Hydroponics: Exploring innovative sustainable technologies and applications across crop production with emphasis on antimicrobial properties Viciafaba (Field beans), Brassica nigra (Mustard) and Ocimum sanctum (Thulasi)

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***Abstract*—Soil based cultivation is now facing difficulties due to different manmade reasons such as Industrialization and urbanization. Hydroponic farming system through the cultivation of different crops like coriander and leafy vegetables. Less time is required for the yield, and no soil-borne diseases. Easy management of crops, zero growth of weeds, and no requirement for spraying water are among the few advantages of the hydroponic farming system A hydroponic farming system can assure minimum water savings of up to 70–80% compared to that of soil-based farming systems. Also, sudden natural disasters, climate change and Unrestricted utilization of chemicals for agriculture purposes cause the depletion of soil fertility and quality. That is why, scientists have developed a new alternative approach for Cultivation system namely soil-less cultivation or hydroponics. Hydroponics is a method of Growing plants in a water based, nutrient rich solution. Through hydroponics a large number of plants and crops or vegetables can be grown. The quality of yield, taste and Nutritive value of end products produced through hydroponically is generally higher than the natural soil-based cultivation. This cultivation is cost effective, disease free, ecofriendly and is gaining popularity all over the world, in both the developed and the developing countries. It has a great prospect in many countries along with high space Research to fulfill the lack of arable land where proper cultivable land is not available. So, Hydroponics would be a better technique to produce the different kinds of fruits, vegetables and fodder as well as meet the global nutrition demand with making advance future. In the Future, hydroponics could be emerging techniques for the supplying of food to the world-Wide population. This study investigated the phytochemical properties and antimicrobial sensitivity of four hydroponically grown plants: *Abelmoschus esculentus* (Ladies finger), *Viciafaba* (Broad Bean), *Brassicanigra* (Black Mustard), and *Ocimum sanctum* (Thulasi). The plants were grown using the hydroponics method, which provides a controlled nutrient environment. The antimicrobial sensitivity test was conducted using Muller Hinton agar, with *Escherichiacoli* (*E. coli*) and *staphylococcus* as the test microorganism. Phytochemical analysis was performed using various chemical reagents, including Mayer's (alkaloids), Wegner's (glycosides), Dragendroff's (alkaloids), Benedict's (reducing sugars), and Tannis reagents (tannins). The results of this study provide valuable insights into the potential medicinal applications of these plants and highlight the effectiveness of hydroponics as a cultivation method.**

***Index Terms*—Hydroponics, Phytochemical Analysis, Antimicrobial Sensitivity Testing, *Abelmoschus esculentus*, *Vicia faba*, *Brassica nigra*, *Ocimum sanctum*, *Escherichiacoli*, *staphylococcus*.**

I. INTRODUCTION

Hydroponics is the practice of growing plants in a nutrient solution with or without a soilless substrate to provide physical support. Hydroponic farming system, commonly known as soil less farming system, is the

modern method of farming in which plants are grown in water and nutrient solution using inert medium such as coco peat to support the roots. The word hydroponics comes from the root words “hydro,” meaning water, and “ponos,” meaning labor, literally “working water.” The concept of hydroponics existed thousands of years ago, with the earliest examples of Hanging Gardens of Babylon and the Floating Gardens of China. However, modern hydroponic systems did not thrive until the advent of the greenhouse and plastics industries. Since then, scientists have developed many hydroponic systems for various crops based on locally available resources. Currently used commercial hydroponic systems are the improved versions of these early systems

Laboratory experiments designed to determine the factors controlling plant growth were conducted as early as the 17th century. During the subsequent centuries scientists discovered that plants could be grown in inert substrates or in water alone, provided the proper nutrients were available. The significance of hydroponics was revealed in the 1930s by W.F. Gericke at

the University of California at Berkeley. By controlling the nutrient levels provided for crop plants grown in water baths, Gericke’s laboratory experiments resulted in tomato plants more than 20 feet (6 meters) high. His findings led to the worldwide use of hydroponics in agriculture.

In a broad sense, hydroponics can be divided into two types: solution culture and soilless medium culture. Soilless medium culture is sometimes not considered as “true” hydroponics, while solution culture is. Main types of solution culture include nutrient film technique (NFT), deepwater culture or floating raft culture, and aeroponics. Soilless medium culture uses a solid medium (also called substrate) to anchor plant roots while the nutrient solution is provided through sub or top irrigation. Substrate and growing media are often used interchangeably.

