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Sustainable Hydroponics using Fermented Plant Juice Nutrition

Replacing Inorganic Chemical Nutrition with FPJ In Hydroponics.

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***Abstract*:- Post green revolution, environment pollution due to chemical inputs, surge in biodegradable agri waste, highly stressed water resources due to conventional irrigation systems etc., has been obstructions in India's aspirations of enhancing food security for its burgeoning population. Precision irrigation systems such as hydroponics efficiently addresses the issues of decreasing land area, require less water and also minimizes chemical inputs in agriculture, along with higher yield. Here, a major disadvantage can be the higher cost of inputs and pollution from the inorganic nutrient solution. This study puts forward a sustainable alternative in the form of fermented plant juice derived from agri residues/weeds and household biodegradable waste, for hydroponics nutrition.**

Keywords:- Hydroponics; Agricultural pollution; precision irrigation; Fermented Plant Juice; solid state fermentation.

I. INTRODUCTION

It is estimated that in India, the land requirement for solid waste processing sites such as landfills would require an additional land area which is double that it occupies today. Also, post green revolution, environment pollution due to chemical inputs, surge in biodegradable agri waste, highly stressed water resources due to conventional irrigation systems etc., has been obstructions in India's aspirations of enhancing food security for its burgeoning population.

The presently employed conventional solutions, which are considered sustainable include, recycling/ composting for biodegradable wastes and waste to energy conversion for non-biodegradable waste. The former process is bulky and often require higher land area and the latter is capital intensive and does not contribute to ensuring food security.

Precision irrigation systems such as hydroponics efficiently addresses the issues of decreasing land area, require less water and also minimizes chemical inputs in agriculture, along with higher yield. Here, a major disadvantage can be the higher cost of inputs and pollution from the inorganic nutrient solution. This study puts forward a sustainable alternative in the form of fermented plant juice derived from agri residues/weeds and household biodegradable waste, for hydroponics nutrition.

The Fermented Plant Juice (FPJ) is an easily available organic substitutes to prepare hydroponic nutrient solution, which would reduce the dependence on their costly commercial counterparts. FPJ naturally optimse the required plant nutrients and is a component of Korean Natural farming system widely popularized by Dr.Chou Han Kyu. [1]

II. ADVANTAGES AND DISADVANTAGES OF HYDROPONICS

A. Advantages

1. High water efficiency (~99%) compared to open soil cultivation.
2. Very less space requirement.
3. Low rate of weed growth and pest infestation owing to controlled growing conditions.
4. Irrigation independent of large unsustainable structures like dams and reservoirs.
5. Better nutrient absorption and high yield.

B. Disadvantages

1. High initial set-up cost
2. Unviable in large agricultural set-ups owing to high cost of the commercially available nutrient solution.

III. FERMENTED PLANT JUICE AS NUTRIENT SOLUTION

FPJ is the fermented extract of plants sap and chlorophyll. It utilizes indigenous micro-organisms to carry out the invigoration process. The usual dilution rates at which it's used, vary from 1:800 to 1000 in water.

The Fermented plant juice is one of the inputs of Korean natural farming practices popularized and known by the name of Chou Han Kyu. It's a versatile mixture of fermented plant parts that can be used as fertilizer, foliar spray as well as an organic pesticide in varying concentrations and hence chosen for the study. If proved to be efficient, it can be widely used in commercial hydroponic cultivations throughout the world with very less economic input.

