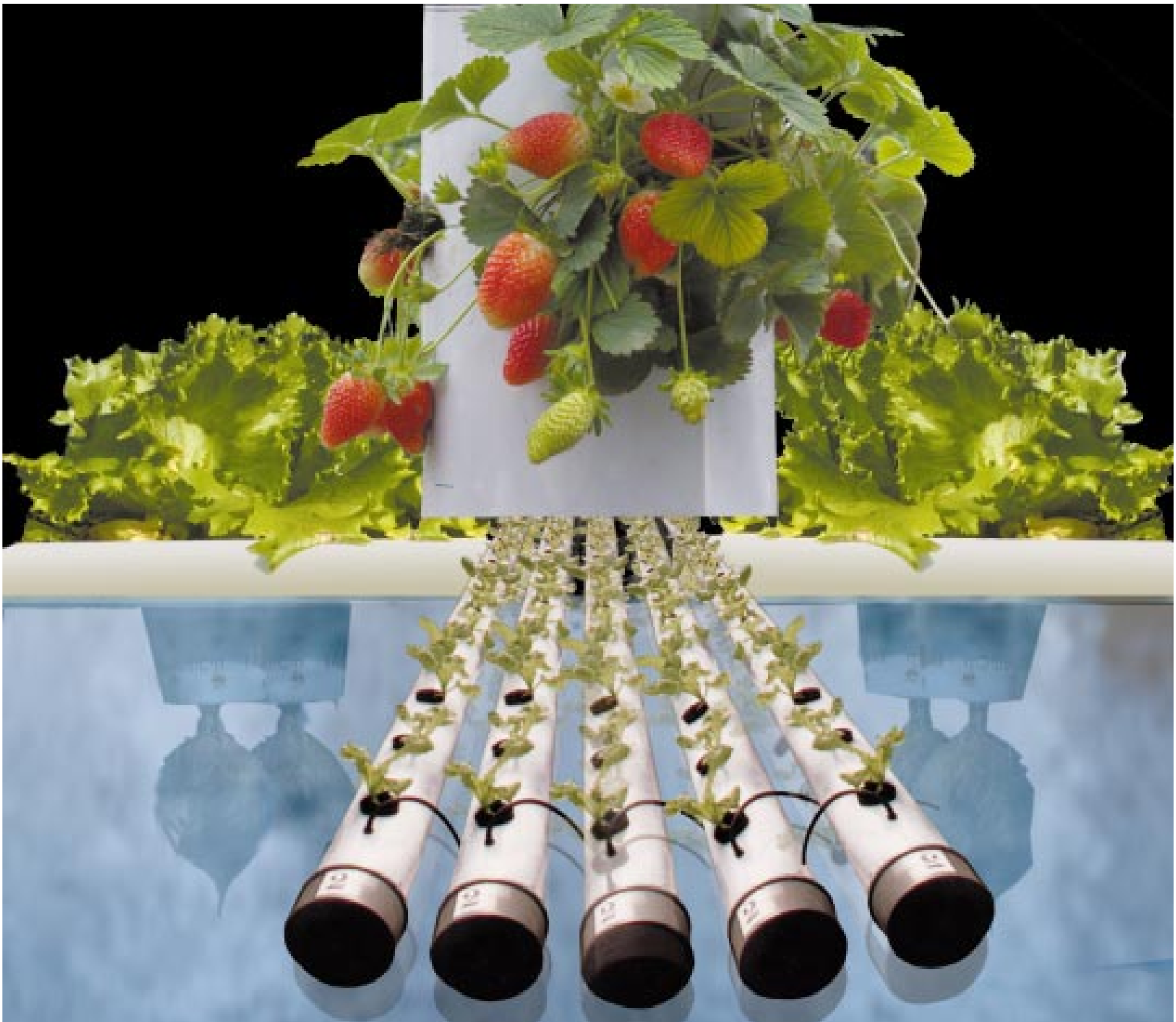

HYDROPONICS

Department of Agriculture
Ministry of Agriculture

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HYDROPONICS/ SOIL-LESS CULTURE

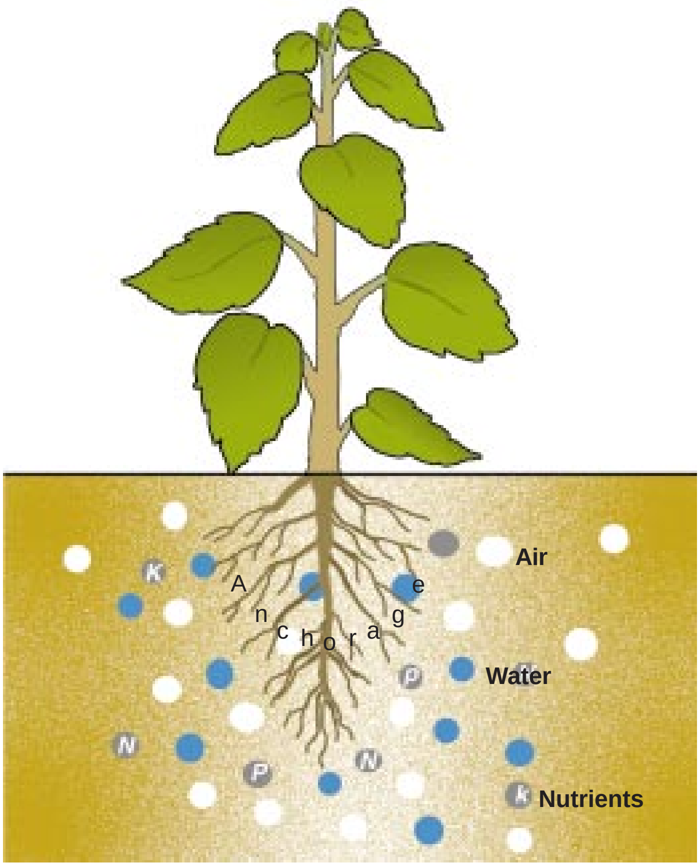

Figure 1: A plant grown in soil

Soil is usually the most available growing medium and plants normally grow in it. It provides anchorage, nutrients, air, water, etc. for successful plant growth. Modification of a soil an alternate growing medium tends to be expensive. However, soils do pose serious limitations for plant growth, at times. Presence of disease causing organisms and nematodes, unsuitable soil reaction, unfavourable soil compaction, poor drainage, degradation due to erosion, etc. are some of them.

Further, continuous cultivation of crops has resulted in poor soil fertility, which in turn has reduced the opportunities for natural soil fertility build up by microbes. This situation has lead to poor yield and quality.

In addition, conventional crop growing in soil (Open Field Agriculture) is difficult as it involves large space, lot of labour and large volume of water. And in some places like metropolitan areas, soil is not available for crop growing. Another serious problem experienced since of late is the difficulty to hire labour for conventional open field agriculture.

Why Hydroponics/ Soil-less Culture?

Hydroponics or soil-less culture is a system of growing plants which helps reduce some of the above mentioned problems experienced in conventional crop cultivation.

Figure 2: Hydroponics lettuce plant

Hydroponics offers opportunities to provide optimal conditions for plant growth and therefore, higher yields can be obtained compared to open field agriculture.

Hydroponics or soil less culture offers a means of control over soil-borne diseases and pests, which is especially desirable in the tropics where the life cycles of these organisms continues uninterrupted and so does the threat of infestation. Thus the costly and time-consuming tasks of soil sterilization, soil amelioration, etc. can be avoided with hydroponics system of cultivation. It offers a clean working environment and thus hiring labour is easy.

Hydroponics/ Soil-less Culture– What is it?

Hydroponics or soil-less culture is a technology for growing plants in nutrient solutions that supply all nutrient elements needed for optimum plant growth with or without the use of an inert medium such as gravel, vermiculite, rockwool, peat moss, saw dust, coir dust, coconut fibre, etc. to provide mechanical support.

Figure 3: Examples for hydroponics/ soil-less culture

History of Hydroponics

Hydroponics was practiced many centuries ago in Amazon, Babylon, Egypt, china and India where ancient men used dissolved manure to grow cucumber, watermelons and other vegetables in sandy riverbeds. The "hanging harden of Babylon" and the Aztec's floating farms were actually prototypes of hydroponic systems. Later, when plant physiologists started to grow plants with specific nutrients for experimental purposes, they gave the name "nutriculture."

Interest in practical application of "nutriculture" developed in 1925 when the green house industry expressed interest in its use. Green house soils had to be replaced frequently to overcome problems of soil structure, fertility and pests. As a result, researchers became interested in the potential use of nutriculture to replace conventional soil culture.

In 1929, Dr. William F. Gericke of the University of California succeeded in growing tomato vines of 7.5 m height in nutrient solutions. He named this new production system "hydroponics" a word derived from Greek to reflect the importance of 'Hydros' (water) and 'Ponos' (working). Thus, hydroponics broke the laboratory bounds and entered the world of practical horticulture. The term hydroponics originally meant nutrient solution culture. However, crop growing in inert solid media using nutrient solution is also included in hydroponics in broad sense.

During 1960s and 70s, commercial hydroponics farms were developed in Abu Dhabi, Arizona, Belgium, California, Denmark, German, Holland, Iran, Italy, Japan, Russian Federation and other countries. During 1980s, many automated and computerized hydroponics farms were established around the world. Home hydroponics kits became popular during 1990s.

In Sri Lanka, the hydroponics system of cultivation is in its infancy. Many use inert solid medium such as coconut fibre or coir-dust with fertigation and some use balanced nutrient solution alone employing both circulating and non-circulating methods in small and medium scales.

Figure 4: Hydroponics strawbery plants in a net house

Basic Requirements of Hydroponics

Soils naturally maintain the temperature and aeration needed for root growth. When the soil is poor, plant growth and yield decline also due to unsuitable aeration and temperature. Plant cultivation is impossible under ill drained condition due to these conditions. Soil adjusts itself to provide suitable conditions for plant growth. It is called the buffer action of the soils. Plants also absorb nutrients released through natural mineralization.

In a solution or inert medium, maintenance of acidity or alkalinity (pH) and electrical conductivity (Ec) in suitable ranges for plant root system is called buffer action. This requirement must be artificially maintained in hydroponics. In any hydroponics system the following basic requirements must be maintained at optimum levels.

- Buffer action of water or the inert medium used.
- The nutrient solution or the fertilizer mixture used must contain all micro and macro elements necessary for plant growth and development.
- Buffer action of the nutrient solution must be in the suitable range so that plant root system or the inert medium is not affected.
- The temperature and aeration of the inert medium or the nutrient solution is suitable for plant root system.

Classification of Hydroponics/ Soil-less Culture

The term hydroponics originally meant nutrient solution culture with no supporting medium. However, plant growing in solid media for anchorage using nutrient solution is also included in hydroponics. This technique is called aggregate system. Hydroponics systems are further categorized as open (i.e., once the nutrient solution is delivered to the plant roots, it is not reused) or closed (i.e., surplus solution is recovered, replenished and recycled). Current hydroponics systems of cultivation can be classified according to the techniques employed. A hydroponic technique refers to the method of applying nutrient solution to the plant roots.

Large numbers of hydroponic techniques are available. However, consider following factors in selecting a technique.

- Space and other resources available
- Expected productivity
- Availability of suitable growing medium
- Expected quality of the produce – colour, appearance, free from pesticides, etc.

1. Solution culture or Liquid hydroponics
   -Circulating methods (closed system)
      Nutrient film technique (NFT)
      Deep flow technique (DFT)
   -Non-circulating method (open systems)
      Root dipping technique
      Floating technique
      Capillary action technique
2. Solid media culture (Aggregate systems) – These can be open systems or closed systems.
      -Hanging bag technique
      -Grow bag technique
      -Trench or trough technique
      -Pot technique
3. Aeroponics
      -Root mist technique
      -Fog feed technique

Liquid or Solution Culture

CIRCULATING METHODS

The nutrient solution is pumped through the plant root system and excess solution is collected, replenished and reused in these methods.

Nutrient Film Technique (NFT)

NFT is a true hydroponics system where the plant roots are directly exposed to nutrient solution. A thin film (0.5 mm) of nutrient solution flows through channels. The main features of a NFT system are shown in figure 5.