For plant factories, almost all production stages use solution culture, while substrate is often used in the propagation stage. Plant factory is an emerging and innovative system for plant production that commonly uses vertically stacked hydroponic systems in an indoor controlled environment. The basic knowledge of hydroponics and the general understanding of plant nutrition and nutrient management for crop production in plant factories are derived from prior studies on greenhouse and growth chamber hydroponics. That is, the basic concept and principles are the same: to provide essential nutrients, water, and oxygen to the root zone, and to create a uniform aerial growing environment to maximize plant growth and quality. Early development of hydroponic farms was seen in places such as., Germany, Holland, Iran, Italy, Japan, Russia Federation, Abu Dhabi, Arizona, Belgium, California, and so on. As we are all aware of the fact that the world’s population is increasing at a very rapid rate that requires for an increase in resources to properly meet the needs of each and every-one one of them. Increased population means increased. Urbanization and a decrease in cultivable lands. So, to sustain human needs to evolve and upgrade existing methods of survival. The most basic need of a human being is food, so first we need to upgrade farming systems that can produce better yield in less time and area. That’s where hydroponic farming system comes into play and meets almost every requirement of modern-day farming system. There are many other alternatives to hydroponic farming system too that includes aquaponics (aqua agriculture) and aeroponics (aerobic agriculture) as well as substrate culture i.e.

growing crops in fungi. But hydroponic farming system is getting the most of the spotlight because of its very efficient management of nutrients and yields. A wide variety of commercial crops can be grown through hydroponics. Some of them are Tomatoes, cucumbers, peppers, strawberries, leafy vegetables. So, this research covers the advantages and limitations of the hydroponic farming system, and various aspects of soil-less farming system.

II. MATERIALS AND METHODOLOGY

Isolation of bacteria from coconut coir

The isolation of bacteria from coconut coir was successfully carried out using a combination of microbiological techniques. The process began with the collection of coconut coir samples, which were then processed to isolate the bacteria present. The goal of the study was to identify the types of bacteria that are associated with coconut coir. The first method employed was the pour plate technique, which involved pouring a molten agar medium into a sterile petri dish containing the coconut coir sample. The medium was then allowed to solidify, and the plate was incubated at a suitable temperature to facilitate the growth of bacteria. This method was used to isolate the bacteria from the coconut coir sample. In addition to the pour plate method, the spread plate technique was also used to isolate bacteria from the coconut coir sample. This involved spreading a known volume of the sample onto the surface of a sterile agar plate, which was then incubated to allow the bacteria to grow. The spread plate method was used to further isolate and purify the bacteria. The isolated bacteria were then cultured on two different types of agar plates: MacConkey agar and Tryptic Soya Agar (TSA). The MacConkey agar plate revealed the growth of pink colonies, which were identified as *Enterobacteriaceae*. On the other hand, the TSA plate showed the growth of white and orange colonies, which were identified as *Bacillus sp*. and *Staphylococcus*, respectively. Gram staining was performed to confirm the identification of the isolated bacteria. The Gram stain results were consistent with the colony morphology observed on the agar plates. The *Enterobacteriaceae, Bacillus sp.,* and *Staphylococcus* species were all successfully identified using this method. Finally, the isolated bacteria were further purified using the streak plate method. This involved streaking a loopful of the isolated bacteria onto the surface of a sterile agar plate, which was then incubated to allow the bacteria to grow. The resulting colonies were then examined to confirm their purity and identity, and the isolated bacteria were successfully stored for further study.

1. *Vicia faba* (Field Beans)

PREPARATION OF FIELD BEANS EXTRACT

The dried plants were ground in a food processor, then sieve, to remove the unwanted stems, weighed (approximately 90g) and Stored in an airtight container. The ground leaves were soaked in a Polar solvent (ethanol), a non-polar solvent (hexane) and a semi-Polar solvent (ethyl acetate). Three (3) large, dark bottles were Sterilized. Thirty grams (30g) of leaves each, were soaked in each Solvent of 300mls of ethanol, 300mls of ethyl acetate and 450mls of hexane for 24 hours at room temperature with occasional Shaking. The extraction was repeated, and the extracts obtained Were filtered using sterilized Whatman No. 1 filter paper. The Concentrated (crude) extracts were stored in the dark until use. Sterile containers were used, and serial dilution was carried Out to obtain the different concentrations (conc.) The crude extract Represented 100% concentration or 100 mg/ml conc. For 50 mg/Ml conc., 1 ml of the crude extract was added to 9mls of the solvent, that is, 1:10 dilution (10-1). For 25 mg/ml conc., 1 ml of the 50 Mg/ml (10-1) was added to 9mls of solvent to give 1:100 dilution (10- 2). The process continued until 0.78 mg/ml (10-7) was achieved. The extracts were then used for antimicrobial investigation and Phytochemical screening. Collect fresh field bean plant parts leaf. Grind the plant material into a fine paste. Extract the bioactive compounds using a suitable solvent (e.g., ethanol, methanol, water) based on the desired components. Filter the extract to remove debris. Prepare agar plates with the appropriate nutrient medium. Spread the bacterial inoculum evenly on the agar surface. Using a sterile cork borer, punch wells into the agar. Add a known volume of the field bean plant extract to each well. Incubate the plates at an optimal temperature for bacterial growth. After incubation, observe the zones of inhibition (clear areas around the wells where bacterial growth is inhibited).

Measure the diameter of the zone of inhibition using a ruler.

