Basics of hydroponics farming

A note on experimental learning at Vigyan ashram

Vigyan Ashram Pabal , Tal-Shirur

Pune . 412403

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

Convectional 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 nutrient from no-mobile to mobile form.	Water soluble nutrient in the form of easy acceptance form.
Nutrients (fertilizers) are given to soil based on soil analysis. So fertilizers doses are higher.	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.

Even after these advantages hydroponics is still high investment technology with poor ROI in Indian context.

We at Vigyan ashram (www.vigyanashram.com) studying various aspect of this technology to understand its science, appropriate methodologies & scope of adoption. Following are some of the challenges in adaptation of hydroponics farming in Indian context.

Technical	Non-technical
• Higher cost of water treatment (mainly requirement of reverse osmosis treatment) • Lack of nutrient balance standardization for particular crop • Lack of scientific approach in system design	• Higher fixed investment • Lack of quality seeds in affordable price • Lack of technical know-how & skill training to farmers • Interrupted power supply

To find way-through to above challenges small experimental system is established at VA-Pabal campus with climate control polyhouse system. Following are some of the objectives marked for first phase experimentation.

1. Trial test different methods of hydroponics cultivation viz. Deep Water culture (DWC), Nutrient Film Technique (NFT), Grow bags (with soil), Grow beds (with coco-pit), flood & drain based hydroponics for its application, easy-ness in implementation, cost-break up & overall usefulness.
2. Standardizing water quality parameters mainly – water hardness, Calcium:Magnesium ratio and source of nitrogen fertilizer with following experiment –

- Experiment with reducing water hardness (higher Calcium – Magnesium content) in cost effective way.
- Convert Ammonical (NH_3 / NH_4) fertilizers in to nitrate (NO_3) form as low cost & lower salt concentration nitrogen source.

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

Experiment duration : 20th January 2020 to 31st March 2020 (70 Day's)

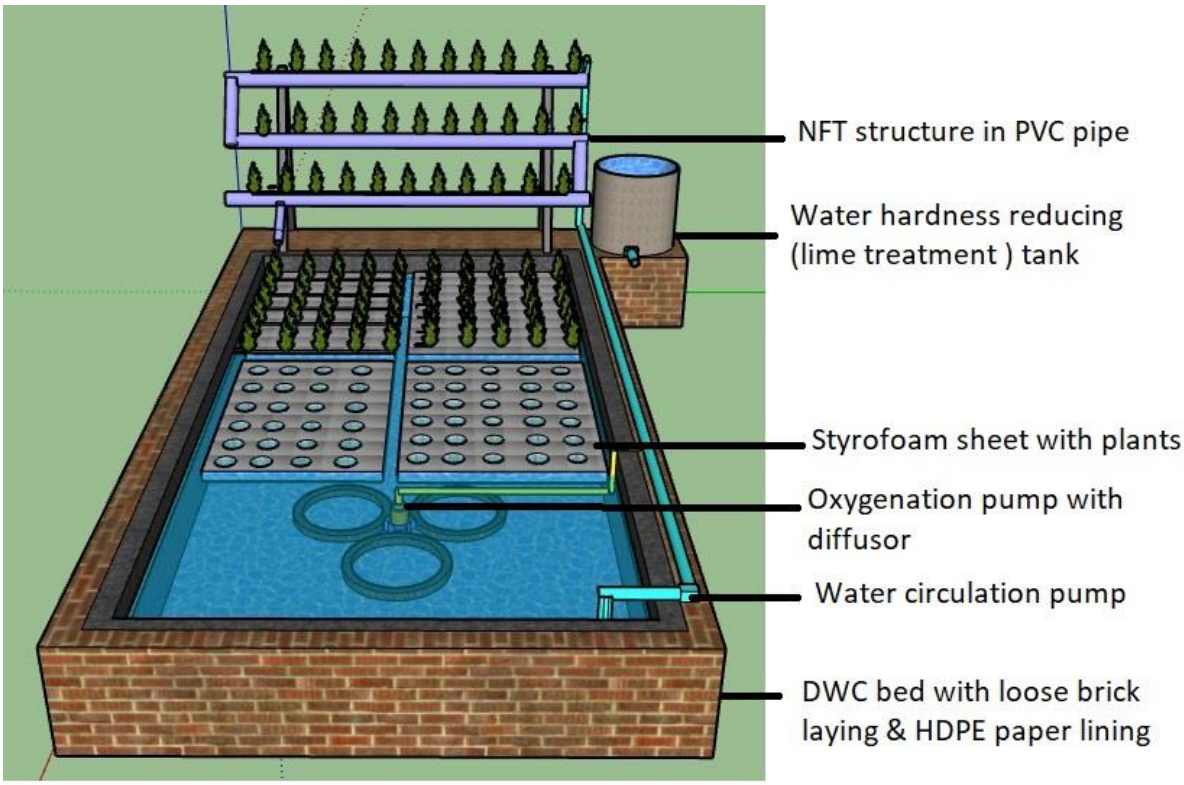
Objective specific experimental finding details:

1. Trial test different methods of hydroponics cultivation for its application, easy-ness in implementation, cost-break up & overall usefulness:

Deep Water Culture (DWC) –

DWC as name suggests it's a system in which plants placed in water in such a way that its roots remains suspended in water containing essential nutrient. Care is take to support plants to make them floating & 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 maintains in way that nutrients will flow easy & efficient way from water to plant. Its bit simple, less expensive and easy to implement system.

There are 2 main types of DWC systems commonly been practiced by farmers as closed loop & open loop system. In open loop system certain amount of water is drained from system regularly & new water added to maintain water quality, where as in closed loop system only evaporation loses or water usage are make up to maintain its level. Now a day 'mixed loop system; are also becoming popular with aquaponics or recirculating aquaculture system (RAS) support.



As shown in above sketch, we designed a close 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)

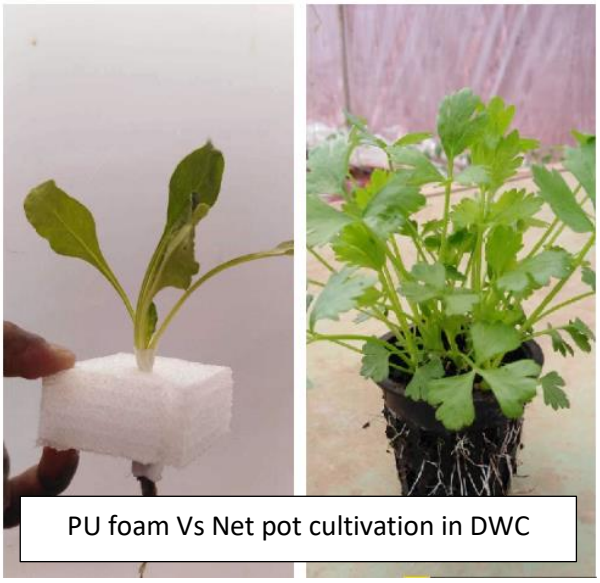
- HDPE 500 GSM black paper used for making it leak-proof pool tank.
- Styrofoam sheet of 1.12*0.88 Mtr (length * width) with 1.5 inch thickness were used to hold plants.
- Individual plant spacing of 0.22*0.15 Mtr is maintained for each floating foam.
- A water circulation submersible pump of 18 watt and air blower of 45 watt with *airoxy* tube diffusor 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 sheet, so that the root-shoot junction should be above water level. If this junction touches water or water enters into tip of seedling *collar rot* (fungal infection) changes increases.
- Polyurethane foam sheet made inch cubes were also tested for planting seeds with a kind capillary sheet (newspaper or brown paper strip) instead of net cups. Its reduced cost of net pots but it's found net pots perform 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 also placed directly with cocopeat. Its found that coco-coir doesn't suits well as it restrict root movement through net pots.
- Major pest was white-fly's, Mealy bugs which can be easily controlled with neem oil & soap mix.