In this study there are two types of fermented plant juices analysed in comparison to inorganic nutrient solution, i.e., FPJ1 (sourced from weeds/agri residue)and FPJ2 (sourced from plant based household waste)

A. Steps of Preparation of FPJ 1

The FPJ1 is derived from common weeds found abundantly growing in Calicut and nearby localities in, Kerala, India, such as Phyllanthus niruri. These weeds show vigorous and quick growth, is found to be resilient to multiple climatic conditions. They have growth hormones that are very active and can therefore pass down these characteristics to

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plants which derive nutrition from FPJ prepared from them. The steps involved in the preparation are as follows:

- Collect the plant in the early hours of the morning to retain the maximum turgor pressure in the plant cells.
- Cut the plant into short pieces of about 3-5 cm.
- Take the plant and jaggery in 1:0.5 ratio by weight.
- Crush the jaggery so as to have maximum uniform contact area with the plant.
- Thoroughly mix the plant pieces and crushed jaggery with hands or a mechanical mixer.
- Put the mixture in a clay pot or a metal container and seal it.
- Label the container with the date of mixing and leave it undisturbed at a cool, dark and dry area, continuously for seven days.
- After seven days open the container, strain the fermented liquid and store it in a clean bottle.

Fig. 1 Steps of preparation of FPJ1.

B. Steps of preparation of FPJ2

The FPJ2 is derived from plant based household biodegradable wastes and include fruit and vegetable peels, tea leaves residue, papers, etc. these are collected from waste generated in a household of five members for seven days. The steps involved in the preparation are as follows:

- Shred the waste collected into short pieces of about 3-5 cm.
- Take the shredded waste and jaggery in 1:0.5 ratio by weight.
- Crush the jaggery so as to have maximum uniform contact area with the waste mixture.
- Thoroughly mix the shredded waste mixture and crushed jaggery with hands or a mechanical mixer.
- Put the mixture in a clay pot or a metal container and seal it.
- Label the container with the date of mixing and leave it undisturbed at a cool, dark and dry area, continuously for seven days.
- After seven days open the container, strain the fermented liquid and store it in a clean bottle.

Fig. 2. Steps of preparation of FPJ2.

IV. EXPERIMENTAL SETUP AND METHODOLOGY.

The experimental setup consist of ; Containers to be used as nutrient reservoir for plants, Net pot and coco peat for support, aeration system to the plant roots, seeds or stem cutting as plant propagules and a TDS meter.

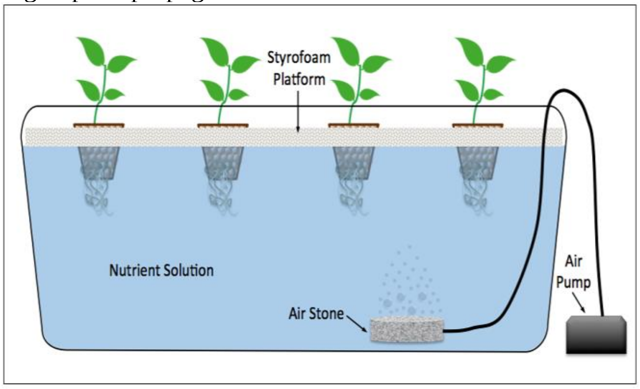

Fig. 3. Schematic diagram of the experimental setup. [10]

A. Methodology

- Step 1: Installation of set-up.
- Step 2: Preparation of Commercial -Nutrient Solution.
- Step 3: Setting up of soil nutrition system.

Phase 1- Water use efficiency calculation.

- Step 4: Water usage monitoring and calculation of Efficiency.

Phase 2 – Comparison of FPJ 1, FPJ 2 and CNS

- Step 5 : Preparation of FPJ 1
- Step 6: Preparation of FPJ 2
- Step 7: Measurement of Growth parameters (For FPJ and CNS systems)
- Step 8: Measurement of mineral uptake in terms of TDS.
- Step 9: Measurement of biomass development. (Using dry weight, wet weight and root-shoot ratio.)

V. EXPERIMENTAL PROCEDURE

The experiment is carried out as described below:

A. Installation of setup.

The experimental setup consist of :

a. Potted plants grown with normal soil nutrition.(Batch 1)
b. Plants grown in hydroponic inorganic commercial nutrition-CNS (Batch 2)
c. Plants grown in hydroponic FPJ1 nutrition (Batch 3)
d. Plants grown in hydroponic FPJ2 nutrition (Batch 4)

B. Preparation of Inorganic nutrient solution.

The inorganic salt containing the essential micro and macro-nutrients essential for plant growth, are mixed in distilled water in correct proportion and filled in the nutrient reservoir for batch1.