2. *Brassica nigra* (Mustard)

PREPARATION OF MUSTARD EXTRACT

The dried plants were ground in a food processor, then sieve, to remove the unwanted stems, weighed (approximately 90g) and Stored in an airtight container. The ground leaves were soaked in a Polar solvent (ethanol), a non-polar solvent (hexane) and a semi-Polar solvent (ethyl acetate). Three (3) large, dark bottles were Sterilised. Thirty grams (30g) of leaves each, were soaked in each Solvent of 300mls of ethanol, 300mls of ethyl acetate and 450mls of hexane for 24 hours at room temperature with occasional Shaking. The extraction was repeated, and the extracts obtained Were filtered using sterilised Whatman No. 1 filter paper and Funnel. Subsequently, the extracts were concentrated to dryness Under reduced pressure using a rotary evaporator at 45 °C. The Concentrated (crude) extracts were stored in the dark until use. Sterile containers were used, and serial dilution was carried Out to obtain the different concentrations (conc.) The crude extract Represented 100% concentration or 100 mg/ml conc. For 50mg/Ml conc., 1 ml of the crude extract was added to 9mls of the solvent, That is, 1:10 dilution (10-1). For 25 mg/ml conc., 1 ml of the 50 Mg/ml (10-1) was added to 9mls of solvent to give 1:100 dilution (10- 2). The process continued until 0.78 mg/ml (10-7) was achieved. The extracts were then used for antimicrobial investigation and Phytochemical screening. Collect fresh mustard plant parts (leaves, seeds, etc.). Grind the plant material into a fine paste. Extract the bioactive compounds using a suitable solvent (e.g., ethanol, methanol, water) based on the desired components. Filter the extract to remove debris. Prepare agar plates with the appropriate nutrient medium. Spread the bacterial inoculum evenly on the agar surface. Using a sterile cork borer, punch wells into the agar. Add a known volume of the mustard plant extract to each well. Incubate the plates at an optimal temperature for bacterial growth. After incubation, observe the zones of inhibition (clear areas around the wells where bacterial growth is inhibited). Measure the diameter of the zone of inhibition using a ruler.

3. Ocimum sanctum

PREPARATION OF THULASI EXTRACT

The preparation of Thulasi extract was carried out using 1 gram of ground Thulasi leaves and 10 milliliters of ethanol. The ground Thulasi leaves were accurately measured and transferred to a clean container. This marked the beginning of the extraction process. Ethanol was then added to the container, and the mixture was stirred well to ensure that the Thulasi leaves were fully saturated with the solvent. The mixture was then allowed to stand for a specified period, enabling the solvent to extract the bioactive compounds from the Thulasi leaves. After the extraction process, the mixture was filtered using Whatman filter paper to separate the solid residue from the liquid extract. This step was crucial in obtaining a pure Thulasi extract.The resulting filtrate was collected, and the solvent was evaporated to obtain a pure Thulasi extract. The extract was then stored in a clean, sterile container for further use in various applications.The use of Whatman filter paper ensured that the extract was free from any impurities or contaminants. This step was essential in obtaining a high-quality Thulasi extract.The prepared Thulasi extract was then ready for use in various experiment antimicrobial assays.

ANTI- MICROBIAL ACTIVITY**:** Nutrient agar composition (0.5% peptone , 0.3% beef extract/yeast extract, carbohydrates, nitrogen, and salts. 1.5% agar).Preparation of test solutions :Antibacterial activities of tested sample were evaluated using well diffusion method on nutrient agar. The bacterial strains *E.coli* (ATCC 10536) and *S.aureus*(ATCC 25923) were used as references for the antibacterial assay. Nutrient Agar plates were inoculated with bacterial strain under aseptic conditions was spread plated by glass L-rod with 100 µl grown culture. Then, round (8 mm) aseptically stainless-steel bunching cork used to make the well for each plate, and different concentration (25–100 µl) of the antimicrobial agent solution is introduced into the well. After that plates were incubated at 37°C for 24 hours. After the incubation period, the zone of inhibition was measured and reported in millimetres (mm). The MIC was considered as the concentration which inhibited the growth of the respective microorganisms.

PHYTOCHEMICAL PROPERTIES

Phytochemical properties refer to the natural chemicals found in plants that have medicinal and health benefits. Alkaloids Use Mayer's, wegnar's, Dragendroff's reagent. A precipitate forms if alkaloids are present. Carbohydrates Use Benedict's reagent. A color change indicates carbohydrates are present. Phenols Use Tannic Acid reagent. A color change or precipitate forms if phenols are present**.**

Test for alkaloids

Mayer's test

- Add 2ml of extract to 3ml of mayer's reagent.
- Formation of white color indicates the presence of alkaloids.

Wegner's test

- Add 2ml of extract to 3ml of wegner's reagent.
- Formation of reddish-brown precipitate indicates the presence of alkaloids.

Dragendroff's test

- Add 2ml of extract to 3ml of dragendroff's reagent.
- Formation of brown color indicates the presence of alkaloids.

Test for carbohydrate

Benedict's test

- Add 2ml of extract to 4ml of benedict's reagent.
- Formation of green or blue color indicates the presence of alkaloids.

