

Various techniques of soilless culture for vegetable production



MASTER'S SEMINAR (VSC-591)

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M.Sc. 2nd year (Vegetable Sciences)

Historical background

- Many ancient civilizations have used soilless culture for their agricultural productions. Egyptian hieroglyphic records and hanging garden of Babylon(600BC) are fine example of soilless culture.
- The technology was first reported in scientific literature in 1600 (Weir, 1991).
- Woodward grew mint plants without soil in England in 1669.
- Gericke was the first person who used the term “hydroponics” in 1929.
- Nutrient solution was first developed by Sachs and Knap in 1938.
- In India hydroponics was first introduced at kalimpong in Darjeeling (W.B.) in 1947.
- Cooper *et al.* developed NFT in 1966.
- Jense and Collins developed aeroponics in 1985.

What is soilless culture ?

- Soilless culture covers all types of planting technologies without soil.
- It is an artificial means of providing plants with support and a reservoir for nutrients and water .
- The plants are grown in an inert growing medium and the nutrition is applied through nutrient solution (water and fertilizer mixed).
- The simplest and oldest method for soilless culture often called as solution culture or water culture but there are literally hundreds of method of soil less gardening with slight modifications.

Advantages

- Better quality produce.
- No soil borne diseases and pests.
- Continuous cultivation is possible.
- Efficient use of available resources.
- More productivity per unit area and time.
- Cultivation of crops are possible in saline and desert areas.
- One can grow the crops who do not have their own field.
- Helps to face challenges of climate change.

Types of production systems

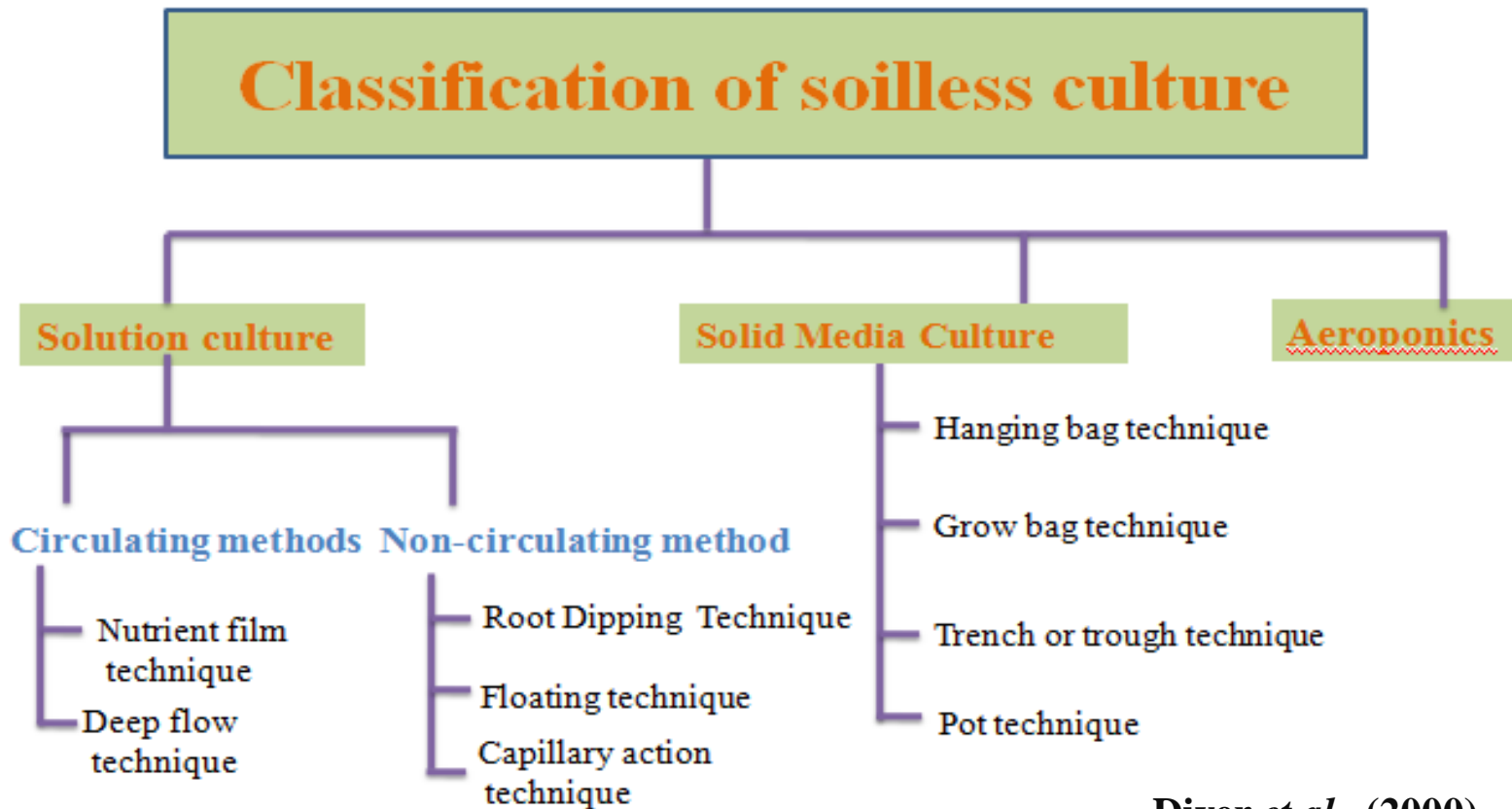
■ 1. Soil culture or geponics :