The channel is made of flexible sheet. The seedlings with little growing medium are placed at the centre of the sheet and both edges are drawn to the base of the seedlings and clipped together (Figure 6) to prevent evaporation and to exclude light. The cross section of the channel is shown in figure 7. The growing medium absorbs nutrient solution for young plants and when the plants grow the roots form a mat in the channels.

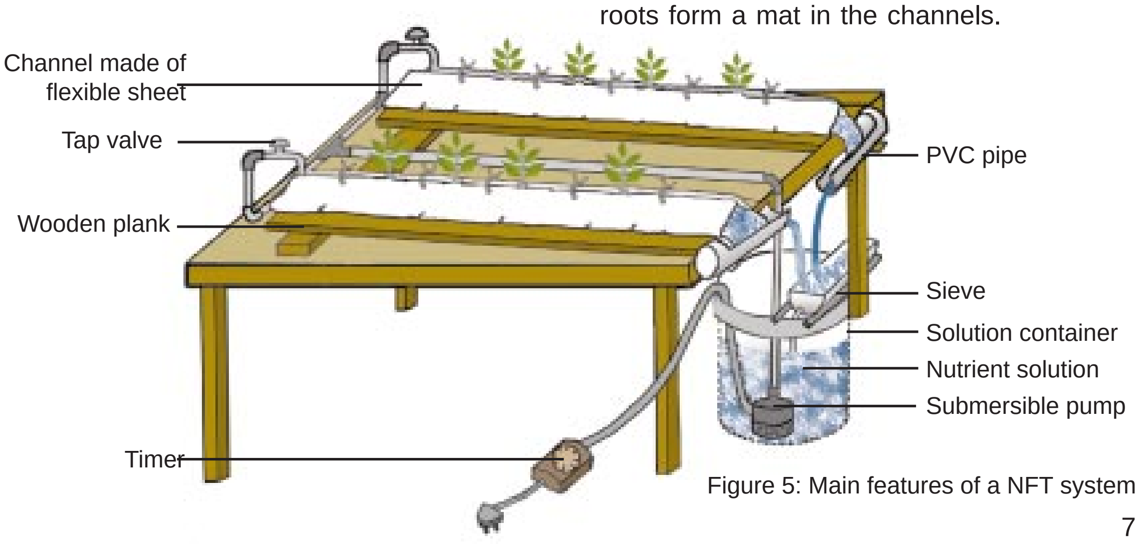

Figure 5: Main features of a NFT system

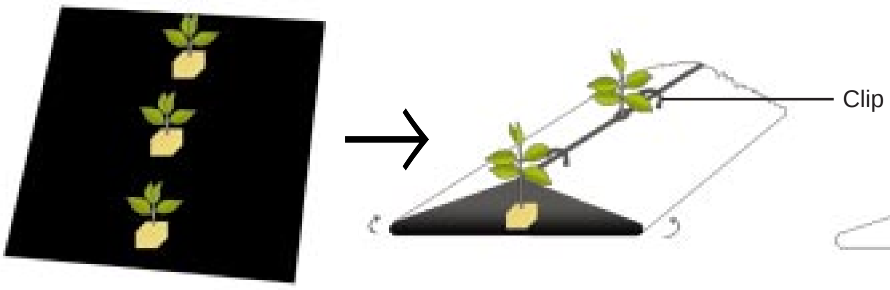

Figure 6: Basic structures of a NFT channel

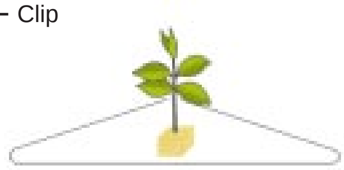

Figure 7: Cross Section of a NFT channel

The maximum length of the channel is 5-10 m and is placed at a slope drop of 1 in 50 to 1 in 75. The nutrient solution is pumped to the higher end of each channel and flows by gravity to the lower end wetting the root mat.

At lower end of the channels nutrient solution gets collected and flows to the nutrient solution tank. The solution is monitored for salt concentration before recycling. Some growers replace the nutrient solution every week with fresh solution.

Adjust the flow rate of the nutrient solution to 2-3 litres per minute depending on the length of the channel. Provide enough support for tall growing plants in this technique.

In practice, it is very difficult to maintain a very thin film of nutrient solution and therefore, this technique has undergone several modifications.

Deep Flow Technique (DFT) – Pipe System

As the name implies, 2-3 cm deep nutrient solution flows through 10 cm diameter PVC pipes to which plastic net pots with plants are fitted. The plastic pots contain planting materials and their bottoms touch the nutrient solution that flows in the pipes. The PVC pipes may be arranged in one plane or in zig zag shape depending on the types of crops grown. The figure 8 and 10 below shows the main features of a DFT – pipe system.

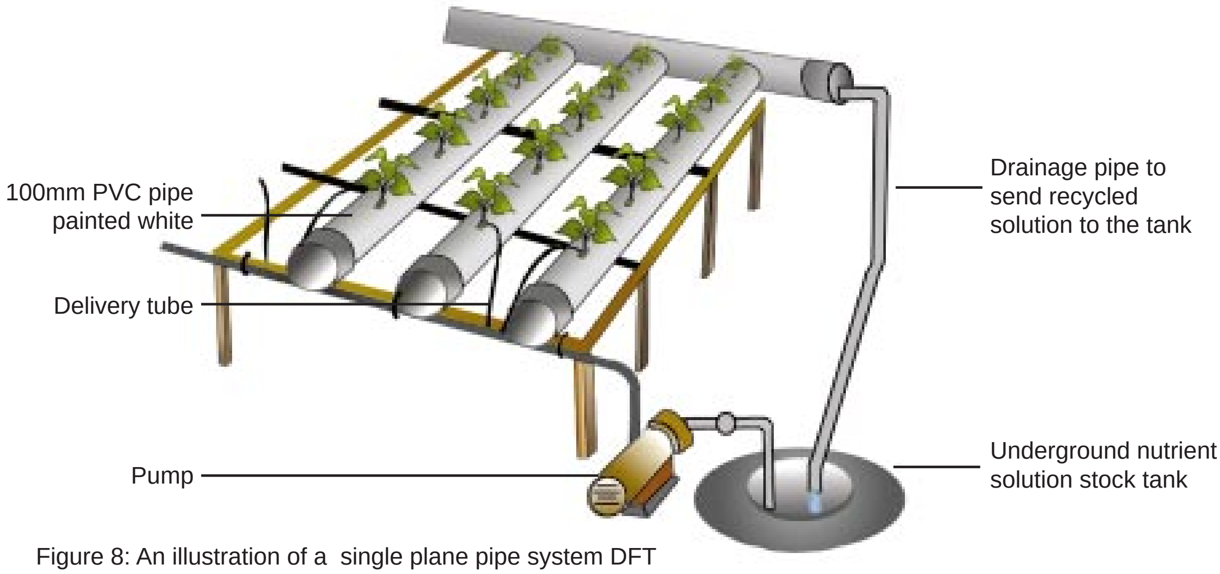

Figure 8: An illustration of a single plane pipe system DFT

Figure 9: A Single plane pipe system DFT

The zig zag system utilizes the space efficiently but suitable for low growing crops. The single plane system is suitable for both tall and short crops.

Figure 11: A zig zag pipe system DFT

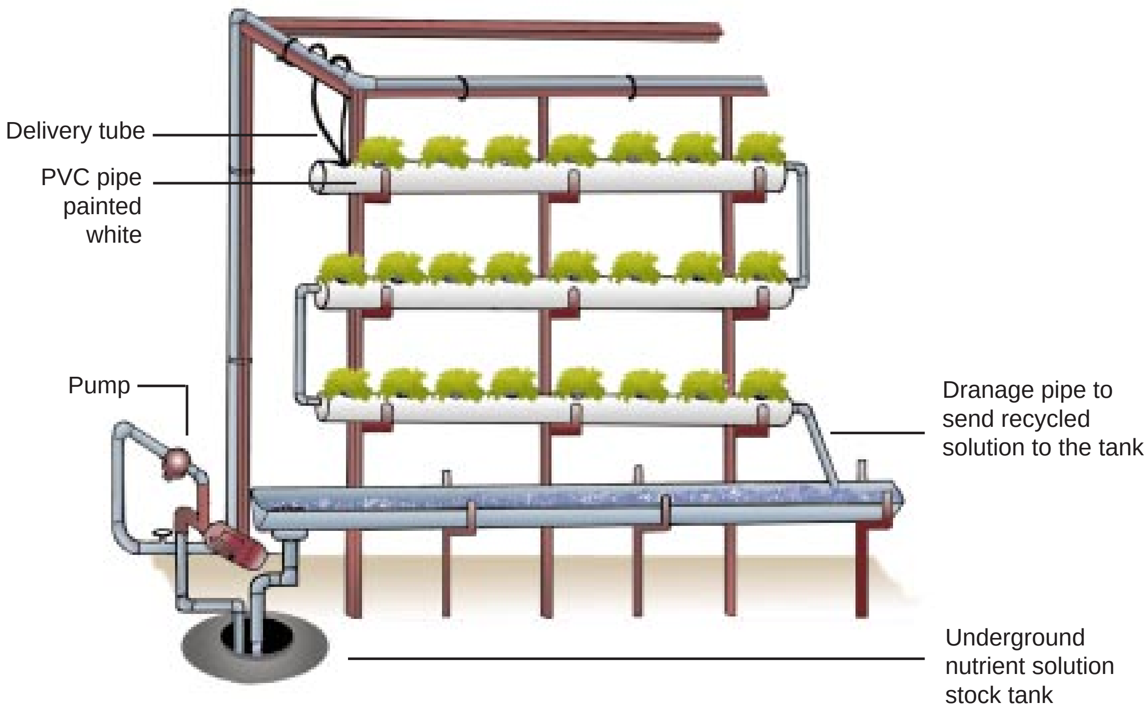

Figure 10: An illustration of a zig zag pipe system DFT

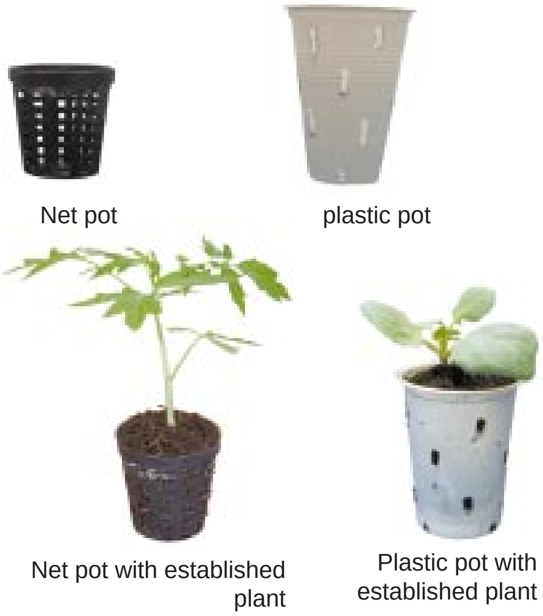

Figure12

Plants are established in plastic net pots and fixed to the holes made in the PVC pipes. Old coir dust or carbonised rice husk or mixture of both may be used as planting material to fill the net pots. Place a small piece of net as a

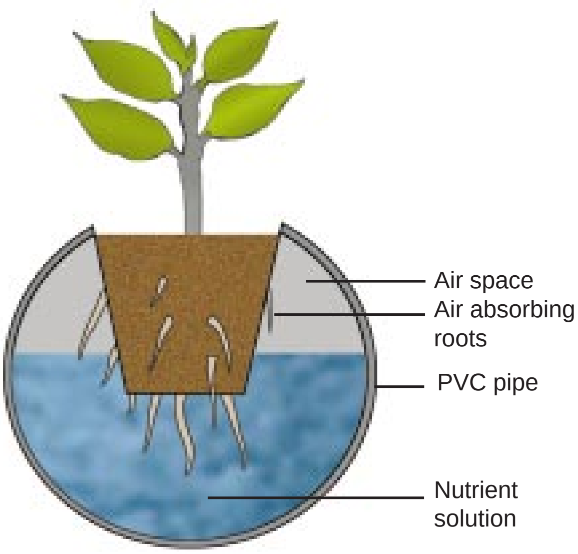

Figure 13: Cross section of a PVC pipe system DFT

lining in the net pots to prevent the planting material falling into the nutrient solution. Small plastic cups with holes on the sides and bottom may be used instead of net pots.