Test for phenol

Tannis test

- Add 2ml of extract to 4ml of 10% ferric chloride solution.
- Formation of brown or black color indicates the presence of alkaloids.

III. RESULTS

Isolation of Coconut Coir

Isolating bacteria from coconut coir using serial dilution, spread plates, gram staining, and streak plates:

The isolation of bacteria from coconut coir was successfully accomplished using a combination of spread plate, Gram staining, and streak plate techniques. The spread plate method revealed the growth of pink colonies, identified as *Enterobacteriaceae*, on MacConkey agar plates, and white and orange colonies, identified as *Bacillus* and *Staphylococcus*, respectively, on Tryptic Soya Agar (TSA) plates. Finally, the isolated bacteria were further purified using the streak plate method, where *Enterobacteriaceae* was streaked on MacConkey agar plates, and *Bacillus sp.* and *Staphylococcus* were streaked on TSA plates, resulting in the successful isolation and identification of these bacterial species from coconut coir.

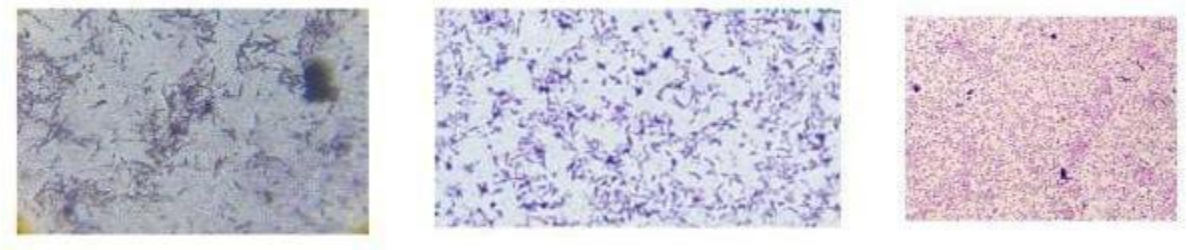
Spread plate and Streak plates

The isolation of bacteria from coconut coir was successfully carried out using a combination of microbiological techniques. The process began with the collection of coconut coir samples, which were then processed to isolate the bacteria present. The spread plate method was employed to isolate the bacteria, which involved spreading a known volume of the sample onto the surface of a sterile agar plate. The agar plates were then incubated at a suitable temperature to facilitate the growth of bacteria. After incubation, the plates were observed for the growth of bacterial colonies. The colonies were then sub-cultured to obtain pure cultures of the isolated bacteria. The isolated bacteria were then subjected to Gram staining to determine their Gram reaction. Gram staining was performed to identify the isolated bacteria. The Gram stain results revealed the presence of Gram-positive and Gram-negative bacteria. The Gram-positive bacteria were identified as *Bacillus sp.* and *Staphylococcus*, while the Gram-negative bacteria were identified as *Enterobacteriaceae*. The isolated bacteria were then further purified using the streak plate method. This involved streaking a loopful of the isolated bacteria onto the surface of a sterile agar plate, which was then incubated to allow the bacteria to grow. The resulting colonies were then examined to confirm their purity and identity. The successful isolation and identification of bacteria from coconut coir using these methods provided valuable insights into the microbial communities present in this environment. The results of this study can be used to inform strategies for the management and utilization of coconut coir.

Figure1 shows enumeration of bacterial colonies from coconut coir.

Gram staining

Gram staining was then employed to confirm the identification of the isolated bacteria, which were found to be *Enterobacteriaceae, Bacillus sp., and Staphylococcus species.*



Enterobactericeae *Bacillussp* *Staphylococcus*

Figure2 shows microscopic view of the Isolated Bacterias

Antimicrobial activity

1. Vicia faba

The antimicrobial sensitivity test for field beans leaf extract soaked in ethanol was conducted using the well diffusion method against *Escherichiacoli*. The results showed that a clear zone of inhibition was formed around the well, measuring 0.2 mm in diameter, indicating that the field beans leaf extract exhibited antimicrobial activity against *E. coli*, although the activity was relatively low. The given figure represents the zone of inhibition.

Figure3 shows the zone of inhibition

2. *Brassica nigra*

The given figures represent the zone of inhibition (mm) for two bacterial strain *E. coli* at different concentrations (25, 50, 75, and 100 µg/ml) of a test compound, compared to a control (16 mm for both strains). The zone of inhibition indicates the effectiveness of the compound in inhibiting bacterial growth. Escherichia *coli* The inhibition zone increases with concentration, from 10 mm at 25 µg/ml to 16 mm at 100 µg/ml. At 100 µg/ml, the inhibition zone (16 mm) matches the control, suggesting comparable efficacy at higher concentrations. The steady increase in inhibition suggests a dose-dependent response. Overall Interpretation: The test compound exhibits dose-dependent antibacterial activity against *Escherichiacoli*. The activity Is stronger against *E.Coli*, suggesting that higher concentrations are required for significant antibacterial action. This data supports the potential use of the compound as an antibacterial agent, but its effectiveness varies between bacterial strains. The given figure represents the zone of inhibition.