- In this production system crops are grown in natural soil.
- Soil is usually most suitable growing medium for plants, it provides anchorage, nutrients, air, water to the plants (Ellis *et al.*, 1974).
- But soil do pose serious problems, at times.

Limitations of soil culture

- Soil borne diseases.
- Unsuitable soil reaction.
- Degradation due to soil erosion
- Unfavourable soil compaction and poor drainage..
- Lot of labour and large volume of water.
- In urban and industrialized areas scarcity of fertile arable lands.
- Adverse effect of climate change on soil health.

2.) Soil less culture : In this production system soil is not used. Soilless culture falls into three general categories : Solution culture, Solid Media Culture and Aeroponics.



Diver *et al.*, (2000)

Hydroponics

- It is the practice of growing plants with their roots suspended in water containing mineral nutrients.
- Hydroponics uses less than 1/10th - 1/5th of the water used in soil cultivation.
- Automated Hydroponic System (AHS) for potato microtuber production in vitro has been also patented in 2008.(ICAR-Project CPRI Shimla)

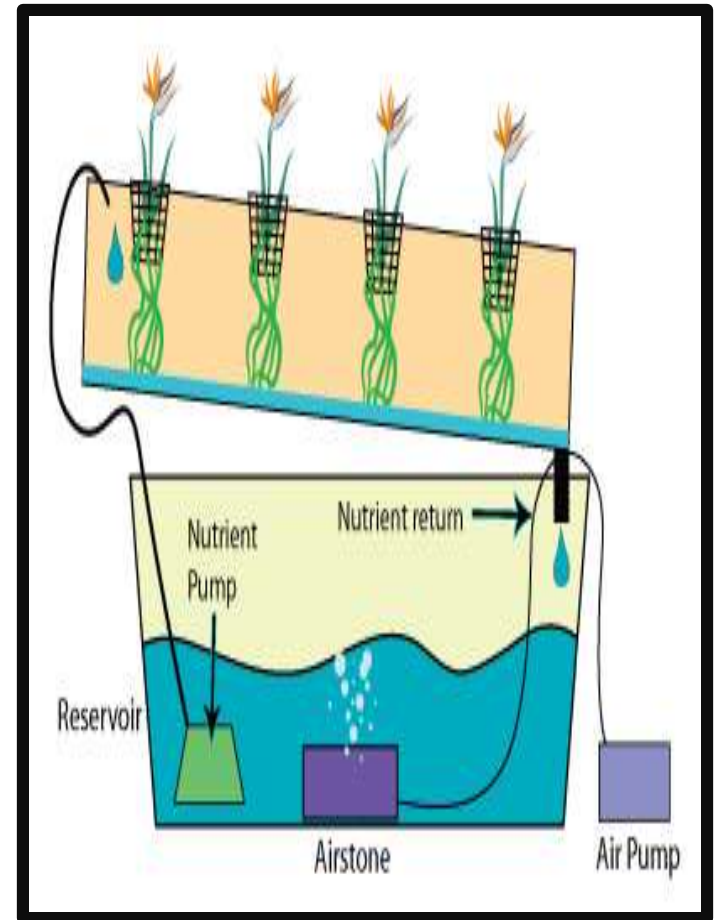


Types of solution culture

❑ Circulating methods :

