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Revolutionizing Tomato Cultivation through Panchgavya Enriched NFT Hydroponics

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Due to various man-made factors, including industrialization and urbanization, soil-based agriculture is currently experiencing difficulties. Additionally, unforeseen natural disasters, climate change, and the uncontrolled use of chemicals in agriculture reduce soil fertility and quality. Because of this, scientists have created a new alternative method of cultivation known as hydroponics or soilless cultivation. One such type of soilless growing is known as "hydroponics," and it uses less water than a typical system. Because it produces high-quality food and manages resources very effectively, hydroponic farming is currently gaining appeal on a global scale. Various hydroponic systems, including wick, ebb and flow, drip, deep water culture, and Nutrient Film

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Technique (NFT) systems, are discussed in this article. In general, hydroponically grown produce has superior nutritional value, flavor, and yield quality than naturally grown produce on the soil [1]. This method of farming is economical, free of diseases, environmentally benign, and gaining appeal both in developed and developing nations worldwide. Crops can be grown in a variety of hydroponic systems. Commercially, the Nutrient Film Technique (NFT) has been applied around the world for the cultivation of leafy and other exotic vegetables. In hydroponic systems, which use a variety of non-soil growing media, mineral fertilizer solutions are used to feed the plants in water. When compared to traditional farming techniques, hydroponics technology offers a wide range of advantages whilst having few drawbacks.

Keywords: Soilless farming; nutrient film technique; hydroponic farming; panchgavya; tomato.

1. INTRODUCTION

The term "hydroponics" refers to a method of growing plants in nutrient solutions with or without the use of an inert medium to give mechanical support, such as gravel, vermiculite, coir dust, coconut fiber, rockwool, peat moss, sawdust, etc. The Greek term hydro means water and ponos means labor, hence the term hydroponics refers literally to "water work." Professor William Gericke first used the term "hydroponics" in the early 1930s. The major contributor to India's economy is Agriculture. There is a rise in interest in indoor farming, such as hydroponics, due to factors including rising food demand, labor costs, unfavorable environmental conditions, and a reduction in agricultural land [2,3] Varsha et al., 2022. Soil-less agriculture may be effectively started in the current context and viewed as an alternate choice for growing nutritious food plants, crops, or vegetables [4]. There is no mention of soil in the context of cultivating plants traditionally. That indicates that plants can develop as long as certain conditions are met. The concept of hydroponic farming is introduced. In this method, mineral fertilizer solutions in water serve as a solvent, allowing plants to absorb nutrients from the soil more effectively. It is possible to cultivate native plants by exposing their roots to the nutrient solution. According to the needs of various plants, most hydroponic systems automatically adjust the amount of water, nutrients, and photoperiod [5]. Various commercial and special crops can be grown using hydroponics including leafy vegetables, tomatoes, cucumber, pepper, strawberry and many more. Non-soil growing media can be used in hydroponics to provide mechanical support to roots, allowing them to hold the plant's weight and stand erect. In hydroponics, media such as sand, gravel, river rock, oasis cubes, floral foam, vermiculite, rockwool, perlite, peat moss, coir, coco-peat, and sawdust are frequently used. Europe is the largest market for hydroponics, with France, the Netherlands, and Spain as the top three producers, followed by the United States of America and the Asia-Pacific region [6].

Growers claim that hydroponic systems are the only way to achieve continuous production, meaning that plants may be grown anywhere, including in small spaces with a controlled growth environment, all year long, and in a short growing period [7]. In response, growers frequently state that hydroponics always enables them to produce more with less effort, regardless of the climate or weather [8]. Additionally, growers frequently state that hydroponic productions are simpler and lighter and cleaner because they don't involve cultural activities like weeding, plowing, fertilizing the soil, or rotating the crops [9]. To prevent excessive salinization and to control microbiological illnesses and pests to prevent any production losses, it is also essential and effective to monitor nutritional solutions and daily measurements of liquid nutrients [10]. According to Taiz and Zeiger [11], an essential element has a distinct physiological function and its absence inhibits the entire plant life cycle. According to [12], 17 elements necessary for the majority of plants. Based on various concentrations of the media described by [13], all 17 elements should be provided for proper growth and development.