When the recycled solution falls into the solution in the stock tank, the nutrient solution gets aerated. The PVC pipes must have a slope of drop of 1 in 30-40 to facilitate the flow of nutrient solution. Painting the PVC pipes white will help reduce the heating up of nutrient solution. This system can be established in the open space or in protected structures as part of CEA.

NON-CIRCULATING METHODS

The nutrient solution is not circulated but used only once. When its nutrient concentration decreases or pH or Ec changes, it is replaced.

Root Dipping Technique

In this technique, plants are grown in small pots filled with little growing medium. The pots are placed in such a way that lower 2 - 3 cm of the pots is submerged in the nutrient solution (figure 14). Some roots are dipped in the solution while others hang in the air above the solution for nutrient and air absorption, respectively.

This technique is easy and can be developed using easily available materials. This 'low tech' growing method is inexpensive to construct and needs little maintenance. Importantly, this technique does not require expensive items such as electricity, water pump, channels, etc. For root crops (beet, raddish, etc.) however, an inert medium has to be used.

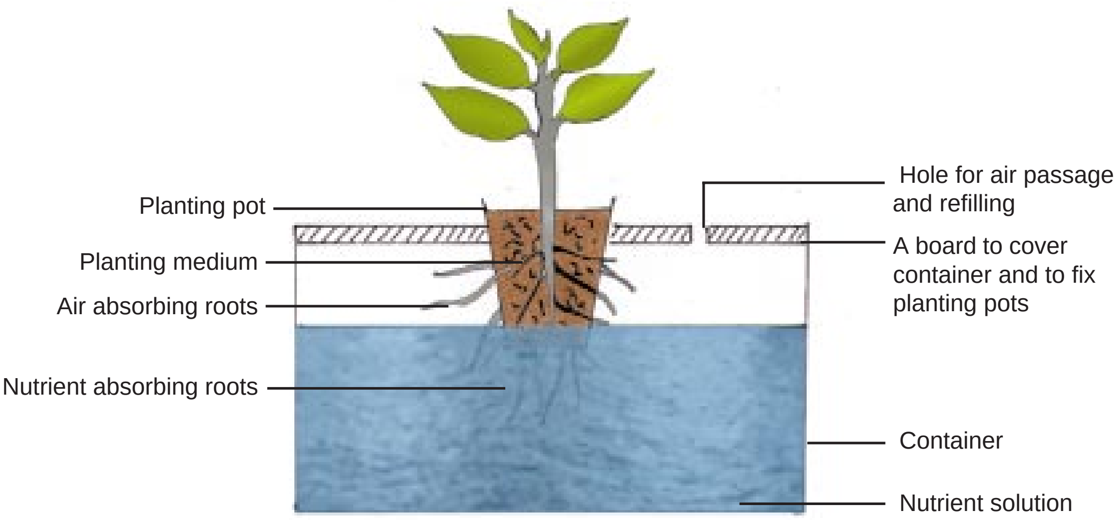

Figure 14: Diagrammatic view of a non-circulating hydroponics non-root tuber plant

1. Root dipping technique for non-root tuber crops

First, select a container for nutrient solution. The container can be almost any kind and shape except metal containers. Styrofoam or wooden boxes, plastic buckets or even cement troughs can be used. Styrofoam boxes are good as they can maintain the temperature of the nutrient solution. Place a black plastic sheet of at least 0.15 mm thickness as lining inside the boxes to avoid leakage and to reduce the light (figure 15). The depth of the box must be about 25 – 30 cm to provide enough solution as well as enough space above the solution for oxygen absorbing roots.

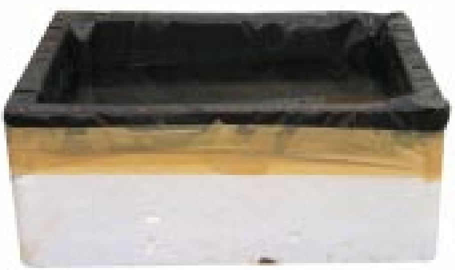

Figure 15: Container with black polythene lining

A board is required to place on the container to prevent light penetration. The planting pots are also fixed to this board (figure 16). The number of holes in the board to fix the pots depends on the crops to be grown. An additional hole is necessary for air circulation and refilling.

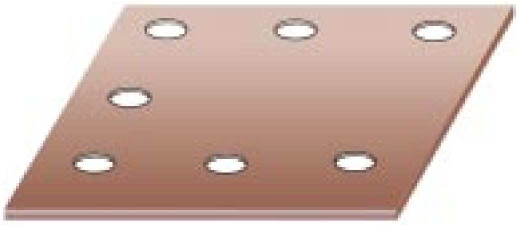

Figure 16: Boards with holes to cover the box and to which pots are fixed

Seedlings are transplanted in plastic pots filled with sterilized old coir-dust or carbonised rice husk or the mixture of the two. Plastic net pots or plastic cups can be used.

Make some holes at the bottom and on sides of the plastic cups for roots to emerge and for the nutrient solution to seep into the potting material (figure 17). Place a small piece of net inside the pots or cups to prevent potting materials falling into the solution. Seeds could also be planted directly in the pots to raise the crop.

Fill 2/3rd of the container with nutrient solution. The pots with the plants are fitted on to the board as shown in figure 18 and will be placed on top of the box. Only the bottom 2 cm of the pots will be submerged in nutrient solution.

Figure 17: planting pots

The above steps complete the formation of non-circulating hydroponics system. These boxes can be placed in net houses or in open space or under rain shelters or in-door. Tall growing plants will require some support to prevent from falling.

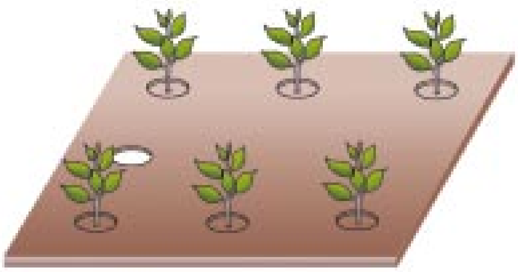

Figure 18: Potted plants fixed to the board to cover the container

Maintain adequate air space above the nutrient solution in the container. Success of the non-circulating hydroponics system depends on the rapid growth and quantity of roots that are exposed to the air. These roots absorb oxygen for the plants. Ideally, top two

Figure 19: Non-circulating hydroponic plants growing in a Styrofoam box

thirds of the young root system must be in the air and the rest must be floating/dipping in the nutrient solution.

During crop growth, when the solution level in the container goes down, the ion concentration may increase. Such increase is detrimental to plant growth. If this condition is observed, siphon out the remaining solution and refill with fresh solution.

2. Root dipping technique for root tuber crops

A 20 – 30 cm deep container can be used. It is lined with black polythene sheet and filled 1/3rd with nutrient solution. Leaving a space of about 7.5 cm above the solution level, fix a wire mesh in the box and fill with an inert medium (Figure 20). The seedlings/seeds are planted in the medium.

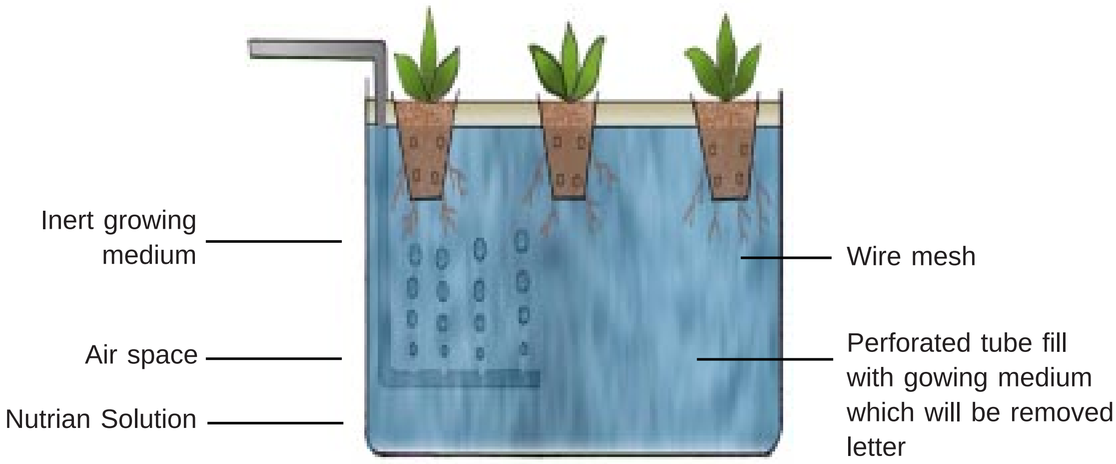

Figure 20: Diagrammatic view of the root dipping technique for root tuber crops

At the early stage, nutrient solution will reach the planting medium through the perforated PVC pipe filled with the growing medium by capillary action. Later, plant roots will grow into the nutrient solution through wire mesh. At this stage, the perforated tube will be removed. The resulting hole will facilitate aeration and refilling.

Floating Technique

This is similar to box method but shallow containers (10 cm deep) can be used. Plants established in small pots are fixed to a Styrofoam sheet or any other light plate and allowed to float on the nutrient solution filled in the container (Figure 21) and solution is artificially aerated.

Capillary Action Technique

Planting pots of different sizes and shapes with holes at the bottom are used. Fill these pots with an inert medium and plant seedlings/seeds in that inert medium. These pots are placed in shallow containers filled with the nutrient solution. Nutrient solution reaches inert medium by capillary action (Figure 22).

Aeration is very important in this technique. Therefore, old coir dust mixed with sand or gravel can be used. This technique is suitable for ornamental, flower and indoor

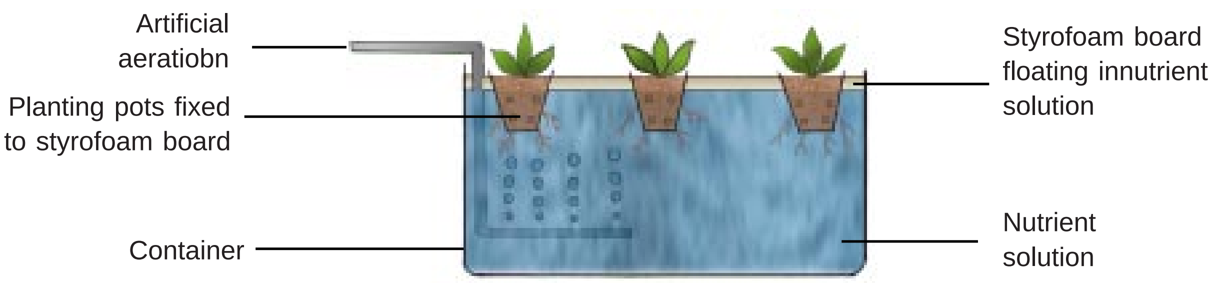

Figure 21: Diagrammatic view of floating technique

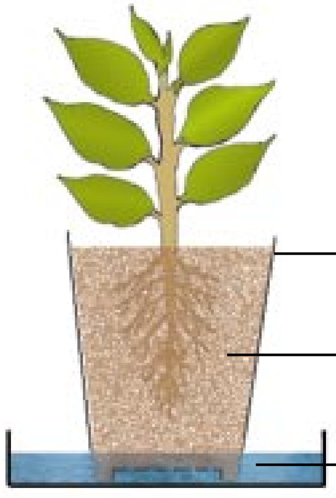

Figure 22: Capillary action technique

plants.

Solid Media Culture or Aggregate System

The following techniques involving inert solid media can be practiced using locally available materials. The media material selected must be flexible, friable, with water and air holding capacity and can be drained easily. In addition, it must be free of toxic substances, pests, disease causing microorganisms, nematodes, etc. The medium used must be thoroughly sterilized before use.