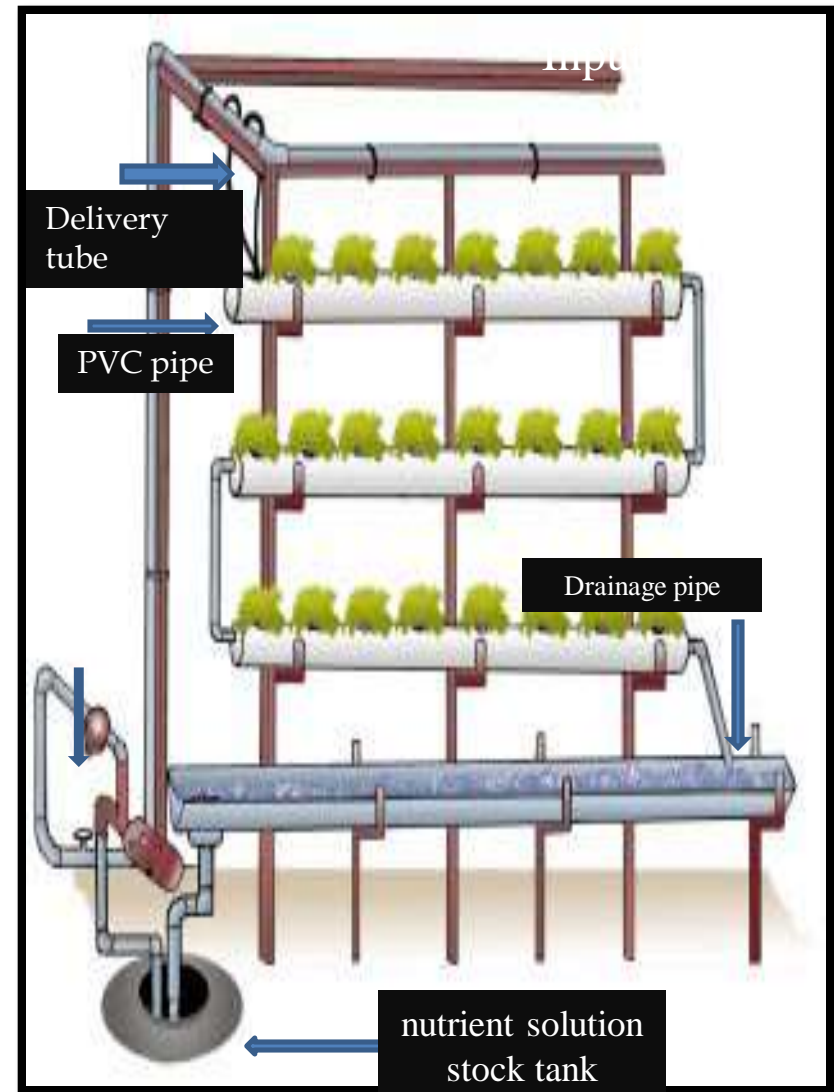
1. NFT (Nutrient Film Technique) :

- Thin film of nutrient solution flows through channels continuously bathing bare roots.
- At lower end of the channels nutrient solution gets collected and flows back to the nutrient solution tank.
- Spinach could be grown year round using NFT in greenhouse, if we choose proper cultivars and appropriate solution temperature. (Ikeda *et al.* 1995 *Acta Horticulture*)