Styrofoam sheet in DWC bed with net pots

Details of material specification is given in Annexure I

Ready to harvest lettuce & Basil plants



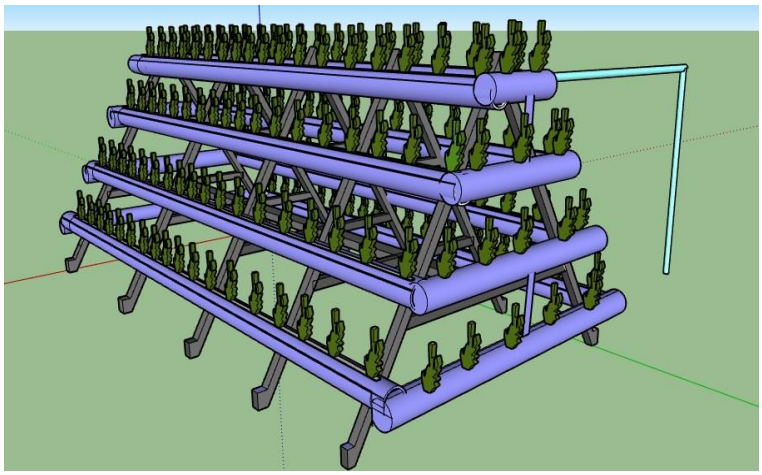
PU foam Vs Net pot cultivation in DWC

Results -

During 70 days 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 trial period are attached separately in Annexure II. Except periodical Magnesium (Mg) deficiency in salads and potash deficiency in tomatoes no other sings were observed. I found that heat stroke blossom lettuce is sensitive to heat stroke of 28 ℃ & above temperature. White fly , mealy bugs were reported on tomatoes, zucchini @ average temperature of 30 ℃ & 60 % humidity.

Nutrient Film Technique (NFT)-

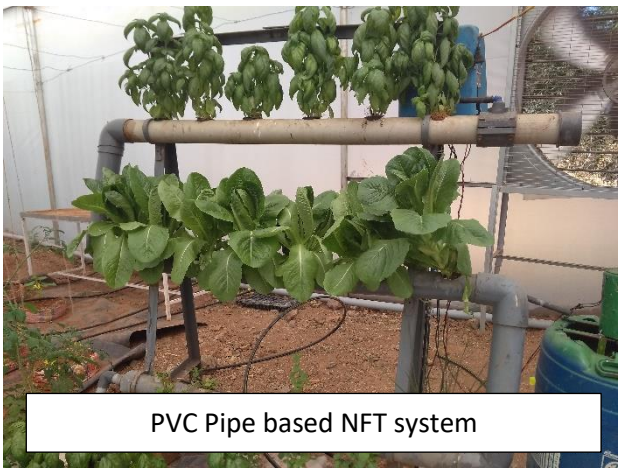
In NFT technique nutrients are transported to plants in the form of thin water film. So basically it's a flow of water with necessary nutrients through plant roots. In NFT root are not completely suspended in water bed but water is circulated to plant roots. By this overall weight load of system get reduced & vertical space can be utilize to increase net output per unit area. Circulation of water also add necessary oxygen in water & avoid nutrient channeling. By this mass flow of nutrients (from water to root surface) encouraged. Specially designed NFT planters (beds) are used for plantation or for smaller



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

Following were the design parameters for our experimental design as:

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



PVC Pipe based NFT system

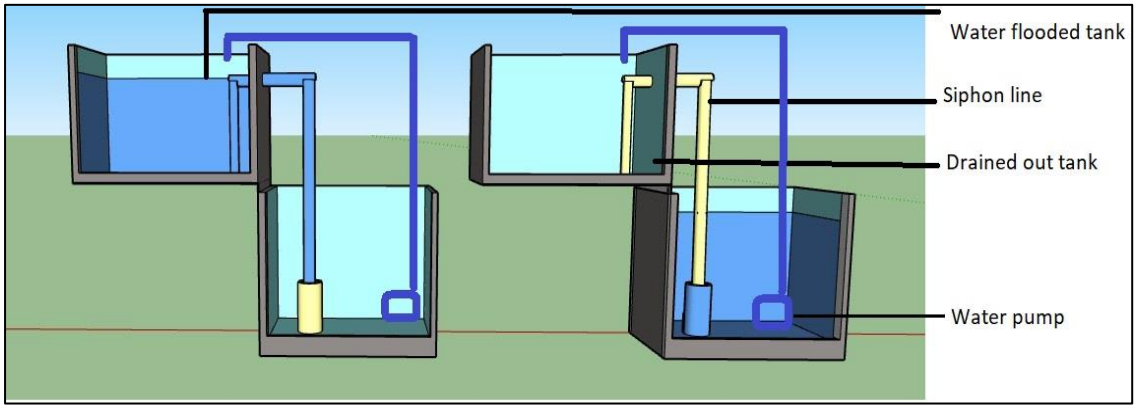
Overall performance of NFT was satisfactory with an added advantage of vertical space utilization. Lettuce, basil, mint like salads performed very well in system. NFT looks attractive, saves space and handy for urban farmers.

