Vigyan Ashram

# FIELD GUIDE FOR HYDROPONICS FARMING

Experiential learning of Vigyan Ashram during 2018-2022

*By Mr. Ranajeet Shanbhag, Dr. Arun Dixit*

# Preface

Hydroponics farming is considered as a futurist farming methodology due its advantage of higher production per unit area. In the Indian context, new age farmers are trying to adopt it as mainstream or as an urban farming model. Most of the time various concepts of hydroponics farming in India are either copied from foreign countries or adopted half-mindedly without proper field trials and economical feasibility, making it capital intensive, technically difficult & non-viable for the farmers.

Developing technology based rural entrepreneurship is an important aspect of Vigyan Ashram's work. Vigyan Ashram (VA) works for understanding science, collect field research data, design localized applications etc. Developmental challenges in the community become a 'problem statement' for research students in VA. More on this please visit www.vigyanashram.com

Work on hydroponics farming started as a small hobby-scale project with enquiries from our dry-land farmers. In fact initially, it was a by-product of the 'aquaponics farming' project. Eventually we completely dragged into it and hopefully collected enough data to share with readers as 'field guide'. Even though it's titled as a 'field guide', we would prefer to share it as an 'experience sharing' document and invite readers for collaborative technology development efforts. We will be more than happy to learn from farmers, institutes, and practitioners' experience.

The booklet is the product of experiments conducted by many enthusiastic & hard working 'Design Innovation Center' (DIC) students at Vigyan Ashram. We have tried to acknowledge most of them through their blog links. We are also thankful to our funding partners, trainee farmers and entrepreneurs for being with us during our field research.

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# Contents

## Interactive index for hydroponics



Beginner Level

Practitioner

Technology explorer

Basic concept / Scope in India / Economics / Major challenges

Structural components – common requirements with its genesis

Farming structure – DWC / NFT / Flood & Drain

Basics of fertilizer application in hydroponics

Fertigation important factors to control

Nutrient specific trials: Magnesium mobility

Nutrient specific trials: Potassium mobility

Nutrient specific trials:  Use of microbial cultures

Nutrient specific trials: Use of vermiwash & human-urine in hydroponics

Water quality standardization in hydroponics: Converting amide nitrogen to nitrate form  (content need to be shuffled)

Water quality standardization in hydroponics: reducing water hardness

Artifical lights in hydroponics

Crop specific trials

CHAPTER 1

# Basic concept of Hydroponics

Hydroponics farming is cultivation of crops with water based nutrient media. It's also referred to as cultivation without soil. Hydroponics is considered as the future of farming due to its advantage over conventional farming in higher production per unit area, low input requirements, clean & safe food production. Hydroponics provides the advantage of utilizing vertical space because of the lower net weight of the system.

| Conventional farming | Hydroponics |
|---|---|
| Soil acts as nutrient storage & support structure for plants | Water acts as nutrient storage & artificial support provided to plants |
| Production limitation due to variables in nutrient mobility, weeds competition etc. | Controlled nutrient mobility, focus on high density cropping leading to higher productivity. |
| Soil hosts microbes & helps in conversion of nutrients from no-mobile to mobile form. | Water soluble nutrients are used & they are easy to absorb. |
| Nutrients (fertilizers) are given to soil based on soil analysis. So heavy fertilizer leaching & fixation losses. | Nutrients given based on plant demand based on tissue analysis so doses are to the lower side. |
| Traditional cultivation requiring larger lands. Useful in field crops, long term fruits etc | Precision farming technique with high density cultivation for vegetables, short term fruits. |

## Green veggies are VERY COSTLY!

Green veggies are very important in regular diet. They provide energy, minerals, vitamins & antioxidants for healthy body. They benefit most when consumed fresh & raw !

Cost of Fenugreek Vs Almond

On dry wet basis Almonds are around Rs.880/kg (with 6 % water content)

A fresh methi is around Rs.10 / bundle. It has useable leaves around 130 gm. On dry wet basis it just 10 gm (93% water). So effective price is Rs.1000/kg

.........COSTLY THAN ALMOND......

India produces around 200 million tons of vegetables per year with 6.5 % annual increase. This production almost 4 times lower than total vegetable requirement of country (as per WHO per capita vegetable consumption need to be around 300 to 400 gm/day). One can easily estimate total scope for high density vegetable production like hydroponics farming. By thumb rule a fixed investment of around Rs.2000 to 3000 per Mtr Sqr & break-even of 3 to 4 Yrs, hydroponics farming would be attractive investment opportunity for new-age farmers.

## Challenges (Indian context):

In the Indian context hydroponics farming technology still has many hitches & gaps. We mainly lack scientific data on important aspects like precious use of fertilizers (study on individual nutrients mobility & impact), crop specific growth & economic viability data, design parameters of the system, water quality parameters, use of organic compounds, use of artificial light etc.

| Technical | Non-technical |
|---|---|
| • Higher cost of water treatment (mainly requirement of reverse osmosis treatment)<br>• Lack of information on fertilizer requirements for Indian veggies.<br>• Lack of nutrient mobility possess by precipitation or ion imbalanced particularly Mg, Fe, P, Ca)<br>• Lack of scientific approach in system design | • Higher fixed investment<br>• Lack of quality seeds in affordable price<br>• Lack of technical know-how & skill training to farmers<br>• Competition with traditional farming<br>• Higher marketing cost in retailing |

**Vigyan ashram** (www.vigyanashram.com ) conducting field trials of hydroponics farming from past 5 Yrs. We are working on data collection on various aspects of this technology to understand its science, appropriate methodologies & scope of adoption. This field guide is collection our learning on common methodologies, scientific concepts & suggestions for hydroponics farmers in India.

Vigyan Ashram (VA) works on development & dissemination of rural technologies with motto of 'Development through Education & Education through Development. VA's Design Innovation Centre (DIC) works on various societal issues with 'design thinking' approach of innovation.

For online training session of Hydroponics & Aquaponics farming please scan code

**I want to venture in hydroponics farming. From where I can start?**

## Hydroponics is still new concept in Indian context. Let's:

- Explore market potential of your locality for exotic veggies, B2C marketing, urban farming etc.
- Build a small prototype first to learn technology & market potential.
- Get enroll for hands-on training to learn basic scientific concepts of cultivation
- Avoid heavy investment & do consider marketing cost.

## Learning in this booklet are categories in following few broad objectives as:

- Trial test different methods of hydroponics cultivation viz. Deep Water culture (DWC), Nutrient Film Technique (NFT), Grow beds/ bags, flood & drain based hydroponics for its application, ease of in implementation, cost-break up & overall usefulness.
- Fertigation in hydroponics- standard practices, trials on individual nutrient mobility, experimentation for effect of organic components (fertilizers) as vermiwash, human-urine, JIVAMRUT etc.
- Study on Improving and standardizing water quality parameters on hydroponics farming as reducing water hardness, converting Ammoniacal ($NH_3$ / $NH_4$) fertilizers into nitrate ($NO_3$) form.
- Study effect of artificial light (LED) in hydroponics farming.
- Learnings from crop specific trials during 2018 - 2022.

All above objectives are small independent experiments. These experiments are discussed below with learning outcomes & further scope of work.

CHAPTER 2

# Structural components in hydroponics farming

Hydroponics is basically cultivation of plants with water-based nutrient media. This media could be water, coco-pit or any other inert material. Different types of cultivation structure used in hydroponics. Design may vary as per structural design, grow-media type & flow of nutrient etc but the basic components remain same as below-

| Basic components | Function/ selection genesis |
|---|---|
| Plant grow media like water, cocopit, vermiculite, rockwool, sphagnum moss, clay-balls etc | Basic function is to hold moisture, nutrients and provide support. Idea media should be non-reactive, pH stable, provide good drainage (water holding capacity of 20 to 25%), lower cost. |
| Grow pot or net cut or bag | To hold grow-media & provide support to seed/ seedling. Has to be non-reactive, low cost, easily available. |
| Aeration pump | Plants roots also requires oxygen. Aerator help in maintaining required Dissolved Oxygen (DO) in water. |
| Water pump & Filtration system | Circulating or application of water, fertilizers in plant root zone. Adjust water Total Dissolved Solids (TDS) as per standard requirement. Design & capacity as per system specification. |

| | |
|---|---|
| Fertigation tank | Mixing fertilizers, avoid precipitation. Design & capacity as per system specification. |
| Hydroponics structure | To hold plants, grow media etc as per design specification. |
| Other components- Grow-light, climatic controls, water quality testing gadgets etc | As per system specification |

*Note: See Annexure for some of the suppliers in market for above material.*

## Do I need Polyhouse for hydroponics?

Not as system requirement. But poyhouse gives advantages of climatic control to avoid seasonal various in yield. Polyhouse also helps in achieving better quality of produce due UV stabilize film cover, pest control ect

To test applications of different hydroponics components, standardize design parameters set of experiments were conducted at Vigyan ashram Pabal campus. Following are some the learning as

# Deep Water Culture (DWC)

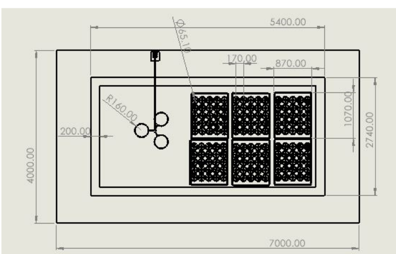
DWC as the name suggests it's a system in which plants are placed in water in such a way that its roots remain suspended in water containing essential nutrients. Care is taken to support plants to float (on water) & get necessary physical support for growth. Normally low-density material like styrofoam, polyurethane sheets etc used to hold plants on water surface. All necessary nutrients are provided in water dissolved form and osmotic pressure is maintained in a way that nutrients will flow easily & efficiently from water to plant. It's a bit simple, less expensive and easy to implement.