1.1 Advantages (Arjina Shrestha & Bruce Dunn)

- It can be employed in regions with harsh climates or dry deserts where in-ground farming or gardening is not feasible.
- Greater control over PH, nutrient supply, and growing conditions.
- Water and nutrient recycling results in lower water and nutrient expenditures.
- Faster growth as a result of greater oxygen being available to roots
- Reduction or eradication of bacteria, fungi, and insects that are associated with soil.

- Increased crop yields
- No cultivation or weeding is necessary.
- For planting, cultivating, and harvesting, some crops, like lettuce and strawberries, can be raised from the ground to a much superior height. As a result, labor costs are reduced and there are significantly better working conditions.
- Crop rotation or foraging is not required.

1.2 Disadvantages

- The initial building cost per acre is rather high.
- The growth operation must be managed by trained workers. It is crucial to understand the fundamentals of nutrition and plant growth.
- Introduced soil-borne illnesses and nematodes may swiftly spread to all beds on the same nutrient tank.
- The majority of plant species now in existence that are acclimated to regulated growth environments will need further study and development.
- The plant responds to excellent or bad nourishment quite quickly. Every day, the grower must keep an eye on the plants.

1.3 The Operation and Hydroponic Structures

The recycling and reuse of nutrient solutions and supporting mediums are customized and adjusted in hydroponic systems.

a) **Drip systems**

Drip systems make it relatively easy to manage moisture with the aid of a pump, individual plant roots are supplied with the proper amount of nutrient solution from the tank or reservoir [14]. Plants are often planted on growth media that is only moderately absorbent in order to make the nutrient solution drip slowly.

b) **Wick System**

This sort of hydroponic system is the simplest and least common because it doesn't need a pump or an electric motor [15]. Plants receive water or fertilizer solutions by capillary action. Use a bigger/wider wick, or more than one, to manage how much water gets to the plant. This approach is good for little plants, herbs, and spices but ineffective for plants that require a lot of water.

c) Deep water culture system

The system that is easiest to utilize is deep water culturing. The plants are kept on a floating platform made of Styrofoam or a comparable material in the fertilizer solution. Through aquarium air pumps, the roots of the plants are given an external supply of oxygen. The method most frequently employed for green vegetables is water culture.

d) Nutrient Film Technique (NFT) system

Water or a nutrient solution circulates throughout the system and enters the growing tray via a water pump with no timer [16]. The system is sloped slightly so that nutrient solution travels through the roots and down into a reservoir. Plants are grown in a channel or tube with their roots dangling in a hydroponic solution. Roots, on the other hand, are prone to fungal infection because they are constantly immersed in water or nutrients. Many leafy greens can be easily grown in this method, which is most commonly utilized for lettuce production professionally.

e) Ebb-Flow (flood and drain) systems:

The design of flood and drain systems can vary quite a bit, and they are said to be the first commercial hydroponic system that uses the flood and drain principle. A water pump pumped nutrient solution from the reservoir into the system. The system recycles the extra water by returning it to the reservoir via gravity.

f) Aeroponic systems:

The most technologically advanced hydroponic farming method is arguably the aeroponic system. In this method, plants are grown while having their roots suspended in the air and receiving constant nutritional solution spraying. The misting often takes place every few minutes. Unlike other systems that run the pump for a brief period every few minutes, the aeroponic system requires a short cycle timer. Image courtesy of Sharma et al., 2018.