Fig. 4. Inorganic nutrients used for batch 1.

C. Setting up of soil nutrition system.

- A container of same volume of that of the hydroponic system is chosen and filled with soil.

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- The plants saplings are transplanted into the soil pot on the same day as the hydroponics system is prepared.
- The plants are nourished with the normal level of nutrients naturally available in the soil.
- The amount of water as per requirement for the plant growth should be provided and measured.
- Ensure that the system receive the same atmospheric conditions of that of the hydroponic system, other than the nutrients.

D. Water usage monitoring and calculation of Efficiency.

The volume of water utilized in the study period for Batch1 and Batch2 are observed and recorded in the following tables:

TABLE I. WATER USAGE MONITORING (BATCH 1)

Cycle	Water usage per cycle (L)
1	14
2	14
3	14
4	14
5	28
6	28
7	28
8	28

Total water usage = Σ (Water usage per cycle) = 168 L.

TABLE II. WATER USAGE MONITORING (BATCH 2)

Cycle	Initial water content (L)	Final water content (L)	Water usage per cycle = Initial - Final (L)
1	3	2.874	0.126
2	3	2.857	0.143
3	3	2.848	0.152
4	3	2.795	0.205
5	3	2.763	0.237
6	3	2.738	0.262
7	3	2.687	0.313
8	3	2.665	0.335

Total water usage = Σ(Water usage per cycle)= 1.773 L.

- Calculations:

Water required for batch 2-hydroponic inorganic nutrition (represented as X%) as a percentage of water required for batch 1 (soil nutrition system)

$= (168 \times X)/100 = 1.773L$

Since, $X = (1.773 \times 100)/168$

$X = 1.055$ %

Water efficiency of hydroponic system compared to open soil system = 100-1.055 **= 98.945 %**

E. Measurement of Growth parameters

The plants Chosen for the study are *Mentha spicata* (Spear mint), whose leaves are of commercial importance and *Capsicum frutescens* (Bird's eye Chilli), whose fruits are of commercial importance. The suitability of the nutrient medium for the plants under consideration are analysed by comparing the growth of these plants when provided individually with each of the four nutrition mediums studied in all the four batches.

a. Growth parameter 1: Length of largest leaf (mm).

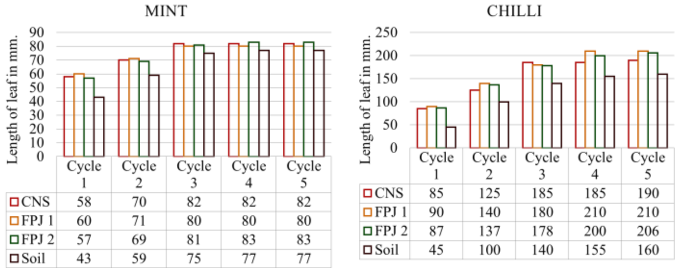

Fig. 5. Comparison of Growth parameter 1 in all the batches.

b. Growth parameter 2: Width of largest leaf (mm)

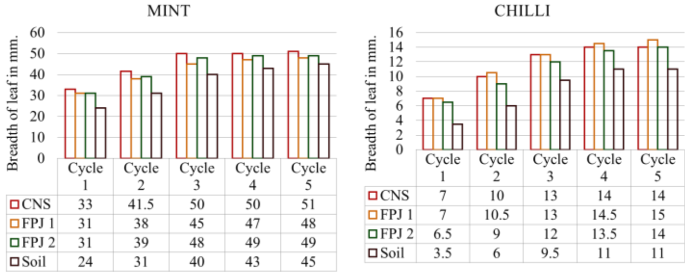

Fig. 6. Comparison of Growth parameter 2 in all the batches.

In analysis of Growth parameters 1&2 (fig.5 and fig.6) representing the size of leaves: While FPJ2 performed best for mint and FPJ1 for Chilli, growth under Inorganic Commercial Nutrient solution (CNS) was comparable.

c. Growth parameter 3:Number of leaves.