2. DFT(Deep Flow Technique)

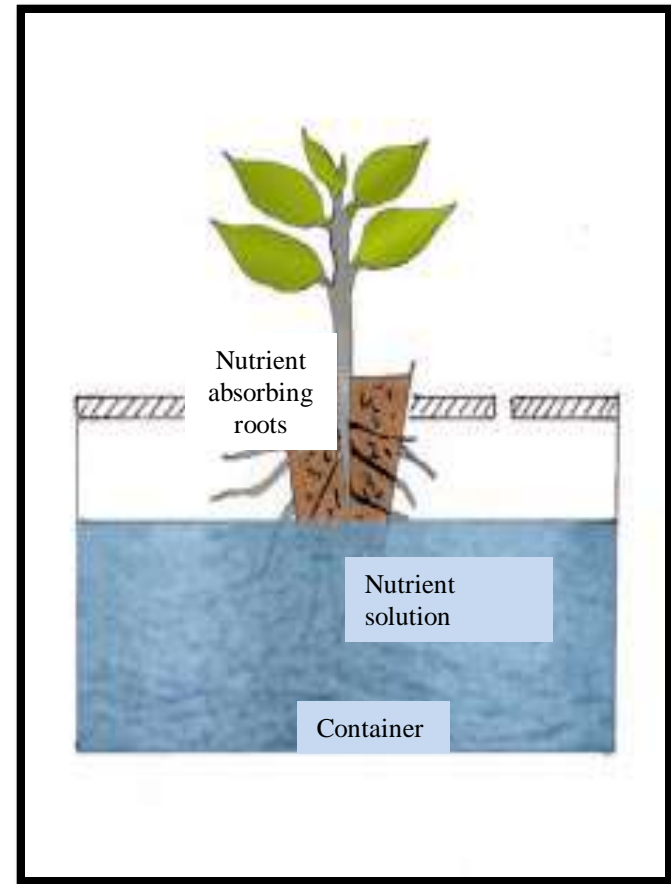
- In DFT nutrient solution flows 2-3cm deep through 10 cm diameter PVC pipes.
- Plastic pot contain planting materials and their bottom touch the nutrient solution that flows in the pipes.
- Potted plants are arranged in one plane or in zigzag shape.



Non circulating methods

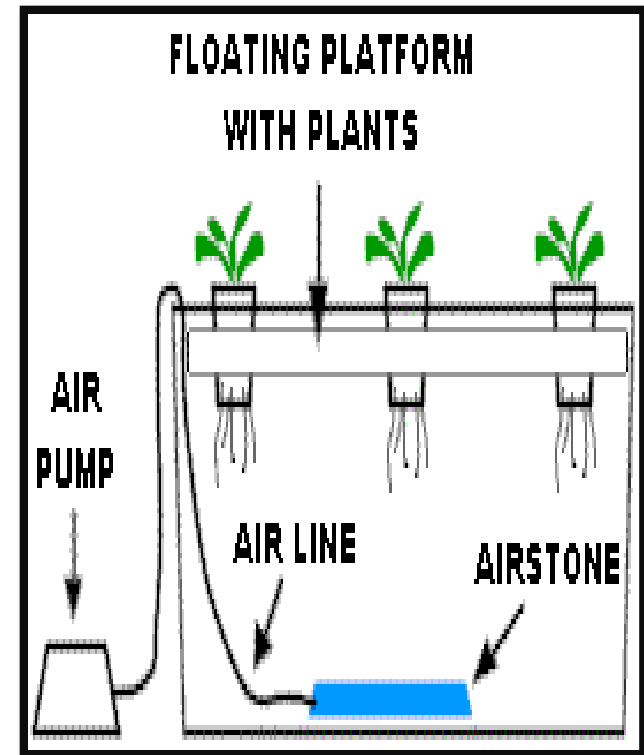
1. Root Dipping Technique:

- In root dipping technique plants are grown in small pots filled with little growing medium.
- Lower 2-3cm of the pots submerged in nutrient solution.
- Some roots are dipped in the solution while others hanging in the air.