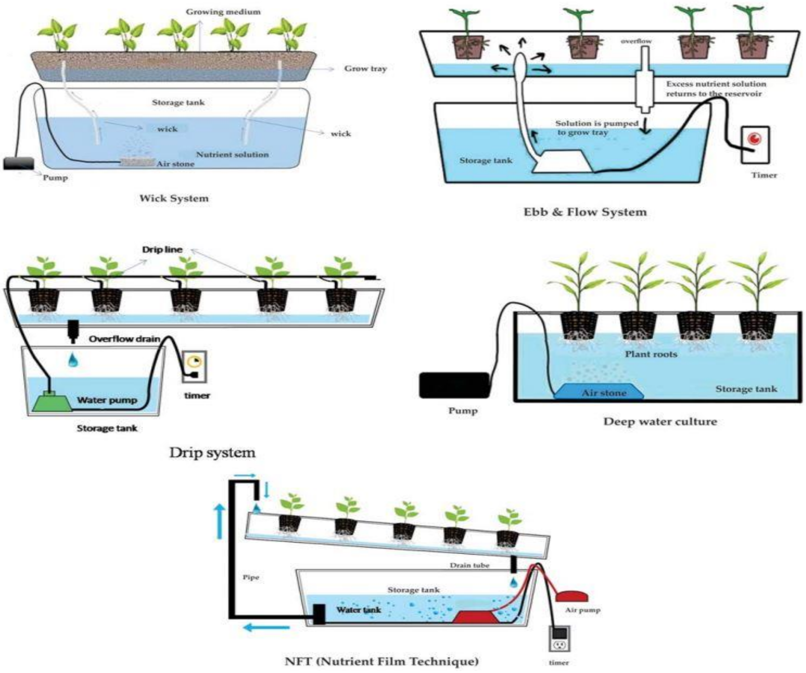

Fig. 1. Diagram of various structures of hydroponic system

2. MATERIALS AND METHODS

2.2 Experimental Setup and Plant Growth

The experiments were conducted at the School of Agricultural Sciences, G D Goenka University, Gurugram. The plants selected for the study were tomatoes (*Solanum lycopersicum*). The growth system utilized was the Nutrient Film Technique (NFT), designed to provide hydroponic conditions for plant growth. The following materials were employed for the experimental setup:

2.3 Materials

1. Plywood: Used to construct the support structure for the NFT system.
2. Soft Drink Bottles: Employed as growing containers for tomato plants.
3. Ice Cream Sticks: Utilized for providing support to the tomato plants within the soft drink bottles.
4. Water Motor: Used to circulate the nutrient solution through the NFT channels.
5. Paper Tray: Placed beneath the NFT channels to collect excess nutrient solution.
6. Pipes: Used to create the NFT channels through which the nutrient solution flowed.
7. Cotton Plugs: Used to secure the tomato plants within the soft drink bottles.

2.4 Plant Propagation

1. Tomato seeds were germinated in a separate nursery setup using standard methods.
2. Once seedlings developed their first set of true leaves, they were transplanted into the prepared soft drink bottles filled with a suitable growing medium.
3. Ice cream sticks were positioned in the growing medium to provide support for the tomato plants as they grew.

2.5 Nutrient Supply: Panchagavya Solution

1. Panchagavya, a natural mixture derived from cow by-products, was prepared using cow urine, cow milk, cow ghee, and cow curd.
2. The Panchagavya solution was composed of a variety of nutrients, including macronutrients (N, P, K) and micronutrients (amino acids, vitamins, auxins, gibberellins) essential for plant growth.
3. The Panchagavya solution also contained beneficial microorganisms important for plant development.

Table 1. Concentration range found in PANCHGAVYA solutions

P^H	6.01
E.C (ds/m)	3.01
Organic carbon (%)	2.07
Nitrogen (%)	6.08
Phosphorous (%)	0.05
Potassium (%)	0.04
Magnesium(mg/kg)	0.24
Copper(mg/kg)	0.28
Zinc(mg/kg)	0.32
Iron(mg/kg)	0.98

Hydroponics necessitates rigorous system monitoring due to the system's limited ability to buffer nutrients and its flexibility to respond quickly. The supply of nutrients from the nutrient delivery system and the plant's reaction to nutrients are two aspects of nutrition that must be taken into account. In order to avoid damaging the leaves and the development of diseases, the solution should only be applied to the roots. The final yield of plants should never be compromised by allowing them to experience water stress. In order to flush away any leftover excess salts, it is typically advised that you water the plants only once per week. Use twice as much water as is typically used, but leave out nutrients.

2.6 Nutrient Solutions

17 key components are needed by plants for vegetative and reproductive growth. Hydrogen, oxygen, and carbon make up the first three.
The other 14 include:

- Nitrogen, phosphorus, potassium, calcium, magnesium, and Sulphur are macronutrients, with the first three of these being categorized as primary nutrients and the other three as secondary nutrients.
- Iron, manganese, copper, zinc, boron, chlorine, molybdenum, and nickel are microelements.
- Nutrient control in hydroponics is fairly simple.
- Nitrogen typically improves plant vegetative growth.
- Potassium and phosphorus support a plant's ability to reproduce and flower.