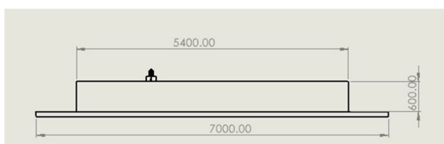
There are 2 main types of DWC systems commonly practiced by farmers as closed loop & open loop systems. In open loop systems a certain amount of water is drained from the system regularly & new water added to maintain water quality, whereas in closed loop systems only evaporation losses or plant water usage are make-up to maintain desired water quality. Nowadays 'mixed loop system; are also becoming popular with aquaponics or recirculating aquaculture systems (RAS).

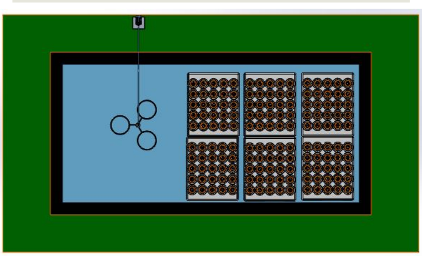
## As shown in above sketch, we designed a closed loop system for experiment with following details –

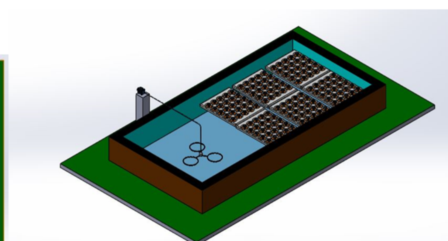
- A loose brick laying bed of 3.53 *1.82 mtr (length * width) with average depth of 0.18 mtrs (Better to have 0.5 mtr depth as root remains hanging downwards, doesn't mixed up, get better nutrient & dissolved oxygen)
- HDPE 500 GSM black paper used for making it leak-proof pool tank.

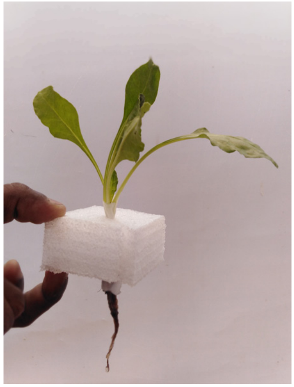
- Styrofoam sheet of 1.12*0.88 Mtr (length * width) with 1.5 inch thickness were used to hold plants.
- Individual plant spacing of 0.22*0.15 Mtr is maintained for each floating foam.
- A water circulation submersible pump of 18 watt and air blower of 45 watt with airoxy tube diffuser fixed for avoiding channeling of nutrients & DO enrichment. (Both run for almost 24 Hrs)
- Net cups of 2 inch & 3 inch were placed by making appropriate holes in Styrofoam. We found 2 inch cups are best suiting for salads & even for tomatoes, zucchini etc.
- Care was taken while placing net pots in floating foam sheets, so that the root-shoot junction should be above water level. If this junction touches water or water enters into the tip of seedling chances collar rot (fungal infection) may increase.




*Details of material specification is given in Annexure I*

- Polyurethane foam & Phenolic Foam (floral-foam) sheet made 1 inch cubes were also tested for planting seeds with a same capillary sheet (newspaper or brown paper strip) instead of net cups. Its reduced cost of net pots but it's found net pots performs much better with seedling transforming over seed sowing. Seedling of 2-3 weeks old transplanted in cups with red-well drain soil (10 – 20 gm) & coco-coir lining. Some plants are also placed directly with cocopeat. It's found that coco-coirs don't suit well as they restrict root movement through net pots.
- Major pest was white-fly's, Mealy bugs which can be easily controlled with neem oil & soap mix.

*Dwc beds at kiya farms, murbad, mumbai*

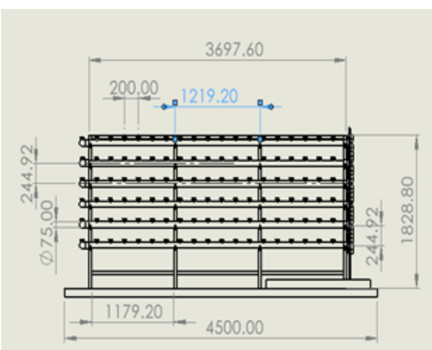
*Dwc beds at landcraft agro, kolhapur*

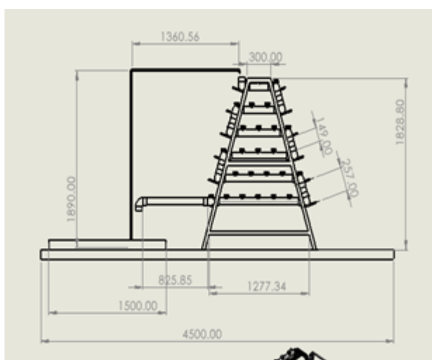
## Results -

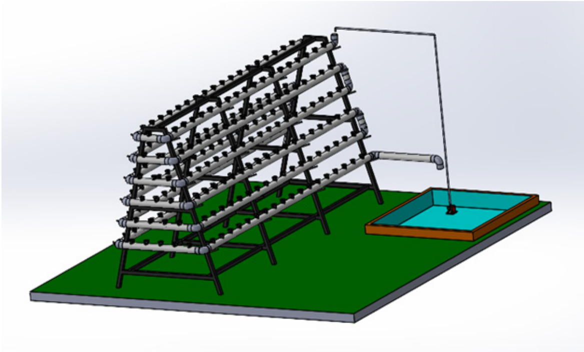
During a 70-day trial, we found, Salads (blossom lettuce, rocket salad, basil etc) were ready for harvest and fruiting crops like tomatoes started yielding with initial fruiting. Average pH was maintained @ 6.9 & Electrical Conductivity (EC) of 800 uS/cm. Details of fertilizer dosing and important deficiency symptoms observed during the trial period are attached separately in Annexure. Except periodical Magnesium (Mg) deficiency in salads and potash deficiency in tomatoes no other signs were observed. It is observed that blossom lettuce is sensitive to heat stroke of $28^{0}$C & above temperature. White fly , mealy bugs were reported on tomatoes, zucchini @ average temperature of 30 °C & 60 % humidity.

# Nutrient Film Technique (NFT)

In NFT technique nutrients are transported to plants in the form of thin water film. So basically it's a flow of water with necessary nutrients through plant roots. In NFT roots are not completely suspended in the water bed but water is circulated to plant roots. By this overall weight load of the system gets reduced & vertical space can be utilized to increase net output per unit area. Circulation of water also adds necessary oxygen in water & avoids nutrient channeling. By this mass flow of nutrients (from water to root surface) is encouraged.  Specially designed NFT planters (beds) are used for plantation or for smaller scale PVC pipes are placed with hole & planting net cups.  Planters can be arranged in square stacking, a wall mounted flat frame or A frame pyramid shape based on space availability & desired





density. NFT requires higher initial cost & special care for maintaining proper water flow, nutrient balance, light intensity etc.

## Following were the material details of system as:

- A PVC of 50 mm fixed with a metal frame. It's a square frame structure with 18 watt submersible (same of DWC system) connection (Plants placed with 0.30 mtr spacing distance.
- Water from the DWC bed circulated to NFT with basil, mint, rocket lettuce plants placed in a 2 inch net pot.
- We used a regular 50 mm bend (L-bow) to connect pipes at different levels, but it's found that it doesn't allow water to rise to plant roots making them dried & nutrient deficient. Instead of PVC L bow an end-cap with a smaller size outlet would serve better.
- Spacing between 2 layers of planters may be adjusted based on desired crop requirement. We kept it identical just for easy operations.

Overall performance of NFT was satisfactory with an added advantage of vertical

space utilization. Lettuce, basil, mint like salads performed very well in the system. NFT looks attractive, saves space and is handy for urban farmers.

The NFT system suits well for balcony or terrace based urban farming models. Various types of NFT structure available in the market. One can easily fabricate their own NFT structure with simple fabrication skills.