- Inorganic natural media (gravel culture)
- Organic natural media (smoked rice husk, saw dust, coconut fibre, coir dust peat moss)
- Inorganic artificial media (rockwool, perlite, vermiculite)
- Organic artificial media (polyurethane, polyphenol, polyether, polyvinyl)

Tanins and acids present in the newly extracted coir-dust affect plants. Therefore, use at least 06 months old coir-dust. Dry, clean compressed coir-dust blocks are available for sale in the market.

Different techniques described below, according to the method of holding the planting medium, can be practiced.

Hanging Bag Technique (Open system)

About 1 m long cylinder shaped, white (interior black) UV treated, thick polythene bags, filled with sterilized coconut fibre are used. These bags are sealed at the bottom end and tied to small PVC pipe at the top.

These bags are suspended vertically from an overhead support above a nutrient solution-collecting channel. Therefore, this technique is also knows as 'verti-grow' technique. Seedlings or other planting materials established in net pots are squeezed into holes on the sides of the hanging bags. The nutrient solution is pumped to top of each hanging bag through a micro sprinkler attached inside the hanging bags at the top. This micro sprinkler evenly distributes the nutrient solution inside the hanging bag. Nutrient solution drips down wetting the coconut fibre and plant roots. Excess solution gets collected in the channel below through holes made at the bottom of the hanging bags and flows back to the nutrient solution stock tank (Figure 23).

This system can be established in the open space or in protected structures. In protected structures, the hanging bags in the rows and amongst the rows must be spaced in such a way that adequate sunlight falls on the bags in the inner rows.

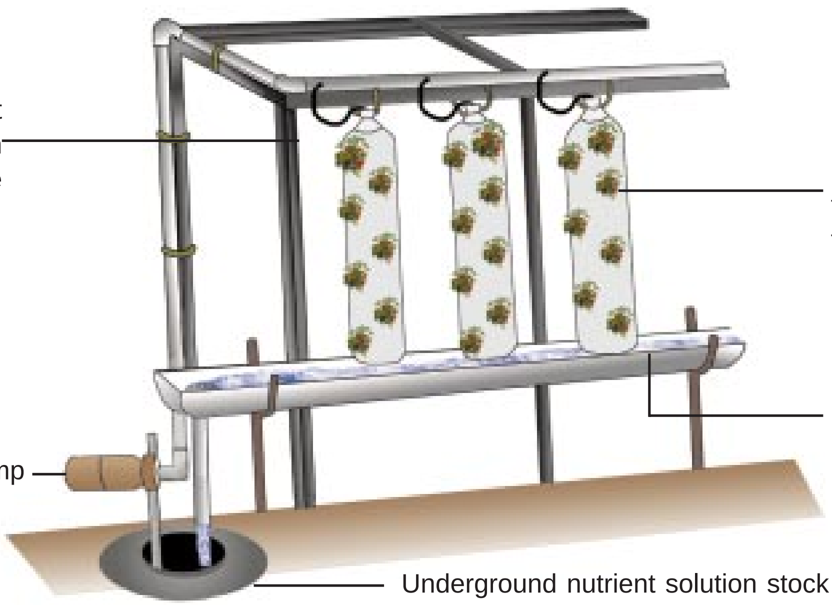

Figure 23: Diagrammatic view of hanging bag technique

Figure 24: Strawbery plants growing in hanging bags

The bags are not heavy as they are filled with coconut fibre and can be used for about 02 years. The number of plants per bag varies depending on the plants. About 20 lettuce plants can be established per bag. This system is suitable for leafy vegetables, strawberry, and small flower plants. Black colour tubes will have to be used for nutrient solution delivery to prevent mould growth inside.

Grow Bag Technique

In this technique 1 – 1.5 m long white (inside black), UV resistant, polythene bags filled with old, sterilized coir-dust are used. These bags are about 6 cm in height and 18 cm wide. These bags are placed end to end horizontally in rows on the floor with walking space in between (Figure 25). The bags may be placed in paired rows depending on the crop to grow.

Make small holes on the upper surface of the bags and squeeze seedlings or other planting materials established in net pots into

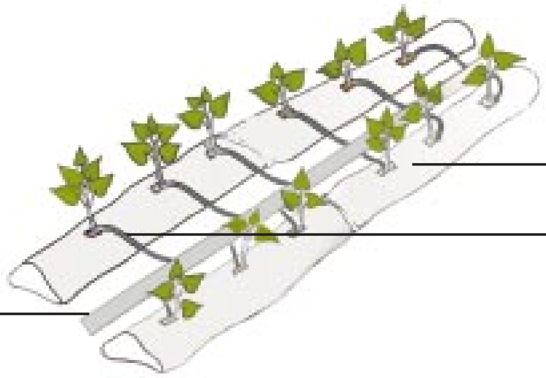

Figure 25: Diagrammatic view of plants in grow bags

the coir-dust. 2-3 plants can be established per bag. Make 02 small slits low on each side of the bags for drainage or leaching.

Fertigation with black capillary tube leading from main supply line to each plant is practiced. The nutrient solution and water may also be added manually to these bags. Depending on the stage of crop growth and the prevailing weather conditions, vary the amount of water applied. Make sure that the growing media is not completely saturated with water or nutrient solution, as it prevents the oxygen supply to plant roots.

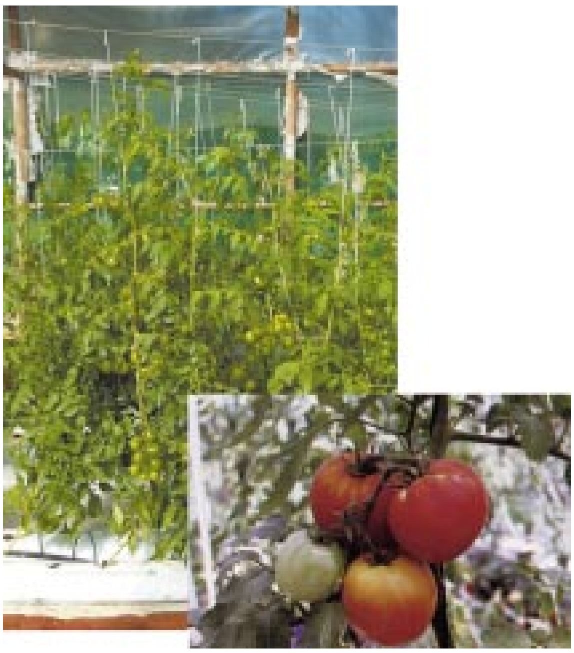

Figure 26: Tomato plants growing in grow bags

Cover the entire floor with white UV resistant polythene before placing the bags. This white polythene reflects the sunlight to the plants. It also reduces the relative humidity in between plants and incidence of fungal diseases. When tall growing plants are established supporting structures will be necessary.

Trench or Trough Technique

In this open system, plants are grown in narrow trenches in the ground (Figure 27) or above ground troughs (figure 28) constructed with bricks or concrete blocks.

Both trenches and troughs are lined with waterproof material (thick UV resistant polythene sheets in two layers) to separate the growing media from rest of the ground. The width of the trench or trough can be decided depending on the ease of operation. Wider trenches or troughs will permit two rows of plants. The depth varies depending on the plants to grow and a minimum of 30 cm may be necessary.

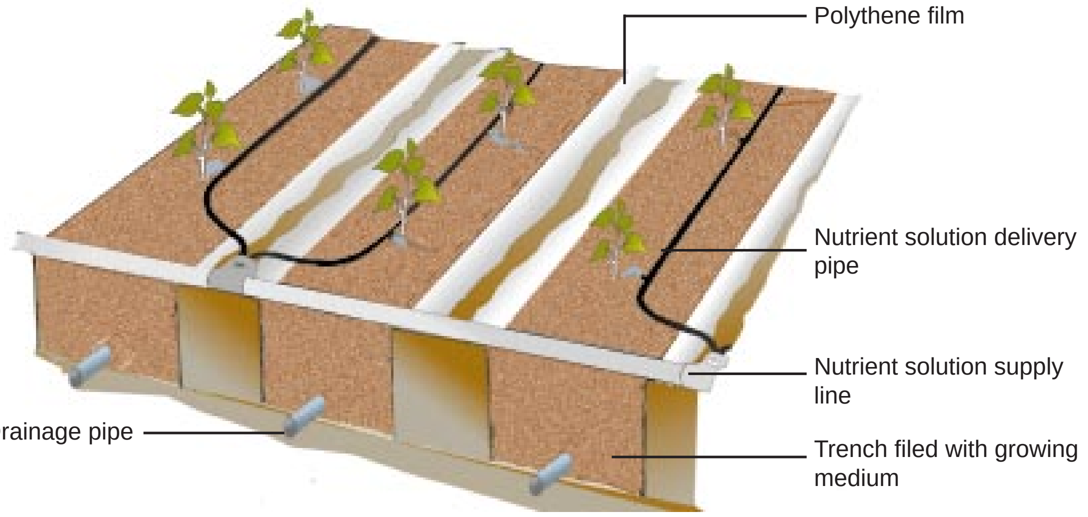

Figure 27: Cross section of hydroponic trenches

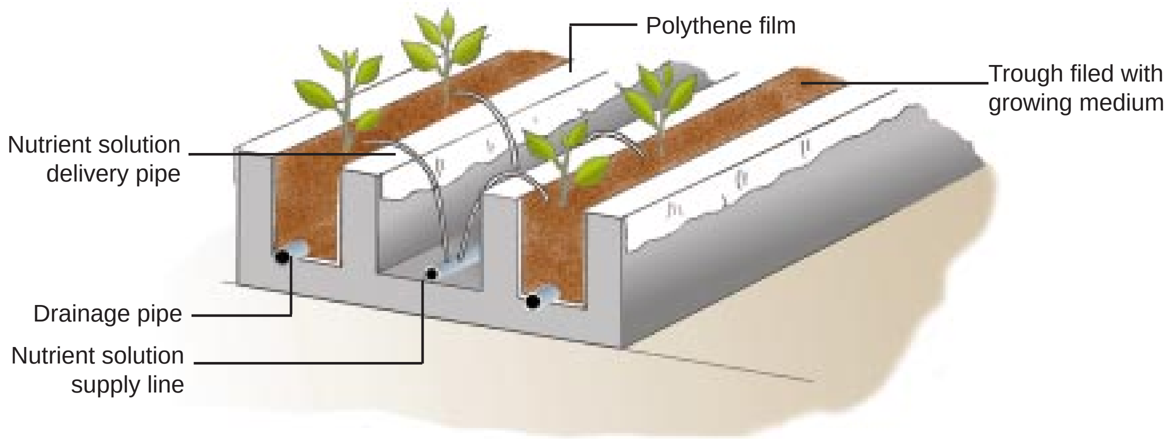

Figure 28: Cross section of above ground troughs

Old coir dust, sand or gravel, peat, vermiculite, perlite, old sawdust or mixture of these materials can be used as the media for this culture. The nutrient solution and water are supplied through a drip irrigation system or manual application is also possible subject to labour availability. A well-perforated pipe of 2.5 cm diameter may be placed at the bottom of the trough or trench to drain out excess nutrient solution.

Tall growing vine plants (cucumber, tomato, etc.) need additional support to withstand the weight of the fruits.

Pot Technique

Pot technique is similar to trench or trough culture but growing media is filled in clay or plastic pots (Figure 29). Volume of the container and growing media depend on the crop growth requirements. The volume ranges generally from 01 to 10 litres.

Growing media, nutrient solution supply, providing support to plants, etc. is similar to that of trough or trench culture.

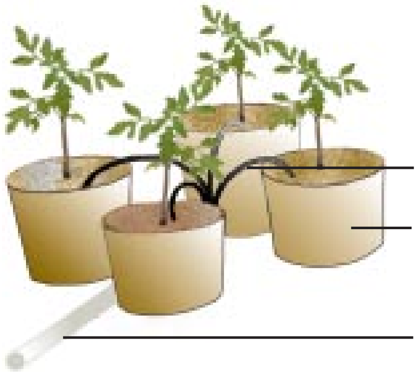

Figure 29: Hydroponics plants in pot technique

Aeroponic Technique

Aeroponic is a method of growing plants where they are anchored in holes in Styrofoam panels and their roots are suspended in air beneath the panel. The panels compose a sealed box to prevent light penetration to encourage root growth and prevent algae growth. The nutrient solution is sprayed in fine mist form to the roots. Misting is done for a few seconds every 2 – 3 minutes. This is sufficient to keep roots moist and nutrient solution aerated. The plants obtain nutrients and water from the solution film that adheres to the roots.