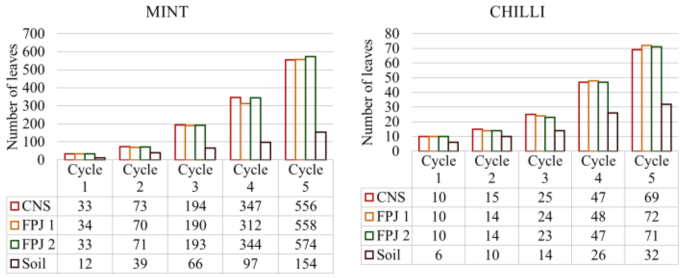

Fig. 7. Comparison of Growth parameter 3 in all the batches.

In analysis of Growth parameter 3 (fig.7) representing the quantity of foliage: FPJ2 performed best for mint while it was nearly same for Chilli in all three hydroponic systems.

d. Growth parameter 4:No.of stolon/buds.

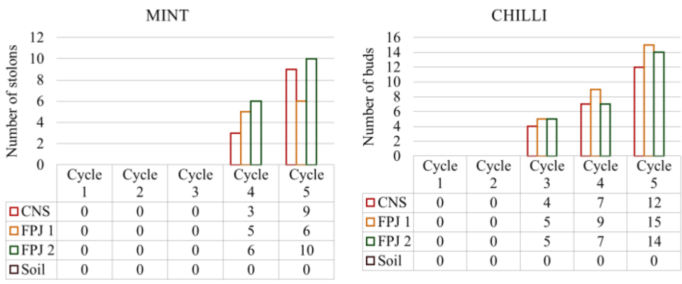

Fig. 8. Comparison of Growth parameter 4 in all the batches.

In analysis of growth parameter 4 (fig.8) representing the vegetative capacity: Number of stolons in mint was highest in FPJ2 whereas number of buds was highest for Chilli in FPJ1 nutrition.

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e. Growth parameter 5: No.of branches.

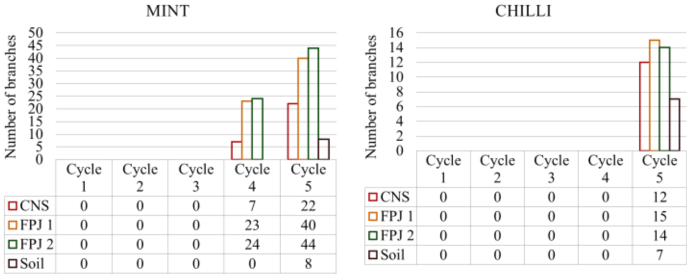

Fig. 9. Comparison of Growth parameter 5 in all the batches.

In analysis of growth parameter 5(fig.9) representing size of the plant: FPJ 1&2 gave better result than CNS in developing branches.

f. Inference- Comparison of growth parameters

- FPJ2 is suitable for mint and similar horticorps whose leaves are commercially important. Therefore CNS can be replaced with FPJ2 for such plants in Hydroponic culture.
- FPJ1 is suitable for Chilli and similar horticorps whose fruits are commercially important. Therefore CNS can be replaced with FPJ1 for such plants in Hydroponic culture.
- Soil nutrition yielded poor results in terms of all the growth parameters studied. This is probably due to lack of micro nutrients in the soil, which is essential for plant growth.