Vigyan ashram has standardized engineering drawing & fabrication protocol for 60 plant-pot NFT structure. Detailed engineering drawing, material list & fabrication steps can be found on following link:

https://vadic.vigyanashram.blog/2020/12/29/hydroponics-structure-2/

Prasad Patil & his collogues at Design Innovation Centre (DIC) at Vigyan Ashram designed, field tested & standardized NFT structure for small-scale farming. Detailed engineering drawing & list of material for fabrication of 60 plant-pots NFT hydroponics structure. Scan QR for more

# Flood & drain based hydroponics system

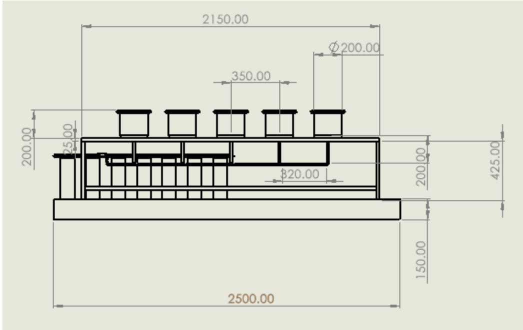
Aeroponics (growing plants on nutrient balance mist spray) is another way of advanced farming. Aeroponics is one step ahead to hydroponics in its space utilization & per unit area production capabilities. But aeroponics involves creating a water mist with high pressure jet nozzles. High pressure nozzles need soft water (probably RO water with less than 200 TDS). It makes the system more costly (fixed as well recurring cost) and requires regular maintenance.

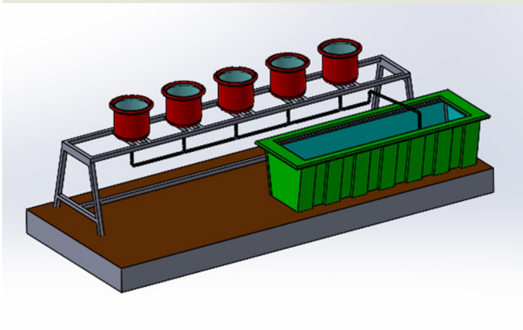
To overcome this difficulty while keeping the advantage of lower weight & cost of nutrient solution, food & drain or ebb & flow hydroponics systems are used. Technically 'flood & drain' will be a mixed approach to DWC and NFT systems. Flood & Drain mechanism normally used in aquaponics & waste water treatment (reed bed technique).

As the name suggests it's basically flooding a planter bed with water & draining out completely usually by siphon drain. By this nutrients spread

Bell & siphon based drainage in flood & drain system is also very common. Videos guide available for it on internet. We found gravity based drainage (single pipe for inlet & outlet) is most easy to fabricate & maintain. Care has to be taken for avoiding choking of inlet/drain pipes because of roots / sand etc.

Ajay Patil worked on designing of flood & drain system for vegetables. For details about his experiment & table top model (5 pot) system please scan code over the entire root zone like DWC and drain it out leaving thin film. Larger advantage of flood & drain is that when water gets replaced by air it makes an oxygen rich environment for the root zone. This system also allows mass flow of nutrients more efficiently. Overall load of the system gets reduced as standing water columns are replaced by sequential flooding. Misting or high pressure fogging isn't required for systems so it becomes less complicated design & lower cost involved.



A simple design for 5 pots (cultivation box) & water (nutrient) reservoir can be fabricated with following component details. For commercial scale application, flood & drain beds are designed as per plant root depth & water tank reservoir.

Details of flood & drain (5 pot) based hydroponics structure can be found on link

https://vadic.vigyanashram.blog/2022/02/20/hydroponics-flood-and-drain-system-2/

## Grow bags or bed with growing media:

Grow bags or troughs are used for hydroponics cultivation as plant containers. It may be debatable as it's not strictly only water based cultivation, but uses neutral media and provides disconnect from field soil. Grow-bags are very handy in urban or terrace farming. Growing media could be anything like coco-peat, coco coir, husk, clay aggregate etc. We are testing following system presently as -

- **Net bags with soil & compost mix:** Net bags normally used in agriculture for onion or potato filling, made of polypropylene, 50-100 GSM, 22 * 50 inch sizes are used with soil (well drain & compost mix (5:1) ratio. Each bag watered with a drip irrigation system. Our assumption is that with improved aeration & soil availability, crops with symbiotic microbial association (leguminous) will perform better here as compared to DWC or NFT. So far results are encouraging. We will update with the end results in the next update.
- A grow media (soil) used in grow-bags has to be well-drained for proper aeration to roots. Experiments in Pabal campus showed good response to 1:1 proportion of soil & compost (C:N ratio of 1:30). Similarly a trial on mixture of kitchen & garden waste as pot mix @ 1 Kg compost + 2.5 Kg soil + 3 Kg of garden waste also performed well in 12*18 inches made from agricultural green shed net.
- **Grow bags with coco-peat:** A ready-made grow bags with cocopeat are also planted with a drip line. Water soluble fertilizers supplied to these bags. Each bed is planted with 3 samplings of tomatoes. pH and EC of the grow bag maintained @ 6.8 to 7.5 and 1200 to 3000 uS/cm.
- **Vertical grow bags with coco-peat & Bajara husk:** Grow bed can also be placed vertically as NFT. We used a PVC blue sheet square box filled with cocopeat. These beds were placed in 3 layers. Each grow-bed was 7 ft length with 20 plants/ each. These beds are mounted on metal fabrication structure. Each bed is fixed with an in-line drip irrigation system connected to an 18 watt submersible motor pump. Extra water from beds are collected & recycled back to the system. Salads are planted in the system , this can be used for fruit crops like strawberries. (Photo attached for details.)

**Hydroponics structures can be summarized as**

| Structure | Advantages | Limitations |
|---|---|---|
| Deep Water Culture (DWC) | Easy to build & Operate Lower cost than NFF Good choice for beginner farmers. | Can use vertical space, Doesn't suit for fruit vegetables Higher water requirement |
| Nutrient Film Technic (NFT) | Can use vertical space Lower water requirement Good for explorer / Urban farmer | Higher cost Requires engineering & fabrication precision Useful for salads |
| Flood & drain / Dutch budgets | Better controls & yield<br>Suits well for fruit crops<br>Useful for urban farmers | Higher cost Difficult design |
| Grow bags | Simple, low cost<br>Easier fertigation | Lack in precision control Grow media required to be replaced |

## Which structure suits me best? (Steps to choose)

- Analysis your need, scale of operation & investment capability
- Test small scale operation before full-scale application (better fabricate yourself to chalk-down design parameters as per need)
- Use locally available material to reduce cost
- Combination 2 or more methodology may be better options as per market need.

CHAPTER 3

# Fertigation in hydroponics

Apart from being physical support & soil also hosts many beneficial microorganisms. These microbes play an important role in holding & mobilizing essential plant nutrients. Hydroponics farming needs water soluble nutrients as it doesn't have support of microbes as soil-based farming. In hydroponics, water acts as media for nutrient transfer & storage. Emphasis is given on supplying essential plant nutrients in water soluble & easily available form so as to facilitate easy uptake & mobility of nutrients.

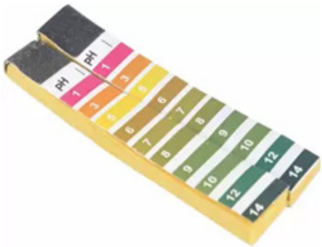
## Factors affecting nutrient mobility in hydroponics:

**pH:** Nutrient mobility affected by water pH. In hydroponics pH of 6.5 to 7.0 is preferred as it fevers most of nutrient mobility. The acidic or basic pH gives a stroke to the plant. pH is adjusted by addition of acid or base. To maintain pH, we have to use the best fitted combination of acid base fertilizers instead of acid or base solution.

Osmotic pressure: Osmotic pressure of root surface area Vs water, plays an important role in ion exchange. Osmotic pressure of nutrients containing water should be higher than the osmotic pressure inside the root. Which controls the flow of the nutrients.

**EC:** Electrical Conductivity (EC) is a way of measuring osmotic pressure. EC has to be critically managed so has to achieve efficient ion exchange. EC of 1000 to 2000 µs/cm is preferred in hydroponics based on specific plant requirement.