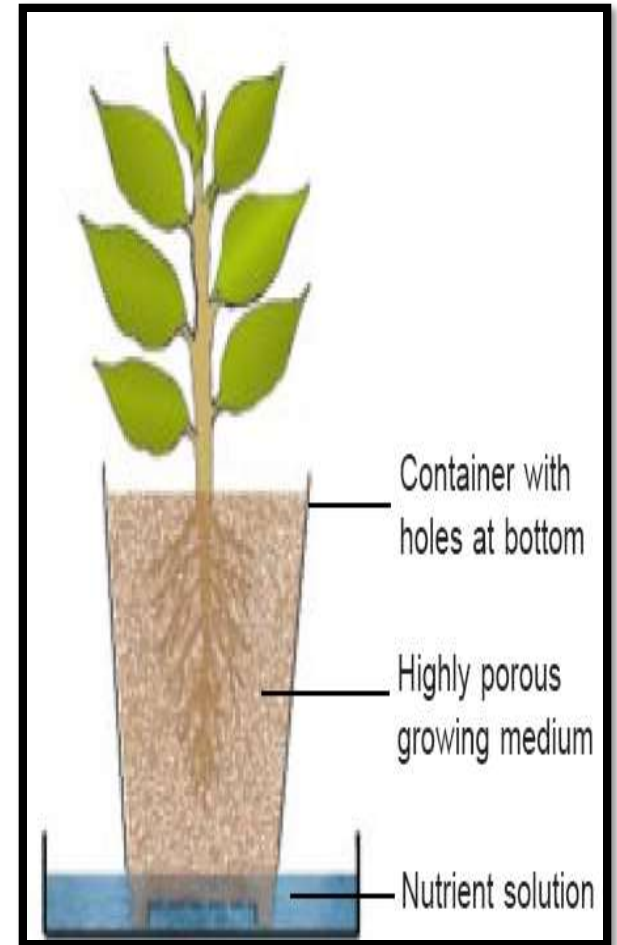
2. Floating technique

- In floating technique shallow containers of 10cm deep can be used.
- Containers are fixed to a styrofoam sheet and any other light plate on the container.
- Styrofoam sheet is allowed to float on the nutrient solution filled in the container.
- Solution is artificially aerated.



3. Capillary action technique:

- Nutrient solution reaches to inert medium by capillary action
- The technique is suitable for ornamentals, flowers and indoor plants.



Yield of lettuce under hoagland nutrient solution and hoagland nutrient solution alongwith jeevamrut

| Parameters | Production/plant | | Production/plant | | Production/plant | |
|-------------------------------------|----------------------------|--|----------------------------|--|----------------------------|--|
| | Hoagland nutrient solution | Hoagland nutrient solution + 5% spray of Jeevamrut | Hoagland nutrient solution | Hoagland nutrient solution + 5% spray of Jeevamrut | Hoagland nutrient solution | Hoagland nutrient solution + 5% spray of Jeevamrut |
| No. of leaves/plant | 21 | 26 | 22 | 25 | 21 | 27 |
| Leaf area (cm ²) | 2137.89 | 2178.22 | 2140.78 | 2172.56 | 2138.65 | 2176.867 |
| Root length (cm) | 19 | 24 | 17 | 23 | 18 | 24 |
| Yield /plant (g) | 169.77 | 199.86 | 171.54 | 200.40 | 178.8 | 195.86 |
| Carbohydrate content in leaves/ 10g | 2.39 | 2.56 | 2.40 | 2.57 | 2.40 | 2.56 |
| Carbohydrate content in roots/10g | 0.56 | 0.71 | 0.57 | 0.70 | 0.56 | 0.72 |
| Protein content in leaves/10g | 1.28 | 1.35 | 1.26 | 1.36 | 1.27 | 1.35 |
| Protein content in roots/10g | 0.43 | 0.56 | 0.42 | 0.55 | 0.43 | 0.58 |
| Days to marketable maturity | 41 | 36 | 40 | 36 | 41 | 35 |

**Growth of lettuce under
Hoagland nutrient
solution**



**Growth of lettuce under
Hoagland nutrient solution
+ 5% spray of jeevamrut**



Crops suitable for soilless culture

| | |
|------------------|---|
| Vegetables | Tomato, Chilli, Brinjal, Green bean, Beet, Winged bean, sweet pepper, Cabbage, Cauliflower, Cucumbers, Melons, Radish, Onion etc. |
| Leafy vegetables | Lettuce, Parsley etc. |



**SOURCE: Hussain *et al.*, 2014
(IJACS)**

Vegetable production under soil-less culture in India

| Vegetables | Production (g/sqm /day) |
|---------------------|-------------------------|
| Carrot | 56.5 |
| Cucumber | 226 |
| Garlic | 57 |
| Ginger | 57 |
| Leek | 57 |
| Green Bean | 113 |
| Lettuce | 226 |
| Onion | 56.5 |
| Peapod | 113 |
| Potato | 56.5 |
| Salad greens | 226 |
| Tomato | 113 |

Singh and Singh (2012) 4th Global conference on
—Horticulture for Food, Nutrition and Livelihood
Options Bhubaneshwar, Odisha, India.