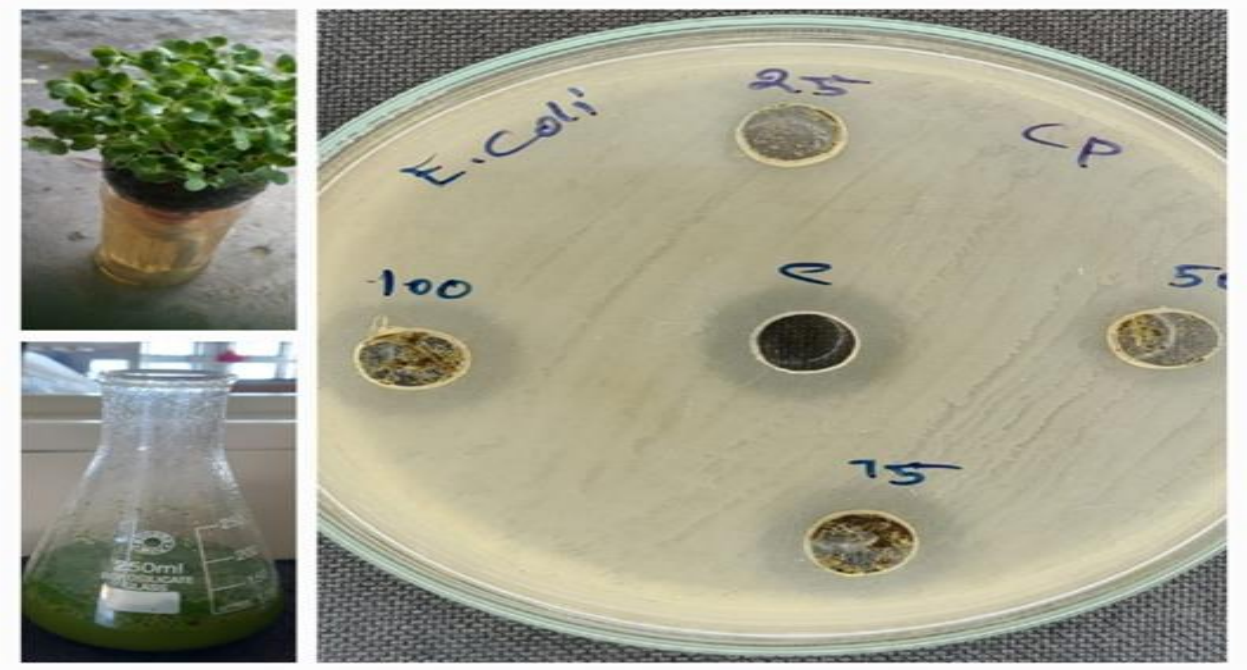


Figure4 shows the zone of inhibition

3. *Ocimum sanctum*

The antimicrobial sensitivity test for Thulasi (Ocimum sanctum) leaf extract soaked in ethanol was conducted using the well diffusion method against *Staphylococcus aureus*. The results showed that a clear zone of inhibition was formed around the well, measuring 1 mm in diameter, indicating that the Thulasi leaf extract exhibited significant antimicrobial activity against *Staphylococcus aureus*. The given figure represents the zone of inhibition.