**TDS:** Total Dissolved Solid (TDS) is measured in hydroponics to know various dissolved salts (nutrients) in water & add deficiency in the right proportion.



pH paper

EC / TDS meter

It's well understood that plants need 18 essential nutrients for their functioning. In hydroponics all these nutrients (apart from CO2, O2, H) are supplied through water. For effective nutrient management, the concept of nutrient mobility from water to root surface & from root surface to inside root membrane has to be understood. Following are some of important factors to be considered while implementing hydroponics farming –

| Concepts | Implication in hydroponics farming |
|---|---|
| Nutrient movement to the root surface is done through Mass flow, Diffusion & interception mechanism (Reference II) | In hydroponics, though nutrients are supplied in water soluble form their mobility from water to root surface may get affected due to channeling within the tank. It's important to avoid this channeling by homogenous distribution of water. Hydroponics systems are efficient as compared to traditional soil based cultivation as mass flow in soil is affected by many factors. The NFT and Flood & Drain system of hydroponics has the advantage over DWC as in these systems water keeps moving in the root zone of plants. |
| | Diffusion is movement of ions from higher concentration toward lower concentration area. Here concentration of different ions in water is important. Potassium & Phosphorus moves largely by diffusion process. It's important to note that, rate of diffusion is very low for both potash & phosphate. |

| | |
|---|---|
| | Root interception is the growth of plant roots toward nutrient availability in soil. It's hardly going to happen in hydroponics as most of the nutrients are readily available in dissolved form within water. When plants save their metabolic energy in development of roots for sourcing them that energy may get utilized for better vegetative growth of plants. |
| Nutrient mobility from root surface to inside of root cell membrane (nutrient uptake mechanism) : Mainly governed by ion exchange, carrier association , microbial association) [Reference III & IV] | Osmotic pressure of root surface area Vs water, play an important role in ion exchange. Electrical Conductivity (EC) is a one-way method of measuring osmotic pressure.  EC has to be critically managed so has to achieve efficient ion exchange. Though it's recorded that plants are capable of holding required ions within the cell against osmotic pressure, it may demand more metabolic energy affecting overall development of the plant. |
| | Total Dissolved Solid (TDS) is measured in hydroponics to know various dissolved salts in water & add required nutrients in the right proportion.<br><br>Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg) are the major nutrients required for plant development.<br><br>Proportion of potash, calcium and magnesium is important in its mobility within the root. Normally 6:2:1 of K:Ca:Mg is considered desirable (crop specific).<br><br>Calcium & Magnesium governs overall hardness of water so generally referred as water-hardness. |

| | |
|---|---|
| | Potassium also plays a very important role in maintaining osmotic movement within cells by participating in water molecule in-out movement. So its optimum level has to be maintained for efficient nutrient mobility. |
| | Nitrogen: mobility of nitrate is much faster than ammonia. So nitrate based fertilizers are dominant in hydroponics farming. Buts it's important to note that as fertilizer nitrate are associated with other salt (cation) like calcium, potassium etc. Converting amide form of nitrogen to nitrate form would help in better management of nitrogen requirement in hydroponics. |
| | Nutrient move within plant cell through different carriers so chelated nutrient fertilizers performs much better in hydroponics system |
| | Hydroponics farming best suits water loving or succulent plants. As these plants don't need to invest their metabolic energy into lignin formation for strength of stem or hard root. They can use this energy for vegetative growth & fruit production. |
| | Dissolved oxygen (DO) levels in water play an important role in nutrient mobility of hydroponics systems. DO impact Potassium (K) mobility (N uptake doesn't impact much) and also support root respiration. It's recorded that DO of water @ 2 -8 mg / lit gives best results which can be achieved by air pumping + liquid oxygen pouring in system. |

Akshay Dhumal did his research internship at Design Innovation Centre (DIC). His experimentation worked on fertigation of spinach @ NFT system can be found on his blog-

### Interesting fact:

- **Osmotic Pressure (OP) of sea water-** Sea water has 3 to 4 % NaCl salt. Its OP at 25 Deg C is around 30 Bar. In other words, it will raise a water column of 1 cm3 up to 300 meters.
- In hydroponics if we have 2000 uS/cm, it will generate of OP of 0.72 bar i.e 7.2 M water column.
- In other words, plants will be required to generate pressure of 7.2 M water column to lift water & nutrients

# Fertigation:

Fertigation is key in the success of hydroponics cultivation. In simple terms it's a required nutrient supply to plants through water soluble elements. In hydroponics plants depend on water and/or grow-media for required nutritional demand.

## Dosing fertilizers in hydroponics system: (Basel dose)

Basic dosing based on water quality & desire EC - While starting hydroponics system basel dose containing major & micro nutrients are added based EC & TDS requirement of specific crop. Generally, 800 to 2200 µs/cm EC is preferred by many vegetable crops. It's recommended to get water analysis for major nutrients (mainly calcium, magnesium and sulfur) and add required nutrients to achieve the desired EC of hydroponics fertigation tank.

Suppose we are dosing nutrients for lettuce (salad crops) of 1000 lit system with following nutrients-

| Target dosing | Selected fertilizer | Amount required for 1000 lit tank |
|---|---|---|
| 150 ppm of Nitrogen | Calcium Nitrate / Potassium nitrate / Nitric acid upto 85 to 90 % of dosing + Urea or any other ammoniacal form (10 to 15 %) | 483 gm<br>553 gm<br>110 gm |
| 30 ppm Phosphorus | Mono-potasium phosphate (0:52:34) | 133 gm (58*2.29) |
| 210 ppm of Potash | Potassium nitrate | Already given |
| 90 ppm Calcium | Calcium carbonate | Already given |
| 24 ppm Magnesium | Magnesium sulphate (9.7 % Mg + 13 % S) | 247 gm |
| 1 ppm Iron | Iron sulphate | 10 gm |
| 3 ppm other micro | Mixed | 10 gm approx |

## Steps to be followed while implementing above dosing:

- Check pH, EC / TDS of water.
- Check nutrient profile of water mainly calcium (water hardness if TDS is higher than 200 ppm), Nitrogen (Ammonia, Nitrate, Nitrite) etc
- Reduce TDS of water by lime treatment or Reverse Osmosis (RO) system (separate note added)
- Prepare a stock solution of above fertilizers (A & B) to avoid precipitation. Normally a 100 times higher concentration stack solution is prepared for application. Phosphate / sulfates shouldn't be mixed with calcium nitrate. (Tank- A - Calcium nitrate + nitric acid + ferrous sulfate + half of potassium nitrate AND Tank B- Ammonium Phosphate, Magnesium sulfate, Potassium Sulfate, Boron and other micronutrients)

## Note:

- *- Calculating dosing requirement
- Calcium nitrate (15.5 % N) - 50 % N source - 75 ppm required quantity
- 75 mg / lit - 75 ppm - 75 / 0.155 = 483 mg / lit - 483 mg *1000 (lit) **= 483 gm**
- Potassium nitrate (13:0:45) - 40 % N source - 60 ppm - 60 / 0.13 **= 461 gm (It's in K2O form so 461 *121 = 553 gm)**
- Urea (47 % N) - 10 % N source -15 ppm - 15/0.47 = 110 mg/lit **= 110 gm**
- Calcium nitrate has got 19 % Ca = 483 * 19 % **= 91 ppm given**
- Potassium nitrate has got 45 % potash= 461 *45 % **= 207 gm given**

- Add A + B in system while adjusting EC to 1000 to 2000 µs/cm in next 2-3 days.
- Adjust pH of the system (by adding phosphoric or nitric acid) to 5.5 to 6.5.
- Regularly observe water EC (if drop) and nutrient deficiency. If EC drops top fertilizers in water and supplies through foliar spray (especially magnesium deficiency).

## Fertilizers topping-up based on leaf analysis & visual symptoms: (top-up dosing)

Topping up of fertilizers in hydroponics fertigation is regular operation. In a closed loop system (where water is not drained out to adjust EC). Closed loop systems are most economically and environmentally sustainable but they require precision fertigation and water quality management. Adding fertilizers in the hydroponics system increases EC of water due to increased salt accumulation. Increased EC affects nutrient flow so water required to be drained out (losing valuable nutrients) and readjustment of nutrients. To avoid this following step can be followed-

- Regularly check for nutrient deficiency symptoms and apply foliar spray to check them.

- Record harvesting and calculate the amount of nutrients harvested from the system.
- Lettuce contains higher amounts of potash, phosphorus, calcium, magnesium, etc. So if your system is working nice and producing good quality lettuce you are harvesting these nutrients on the higher side.
- For example- 1000 gm of lettuce will remove approximately 8.84 gm N, 0.194 gm K, 0.036 gm Ca, 0.029 gm P. So at least that much number of fertilizers has to be added to the system.
- Similarly with Spinach: Let's assume we harvest 4 kg spinach from system (1000 lit fertigation tank) then we have harvested around: Nitrogen - 18.56 g, Potash - 22.32 g, Calcium- 3.96 g, Magnesium - 3.16 g, Phosphorus- 1.96 g, Iron- 0.1 g

**Fertilizer top-up can be done as below:**

| S.N. | Name of Fertilizer | Genesis | Quantity taken |
|---|---|---|---|
| 1 | Nitrogen:<br>18.56 gm required | 1 part (3.09 gm) from Urea (ammoniacal form), 1 parts Mg $(NO_3)_2$, 2 Parts (6.18 gm) from $KNO_3$ and 2 parts from Ca $(NO_3)_2$ | Urea - 6.71 gm<br>Mg $(NO_3)_2$- 28.09 gm<br>$KNO_3$ - 47.52 gm<br>Ca $(NO_3)_2$- 41.2 gm |
| 2 | Potassium:<br>22.32 gm required | $KNO_3$ has 45 % potassium so 21.38 gm already given | 0 |
| 3 | Phosphorus:<br>1.96 gm | Very less required can be fulfilled while adjusting pH with phosphoric acid | 0 |
| 4 | Calcium:<br>3.96 gm required | Ca $(NO_3)_2$ has 19 % calcium so 7.82 gm already given* | 0 |
| 5 | Magnesium:<br>3.16 gm | Mg $(NO_3)_2$ has 16 % Mg so 4.49 gm already given | 0 |
| 6 | Iron:<br>0.1 gm | Very less required can be fulfilled with micronutrient mix | 0 |

## Note:

*- higher dosing of calcium may create problems for magnesium mobility. In that case Mg EDTA (chelated Mg) can be used.