F. Mineral uptake in terms of TDS

The Total dissolved Solids (TDS) can be taken as a direct measurement of the minerals dissolved in a solution. In this study the TDS variation over time is measured for the solution of nutrient reservoirs in the hydroponic systems. As the plant utilizes minerals for its growth, the decrease in TDS in the reservoir nutrient solution, is an indirect measurement of mineral uptake by the plants during the observation period.

a. Mineral uptake in terms of TDS (CNS)

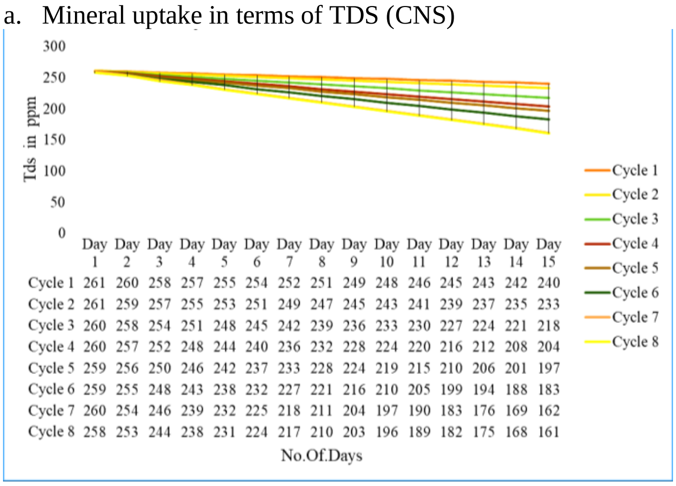

Fig. 10. Mineral uptake in TDS (ppm) for CNS (Batch2)

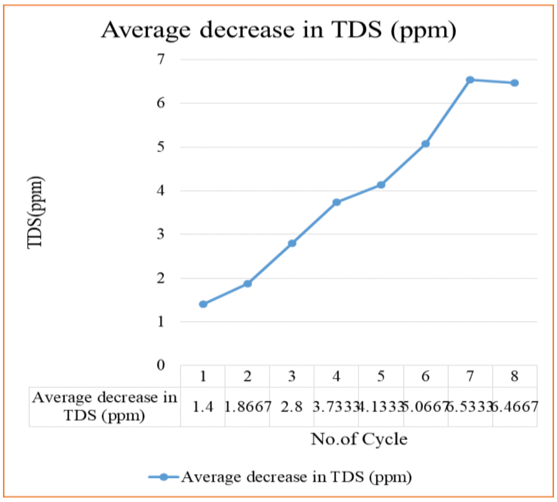

Fig.11. Average decrease in TDS (ppm) for CNS (Batch2)

b. Mineral uptake in terms of TDS (FPJ 1)

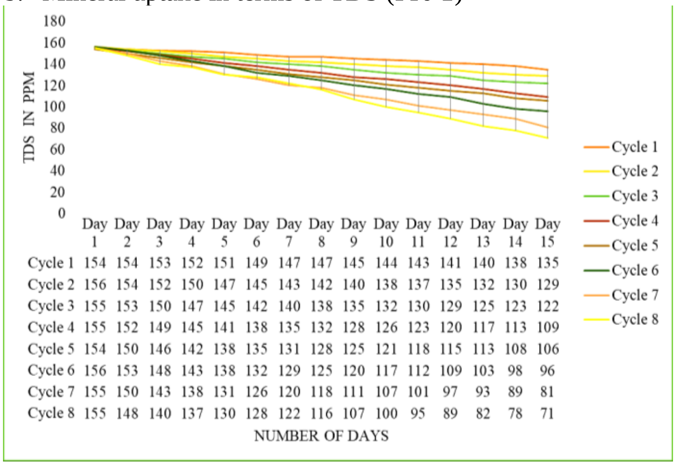

Fig.12. Mineral uptake in TDS (ppm) for FPJ 1 (Batch 3).

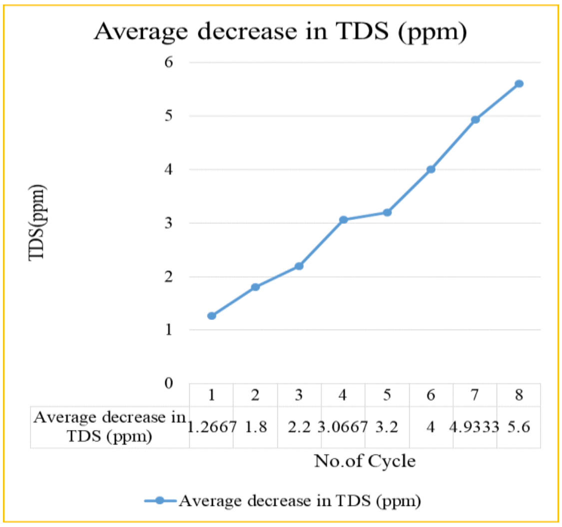

Fig. 13. Average decrease in TDS (ppm) for FPJ 1 (Batch 3).