The aeroponic culture is usually practiced in protected structures and is suitable for low leafy vegetables like lettuce, spinach, etc.

The principal advantage of this technique is the maximum utilization of space. In this technique twice as many plants may be accommodated per unit floor area as in other systems. Another potential application of this technique is in the production of plants free of soil particles from cuttings for exports.

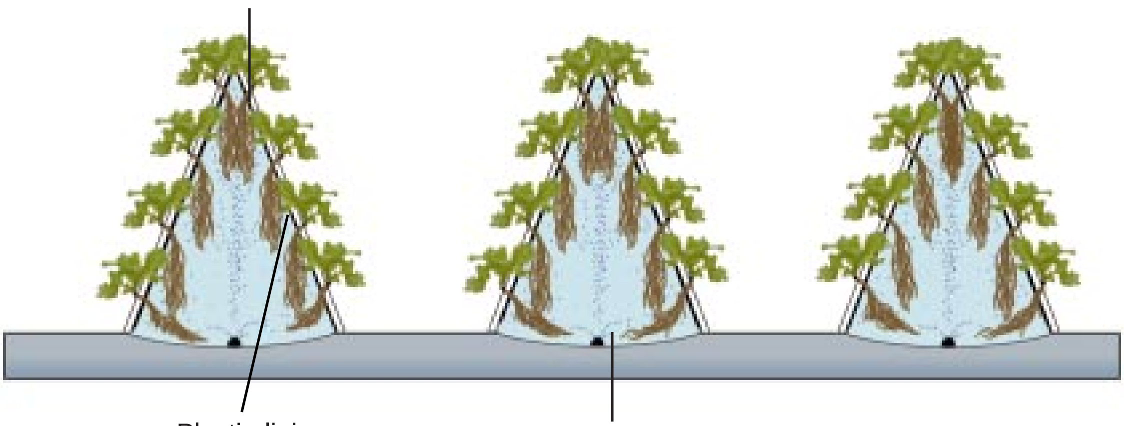

Figure 30: Aeroponic A-frame unit, developed by Jensen and Collins in 1985 at the University of Arizona

Nursery Techniques for Hydroponics

As in open field agriculture, production of vigorous seedlings or planting material of high yielding varieties is an essential step of hydroponics/soil-less culture, to obtain economic yields.

Nursery Medium

The growing medium must provide satisfactory conditions for seed germination and to raise pest and disease free seedlings. A material that is friable, moderately fertile, well drained yet have sufficient water holding capacity and good aeration and free of pests and disease causing organisms must be selected as medium for seed germination or rooting the planting materials.

The following materials can be used as medium to raise seedlings or to root planting materials.

- Old coir-dust
- Carbonised rice husk
- Fine sand or fine sand and old coir dust mixture
- Rockwool, Peat, perlite or vermiculite, etc.

Sterilize the medium before use. For coir-dust, add hydrated lime to bring its pH to neutral. For a 05 kg coir-dust block, about 100 – 250 g hydrated lime is needed.

Nursery Containers/ Trays

Use a container that provides the suitable condition for seed germination and also according to crop and cultivation method.

Individual containers / Growing blocks:
paper pots, plastic pots, clay pots, Styrofoam pots, coconut fibre pots, rockwool blocks, sponge blocks

Figure 31: Some individual containers

Trays:
Styrofoam trays, speedling/cell plug trays

Figure 32: Trays

Trays made up of different materials are available for sale in market. Depending on the requirements, trays may be selected.

Seed Germination

Thorough cleaning of the pots followed by washing with 10% Calcium or Sodium hypochloride will ensure disease free condition. Place one seed per block filled with growing medium at the correct depth in the pots or trays.

Such necessary conditions for seed germination as moisture, temperature, humidity must be provided. Germination trays can be covered with wet papers or cloth to provide adequate temperature for germination until the seeds sprout. Remove these papers at the time of seedling emergence.

Maintain the moisture level of the medium at correct level for uniform germination and application of water in the mornings is preferred.

Planting Material Production

Vegetative parts separated from mother plants can also be rooted and used as planting materials. Individual containers or trays filled with growing medium are used for rooting these vegetative parts. Select vegetative parts that are free from pests, disease causing organisms and nematodes for propagation. For example, following materials can be used for propagation.

Figure 33: Selected Kang Kong stem cutting

Gotukola- Plantlets or runners separated from mother plants.

Strawberry- Plantlets or runners separated from mother plants

Gerbera- Plantlets separated from mother plants

Mukunuwenna- 10 – 12 cm long semi-hardwood or hardwood stem cuttings.

Kang Kong- 20 cm long semi-hardwood cuttings with 3-4 nodes.

Mint- 10 – 12 cm long semi-hardwood stem cuttings

Sarana- Semi-hardwood stem cuttings.

Figure 34: Rooted Kang Kong stem cutting ready for planting

Nutrient Supply

Nutrient supply is not necessary until the emergence of first two true leaves. Until such time apply only clean water. However, when they unfold, nutrient supply must begin gradually as the growing medium contains very little plant nutrients. The fertilizer mixture meant hydroponics plants could also be used for nursery plants. Diluted nutrient solution can be applied every day or nutrient solution prepared by dissolving 10 g of Albert's mixture in 10 litre of water can applied every other day.

At the early stage, place the trays or pots in shallow containers that is filled with nutrient solution in such a way that the tray's or pots' lower portion is submerged in the solution. The nutrient solution will reach the media through the holes at the bottom of the pots or nursery trays by capillary action. Vegetative parts for propagation planted in individual containers or trays are also placed in shallow nutrient solution containers as seedling trays.

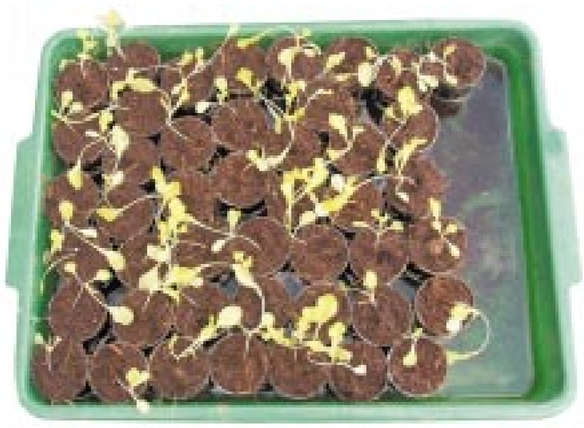

Figure 35: Nursery pots placed in shallow nutrient solution containers

The nutrient solution can also be applied directly to nursery pots after seed germination or sprouting of planting materials. When applying nutrient solution directly to nursery pots,

- place the pots or trays on a flat plane and pour solution so that it does not come into direct contact with the small plant;
- at the early stage apply 5-10 ml solution once a day; and
- when plants grow, 10-25 ml a day once or twice till establishment.

Once the seedlings or planting materials reach the correct size for planting, they can be planted with the medium. Vegetative parts can sometimes be directly established in the hydroponics system.

Nursery Period

The nursery period varies with the crops.

Tomato	3 - 4 weeks (2-3 true leaves stage)
Cabbage	4 - 5 weeks (3-4 true leaves stage)
Salad cucumber	3 weeks (3-4 true leaves stage)
Lettuce	2 - 3 weeks
Bell Pepper	4 - 5 weeks

Select vigorous seedlings with the characteristics for the variety concerned for establishment in hydroponics. Also tissue-cultured plants can be established in hydroponics.

Sponge Nursery Technique

Sponge pieces can be used as nursery medium instead of the above mentioned media materials. 2.5 cm cube sponge blocks can be used for this purpose. Place the seeds at the centre in a cut made on the topside of the sponge block.

Sponge nursery is maintained as other nurseries. Nutrient supply must begin when the first true leaf begin to unfold. Depending on the cultivation method, the seedlings can be planted in hydroponics system with the sponge block intact. The sponge block may be removed with minimum damage to roots when plants begin to grow .

Figure 36: Sponge block for seed germination

Figure 37: Seedling in a sponge block ready for transplanting

Nutrient Solution for Hydroponics

Plants require 17 essential elements for their growth and development. Without these nutrients plants cannot complete their life cycles and their roles in plant growth cannot be replaced by any other elements. These 17 essential elements are divided into macro-elements (required in relatively large quantities) and micro or trace elements (required in considerably small quantities).

The macro elements are carbon (C), hydrogen (H), Oxygen (O), nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S). The micro elements are iron (Fe), chlorine (Cl), boron (B), manganese (Mn), copper (Cu), zinc (Zn), molybdenum (Mo) and nickel (Ni).

All essential nutrients are supplied to hydroponics plants in the form of nutrient solution, which consists of fertilizers salts dissolved in water. The hydroponic grower must have a good knowledge of the plant nutrients,

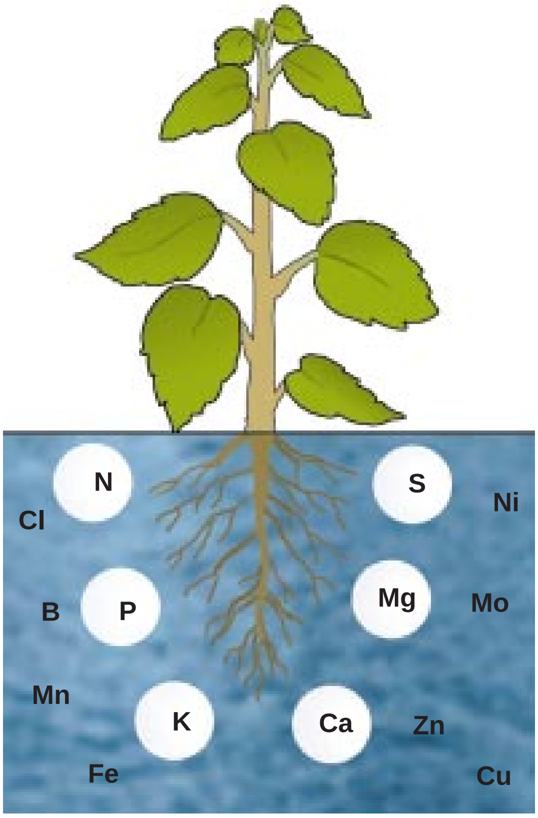

Figure 38: Plant nutrients in nutrient solution

as management of plant nutrition through management of nutrient solution is the key to success in hydroponic gardening.

The hydroponic methods enable growers to control the availability of essential elements by adjusting or changing the nutrient solution to suit the plant growth stage and to provide them in balanced amounts. As the nutrients are present in ionic forms in the nutrient solution and also, not needing to search or compete for available nutrients as they do in soil, hydroponic plants reach maturity much sooner. Optimization of plant nutrition is easily achieved in hydroponics than in soil.

Nutrient Solution Management

While optimum nutrition is easy to achieve in hydroponics, incorrect management of the nutrient solution can damage the plants and lead to complete failure. The success or failure of a hydroponic garden therefore, depends primarily on the strict nutrient management programme. Carefully manipulating the nutrient solution pH level, temperature and electrical conductivity and replacing the solution whenever necessary, will lead to a successful hydroponic garden.

pH Level

In simple terms, pH is a measure of acidity or alkalinity on a scale of 1 to 14. In a nutrient solution, pH determines the availability of essential plant elements. A solution is considered to be neutral at pH 7.0, alkaline if above and acidic if below.

For pH values above 7.5, iron, manganese, copper, zinc and boron becomes less available to plants. Should the pH of a nutrient solution fall below 6.0, then the solubility of phosphoric acid, calcium and manganese drops sharply. **The optimum pH range for hydroponic nutrient solution is between 5.8 and 6.5.**

Figure 39: Measuring nutrient solution pH using a portable digital pH meter

The further the pH of a nutrient solution from recommended pH range, the greater the odds against the success.