**Student blog reference:** https://vadic.vigyanashram.blog/2020/12/30/cost-effective-hydroponics-system-for-spinach/

## Salt Index of fertilizers:

Salt index of fertilizer affects osmotic pressure in fertigation. $NaNO_3$ (sodium nitrate) salt index is considered @ 100 and other fertilizers are compared with it accordingly. N & K fertilizers have a higher salt index as compared to P. A lesser salt index is considered better especially for during seed germination & hydroponics farming.

For more -Calculating Salt Index (fluidfertilizer.org)

## Hydroponics fertilizers:

They are essentially water-soluble fertilizers with 1 or more essential plant nutrients

It's important to check available nutrients for their forms (quality) & quantity. For example Mono-Ammonium Phosphate has nitrogen in ammoniacal ($NH_3$) form while phosphate as $P_2O_5$ (its a qualitative parameter). Now its has 12 % nitrogen & 61 % phosphate. These % are nothing but a molecular weight of individual molecule. As Mono-Ammonium Phosphate $NH_4H_2PO_4$ molecular weight is 115 g/mol. Its as $NH_3$ of 14 g/mol so 12/115= 12 % nitrogen and $PO_4$ as $P_2O_5$ - 71g/mol = 71/115= 61%

Phosphorus is considered as $P_2O_5$ and Potassium is considered as $K_2O$ in fertilizer.

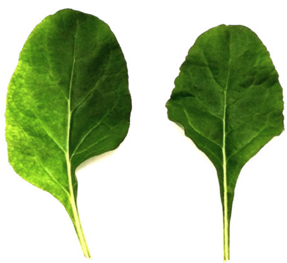
## From where I can start in fertigation?

Key of successful fertigation is understanding basic science & arithmetic calculation. It doesn't need any specialized skill or training. But for commercial plantation, its better have expert guidance for avoiding fertilizer deficiency or injury in system. For home scale or experimentation level setups apply doses in small quantity (may be 10 to 20 % of actual dose) on daily basis. Keep eye on pH, EC & TDS level while noting plant performance. Within 1-2 weeks your plants will tell you whether they are happy or not.

# Deficiency symptoms on selected crops

*Magnesium deficiency in Broccoli (Right side- healthy leaf)*

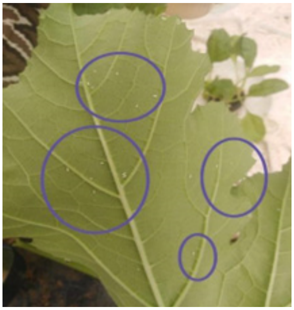
*Magnesium deficiency in Basil (Right side- healthy leaf)*



*Magnesium deficiency in Spinach (Right side- healthy leaf)*

*Potash deficiency in tomato (Right side- healthy leaf)*

*Powdery Mildew in Zucchini*



*White fly in Zucchini*

CHAPTER 4

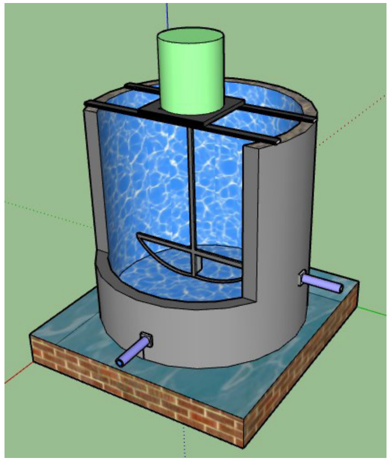
# Experiments for improving water quality parameters, fertigation & use of organic fertilizers in hydroponics

As stated earlier we lack in scientific data & economical data for hydroponics farminarticularly experimental data on crop specific performance, nutrient mobility, water quality management, economics of cultivation etc not available for Indian vegetables. Following are some of the experiments on fertigation & water quality management conducted at Vigyan Ashram in this regard.

## Experiment with reducing water hardness (higher Calcium – Magnesium content) in cost effective way

Higher hardness increases in low rainfall areas due to higher calcium & magnesium salts (carbonate hardness) accumulation in ground water. In hydroponics higher TDS limits nutrient mobility as it increases osmotic pressure. Most hydroponics growers prefer Reserve Osmosis (RO) units to reduce water TDS. But RO's required higher initial investment and recurring cost (as membrane filters need to change frequently). By using RO net water, the requirement of the system is also increased. It's also unethical to put so much energy to filter out naturally available minerals (nutrients) in water and add them as fertilizer with added cost.

We found, use of lime treatment is the most economical and easiest way to reduce TDS of irrigation water. Lime (Calcium Hydroxide) reacts with calcium hydrogen carbonate and calcium precipitate as calcium carbonate & magnesium as magnesium carbonate. Details on various water softening treatments reference (VI)



*Schematic of*
*Lime treatment drum system*

Regular agitation of water & calcium carbonate precipitate removal is required for this treatment on a larger scale. We fabricated a simple mixing drum with bottom drain (as shown in figure). It found that for 1 liter of water, addition of 0.5gm of lime can reduce water TDS from 467 ppm to 273 ppm in just 3 hrs treatment. In closed loop hydroponics systems this method can be easily used to top-up evaporation or other water loss makeup with such simple water treatment drums.

To know more on above experiment details scan these QR codes

## Permanent & temporary hardness of water:

Temporary hardness is due to bicarbonate of calcium & magnesium. Its can be removed by above discussed lime treatment.

Permanent hardness has chlorides, sulfates of calcium, magnesium etc and they are hard to precipitate.

In hydroponics farming lower hardness is preferable but too low hardness reduces buffering capacity of water. So pH of system gets affected frequently. (water becomes acidic affecting root growth & nutrient mobility)

Flow of work would be treating water with lime to make it soft (initial TDS of 220-250 reducing to 130-140 ppm) then analyzing it for Ca: Mg ratio and adding water soluble fertilizers in appropriate proportion (given in table separately) & desired EC levels.

## Convert Amide ($NH_3$ / $NH_4$) fertilizers in to nitrate (NO3) form as low cost & lower calcium content nitrogen source:

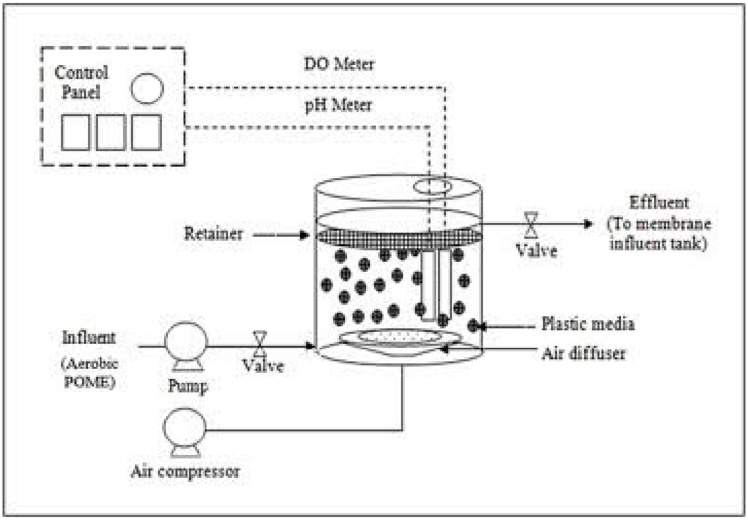
While preparing nutrient balance for hydroponics systems, keeping lower TDS or EC would be the primary challenge for any grower. Higher calcium, magnesium or other salts along with added minerals increases salts in water increasing its EC. Higher EC limits nutrient mobility due to higher osmotic pressure in nutrient solution.

Nitrogen is one of the major nutrients required by plants on a regular basis. On a dry weight basis, the plant contains around 4 % of nitrogen in its cells. Nitrogen required for photosynthesis and protein formation. Plants can take up nitrogen in the form of ammonia (NH4 / NH3) , Nitrate (NO3 ) and amino acid form. When nitrate (NO3) is abundant almost 90 % nitrogen demand is fulfilled by it due to its faster mobility (reference IV).

Amide form of nitrogen is readily available in the market as urea but nitrate fertilizers get salt ions like calcium, potassium, sulphate, phosphate etc. Ammonium nitrate is an explosive category not available to farmers in India. Salt associated nitrate fertilizers imbalances nutrient solution with un-necessary salt ion and also increases overall cost of fertigation.