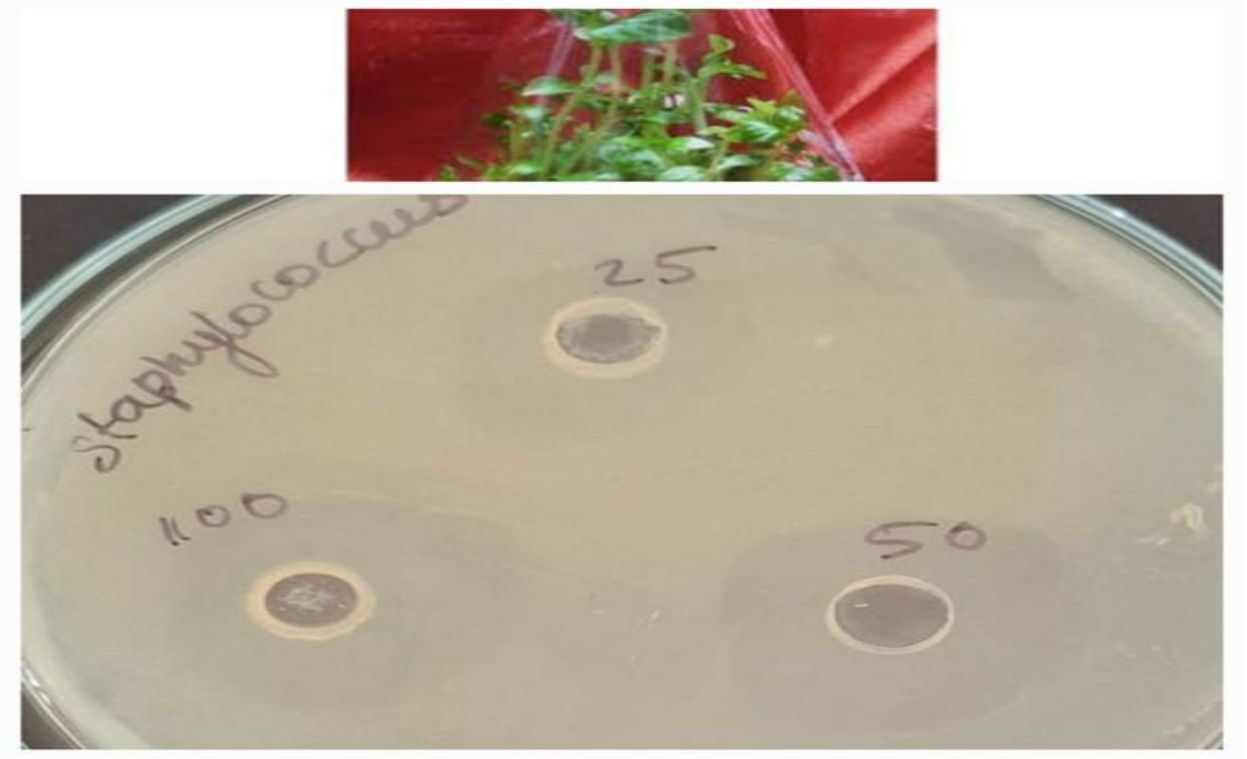


Figure5 shows the zone of inhibition

Phytochemical properties

1. *Vicia faba*

S.NO	DETECTION	RESULT
1	Alkaloids • Mayer's test • Wegner's test • Dragendorff's test	 Positive Positive Positive
2	Carbohydrate • Benedict's test	Positive
3	Phenols • Tannis test	Positive

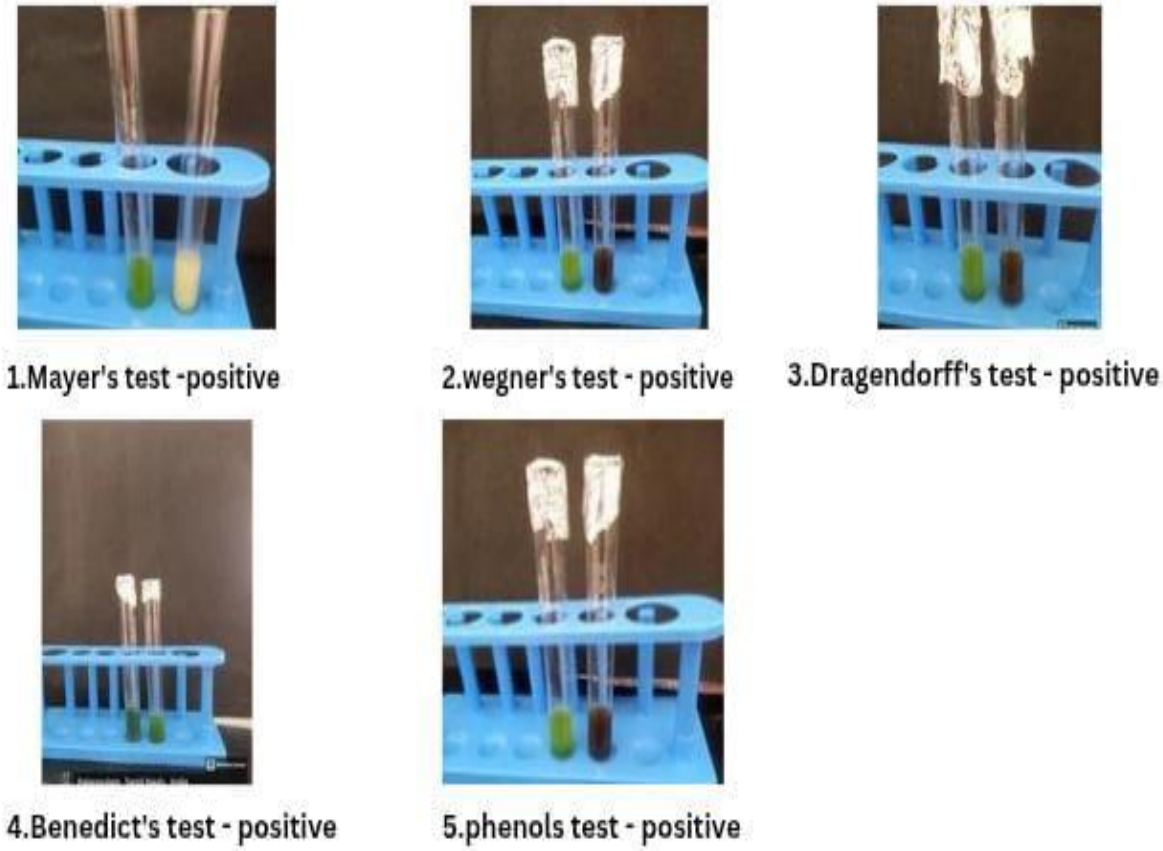


Figure6 shows the phytochemical test of *Vicia faba*

2. Brassica nigra

S.NO	DETECTION	RESULT
1	Alkaloids Mayer's test Wegner's test Dragendorff's test	 Positive Positive Positive
2	Carbohydrate Benedict's test	 Positive
3	Phenols Tannis test	 Positive