Flood & drain based hydroponics system:

Aeroponics (growing plants on nutrient balance mist spray) is another way of advance 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 higher pressure jet nozzles. High pressure nozzles needs a soft water (probably RO). Its makes system high investing (fixed as well recurring cost) and requires regular maintains.

To overcome this difficult while keeping advantage of lower weight & cost of nutrient solution, we are working on designing a 'flood & drain' based hydroponics system.

Technically 'flood & drain' will be mixed approach to DWC and NFT system. Flood & Drain mechanism normally used in aquaponics & waste water treatment. As name suggest its



basically flooding a planter bed with water & draining out completely usually by siphon drain. By this nutrients spread over root zone like DWC and drain it out leaving thin film. Larger advantage of flood & drain is that when water get replaced by air it makes oxygen rich environment for root zone. This system also allows mass flow of nutrient more efficiently. Overall load of system get reduced as standing water column is replaced by sequential flooding. Misting or high pressure fogging doesn't required for system become less completed & cost involving. System can be built easily with simple material like trays, water pump, gravity based siphon etc. (Reference I)

Flood & Drain pot based hydroponics system

Present system simply takes nutrient solution to 'plant pots' (5 Lit capacity plastic container) with very low weight grow media & drains back to reservoir tank. A automated timer operate 12V DC 36 Watts DC pump with a flow rate of 4.5l/min for duration of 4 min / 30 min cycle time. Experiment show potential in larger scale replication especially in urban farming link with garbage recycling (compost tea application) . This work is at very primitive stage more details can be found on http://vadic.vigyanashram.blog/2020/02/15/aeroponics-flood-drain/

Grow bags or bed with growing media:

Grow bags or troughs are used hydroponics cultivation as plant container. It may be debatable as its not strictly only water based cultivation, but uses neutral media and provide disconnect from field soil. Growbags 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 size are used with soil (well drain& compost mix (5:1) ratio. Each bag watered with drip irrigation system. Our assumption is with improved aeration & soil availability, crops with symbiotic microbial association (leguminous) will perform better here as compare to DWC or NFT. So far results are encouraging we will update with end results in next update.

- A separate trial is also under way to use misture of kitchen & garden waste as pot mix @ 1 Kg compost + 2.5 Kg soil + 3 Kg of garden waste. Grow bags of 12*18 inch made from agricultural green shed net.

- **Grow bags with coco-peat:** A ready-made grow bags with cocopeat are also planted with drip line. Water soluble fertilizers supplied to these bags. Each bed planted with 3 samplings of tomatoes. pH and EC of grow bag maintained @ 6.8 to 7.5 and 1200 to 3000 uS/cm.

Cocopeat based grow beds

- **Vertical grow bags with coco-peat & Bajara husk:**

Grow bed can also be placed vertically as NFT. We used PVC blue sheet square box filled with cocopeat. These beds were placed in 3 layers. Each grow bed is of 7 ft length with 20 plants/ each. These beds are mounted on metal fabrication structure. Each bed is fixed with in-line drip irrigation system connected to 18 watt submersible motor pump. Extra water from beds are collected & recycled back to system. Salads are planted in system , this can be used for fruit crop like strawberry. (Photo attached for details.)

Vertical stacking grow beds with cocopeat & drip line irrigation system

Overall performance of above systems, maintains issues, cost-break up will be updated as trial progress.