Another option would be getting nitrate from aquaponics (fish farming). It again involves a separate cost proportion & system complication.

Converting ammoniacal nitrogen to nitrate in a common bacterial process.




*Schematic of MBBR & Oxygen blower for Amid to Nitrate conversion*

Chemotropic nitrifying bacteria involved in the process. We are trying to use these bacterial cultures to convert readily available urea into nitrate for hydroponics farming. A small experimental setup designed for this by using a plastic drum (50 lit), Moving Bio-Bed Reactor (MBBR) @ 5 lit, oxygenation pump (45 watt). Initial dosing of Urea 5g with common composting bacterial Consortium (Nitronomus Sp./Nitrobactor Sp.) are added 1000ml along with sucrose 10g as carbon source.

It's found that bacteria are able to convert amid nitrogen 100 ppm into nitrate up 150-160 ppm in 70-72hrs. These results are very encouraging as it not only saves cost ( Urea costs- 5 Rs / Kg against average cost Rs.50 / Kg for nitrate fertilizers ) on nitrate dosing but also gives nitrate at very low TDS levels. We are presently standardizing processes & scaling up for larger applications.

We are further exploring the isolation of effective (species) bacteria, using cow dung + urine (Jivamrut / Panchamrut) and standardization of systems for scaling up for larger applications.

# Experiment on specific nutrient mobility:

## i. Experiment on magnesium mobility in hydroponics:

Magnesium (Mg) is one of the important plant nutrients. Mg is part of chlorophyll in plants. Within the plant body, 20 % Mg bonds to chlorophyll while 80 % remain in mobile form. Mg is also involved in dry matter formation & carbon partitioning to sink organs. A common symptom of Mg deficiency is leaf vein chlorosis, but it's very lately visible. Before symptoms get visible root growth may get affected due to lower carbohydrate supply to roots. Hence reducing yield considerably. Mg availability may be higher in soil based farming as it moves by mass-flow at a faster rate than other cations (K,Ca, Fe).

Proportion of potash, calcium and magnesium is important in Mg mobility within the root. Normally 6:2:1 of K:Ca:Mg is considered desirable (crop specific). Calcium & magnesium governs overall hardness of water so generally referred as water-hardness.

### Specific to hydroponics farming:

- Calcium supplied in the form of Calcium Nitrate Ca(No3)2 and Magnesium from MgSO4 / Mg (NO3)2. Apart from this chelated Ca and Mg – EDTA or EDTAH available, but they are costly.
- Mg-EDTA showed good results for NFT based hydroponics spinach at Pabal during August - September 2022 trial.
- MgSO4 can be applied as foliar spray but Mg-EDTA has to be supplied as water application.

Symptoms of nutrient deficiency mostly get confused with disease infection & fertilizer toxicity. It requires some experience to identify deficiency symptoms.

Mg deficiency is most common & predominant in Spinach

### Trial to check mobility of MgSO4 through biogas slurry based chelation:

- In September 2022 : A magnesium deficiency in hydroponics spinach (NFT) system was corrected with dosing of biogas slurry + 90 ppm MgSo4.
- 90 ppm MgSO4 + 5 lit bio-gas slurry – air blowing for 2 days – fed to 400 lit NFT tank. It is observed that Mg deficiency recovered in 7-10 days of water circulation.

Chelated Vs non-chelated fertilizers:

Chelated fertilizers are efficient for hydroponics (they move faster).

They are costly due to additional cost of chelation & lower production volume.

Use of organic molecules (humic acid, fulvic acid etc) is common for chelation.

Use of vermiwash, Jivamrut, biogas slurry etc has to be explored for chelation of chemical fertilizers

The above trial showed the possibility of correcting Mg deficiency through biogas or cow-dung slurry or JIVAMRUT / vermiwash based (chillation) dosing of MgSO4.

## ii. Experiment on getting Potassium nitrate from wood ash:

Potassium (K) is another major nutrient for plants. K moves by diffusion in plants. It's required in water soluble form.

An experiment (lab analysis) conducted to find solubility of potassium from wood-ash as an organic source of nutrient.

- Potassium (K2O) & Nitrate (NO2) are mostly required in 2:1 ratio (210 ppm K : 100 ppm NO3)
- Potassium nitrate (KNO3), Potassium sulphate (K2SO4), Potassium phosphate (KH2PO4) are some of the common sources for hydroponics.
- Calcium nitrate ($Ca(NO_3)_2$), Ammonium Nitrate ($NH_4NO_3$) (fertilizer grade),

Magnesium Nitrate (Mg(NO3)2) etc are common nitrate sources. Potassium Nitrate (13:0:45), Potassium Sulphate, Potassium Phosphate etc are some of the potassium sources for hydroponics farming.

- Wood-ash is a rich organic source of Potassium for plants. But potassium is bound in non-soluble form so it doesn't dissolve & can't be used in hydroponics.A flame-photometer analysis of wood-ash showed 250 ppm potassium.
- A lab experiment on solubility of potassium in wood-ash with nitric acid carried out at VA @ October 2022. Results are encouraging as wood-ash + nitric acid (500 gm ash + 25 ml nitric acid + 5 lit water).
- Flamephotometer analysis (after 48 hr) showed 50 % increase in soluble potassium (i.e 450 ppm).
- Potassium (450 ppm) + (1150 ppm) nitrate would be very good organic fertilizer for hydroponics
- It was a lab experiment, further trial will be required to check mobility of potassium in hydroponics.

## iii. Experiment on use of microbial culture (PSB & KSB) for increasing solubility of hydroponics nutrients:

Use of Bio-fertilizers are very common in traditional soil-based farming. Microbes in biofertilizers mobilize nutrients through symbiotic or non-symbiotic association. Metabolic pathways of these microbes are a bit complex & dynamic but it seems that they help in multiple-way in farming.

An experiment (lab analysis) conducted to check use of

As per Dr.A.D.Karve , plants can't derive necessary minerals from soil as they below 5 ppm level. But microbes can do it as surface area for given biomass is much higher for microbes than plants. So they use these nutrients & plant get it from them by selective killing as per nutritional requirement. We at Vigyan Ashram, trying to check this hypothesis through field trials at Pabal campus.

beneficial microbial cultures in increasing solubility of Potassium for hydroponics farming. A biogas digester slurry used for microbial inoculation. Biogas slurry is a rich source of plant nutrients. It has around 2 % nitrogen, 1 % P & K (on a dry weight basis).

- Flame photometer analysis showed 20 ppm K in biogas slurry
- 5 lit Slurry + KSB + PSB (set 1) & 5 lit slurry + KSB (set 2) air bubbled for 48 hrs
- Availability of K increased to 180 ppm for slurry + PSB + KSB (48 hr blowing) while K in slurry + KSB increased to 50 ppm.
- It shows that microbial inoculation can increase availability of K up to 2.5 to 9 times.
- Probable reasons for higher availability of K @ PSB+KSB inoculation could be because K locked with P may have been made available with PSB. And similarly p locked with anion might be made available with KSB.
- It was a lab experiment; further trial will be required to check mobility of potassium in hydroponics.

## iv. Experiment on use of vermi-wash + human urine in hydroponics:

Nitrogen, Phosphorus & Potash (NPK)are major nutrients for plant growth. In hydroponics farming normally they are required in water soluble form with 1:0.5:2 ratio (for salads). Nitrogen required in Ammoniacal (10 %) and Nitrate (90%) form. Vermiwash nutritional composition is largely based on organic-waste composition but it is a rich source of nitrogen, potassium and magnesium along with any useful hormones & enzymes.

Human urine is rich in Ammoniacal form (NH3) nitrogen, potassium, Phosphorus and sodium. A person can produce 400 lit urine per year sufficient for 400 kg grain production. A lot of references available for human-urine as a source of fertilizer. But its use is still limited due to taboo, fear of infection, higher sodium & ammonical nitrogen levels etc. Human-urine may require pre-processing, dilution, microbial digestion etc before use.

Ammonia Oxidizing Bacteria (AOB) and Nitrate Oxidizing Bacteria (NOB) play an important role in converting Amonnical form of nitrogen to useful nitrate form of nitrogen. This process requires 21 day incubation in a dark environment.

Urea —-hydrolysis—--Ammonia—-Ammonia Oxidizing Bacteria (AOB)----Nitrate—---Nitrate Oxidizing Bacteria (NOB)----Nitrite

Experiments on use of vermiwash (obtained from biogas slurry) & human urine were conducted at Pabal during 2020-2022. Following are some of the key learnings-

## v. Using human urine as fertilizer source:

An experiment conducted to use human urine in NFT based spinach during August 2020. This experiment failed (could be due to over-dosing of urine Ammonia). IN this experiment human urine was treated with nitrifying bacteria to get 490 ppm nitrate (from 140 ppm Ammonia). Nitrification was done in fertigation tank. Student blog details

https://vadic.vigyanashram.blog/2020/08/25/conversion-of-ammonia-to-nitrate-using-mbbrmoving-bed-bio-reactor/).