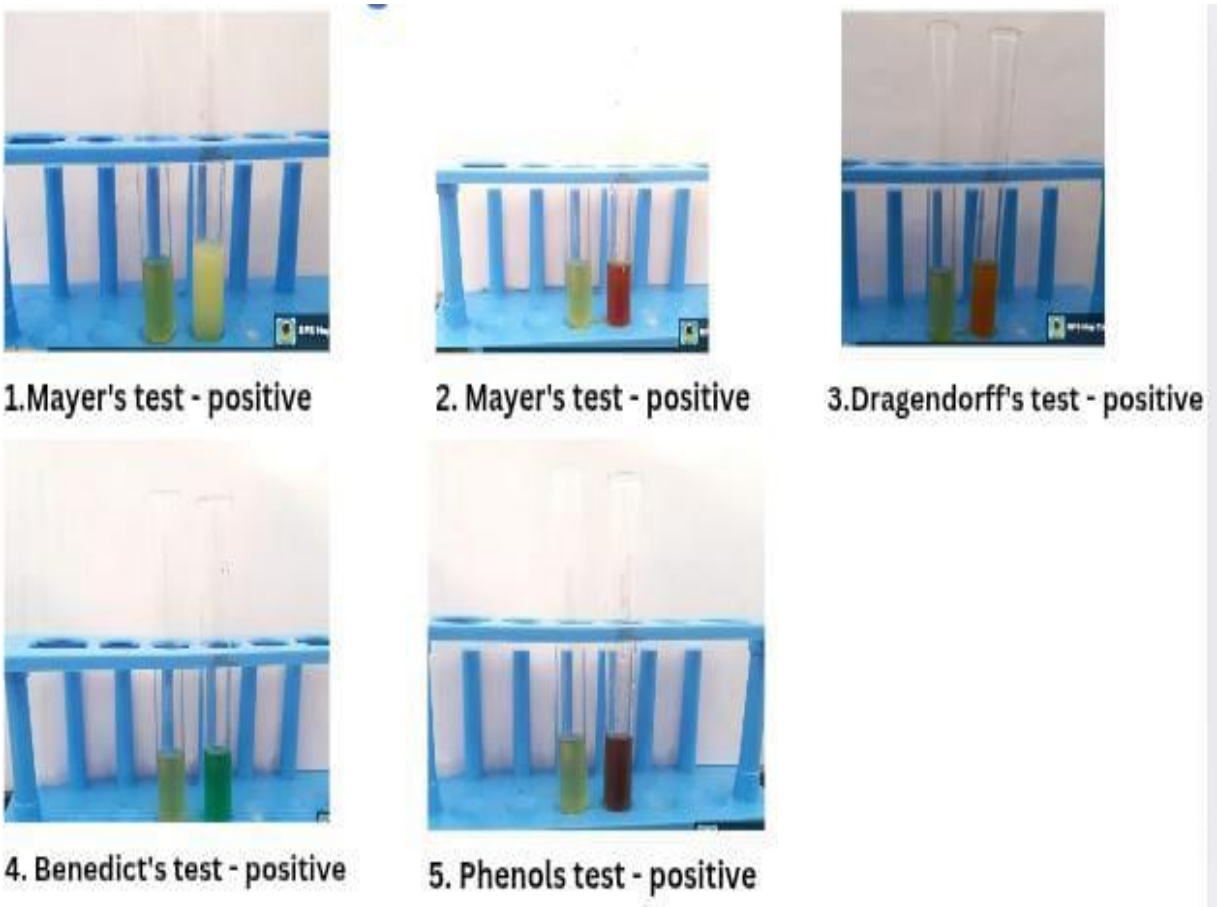


Figure7 shows the phytochemical test of *Brassica nigra*

3. Ocimum sanctum

S.NO	DETECTION	RESULT
1	Alkaloids • Mayer's test • Wegner's test • Dragendorff's test	 Positive Positive Positive
2	Carbohydrate • Benedict's test	Negative
3	Phenols • Tannis test	Positive