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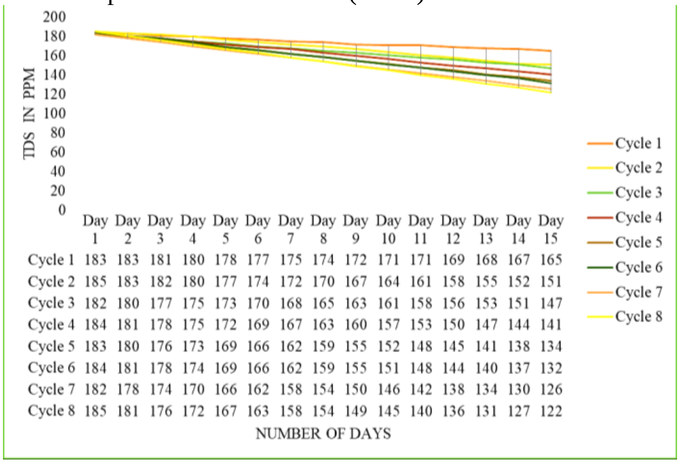
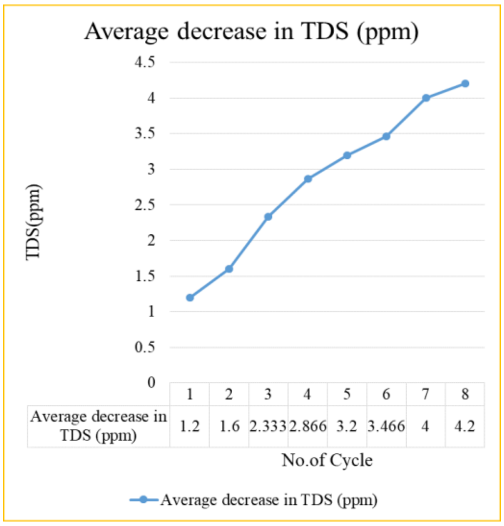
c. Mineral uptake in terms of TDS (FPJ 2)



	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15
Cycle 1	183	183	181	180	178	177	175	174	172	171	171	169	168	167	165
Cycle 2	185	183	182	180	177	174	172	170	167	164	161	158	155	152	151
Cycle 3	182	180	177	175	173	170	168	165	163	161	158	156	153	151	147
Cycle 4	184	181	178	175	172	169	167	163	160	157	153	150	147	144	141
Cycle 5	183	180	176	173	169	166	162	159	155	152	148	145	141	138	134
Cycle 6	184	181	178	174	169	166	162	159	155	151	148	144	140	137	132
Cycle 7	182	178	174	170	166	162	158	154	150	146	142	138	134	130	126
Cycle 8	185	181	176	172	167	163	158	154	149	145	140	136	131	127	122

Fig. 14. Mineral uptake in TDS (ppm) for FPJ 2 (Batch 4)



	1	2	3	4	5	6	7	8
Average decrease in TDS (ppm)	1.2	1.6	2.333	2.866	3.2	3.466	4	4.2

Fig. 15. Average decrease in TDS (ppm) for FPJ 2 (Batch 4).