**The second set of experiment conducted during August-December 2022. Based on earlier experience nitrification was done separately for 21 days. Details of experiment as below -**

- Urine 50 lit + nitric acid for reducing pH to 1-3. Nitric acid stops urines enzyme activity so as to avoid loss of ammonia due to volatilization & reduce smell.
- Urine diluted to 1:4 ratio with water (added to DWC bed of 200 lit)
- Added MBBR and air-blower (1:8 ratio)
- Added composting culture (kitchen waste culture) and cane sugar as carbon source (1:8 ratio)

- MBBR removed after 21 days. Spinach seedlings transplanted to DWC bed.
- Water quality - at start of trial - pH-6.7, EC-2553, TDS-1276
- Magnesium deficiency observed after 4th week of transplanting. Deficiency overcome after spraying 2 % $MgSO_4$.
- Spinach harvested after 40 days.
- 41 % more yield recorded as compared to control plot (chemical fertilizer).

Student blog link

https://vadic.vigyanashram.blog/2022/08/02/poly-house-deep-water-culture-hydroponics/

## vi. Using human-urine + vermi-wash for NFT (Spinach) & Flood-Drain based brinjal:

### Spinach @ NFT system:

A comparative trial of vermi-wash (biogas slurry) and vermi-wash + human urine conducted on NFT based spinach. Trial conducted @ September to November 2022.

- NFT spinach cultivation (60 plants per trail).
- Chemical dose Vs Vermiwash from biogas slurry Vs Vermiwash from human-urine.

#### Preparing vermiwash with human urine:

- Vermiculture bed prepared by using 3 layer composting bed.
- Earthworms (Eisenia fedita) introduced in beds.
- Worms fed with wheat-straw + biogas slurry, kitchen waste as organic waste.
- Vermi-wash collected regularly in water bath.
- Human urine – Dilution (1:4)—circulated in vermicompost bed for 2 weeks. And a vermibed without biogas slurry
- Vermiwash from all 3 bed were used in hydroponics with 1:3 dilution.

**System details & results summarized in table below-**

| Given input | Water quality at start of trial | Water quality at end of trial | Results / observations |
|---|---|---|---|
| Chemical fertilizer dosing<br>Potassium sulphate- 75 ppm, magnesium sulphate – 63 ppm, urea- 53 ppm, phosphoric acid- pH adjustment | pH- 6.8<br>EC- 846<br>TDS- 424 | pH- 7.07<br>EC- 1494<br>TDS- 748<br>Higher EC due to evaporation of water | Better growth in vermiwash (urine & bioslurry) as compare to chemical dosing<br>Though as compare EC / TDS were lower as compare to vermiwash trial showed plant can be grown with organic inputs<br>Cost of vermiwash much less than chemical inputs |
| Human urine based vermiwash | pH- 8.59<br>EC- 3453<br>TDS- 1720 | pH- 7.68<br>EC- 2475<br>TDS- 1142 | Plants were better than chemical dosing but less growth as compare to biogas slurry vermiwash<br>Higher TDS / EC could be due to higher sodium in urine |
| Biogas slurry based vermiwash | pH- 7.79<br>EC-1574<br>TDS-777 | pH- 6.89<br>EC- 1972<br>TDS- 934 | Best growth observed for this treatment. |

Note: Trial was disturbed due to heat stroke / root rot etc. It will be repeated in future experiments.

# Brinjal trial (F & D system)

**An experimental trial conducted during October to November 2022 to check response of brinjal plants for vermiwash + human urine in flood & drain systems. System details & results summarized below-**

- A brinjal seedlings planted in 5 lit food & drain buckets (5 plants of same age / height)
- Water reservoir – 60 lot capacity tub, connected to buckets with submersible pump (48 watt), a timer & gravity based drainage (single pipe for water inlet & outlet connected at base of buckets) Grow media – red brick piece
- Human urine based vermiwash dosing @ 3.21 : 1 (water : vermiwash), TDS maintained – 800 to 1100 , Nitrate level – 140 ppm
- Good growth, flowering, fruiting observed during trail. Harvest of 157 gm brinjal.
- Problems- Plants disturbed & trial hampered due to blockage in water inlet-outlet (due to heavy root growth), disease infection and heat stroke in polyhouse
- Result: Human urine based vermiwash can be used in hydroponics systems. Brinjal can be grown in hydroponics with flood & drain system

Both trials showed feasibility of using vermiwash in hydroponics farming. Protocols for processing of human urine & its field application in hydroponics need to be developed. .

For more information on various research & educational activities of Vigyan Ashram please visit our webpage-

## Possibility of use of organic compounds in hydroponics:

Hydroponics farming require precious use of fertilizers (mostly synthetic) for effective production. Though cost of these fertilization is not very high in comparison with total cost of production, they may harm environment & impact overall system sustainability. A regular draining of extra chemical fertilizers & addition of lower TDS (Total Dissolved Solids) water is common practice in hydroponics.

We in Vigyan ashram, working of reducing & replacing chemical (in-organic) hydroponics fertilizers with organic source like vermiwash, biogas slurry, human-urine, wood ash etc. Initial trials have shown encouraging results. Details of experiment can be found in document further.

## What next for me?

The above trials showed that use organic formulation like Jivamrut, Vermiwash, human urine etc is very much possible in hydroponics. They provide advantage of lowering of input cost and environmental sustainability. But the challenges like changing quality of input material, dynamics microbial growth, fear of fungal or bacterial disease spread need to address on commercial scale.

We are exploring use of organic fertilizers for precision farming application (like hydroponics / Aquaponics) at Pabal campus. We wish to collaborate with like-minded research institutes, farming communities for testing our claims on commercial scale.

CHAPTER 5

# Use of artificial lights in hydroponics system

Interest in indoor hydroponics or increasing efficiency of hydroponics systems by using artificial light is increasing nowadays with increase in affordability of solar PV based electrification & LED lamps. Plants need light within the wavelength range from 400nm to 700nm. White, Red and Blue light spectrum are most useful for plants. Plants need it in combination as each wavelength serves a different purpose for example white light wavelength useful in vegetable growth, while red light wavelength in flowering/ fruiting. selection or fabrication of effective grow-light is very much possible. But most important is to choose & use grow light in the most effective way. Again, in Indian context very less scientific data available in this regard. We at Vigyan ashram, conducting experiments on application of LED light in hydroponics. Following are few details-

## Selecting grow light as per need (good read) -

https://www.geturbanleaf.com/blogs/lighting/measuring-light-for-indoor-plants

## Hydroponics in urban context:

With availability of Solar PV based electrification solutions and LED lamps, hydroponics systems will be more affordable. It can be used as indoor multilayer farming in urban spaces.

With advantage of less weight, use of vertical space, zero water-seepage, automated controls etc one can have green-wall within house. This green wall can be of daily use salads, flowering & decorative plants. A part from some veggies it can reduce stress, pollution and harvest solar energy for better environment.

# Experiment 1:
# Coriander + Chrysanthemum

Experiment conducted during November – December 2022 on using LED lamps for indoor flood & drain based hydroponics system. Experiment details were as follow-

- Flood & drain system with 10 lit reservoir + 10 lit growing box
- Gravity based F & D
- LED lights – 1.5 watt (??) each with 3 RED + 6 White + 4 Blue LED & timer
- System light intensity – 26 cm height – 5600 lux, 13 cm height- 11000 lux
- LED timings – 7 Am to 7 Pm for chrysanthemum while 24 Hr lightning for Corindar.
- Input water parameters: pH- 6.8, EC-270 uS/cm, TDS- 53 ppm
- Fertilizers for 10 lit system: 19:19:19 (1.06 gm), $CaNO_3$ (1.163 gm), $MgSO_4$ (0.520 gm), Micro nutrients (0.340 gm), Phosphoric acid (for adjusting pH)
- Water parameter (final): pH-5.7, EC- 822, TDS- 412
- Water circulation: 15 min flooding/ Hr
- Grow media: Vermiculite + gravels

## Results:

- Coriander vegetative growth – more vine growth in white (6 LED) + red (3 LED) without blue light. With addition of blue light (4 LED) – greenish leaf color + erect growth. Healthy leaves & root growth
- Harvesting of coriander @ 42 days
- Chrysanthemum- RED + BLUE + WHITE light very healthy vegetative growth. But no flowering in 90 days. (Dark period – 10 Hrs)

## Does every hydroponics system require artificial light? Do I need to purchase expensive grow-light for hydroponics?

Certainly not. Hydroponics does need artificial lighting when plants placed in a dark room or competing for light in NFT like system. And you don't need to buy an expensive artificial lighting system. An all-spectrum LED strip (tub-light) is sufficient for hobby or home scaled hydroponics system. For commercial scale application measuring lux, photo-period etc will be necessary as we expect increase in yield with artificial light cost.

