2.5 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) [3].

3. Results and Discussion

3.1 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.

3.2 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. 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 6. 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.

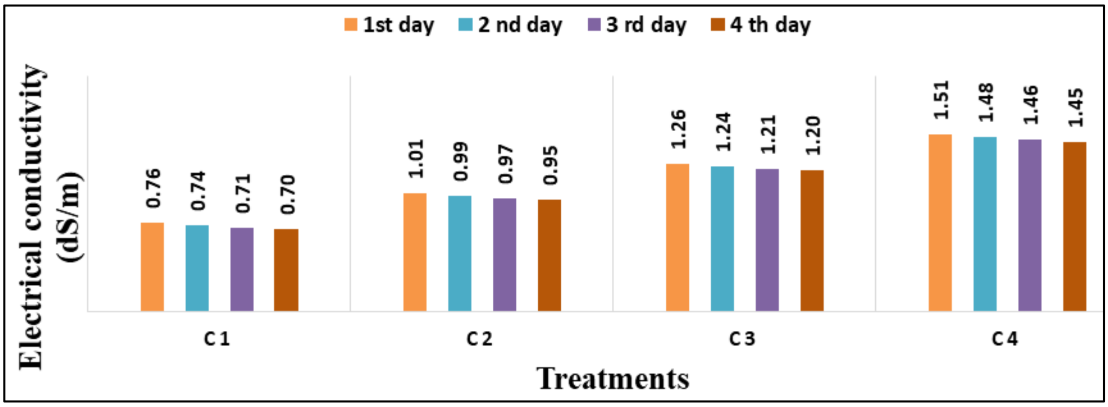

Fig 6: Daily average EC variation during the crop growing period in different levels of nutrient solution

3.3 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. 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 nutrient 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. 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.

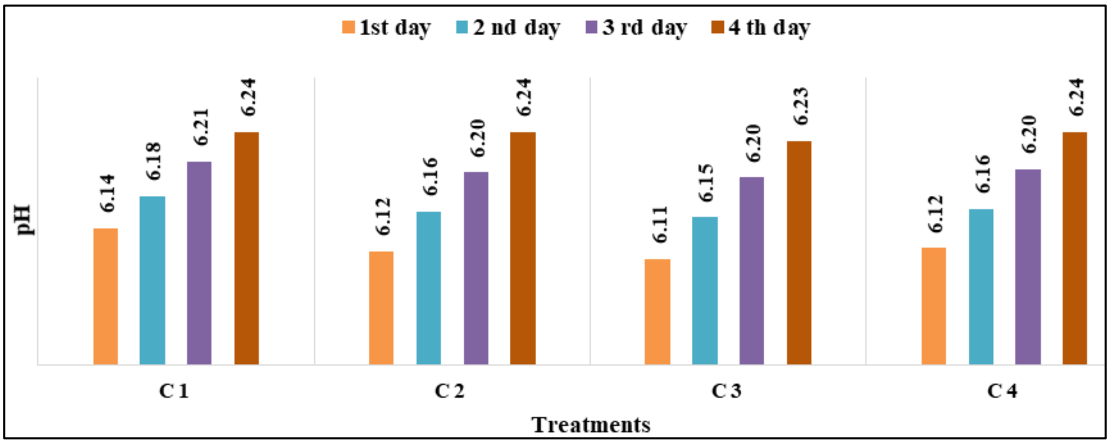

Fig 7: Average daily pH variation of nutrient solution during the crop growing period

Yield of stevia crop

The observations recorded on the dry weight of stevia leaves after drying the leaves in a natural ventilated polyhouse**.** 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 (228.8 g) 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 2) 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). 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 2) 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 1: Effect of nutrient concentration levels and growing media on dry weight 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

Table 2: 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	.000
Intercept	2080209.505	1	2080209.505	233731.405	.000
Rep	61.330	2	30.665	3.446	.048
Main	14145.672	3	4715.224	529.800	.000
Main*replication	138.370	6	23.062	2.591	.044
Sub	331.174	3	110.391	12.404	.000
Main * Sub	155.859	9	17.318	1.946	.093
Error	213.600	24	8.900		
Total	2095255.510	48			
Corrected Total	15046.005	47			
a. R Squared = .986 (Adjusted R Squared = .972)					

Table 3: Duncan test for comparing treatment means for main plots (EC of nutrient concentration) of yield at 60 DAT

	Main plot	N	1	2	3
Duncan[a,b]	C_1	12	181.1667		
	C_2	12		205.7333	
	C_4	12			220.7250
	C_3	12			
	Sig.		1.000	1.000	1.000

Based on observed means.
The error term is Mean Square (Error) = 8.90
a. Uses Harmonic Mean Sample Size = 12.000.
b. Alpha = 0.05

Table 4: Duncan test for comparing treatment means for sub plots (growing media) of yield at 60 DAT

	Sub plot	N	1	2	3
Duncan[a,b]	M_1	12	204.5917		
	M_2	12		207.7750	
	M_4	12		208.3500	
	M_3	12			211.9917
	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

From the above study the following conclusions were drawn

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 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.

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