2. Standardizing water quality parameters mainly – water hardness, Calcium : Magnesium ratio and source of nitrogen fertilizer with following experiment –

Apart from being physical support & hosting many beneficial micro-organism soil also plays very important role in holding & mobilizing essential plant nutrients. We need to understand difference between nutrient mobility from water or soil in regular (soil based) farming and hydroponics / aeroponics. In hydroponics cultivation water acts as media for nutrient transfer & storage. Emphasis is given on suppling essential plant nutrients in water soluble & easily available form so as to facilitate easy uptake & reduce dependency on microbial conversion.

It's well understood that plants need 18 essential nutrient for its functioning. In hydroponics all these nutrients (apart from CO_2 & O_2) are supplied through water. For effective nutrient management, 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 wile 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 withing water tank. So it's important to avoid this channeling by giving movement to water. Hydroponics systems are efficient as compare to traditional soil based cultivation as mass flow in soil affects by many factors. In various method of hydroponics NFT and flood & drain system of hydroponics is much more efficient than DWC as in these system water keeps moving in 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. But it's important to note that when plants saves their metabolic energy in development of roots for sourcing them that energy may get utilized for better vegetative growth of plant. It could be one of the reason behind higher productivity in hydroponics farming.

Nutrient mobility from root surface to inside of root cell membrane (nutrient uptake mechanism) : Its mainly govern by ion exchange, carrier association , microbial association) [Reference III & IV]	Osmotic pressure of root surface area Vs water, play important role in ion exchange. Electrical Conductivity (EC) is one-way of measuring osmatic pressure. EC has to be critically managed so has to achieve efficient ion exchange. Though its recorded that plant are capable of holding required ion within cell against osmotic pressure but it may demand more metabolic energy affecting overall development of plant.
	Total Dissolved Solid (TDS) is measured in hydroponics to know various dissolved salts in water & add deficient in right proportion. Proportion of potash, calcium and magnesium is important in its mobility within root. Normally 6:2:1 of K:Ca:Mg is considered desirable (crop specific). Calcium & Magnesium governs overall harness of water so generally referred as water-hardness.
	Potassium also play very important role in maintaining osmatic movement within cell by participating in water molecule in-out movement. So its optimum level has to maintained for efficient nutrient mobility.
	In case of nitrogen (which the most important nutrient), mobility of nitrate is much faster than ammonia. So nitrate based fertilizers are dominant in hydroponics farming. Buts its important to note that nitrate should not be associated with any other salt (cation) like calcium, sulpher etc. So 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 may perform better in hydroponics system
	Hydroponics farming best suits for water loving or succulent plants. As these plants doesn'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. Its recorded that DO of water @ 10 -15 mg / lit gives best results which can be achieved by air pumping + liquid oxygen pouring in system.

One of the major challenge in hydroponics farming is maintaining desire water quality. Hydroponics water is not only important in terms of its nutrient but also it should have proper osmotic pressure (EC) for transfer of nutrient from water to plant. In general (non-crop specific) water quality parameter are - Total dissolved solid (TDS) 500 to 1200 ppm, Electrical conductivity (EC) – 800 to 3000 uS/cm, Hardness – 100 to 150 ppm (hardness is also important in relation to calcium: magnesium ration & it has to 2:1). A part from this , need of vital nutrient in water varies with crop and there are many formulation / quantitative specification available on internet. These fertilizers are prepared in concentrated solution form as A & B solutions to avoid precipitation of slats & added to system based on crop specific or water EC / TDS based dosing. Farmers doesn't need to buy ready-made formulation as all water soluble fertilizers are easily available in market. Major nutrients (N, P, K, S, Ca, Mg) can be added in

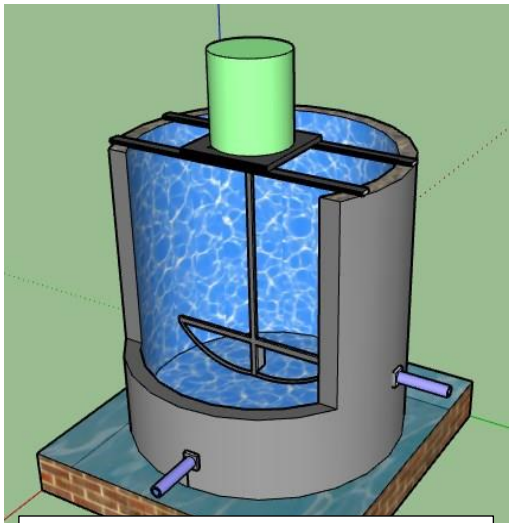
combination with related salts based or chelated form. For example potassium (K) can added as Potassium nitrate (KNO_3) or Potassium sulphate (K_2SO_4) or chelated potassium based on availability in market, cost (chelated are costly but more effective) & desire nutrient mix. Details on prescribed levels of water quality parameters can be found in reference (V).