The combination of macro and micronutrients, such as nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, boron, zinc, copper, molybdenum, and chlorine, is necessary for plants to grow properly. The range of nutrient solutions acceptable for plant growth can be quite extensive, within specified bounds of composition and total concentrations. The minor amount of minerals in the water supply may typically be disregarded. However, the plants will suffer if there is an excess or lack of nutrients in the solution.

2.7 Experimental Design

1. The tomato plants were divided into different treatment groups based on the nutrient solutions they received.
2. The control group received a standard nutrient solution that provided all necessary nutrients for plant growth except those being tested.
3. Other treatment groups received the Panchagavya solution in varying concentrations.

2.8 Data Collection and Analysis

1. The tomato plants were regularly monitored for growth parameters such as height, number of leaves, and flowering.
2. Data on plant growth was collected and statistically analyzed to determine the effects of the Panchagavya solution on tomato growth.

Calculation of the yield for each treatment group was done by the formula:

Yield (kg/plant) = (Number of Fruits per plant) x (Average Fruit Weight per fruit) / 1000

Fig. 2. NFT system Hydroponics Model

3. RESULTS

The effects of different concentrations (0.5%, 1%, and 1.5%) of Panchagavya solution on the growth and productivity of tomato plants in a Nutrient Film Technique (NFT) hydroponic system were observed and analyzed. Here are the results and discussions for each concentration:

3.1 Control Group (0% Panchagavya)

- Height: The control group showed standard growth, with plants reaching an average height of 10.2cm, 22.32cm, 31.26 cm at 30,60 and 90 DAT
- Number of Branches: The control group exhibited an average of 5.13 Branches per plant.
- Flowering: Flowering in the control group occurred at the expected time.
- Number of fruits: The control group exhibited an average of 6 fruits per plant
- Fruit weight: Average fruit weight was 20g
- Fruit diameter: Average fruit diameter was 35mm

3.2 Treatment Group 1 (0.5% Panchagavya)

- Height: Tomato plants in this group grew significantly taller, with an average height of 13.1cm, 25.7cm, 34.52 cm at 30,60 and 90 DAT cm compared to the control group.
- Number of Branches: The number of Branches increased to an average of 7.52 Branches per plant.
- Flowering: Plants in this group started flowering slightly earlier than the control group.
- Number of fruits: The control group exhibited an average of 9 fruits per plant
- Fruit weight: Average fruit weight was 29g
- Fruit diameter: Average fruit diameter was 42mm

3.3 Treatment Group 2 (1% Panchagavya)

- Height: Tomato plants in this group exhibited robust growth, reaching an average height of 14.03cm, 27.89 cm, 37.31 cm at 30,60 and 90 DAT cm indicating a substantial increase compared to the control group.
- Number of: The Branches: Number of Branches per plant increased to an average of 9.09 branches
- Flowering: Early flowering was observed in this group, with plants flowering noticeably ahead of the control group.
- Number of fruits: The control group exhibited an average of 16 fruits per plant
- Fruit weight: Average fruit weight was 37g
- Fruit diameter: Average fruit diameter was 48mm

3.4 Treatment Group 3 (1.5% Panchagavya)

- Height: Tomato plants in this group displayed the most significant growth, with an average height of 15.9cm, 30.23cm, 38.67 cm at 30,60 and 90 DAT cm showcasing the highest increase compared to the control group.
- Number of Branches: The number of Branches per plant significantly increased to an average of 11.6 Branches
- Flowering: Plants in this group exhibited the earliest flowering, surpassing all other groups.
- Number of fruits: The control group exhibited an average of 21 fruits per plant
- Fruit weight: Average fruit weight was 41g
- Fruit diameter: Average fruit diameter was 57mm

4. DISCUSSION

- The results indicate that the application of Panchagavya solution in varying concentrations had a positive impact on the growth and productivity of tomato plants in the NFT hydroponic system [17,18].
- Higher concentrations of Panchagavya solution (1% and 1.5%) resulted in more substantial increases in plant height, number of leaves, and early flowering compared to the control group and the group with a lower concentration (0.5%).
- The observed trend suggests that the effect of Panchagavya on plant growth is concentration-dependent, with higher concentrations yielding more pronounced results.
- The increased growth and early flowering in treatment groups with Panchagavya application can be attributed to the nutrient-rich composition of Panchagavya, including macronutrients, micronutrients,

amino acids, vitamins, and beneficial microorganisms.
- These findings support the hypothesis that the application of Panchagavya solution enhances the growth and productivity of tomato plants in hydroponic systems, with higher concentrations providing the most significant benefits.