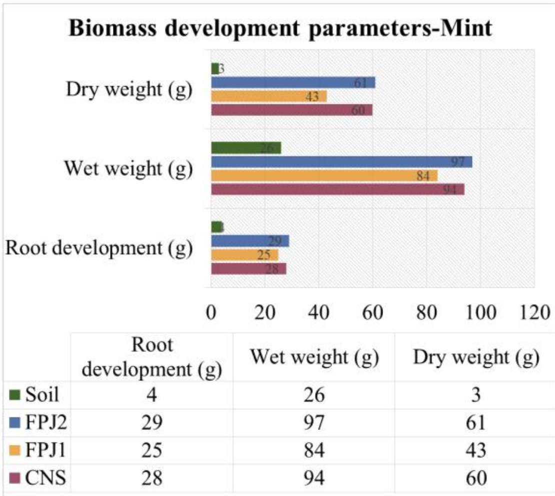
d. Inference – Mineral Uptake measurement.

- A decline in TDS of the nutrient medium overtime is a representation of dissolved minerals of the media being used for plant growth.
- The average decrease in TDS increased from Cycle 1 to 8 i.e., the mineral uptake increased gradually as the plants grew.
- The difference in mineral uptake in first four cycles to the next four indicates a higher uptake of minerals during the vegetative phase of the plants.

G. Comparison of biomass development

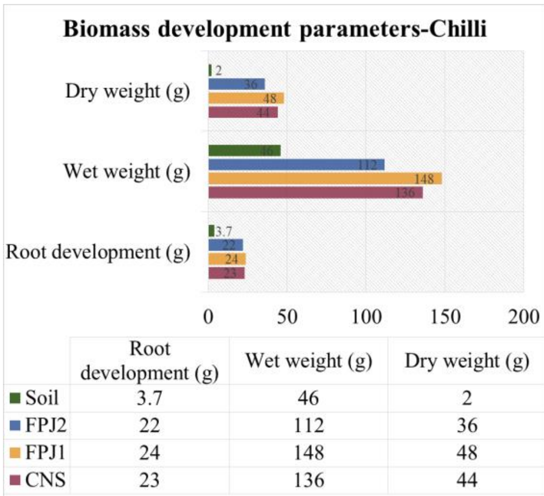
- Parameters used: Dry weight, Wet weight and Root development.
- Procedure:
  - Gently uproot the plants and carefully remove and wash the medium from the roots.
  - Carefully dry the plants between paper towels.
  - Using the digital scale, weigh the uprooted plants.(Wet weight)
  - Weigh the roots separately to find the root development.
  - Dry the uprooted plants in an oven to constant weight at 80°C and further allowed to cool to room temperature.
  - Once again weigh the dried plants (dry weight).
  - Record all the observations in the final table.

Fig. 16. Measurement of biomass.



	Root development (g)	Wet weight (g)	Dry weight (g)
Soil	4	26	3
FPJ2	29	97	61
FPJ1	25	84	43
CNS	28	94	60

Fig.17.Biomass development parameters of *Mentha spicata*



	Root development (g)	Wet weight (g)	Dry weight (g)
Soil	3.7	46	2
FPJ2	22	112	36
FPJ1	24	148	48
CNS	23	136	44

Fig. 18. Biomass development parameters in *Capsicum frutescens.*

- Inference – Comparison of biomass development.
  - Mint showed comparable Biomass development under FPJ2 to that of CNS, but yielded comparatively less under FPJ 1nutrition.
  - Chilli showed comparable biomass development under FPJ1 to that of CNS, but yielded comparatively less under FPJ 2 nutrition.

- In both the cases soil nutrition yielded nearly half or less biomass development compared to hydroponic culture.
- It can thus be inferred that better yield and healthier plants are obtained in hydroponic culture where it can be made economically viable as well as environmental friendly with organic substitutes such as FPJ.

CONCLUSION

The result of this study proved that the inorganic commercial nutrients used in conventional hydroponics, can be replaced with a sustainable organic alternative. It also showed that fermented plant juice nutrition is suitable for fruit bearing plants such as chilli and foliage crop such as mint. By deriving the fermented plant juice from weeds, agri-residues and household waste, this study provides an additional sustainable method for the disposal and up cycling of biodegradable waste at the same time helping to enhance food security. The hydroponics system can thus be made more environment friendly, easily adopted for urban areas, with greater efficiency than the conventional irrigation systems, especially in terms of water utility.

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