In hydroponics cultivation widely used practice is to filter water through reverse osmosis (RO) filters to reduce TDS & EC of water at desire level and them again adding essential plant nutrient in desire quantity.

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

Higher hardness in irrigation water especially in low rain fall area is due to higher calcium & magnesium salts (carbonate hardness). It limits hydroponics cultivation as with higher TDS nutrient mobility adversely affects. We found most of hydroponics growers forced to use Reserve Osmosis (RO) unit to overcome it. But RO's increases initial investment and its recurring cost is also very high (as membrane filter need to change frequently). By using RO net water requirement of system is also increases due to rejection of higher TDS water. It's also un-ethical to put so much of energy to filter out naturally available minerals (nutrient) 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) react with calcium hydrogen carbonate and precipitate calcium as calcium carbonate & magnesium as magnesium carbonate Details on various water softening treatments reference (VI)

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



Schematic of Lime treatment drum system

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

We are experimenting on appropriate Ca: Mg ratio for broccoli & tomato crop. Will update as trial progress.

Convert Amide (NH3 / NH4) fertilizers in to nitrate (NO3) form as low cost & lower calcium content nitrogen source:

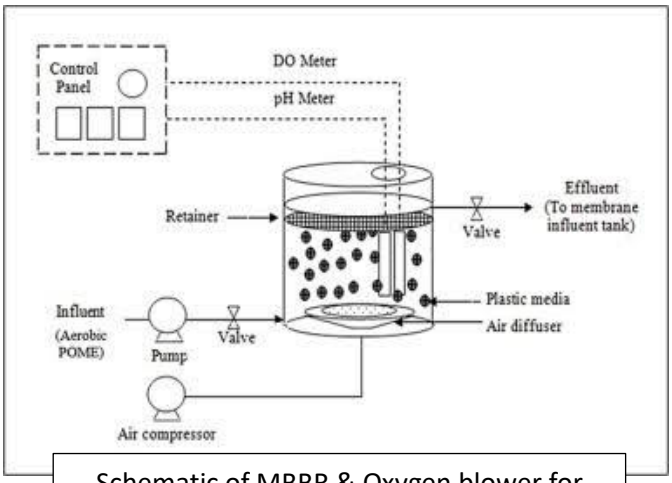
While preparing nutrient balance for hydroponics system, keeping lower TDS or EC would be primary challenge for any grower. Higher calcium, magnesium or other salts along with added minerals increases salts in water increasing its EC. Higher EC limits nutrient mobility due to higher osmatic pressure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

Nitrogen is one of the major nutrient required by plants in regular basis. On dry weight basis plant content around 4 % of nitrogen in its cells. Nitrogen required for photosynthesis and protein formation. Plants can take up nitrogen in the form of ammonia (NH_4 / NH_3) , Nitrate (NO_3) and amino acid form. When nitrate (NO3) available in abundant almost 90 % nitrogen demand get fulfill by it due to its faster mobility (reference IV).

Amide form of nitrogen is readily available in market as urea but nitrate fertilizers gets salt ion like calcium, potassium, sulphate, phosphate etc. Ammonium nitrate been 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.

Other option would be getting nitrate the from aquaponics (fish farming). Its again involve a separate cost proportion & system complications.

Converting ammoniacal nitrogen to nitrate in common bacterial process. Chemotropic nitrifying bacteria involved in the process. We are trying to use these bacterial culture 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.



Schematic of MBBR & Oxygen blower for Amid to Nitrate conversion

It's found that bacteria's are able to convert amid nitrogen 100 ppm into nitrate up 150-160 ppm in 70-72hrs. These results are very encouraging as it's 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 process & scaling up for larger application.