Suitable systems for crop production

| CROPS | SUITABLE SYSTEM |
|--|-----------------------|
| Temperate lettuces | NFT, DFT, aeroponics. |
| Temperate herbs (leafy vegetables, sweet basil) | NFT,,DFT |
| Local vegetables (Chinese cabbage, Chinese celery, Chinese kale, etc.) | NFT, DFT |
| Fruit vegetables like sweet pepper, tomato, muskmelon | Substrate culture |

Source : Wattanaprechanon K & Wattanapreechanon E (1997).
Proceedingsoftheinternationalconference.Chulalongkorn University

Income and expenses for producing hydroponic vegetables/sq m area

| COST (US\$) | Celery | Pepper | Lettuce | Cucumber | Radish | Tomato |
|---------------------------------|---------------|---------------|---------------------|-----------------|---------------|---------------|
| Total cost/m² | 2.31 | 2.87 | 1.67 | 2.12 | 1.82 | 2.84 |
| Net Income/m² | 28.55 | 14.25 | <u>40.26</u> | 5.28 | 33.03 | 25.15 |

UNDP, (2000)

Yield of tomato under hydroponics and field conditions

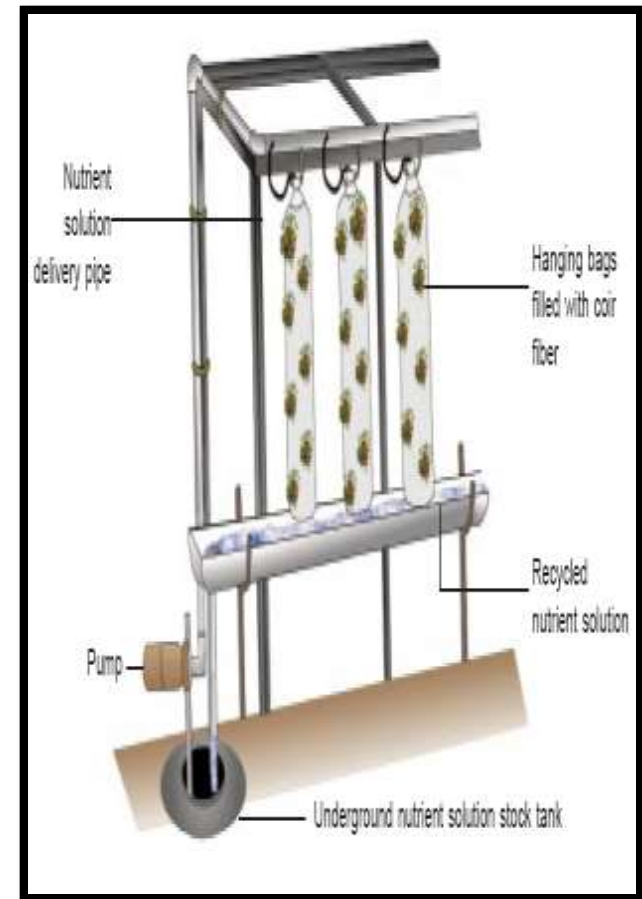
| Parameter | Hydroponics | Field conditions |
|-------------------------------|--------------------|-------------------------|
| No. of fruits/plant | 64 | 38 |
| Yield/plant (kg) | 2.05 | 1.2 |
| Yield (q/ha) | 820 | 480 |
| Days to fruit ripening | 58 | 62 |

Pant et al. (2005)