Tomato growth, productivity, and mineral composition improved when grown in an NFT system with frequent recycling of nutrient solutions; however, yield increased in an NFT system with prolonged recycling of nutrient solutions [19-22]. Cucurbits, such as cucumber and cantaloupe, are also effectively cultivated in a variety of hydroponic systems in addition to tomatoes and peppers. Cucumber optimization experiments were done in several hydroponic systems for salinity, EC, and nutrients. The NFT system was discovered to be.

Table 2. Data of different treatment groups (Control, 0.5%, 1%, and 1.5% Panchagavya concentrations) of tomato plants in a Nutrient Film Technique (NFT) hydroponic system

Parameters	Control Group (0% Panchagavya)	Treatment Group 1 (0.5% Panchagavya)	Treatment Group 2 (1% Panchagavya)	Treatment Group 3 (1.5% Panchagavya)
Height (30 DAT) (cm)	10.2	13.1	14.03	15.9
Height (60 DAT) (cm)	22.32	25.7	27.89	30.23
Height (90 DAT) (cm)	31.26	34.52	37.31	38.67
Number of Branches	5.13	7.52	9.09	11.6
Flowering	On time	Slightly earlier	Early	Earliest
Number of Fruits	6	9	16	21
Fruit Weight (g)	20	29	37	41
Fruit Diameter (mm)	35	42	48	57
Yield (kg/plant)	0.122	0.261	0.592	0.861

List of Crops that can be grown without Soil [23]

Table 3. List of crops that can be grown on a commercial level using soil-less culture

Type of crops	Name of the crops
Cereals	*Oryza sativa* (Rice), *Zea mays* (Maize)
Fruits	*Fragaria ananassa* (Strawberry)
Vegetables	*Lycopersicon esculentum (*Tomato*), Capsicum frutescens (*Chilli*), Solanum melongena (*Brinjal*), Phaseolus vulgaris (*Green bean*), Beta vulgaris (*Beet*), Psophocarpus tetragonolobus (*Winged bean*), Capsicum annum (*Bell pepper*), Brassica oleracea var. Capitata (*Cabbage*), Brassica oleracea var. Botrytis (*Cauliflower*), Cucumis sativus (*Cucumbers*), Cucumis melo (*Melons*), Raphanus sativus (*Radish*), Allium cepa (*Onion*)*
Condiments	*Petroselinum crispum* (Parsley), *Mentha spicata* (Mint), *Ocimum basilicum* (Sweet basil), *Origanum vulgare* (Oregano)
Flower/ Ornamental crops	*Tagetes patula* (Marigold), *Rosa berberifolia* (Roses), *Dianthus caryophyllus* (Carnations), *Chrysanthemum indicum* (Chrysanthemum)
Medicinal crops	*Aloe vera* (Indian Aloe), *Solenostemon scutellarioides* (Coleus)
Fodder crops	*Sorghum bicolor* (Sorghum), *Medicago sativa* (Alphalfa), *Hordeum vulgare* (Barley), *Cynodon dactylon* (Bermuda grass), *Axonopus compressus* (Carpet grass)

the most effective for cantaloupe growth and productivity. The idea is that plants are capable of absorbing enough nutrients for typical growth from flowing solutions at high concentrations [24]. This may be related to the flow of solution, which prevents local depletion near the roots, as well as a compensating increase in the rate of uptake, as with P [25]. Therefore, when high nutrient concentrations are consistently maintained and never allowed to decrease, normal growth is possible [26-28].

5. CONCLUSION

The most intensive type of crop production now employed in the agriculture sector, hydroponic culture, is mostly used in industrialized and developing nations to produce food in small spaces. Hydroponics can make a significant contribution in locations with limited soil and water as well as for the impoverished and landless people because it is feasible to grow short-duration crops like vegetables year-round in relatively small spaces with little labor. In a short period of time, hydroponics' notoriety has grown significantly, spurring further experimentation and study in the field of indoor and outdoor hydroponic farming. The hydroponic sector in India is anticipated to expand rapidly in the near future.

In conclusion, the use of Panchagavya solution in hydroponic tomato cultivation can be an effective strategy to maximize plant growth and yield. Further studies may focus on optimizing the concentration of Panchagavya for specific crops and growth conditions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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