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

Conclusion / future scope of work:

Precision farming techniques like hydroponics, aeroponics, aquaponics etc are definitely has future in Indian context. Day by day stress on agricultural resources increasing. Fertility of land & deuterating 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 also inclining toward adoption of such technologies.

We found hydroponics cultivation requires knowledge of biology (plant physiology) and engineering domain. Different method of hydroponics cultivation has its own merits & de-merits 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 understanding of 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 compares 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 renewable energy sector & advancement of AI technique will open new ventures in future farming! By that time hydroponics kind of systems will defiantly 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.

Annexure-

Annexure I:

List of material used in setting up of hydroponics systems.

Name of material	Specification	Online source
Floating bed for hydroponics	Styrofoam , PU fom, PVC sheets etc	NA
Net pot cups	2 – 3 inch 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

Annexure II:

Fertilizer dosing and deficiency symptoms observation during trial:

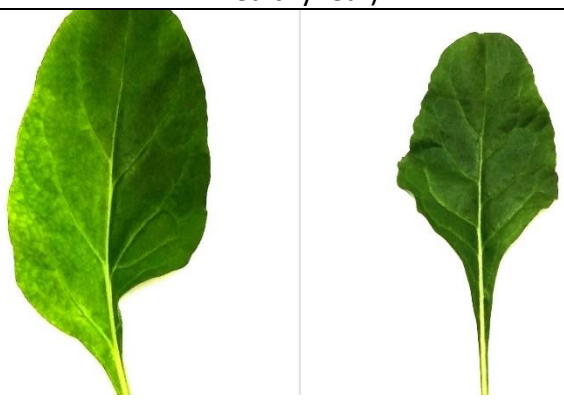
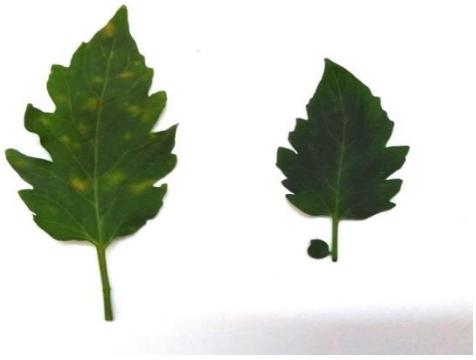
Fertigation record during trial period (during 2 months trial)

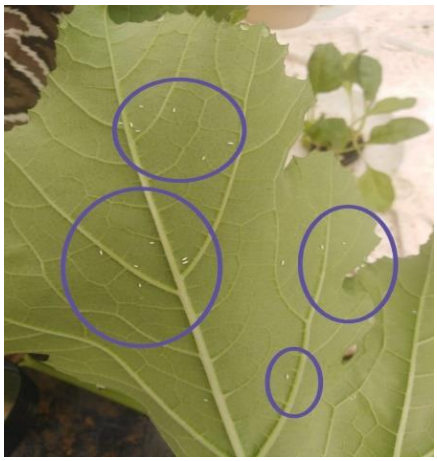
Nutrient	**Dosing**	**Remark**
Phosphoric acid	140 Ml	For lowering pH. It would have supplied phosphorus
Calcium Nitrate	878 gm	Total of 6 dosing's
Potassium Nitrate	250 gm	Total of 3 dosing's
Potassium Phosphate	50 gm	1 dosing
Potassium Sulphate	NIL	--------
Magnesium Sulphate	500 gm	Total of 3 dosing's

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

We are working on further exploration to derive crop specific nutrient balance & water quality management.

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

Annexure III:

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 CaCO3 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 CaCO3) = (V× N × 50 ×1000) / (SV)

Where:

- V = volume of titrant (mL);
- N = normality of EDTA
- 50 = equivalent weight of CaCO3
- 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 CaCO3) = (V_1× N × 50 ×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 CaCO3 and transfer to 250 ml conical flask. Then add 1:1 HCl till CaCO3 dissolve completely. Add 200 ml dist.water and boil for 20 to 30 min. then cool and add methyl red indicator. Add NH4OH 3N drop wise till intermediate orange colour develops. Dilute to 1000 ml to obtain 1ml=1mg CaCO3.

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.

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