The figure 40 indicates the nutrient element availability at different pH levels of the solution. Nutrient deficiencies will become apparent or toxicity symptoms will develop if the pH is higher or lower than the recommended range for individual crops. For example, if pH is consistently 7.5, one can expect intra-veinal chlorosis to occur, an indication of iron deficiency.

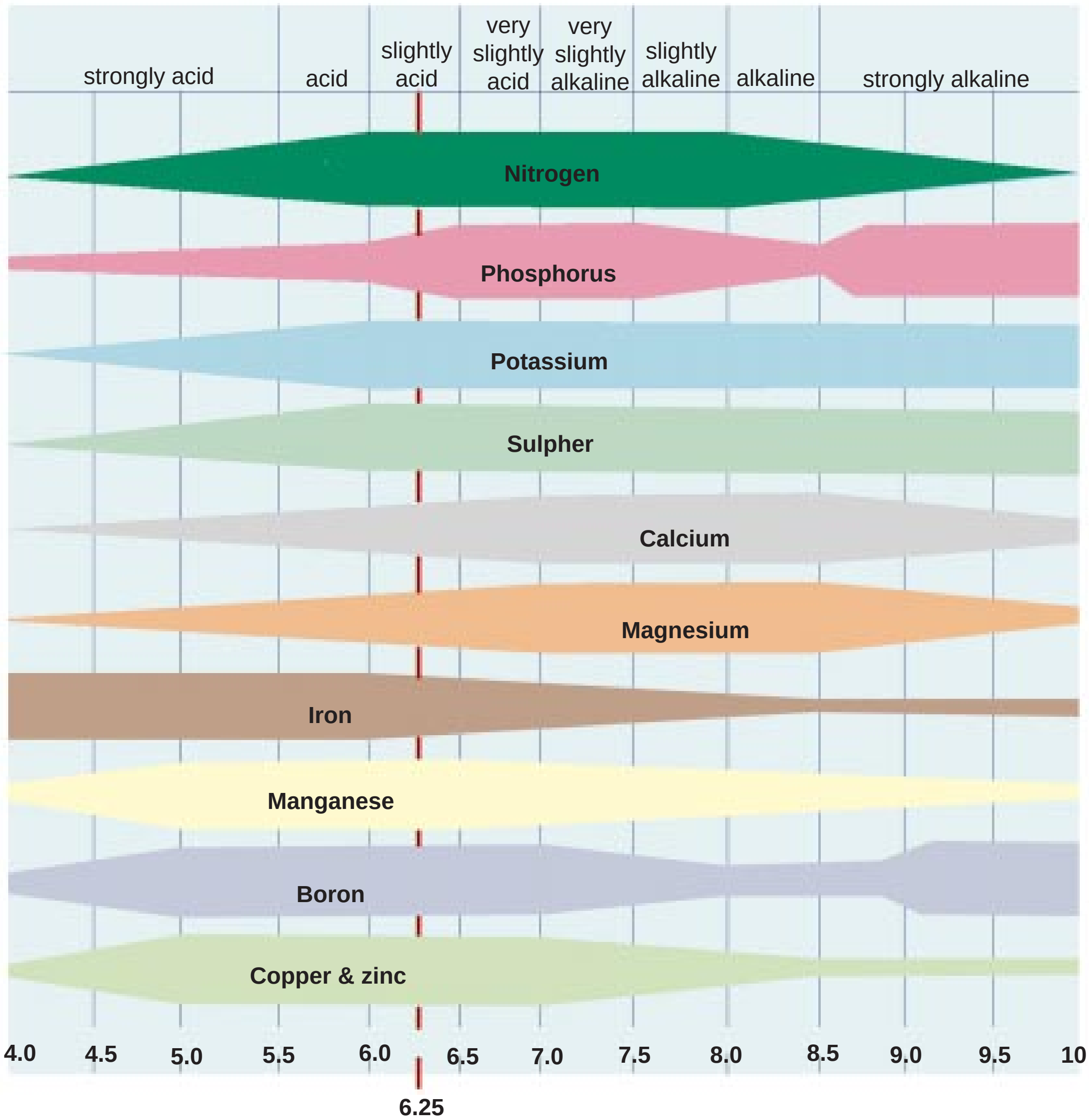

Figure 40: Chart showing the availability of nutrient elements at different pH levels.

The chart shows a pH range of 4.0 to 10.0. The width of the coloured section for each nutrient represents the availability of that nutrient. The widest place denotes the maximum availability. The narrowest place denotes the least availability. The red line at pH 6.25 indicates the maximum number of elements at their highest availability.

When plants absorb nutrients and water from solution, pH of the solution changes. Therefore, it must be monitored daily, and adjusted to be between the recommended ranges. Chemical buffers can adjust the pH of a nutrient solution, when it strays outside the ideal. It can be lowered by adding dilute concentrations of phosphoric or nitric acids and raised by adding a dilute concentration of potassium hydroxide. Although it is important to stay within recommended range, it is far more important to prevent large fluctuations.

Electrical Conductivity (Ec)

The electrical conductivity indicates the strength of nutrient solution, as measured by an Ec meter. The unit for measuring Ec is dS/m. A limitation of Ec is that it indicates only the total concentration of the solution and not the individual nutrient components.

The ideal Ec range for hydroponics is between 1.5 and 2.5 dS/m. Higher Ec will prevent nutrient absorption due to osmotic pressure and lower Ec severely affect plant health and yield.

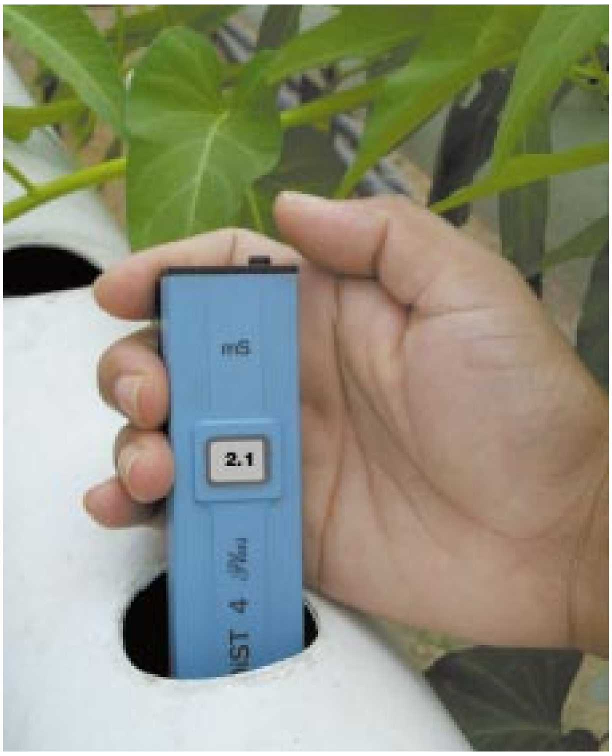

Figure 41: Measuring nutrient solution Ec using a portable digital Ec meter

When plants take up nutrients and water from the solution, the total salt concentration, i.e., the Ec of the solution changes. If the Ec is higher than the recommended range, fresh water must be added to reduce it. If it is lower, add nutrients to raise it.

Preparation of Nutrient Solution

Though hydroponic growers can formulate their own fertilizer mixtures to prepare nutrient solutions using completely water-soluble nutrients salts, a number of formulations are available in the market to choose.

It is important to avoid any formulations that contain impurities like sand, clay or silt. Such impurities do not supply any nutrients but they are harmful as they can block the delivery tubes.

Also avoid any formulation that has insoluble or less soluble salts. In hydroponics, the nutrients must be available in solution in ionic form for plant absorption. If they are found as salts, plants will suffer from nutrient deficiency symptoms.

Although urea is completely soluble in water, it cannot be used in hydroponics, as it does not break into ionic form in the solution as it does in soils.

Some fertilizer salts react with each other to produce insoluble precipitations. For example, ammonium sulphate and potassium chloride form less soluble potassium sulphate in the tank. Phosphate fertilizers act problematic in the presence of high calcium and magnesium concentrations, causing precipitation of low soluble phosphates. Therefore, select fertilizers that are compatible with each other. The table 1 indicates compatibility of some saltsFertilizer Mixtures for Hydroponics

Table 1: Compatibility chart for some soluble fertilizers

Soluble fertilizers	AN	AS	CAN	MAP	SOP	MOP
Ammonium nitrare (AN)	-	C	C	C	C	C
Ammonium sulphate (AS)	C	-	L	C	C	C
Calcium nitrate (CAN)	C	L	-	X	C	C
Mono ammonium phosphate (MAP)	C	C	X	-	C	C
Potassium sulphate (SOP)	C	C	L	C	-	C
Potassium chloride (MOP)	C	C	X	C	C	-
Gypsum (G)	X	X	X	X	C	C
Kieserite (KS)	C	C	C	X	C	C
Potassium nitrate (PN)	C	L	C	C	-	C

C: compatible, can be mixed in the solution
L: Limited compatibility, mix at the time of use or some precautions must be taken
X: Incompatible, do not mix

Fertilizer Mixtures for Hydroponics

The tables 2 and 3 give nutrient salt contents of two hydroponics formulations.

These fertilizer mixtures are not suitable as foliar spray as the EDTA iron (iron chelate) does not disintegrate easily on plant surface and therefore, can be harmful to consumers.

Table 2: Chemicals needed to prepare 1000 litres of nutrient solution proposed by Dr. Alan Cooper.

Nutrient chemicals	Weight in grams
Potassium dihydrogen phosphate	263.00
Potassium nitrate	583.00
Calcium nitrate	1003.00
Magnesium sulphate	513.00
EDTA iron	79.00
Manganese sulphate	6.10
Boric acid	1.70
Copper sulphate	0.39
Ammonium molybdate	0.37
Zinc sulphate	0.44

Table 3: Chemicals needed to prepare 1000 litres of nutrient solution (Albert's mixture, locally available in the market).

Nutrient chemicals	**Weight in** grams
Multi-K (Potassium nitrate)	38.00
Refined grade calcium nitrate	952.00
Magnesium sulphate	308.00
EDTA iron	8.00
Zinc sulphate	0.15
Boric acid	0.20
Manganese sulphate	1.15
Copper sulphate	0.10
Mono potassium phosphate	269.00
Potassium sulphate	423.00
Ammonium molybdate	0.03

Figure 42: Fertilizer mixing tank

Fertigation

Fertigation combines the two main factors of supplying water and plant nutrients that are essential for plant growth. The right combination of the two is the key to obtain high yields and quality produce.

Advantages of Fertigation

- Accurate and uniform application of fertilizers
- Ability to meet plant nutrient demand under given climatic conditions and during different crop growth stages
- Improving fertilizer use efficiency and reducing leaching below root zone thus minimizing pollution
- Saving on labour
- Increasing both yield and quality of produce

Factors to be Considered in Fertigation

1. Growing media
2. Fertilizers used
3. Irrigation water quality

As the first two factors were discussed earlier, only irrigation water quality is discussed here.

Irrigation Water Quality

Use good quality water with its pH and Ec suitable for plant growth. Based on pH, Ec and soluble salt content, water quality can be divided into 03 classes (Table 4).

Non-hazardous and medium class water can be used for fertigation. However, when latter is used for fertigation, thoroughly leach the growing medium at least once a year.

Methods of Fertigation

Mix the fertilizers required for a particular crop with daily water requirement of that crop and apply manually or through fertigation system.

The amounts of fertilizers mixed with irrigation water will vary depending on the crops, crop growth stage and the hydroponics technique used. The example below explains this situation.

However, at all stages of crop growth, the pH of the nutrient solution must be maintained between 5.8 - 6.5 and Ec between 1.5 - 2.5 dS/m.

For circulating techniques (DFT and NFT), supply the nutrient solution for a predetermined time period.

For aggregate systems (solid media culture), fertigation can be done manually or through drip irrigation system. Supply the fertilizers with irrigation water for a predetermined time period so that the water content of the growing media does not increase beyond field capacity. When fertigation is not done, the crop must be irrigated with water to maintain the medium at field capacity.