CHAPTER 6

# Moving forward

Precision farming techniques like hydroponics, aeroponics, aquaponics etc definitely have a future in the Indian context. Day by day stress on agricultural resources is increasing. Fertility of land & deteriorating quality of irrigation water are going to be big challenges affecting agricultural productivity & profitability. Scope of hydroponics farming is increasing with increase in awareness on clean food, change in eating habits, technological advancements etc. Urban farming, terrace farming, grow-own-food etc movements are also inclining toward adoption of such technologies.

We found hydroponics cultivation requires knowledge of biology (plant physiology) and engineering domain. Different methods of hydroponics cultivation has its own merits & demerits; the user has to understand them and adopt appropriate methodology as per resources & target yield. There is no need to invest in very high end system and one can build them very easily by understanding basic designing concepts & plant requirements. Similarly aspects like

water quality management, fertigation, DO management, nutrient deficiency identification can be adopted by trial-error method & experience. Following are some of the concept we will be exploring in our future trial in this regard-

- Trials on various Indian vegetable crops to get SOPs of cultivation.
- Conducting trials to better understand nutrient flow & uptake mechanism, role of DO in water, exploring microbial rhizosphere effect, exploring use of vermiwash / compost tea, net energy balance of system in comparison with natural farming.
- Documenting ROI of various systems.

We suggest farmers to build their own experimental or demo farming model first & leverage their learning for commercial cultivation.

Though it will be still debatable whether such energy demanding systems are going to be really sustainable ? But in our view, very fast development in the renewable energy sector & advancement of AI techniques will open new ventures in future farming! By that time hydroponics will definitely provide better learning & exploration ground for innovative farmers.

We will keep on updating our learning through timely publishing and request our views to share their feedback, experiences (good & bad) and difficulties for better collaborative learning & mutual benefit.

# Annexures

## Crop specific experiment trial results during 2018 to 2022 at Vigyan ashram campus (summarized)

### Crop Specific Data :

https://vadic.vigyanashram.blog/ipg/hydroponics-crop-specific-experiment-results-at-vigyan-ashram-summarized/

### Hydroponics structure design details:

1. **Deep Water Culture :**
   https://vadic.vigyanashram.blog/ipg hydroponics-structure-design-deep-water-culture/

2. **Nutrient Film Technique:**
   https://vadic.vigyanashram.blog/ipg/hydroponics-structure-design-nutrient-film-technique/

3. **Flood & Drain:**
   https://vadic.vigyanashram.blog/ipg/hydroponics-farming-flood-drain-structure-design/

Fertilizer schedule during spinach trial January 2020-

| Nutrient | Dosing | Remark |
|---|---|---|
| Phosphoric acid | 140 Ml | For lowering pH. It would have supplied phosphorus |
| Calcium Nitrate | 878 gm | Total of 6 dosing's |
| Potassium Nitrate | 250 gm | Total of 3 dosing's |
| Potassium Phosphate | 50 gm | 1 dosing |
| Potassium Sulphate | NIL | -------- |
| Magnesium Sulphate | 500 gm | Total of 3 dosing's |

Average pH- 6.8 to 7.3, Average EC – 600 to 900, Average TDS – 250 to 650.

## List of materials used in setting up of hydroponics systems.

| Name of material | Specification | Online source |
|---|---|---|
| Floating bed for hydroponics | Styrofoam, PU foam, PVC sheets etc | NA |
| Net pot cups | 2 – 3 " diameter, recycled HDPE or virgin plastic made | https://www.indiamart.com/proddetail/unbreakable-hydroponic-net-pots-7746305788.html |
| Timer / auto switches | Plug timer or rail mounted (analog or digital) of | https://www.selec.com/product/rtc-timer-self-powered |
| Air blower (for small system) | Diaphragm or magnetic pumps of 45 watt with air flow of ........ | https://www.amazon.in/ANMSALES-ACO-003-Magnetic-Aquarium-Hydroponics/dp/B07HD5Q1FJ |

| | | |
|---|---|---|
| Air diffusor | Airoxy make with necessary fittings | https://www.airoxitube.com/aeration-tubing-products/floating-diffuser-grid/ |
| Submersible pump | Magnetic 18 to 35 watt ( Desert cooler pump) | https://www.amazon.in/Amicikart-Submersible-Desert-Aquarium-Fountains/dp/B01BX94DEK |
| Grow bags | 1 mtr length with pH balanced cocopeat | https://www.indiamart.com/proddetail/coco-peat-grow-bags-7347878355.html |
| Water testing kit | Hand-held , colorimetric kits for ammonia, nitrate, Calcium hardness etc | https://www.amazon.in/API-Fresh-Water-Master-Test/dp/B000255NCI |
| pH / EC meter | Digital hand held or colorimetric | https://hannainst.in/economical-pocket-testers/phep-pocket-sized-ph-tester-hi98107p.html |
| MBBR / biofilm media | Recycled HDPE | https://www.indiamart.com/proddetail/mbbr-media-11531832512.html |

## Testing protocol for water quality parameters as total harness, Calcium : Magnesium and Potassium

Many hand-held DIY on-field testing kits are available for analysing hydroponics water quality & nutrient balance. Our approach is to know science of testing & standardization of analytical procedures for farmers as well testing labs. Following important process tested & SOP's developed for its applicability in hydroponics water analysis:

**Testing of Water hardness:**

# A. Testing total hardness

**List of chemicals:**

EDTA solution, standard $CaCO_3$ solution, Eriochrome Black –T Indicator, Buffer Solution, Mercurex indicator, Inhibitor.

**Working principle:**

EDTA (Ethylenediamine tetra acetic acid) forms colorless stable complexes with $Ca^{2+}$ and $Mg^{2+}$ ions present in water at pH = 9-10. To maintain the pH of the solution at 9-10, buffer solution ($NH_4Cl$ + $NH_4OH$) is used. Eriochrome Black-T (E.B.T) is used as an indicator. The sample of hard water must be treated with buffer solution and EBT indicator which forms unstable, wine-red colored complex s with $Ca^{2+}$ and $Mg^{2+}$ present in water.

- Procedure for testing:
- Take 100 ml of the sample and add 2 ml buffer solution in it and add 2- 3 drops of Black T.
- Titrate it with standard EDTA solution (with continuous stirring) until the last reddish colour disappears.
- At the end point the solution turns blue. Note down the volume used.

**Calculate Hardness as follows:**

**Total Hardness (in mg/L as $CaCO_3$) = (V× N × 50 ×1000) / (SV)**

**Where:**

- o V = volume of titrant (mL);
- o N = normality of EDTA
- o 50 = equivalent weight of $CaCO_3$
- o SV = sample volume (mL)

## B. Testing Ca-Hardness:

- Take 50 ml of the sample and add 1 ml Sodium Hydroxide solution (8%) in it and add pinch of Mercurex Powder.
- Titrate with standard EDTA solution until the light pink colour of solution converts into light blue color.

Calcium Hardness (in mg/L as $CaCO_3$) = ($V_1 \times N \times 50 \times 1000$) / (SV)

## C. Thermotical calculation Magnesium:

Magnesium = Total hardness as $CaCO_3$ – Calcium hardness as $CaCO_3$

Key observation (do's / don'ts )

- Weigh accurately 1gm $CaCO_3$ and transfer to 250 ml conical flask. Then add 1:1 HCl till $CaCO_3$ dissolve completely. Add 200 ml dist.water and boil for 20 to 30 min. then cool and add methyl red indicator. Add $NH_4OH$ 3N drop wise till intermediate orange colour develops. Dilute to 1000 ml to obtain 1ml=1mg $CaCO_3$.

**Potassium determination:**

- List of chemicals: Ammonium acetate 1 N, KCl
- Apparatus: Flame photometer
- Science / Principle

Potassium ions can be determined quantitatively when they are atomized from solution, led to burner and exited to spectral emission in a flame. Since the intensity of the light emitted by each element depends primarily on the concentration of its atoms in the flame at any given instant, a measurement of the light intensity produced by a given element makes possible the quantitative determination of that element.

- Procedure: Preparing standard curve solutions:
- Dissolve 1.9117 g dried KCl in distilled water and make to 1 L volume.
- 1N ammonium acetate solution- dissolve 77 g ammonium acetate in 1 liter dist. Water.

Prepare the following dilution 10, 20, 30, ....., 100 ppm from the standard 1000 ppm solution in solution of 1 N ammonium acetate pH 7.0.

**Procedure:**

1. Add 50 ml of ammonium acetate solution to 50 ml sample. Place the bottles in the shaker.
2. Shake for 1 hour.
3. Filtrate through filter paper whatmann paper.
4. Determine the potassium concentration by use of the flame photometer and the appropriate calibration curve.

## References: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VI. https://www.suezwaterhandbook.com/water-and-generalities/fundamental-physical-chemical-engineering-processes-applicable-to-water-treatment/chemical-precipitations/removing-hardness-calcium-and-magnesium


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