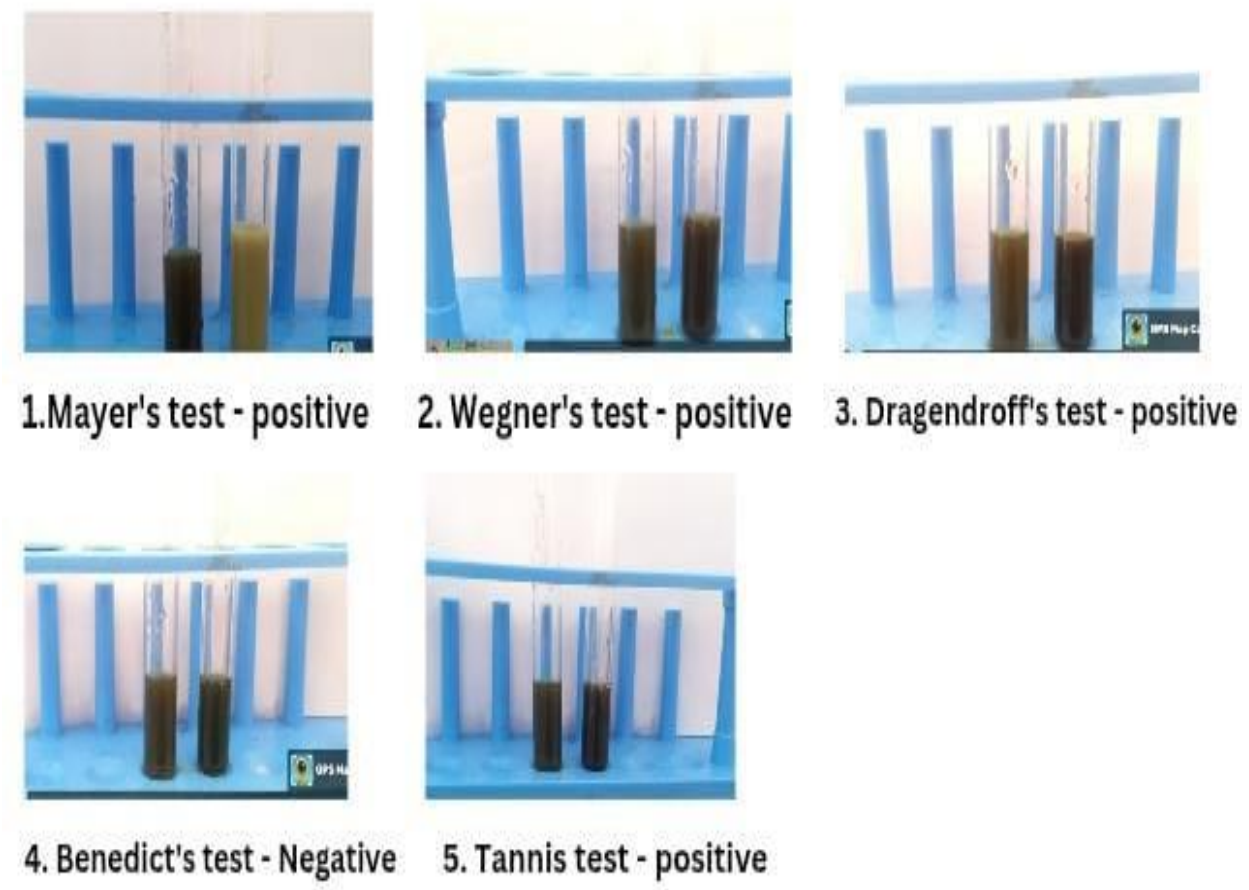


Figure8 shows the phytochemical test of *Ocimum sanctum*

IV. DISCUSSION

Researchers previously investigated the use of hydroponics for sustainable crop production. A 2020 study published in the Journal of Agricultural Engineering Research explored the potential of hydroponics for growing leafy greens in urban areas. The researchers found that hydroponics increased crop yields and reduced water consumption compared to traditional soil-based farming methods. Another study published in 2022 in the journal Horticulturae examined the effects of different nutrient solutions on plant growth in hydroponic systems. The researchers discovered that a customized nutrient solution improved plant growth and reduced nutrient waste. These findings have contributed to the development of more efficient and sustainable hydroponic systems for commercial crop production. Researchers previously analyzed the nutritional composition of coconut coir and found that it contained a range of beneficial nutrients for plant growth. A 2020 study published in the Journal of Horticultural Science and Biotechnology reported that coconut coir was rich in potassium, magnesium, and sulfur, which are essential macronutrients for plant development. The study also detected the presence of micronutrients like boron, copper, and zinc in coconut coir. Another study published in 2022 in the journal Agriculture found that coconut coir contained humic acids, which are natural plant growth promoters. The researchers discovered that the humic acids in coconut coir increased plant root growth, nutrient uptake, and water retention, leading to improved plant yields and drought tolerance. These findings highlighted the potential of coconut coir as a sustainable and effective growing medium for promoting plant growth and development. Researchers previously isolated *Enterobacteriaceae*, a family of beneficial bacteria, from coconut coir using MacConkey agar plates. These bacteria were found to play a crucial role in promoting plant growth by producing plant growth-promoting substances, such as auxins and cytokinins. Additionally, *Bacillus spp.* and *Staphylococcus spp*. were also isolated from coconut coir using Tryptic Soy Agar (TSA) plates. These bacteria were found to have antagonistic effects against plant pathogens, thereby promoting a healthy plant microbiome. The presence of these beneficial microorganisms in coconut coir was found to have a positive impact on plant growth and development. Studies showed that coconut coir inoculated with these microorganisms resulted in increased plant biomass, root growth, and nutrient uptake. The beneficial effects of these microorganisms on plant growth were attributed to their ability to produce plant growth-promoting substances, solubilize minerals, and suppress plant pathogens. These findings highlighted the potential of coconut coir as a natural and sustainable medium for promoting plant growth and development.

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