Table 4: Irrigation water quality classes

Quality Factors	Unit	Water Quality classes		
		Non-hazardous	Slight to Moderate	Severe
pH		--- Normal Range 6.5 - 8.4 ---		
Salinity Ec_w	dS/m	0.00 – 0.8	0.8 – 3.0	>3
Sodium	me/lit	<3	>3	-
Chloride	me/lit	<3	>3	-
Boron	mg/lit	<0.7	0.7-3	>3
Bicarbonates	me/lit	<1.5	1.5-8.5	>8.5

(Courtesy: Guidelines for interpretation of water quality for irrigation. Western fertilizer handbook. Page 38).

Training and Pruning

In hydroponics, the growing medium does not provide enough anchorage as soils. This is more so in liquid cultures as no planting medium is used. Therefore, growers must provide artificial supporting structures and train plants along those structures. Support is especially important, when tall growing indeterminate type crop varieties (tomatoes, cucumber, etc.) or crops bearing relatively heavy fruits (bell pepper, egg plant, etc.) are used in hydroponics.

A polythene string can be tied at the base of each plant using a plastic plant clip or by a loose non-slip knot as shown in figure 43 and the string is tied vertically to the overhead horizontal support to hold the plants. When plants grow, wind the main stems loosely around the string for support. In the case of tall growing indeterminate tomato varieties, placing additional plant clips every 3rd to 4th nodes will be necessary to prevent the plants from slipping down.

For salad cucumbers, the vertical string is attached to each plant with plastic plant clips or by a loose non-slip knot at the base. As the plants grow, wind the main stem loosely around the string for support. Additional plant clips are attached to prevent plants from slipping.

Tall growing indeterminate type tomatoes are trained to a single stem. All lateral branches are removed when they are about 5 cm long (Figure 44). Prune the lateral branches every 3 – 4 days, and it is best done early in the day.

Indeterminate type tomato plants that produce long term crops are lowered to a working height as they grow, keeping production limited to fruit grown on the 2 – 2.5 m of the main stem. When plants grow taller, remove about 04 leaves at the bottom and untie the string from the overhead horizontal support and lower the plants about 60 cm and tie the string shifting to a side (figure 45). This must be done every 2 weeks, and the strings must be long enough to permit lowering during the entire cropping period.

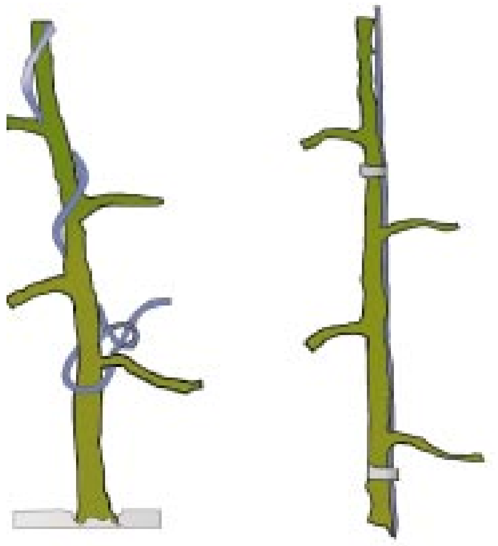

Figure 43: Training plants on vertical support.

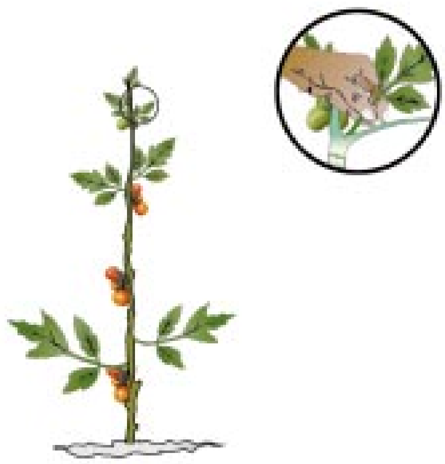

Figure 44: Removal of side branches in tomato plants

Tomatoes produce large number of fruits at each cluster. To get large, quality fruits, fruit thing will be necessary. Depending on the size required, 3 to 5 fruits may be left in a cluster.

For salad cucumbers, umbrella system of pruning can be adopted. It involves pruning all lateral branches until the plant reaches the overhead horizontal support (figure 46). There, the terminal bud is removed and two side branches are allowed to grow downwards. Vigorous plants will continue to produce fruits on the downward growing lateral branches, although the rate of fruit production tends to slow down.

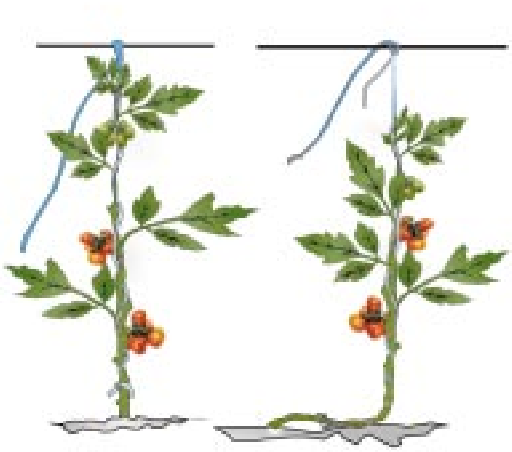

Figure 45: Tomato plant at left will be lowered the position at right by retying the support string to the overhead horizontal support several cm to the right

Figure 46: The umbrella training system for cucumber

Salad cucumber may produce more than one fruit per node; these can be thinned out to one fruit per node or allowed to develop if they are not curved or otherwise distorted in shape. Heavy fruiting at lower part of the vine will reduce production higher up.

Bell pepper plants are trained to two stems. Vertical strings tied to overhead horizontal support, support them. Guide these side stems to the vertical strings. Flowers occur in axils of each branch. Side shoots arising from the stems must be pruned after 2 – 3 leaves so that fruiting takes place only on the two main branches. Periodic fruit thinning may be required to obtain large, good quality fruits.

Management Requirements of Hydroponics/ Soil-less Culture

Meet the following requirements to develop and maintain a successful hydroponics/soil-less cultivation of crops. If any of these conditions are not fulfilled, one cannot obtain economical yields.

- Maintain the nutrient solution pH in the range of 5.8 to 6.5, and electrical conductivity (Ec) in the range of 1.5 to 2.5 dS/m, as these ranges are suitable for plant growth. Any pH or Ec outside these ranges will reduce availability and uptake of nutrients and will also damage plant roots.

  Plants are the best indicators of the nutrient availability. Look for nutritional disorder symptoms in plants and adjust nutrient solution accordingly (Figure 47).

Figure 47: Iron deficiency symptom in strawberry

- Avoid any sudden changes in nutrient solution concentration as it can result in unsuitable pH and Ec.

- Maintain adequate solution temperature. As the temperature goes up, plant respiration increases causing a higher demand for oxygen. At the same time, the solubility of oxygen decreases. This requirement is more critical in green houses and net houses where the temperature is bound to increase during mid afternoons. Steps must be taken to counter such increase.

- Always ensure that there is plenty of dissolved oxygen in the nutrient solution as the plant roots absorb oxygen. Lack of oxygen will reduces up take of nutrients and thereby the yield and also causes root rot. In closed systems, if the recollected solution is allowed to fall into the solution tank from a height, natural aeration will take place.

- In root dipping techniques, maintain adequate air space above the nutrient solution in the container as success depends on the rapid growth and quantity of roots that are exposed to the air. These roots absorb oxygen for the plants. Ideally, top two thirds of the young root system must be in the air and the rest must be floating in the nutrient solution.

Figure 48: Luxuriant growth of water and air absorbing roots takes place when there is adequate air space above solution

- In root dipping techniques, during crop growth, when the solution level in the container goes down, the ion concentration may increase. Such increase is detrimental to plant growth. If this condition is observed, siphon out the remaining solution and refill with fresh solution.

- Ensure adequate light for the hydroponics/ soil-less culture plants. Light and all other requirements are the same as though grown in open fields.

- Always use pest and disease free seedlings and planting materials for establishment of hydroponics crops. Remove and destroy any infected plants as soon as they are found.

- If nematode problem is observed in solid media culture, discard the plants and sterilize the growing medium. If in doubt, discard and replace the medium. Also ensure that he water supply is also free from nematodes.

- Algae can build up in the system and block the small tubes used for the delivery of nutrient solution. Use black colour tubes to avoid such problems. Between crops, thoroughly clean the system using a mild solution of chlorine. After cleaning, thoroughly flush the system with fresh water before replanting.

- Adequate spacing is necessary for plant growth and when vine crops are grown, supports must be provided.

- In open aggregate techniques, there is a possibility for nutrients to leach when water is applied. Therefore nutrient solution may be applied continuously instead of water to supply both water and nutrients.

Soil-less Culture and Controlled Environment Agriculture

Hydroponics culture is probably the most intensive method of crop production in today's agricultural industry. In combination with green houses and protective covers (controlled environment agriculture), it is high technology and capital intensive. With the possibility of adjusting air and root temperature, light, water, plant nutrition, and adverse climate, this combination can be made highly productive, conservative of water and land and protective of the environment.

Figure 49: Protected structure

Advantages

High-density maximum crop yield, crop production where no suitable land exists, crop cultivation regardless of seasonality, more efficient use of water and fertilizers and minimal use of land area are the principal advantages of soil-less culture in combination with controlled environment agriculture. Another major benefit is the possibility of obtaining pesticide free products, which fetch higher prices at the increasingly ready markets, at present.

Precautions

High temperature

One serious concern in Sri Lanka and other tropical countries is the rise of solution temperature during mid afternoons in green/ net houses and under protective covers. Adoption of closed system of hydroponics where the solution is recycled helps reduce such rise in temperature to some extend. Further, misting of water to crops when temperature rises, use of exhaust fans, use of white colour containers to hold solutions, painting gullies/pipes with white colour, etc. will help reduce the build up of heat from sunlight.

Sunlight

In protected structures, it was observed that growth and yield of plants of inner rows of hanging bag and grow bag techniques were poor due to low sunlight availability. Therefore, ensure that enough sunlight reaches the inner rows of these techniques.

Pollination

As protected structures effectively prevent insects reaching crops, pollination by insects does not take place in the protected structures. Also lack of natural airflow also reduces the chances of natural pollination. High temperatures normally experienced inside protected structures also interfere with pollination as it reduces pollen viability. Therefore, artificial pollination must be done by the use of mechanical vibrators. Blowers can be used to improve the airflow inside the structures.

Hormones may also be used to increase the chances of pollination inside protected structures. For example, 0.15% 4-CPA (Para chlorophenoxy acetic acid - a kind of auxin) is widely used to induce fruiting of tomato in Japan. Hormone application is effective for tomato 3 days before and 3 days after blooming. Application more than once, higher concentration or too early application can result in malformed fruits.

Some Problems and Solutions in Hydroponics

As experienced in normal crop husbandry, pests diseases and too affect hydroponics plants and they also show physiological as well as nutritional disorders under unfavourable conditions.

Physiological Disorders

Sudden changes in environmental factors, incorrect nutrition supply or irrigation can bring about physiological disorder symptoms in plants. Some crop varieties are more prone to these conditions than others.

Blossom end rot of tomato

At the bottom end of tomato fruits, brown, sunken leathery spots appear (Figure 50). Calcium deficiency, dry growing medium and sudden supply of water, salt accumulation in root zone are some causal factors. Avoiding these conditions will prevent blossom end rot.

Figure 50: Blossom end rot of tomato

Figure 52: Cracks extending from stalk

Concentric fruit cracking of tomato

Concentric cracks appear around the fruit stalk (Figure 51) or cracks extending from fruit stalk (Figure 52) appear. High day temperatures, large differences between day and night temperature and sudden change in growing media moisture content are the causes of this condition.

Figure 51: Concentric fruit cracking of tomato

Shrink cracks of bell pepper

Shrink cracks appear commonly around the fruit shoulders. Rapid evaporation of condensed moisture on fruit surface causes shrink cracks. Gradual change from day to night temperatures and night ventilation can prevent this condition.

Figure 53: Shrink cracks of bell pepper

Fruit crooking of cucumber

Fruit crooking is a serious physiological disorder in cucumber (Figure 54). The curvature of known as fruit crooking begins at early stages of fruit development and may be caused by adverse temperature, excessive moisture in growing medium, poor nutrition, excessive fruit load or insect damage. Affected fruits must be removed as soon as noticed.

Figure 54: Fruit crooking of cucumber

Insect Pest and Disease Damage in Hydroponics

In hydroponics, soil borne diseases are virtually eliminated. Certain common pests and diseases however, can affect these plants. Vigilance and early identification are important in controlling such problems. Keep the environment of the hydroponics plants clean and adopt correct cultural practices such as supply of well-balanced nutrients to maintain the plants healthy. Pests and diseases less affect healthy plants. Always start the cultivation with healthy seedlings/planting materials.

Adopt Integrated Pest Management (IPM) strategies recommended for vegetables. If necessary apply recommended chemicals to control insect pests or diseases and always strictly adhere to recommended pre-harvest intervals.

Nutritional Disorders

In hydroponics all the essential nutrients are supplied through the nutrient solution. If the solution is deficient or excess (toxic) in any of these nutrients or the pH or the Ec of the solution is beyond the suitable range, the plants will show nutritional disorder symptoms.

These symptoms include changes in growth rate, size of plants, leaf shape and colour, leaf thickness, stem colour, inter node distance, nature of root system, etc. In addition, fruiting characteristics may change. Although these external symptoms vary according to crops and varieties, some common symptoms are described in table 5 and figures 55 to 62.

Table 5: Some common nutritional disorder visual symptoms exhibited by plants

Nutrient Element	Deficiency Symptom	Excessive/Toxicity symptoms
Nitrogen	Growth is restricted and plants are generally yellow (chlorotic) from lack of chlorophyll, especially older leaves. Younger leaves remain green longer. Stems, petioles and lower leaf surfaces of tomato can turn purple.	Plants usually dark green in colour abundant foliage but usually with a restricted root system.Flowering and seed production can be retarded.
Phosphorus	Plants are stunted and often a dark green colour. Anthocyanin pigments may acumulate. Dificiency sympems occur first in mature leaves. Plant maturit is often delayed.	No primary symptems yet noted. Sometimes copper and Zinc dificiency occurs in the presence of excess Phosphorus.
Pottassium	Symptoms first visible on orlder leaves. In dicots, these leaves are initially chlorotic but soon scattered dark necrotic lesions (dead areas) develop. In many monocots, the tips and margins of the leaves die first.	Usually not exesively absorbed by plants. Exess potassium may lead to magnesium dificiency and possible manganese, zinc or iron dificiency.
Sulfur	It not often encountered. Generally yellowing of leaves, usually first visible in younger leaves.	Reduction in growth and leaf size. Leaf symptoms often absent or poorly defineed. Sometimes intervienal yellowing or leaf burning.
Magnesium	Intervienal chlorosis which first develops on the older leaves. The chlorosis may start at leaf margins or tip and progress inward intervienally.	Very little information available on visual symptoms.
Calcium	Bud development is inhibited and root tips often die.Young leaves are affected before old leaves and become distorted and small with irregular margins and spotted or necrotic areas.	No consistent visible symptoms.Usually associated with excess carbonate.

Table 5: Continued

Nutrient Element	Deficiency Symptom	Excessive/Toxicity symptoms
Iron	Pronounce intervienal chlorosis similar to that caused by magnesium deficiency but on the younger leaves.	not often evident in natural conditions. Has been observed after the application of sprys where it appears as necrotic spots.
Chlorine	Wilted leaves which then become chlorotic and necrotic,eventually attaining a bronze colour. Roots become stunted and thikened near tips.	Burning or firing of leaf tip or margins. Bronzing, yellowing and leaf abscission and sometimes chlorosis. Reduced leaf size and lower growth rate.
Manganese	Initial symptoms are often intervienal chlorosis on younger or older leaves depending on species. Necrotic lesions and leaf sheding can develop later.	Some times chlorosis, uneven chlorophyll distribution. Reduction in growth.
Boron	Symptoms vary with species. Stem and root apical meristems often die. Root tips often become swollen and discoloured. Internal tisues sometimes disintegrate (or discolour) (e.g."heart rot" of beets). leaves show various symptoms including thikening, brittleness,curling, wilting, and chlorotic spotting.	Yellowing of leaf tip followed by progressive necrosis of the leaf beginning at tip or margins and proceeding toward midrib.
Zinc	Reduction in internode length and leaf size. Leaf margins are often distorted or puckered. Sometimes intervienal chlorosis.	Exess zinc commonly produces iron chlorosis in plants.
Copper	Natural deficiency is rare. Young leaves often become dark green and twisted or misshapen, often with necrotic spots.	Reduced growth followed by symptoms of iron chlorosis, stunting, reduced branching, thickening and abnormal darkening of rootlets.
Molybdenum	Often intervienal chlorosis developing first on older or midstem leaves, then progressing to the youngest (similar to nitrogen deficiency). sometimes marginal scoching or cupping of leaves.	Rarely observed. Tomato leaves turn golden yellow.

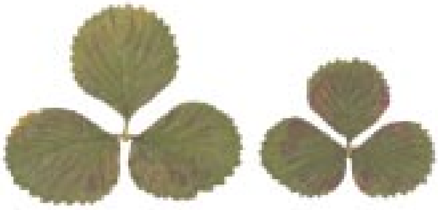

Figure 55: Calcium deficiency in strowberry

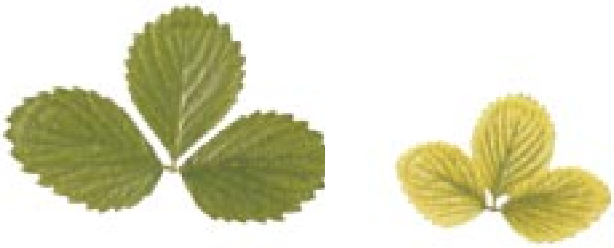

Figure 56: Iron deficiency in strowberry

Figure 57: Manganese deficiency in tomato

Figure 58: Iron defRiciency in tomato

Figure 59: Nitrogen deficiency in tomato

Figure 60: Zinc deficiency in strowberry

Figure 61: Magnesium deficiency in tomato

Figure 62: Sulphur deficiency in strowberry

Pictures curtsey: Compendium of strawberry diseases and compendium of tomato diseases by American Pathological Society.

Advantages of Hydroponics/ Soil-less Culture

- Land is not necessary. It can be practiced even in upstairs, open spaces and in protected structures.
- Clean working environment. The grower will not have any direct contact with soil.
- Low drudgery. No need of making beds, weeding, watering, etc.
- Continuous cultivation is possible.
- No soil borne diseases or nematode damage.
- Off-season production is possible.
- Vegetable cultivation can be done with leisure sense.
- Many plants were found to give yield early in hydroponics system.
- Higher yields possible with correct management practices.
- Easy to hire labour as hydroponics system is more attractive and easier than cultivation in soil.
- No need of electricity, pumps, etc. for the non-circulating systems of solution culture.
- Possibility of growing a wide variety of vegetable and flower crops including Anthurium, marigolds, etc.
- Water wastage is reduced to minimum.
- Possible to grow plants and rooted cuttings free from soil particles for export.

Limitations of Hydroponics/ Soil-less Culture

- Higher initial capital expenditure. This will be further high if the soil-less culture is combined with controlled environment agriculture.
- High degree of management skills is necessary for solution preparation, maintenance of pH and Ec, nutrient deficiency judgment and correction, ensuring aeration, maintenance of favourable condition inside protected structures, etc.
- Considering the significantly high cost, the soil-less culture is limited to high value crops of the area of cultivation.
- A large-scale cultivator may have to purchase instruments to measure pH and Ec of the nutrient solution.
- Energy inputs are necessary to run the system.
- Yields were found to decrease when temperature of the solution rises during warm periods.

Crops to Grow with Hydroponics/ Soil-less Culture

A variety of crops can be grown using hydroponics/soil-less culture. However, priority must be given to high-value crops depending on the market situation.

Leafy vegetables - Lettuce, Head lettuce, Kang kong, Gotukola

Vegetables - Tomato, Egg Plant, Green bean,Beet, Winged bean, Capsicum,Bell pepper, Cabbage,Cauliflower, cucumbers, melons, raddish

Fodder crops - Sorghum, Alphalfa, Barley, Bermuda grass, Carpet grass

Cereals - Rice, Maize

Condiments - Parsley, Mint, Oregano, Sweet basil

Fruit crops - Strawberry,

Flower/ornamental crops - Anthurium, Merrygold, Coleus, roses, carnations, orchids, chrysanthemums,

Medicinal crops - Alovera

Harvesting, Grading, Storage and Marketing

Harvesting

Harvesting at correct maturity will reduce post harvest loses. One must know the age of the fruits or plants to correctly identify maturity. Reports on crops may be maintained for this purpose. Harvest fruits by cutting with a sharp knife with minimum damage to fruits and plant stem.

Figure 63: Some crops that can be hydroponically grown

Harvest bell pepper after they develop their standard colour. For salads, harvests before the fruits reach full red ripen stage; when they are at yellow-red stage. It is better to wear a pair of gloves while harvesting and use disinfected knife or scissors.

At least some colour should be showing in tomato fruit before harvest. If the stems are attached care should be taken during handling to avoid any cuts or bruises.

Cucumbers must be harvested with no attached stem when they reach a uniform diameter throughout the fruit length, but before any yellowing appears at the blossom end. Harvest strawberry fruits when they begin to turn red.

Leafy vegetables must be harvested before they reach their full maturity. Select the correct stage of maturity for ornamental plants and fruits depending on the market requirements.

Grading

When the harvest is in fruit form, discard odd shaped, damaged, or spotted fruits and grade according to their sizes into large, medium and small size groups. It may be suitably labelled to indicate its quality (for example, free of pesticides).

Storage

After grading, most vegetables must be stored in cool dry place. Storing in large plastic containers with large holes for aeration is advisable.

Marketing

Depending on the market requirement, produce can be sold in small packing. They can be suitably labelled. The packing must have aeration holes.

Figure 64: Packing of tomato for marketing

Equipment for Hydroponics

Submersible or ordinary water pumps, Ec meter, pH meter are the essential equipment necessary to operate a circulating hydroponics. PVC pipes can be used as channels in these systems.

Figure 66: A submersible water pump

Water Pumps

The water pump must be made up of materials that are non-reactive with nutrient salt solution. Stainless steel shaft, polycarbonate or stainless steel impeller, pump-house and water seal must be there in the pump to be used in hydroponics.

One does not require a pump with very high head for circulating the nutrient solution in hydroponics systems. Therefore, a domestic water pump with 0.5 HP will suffice. A safety device is a must with the water pump as the nutrient solution more effectively conducts electricity compared to water. Therefore, a very sensitive trip switch must be used to disconnect electricity supply whenever the need arises.

Figure 65: A domestic water pump

Timer and Oxygen Detection Sensor

When the plants are small, their oxygen requirement is low. Therefore, the nutrient solution circulating time period can be limited. Limiting the circulating time periods can also reduce the electricity consumption. For this purpose a timer may be used to set the circulating time manually or an oxygen concentration detection sensor may be included in the system, so the sensor can activate the pump whenever the oxygen concentration of the nutrient solution level goes down.

PVC Pipes

Type 400 or class 4 100 mm PVC pipes have to be used in circulating hydroponics as the channels. PVC pipes with thinner walls will sag and thereby reduce the flow rate of nutrient solution. The result will be lack of oxygen supply for the plant roots. UV resistant pipelines are preferable. Painting these pipes white will prevent the increase of nutrient solution temperature. The flow rate required in hydroponics is very small ranging from 1 to 3 litres per minute. Therefore, an over-flow pipe will have to be fitted to adjust the flow rate.

Figure 67: PVC pipe system for hydroponics

pH and Ec Meters

Simple and portable Ec and pH meters must be used to monitor and maintain the Ec and pH at correct levels.

Blowers

These devices help send airflow through the plants so that plants shake and pollens are distributed to facilitate pollination inside protected structures.

Figure 68: Simple digital pH and Ec meters

Figure 69: A simple blower

Pollinators

These simple electrical device vibrate the individual plants when touch them so that pollination is facilitated inside the protected structures.

Nurtimeter

In addition to the Ec, this meter helps measure the nutrient contents of the solution.

Figure 70: A nutri-meter