Solid media culture or aggregate system

1. HANGING BAG TECHNIQUE:

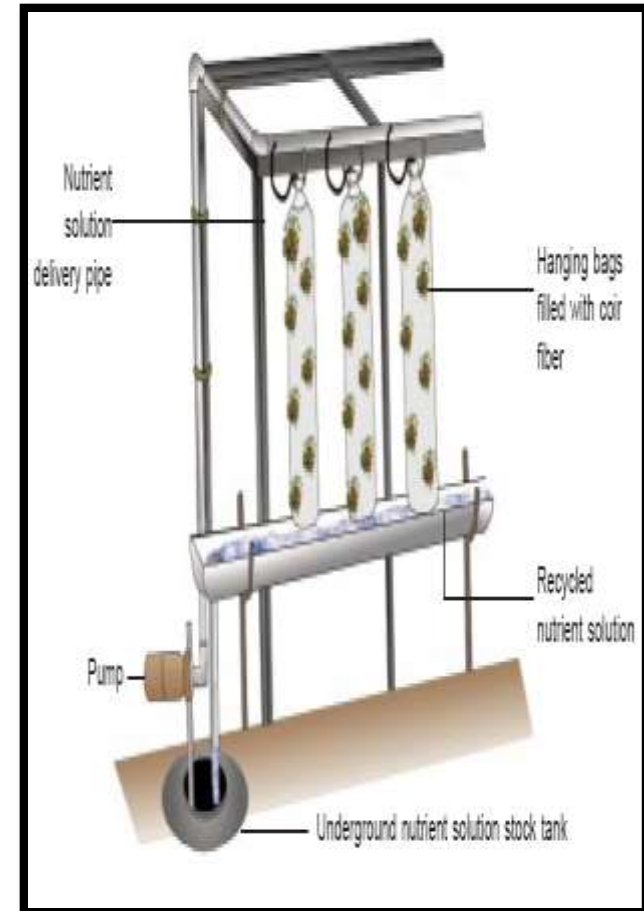
- In hanging bag technique 1m long cylindrical structure, white from outside and black from inside thick polythene bags, filled with sterilized media and sealed at the bottom end and tied at the top small PVC pipe.
- Bags are suspended vertically and nutrient is supplied through nutrient delivery tube.
- Planting material squeezed into holes on the side of hanging bags.



Solid media culture or aggregate system

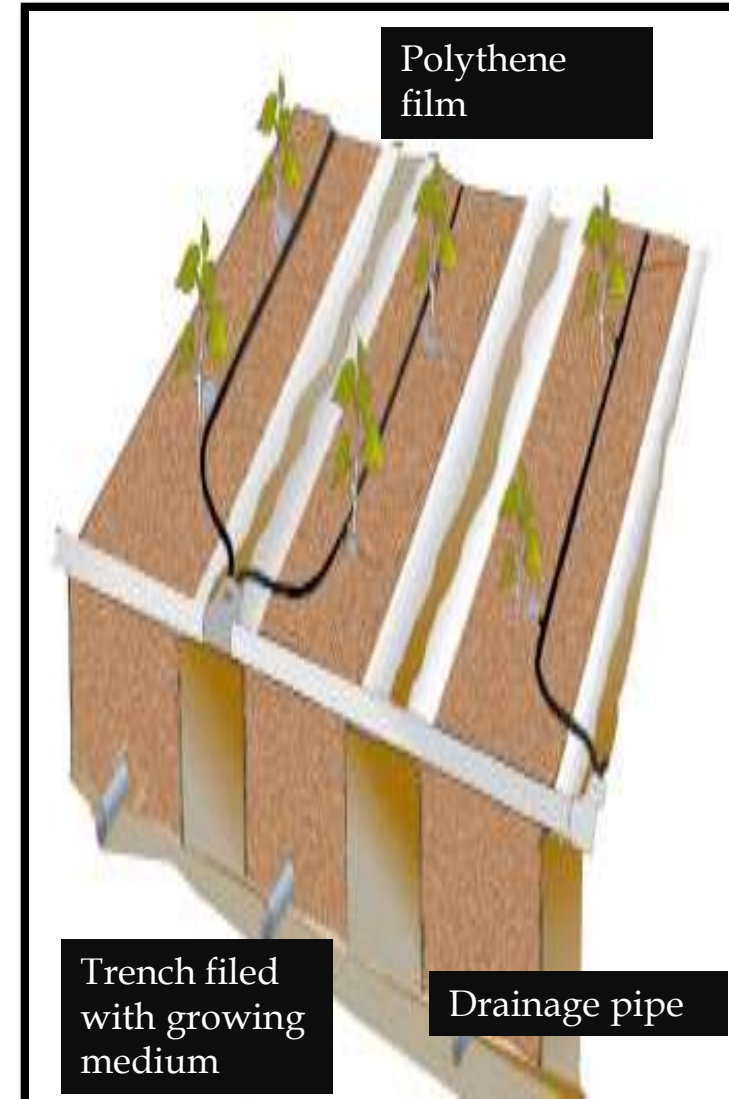
HANGING BAG TECHNIQUE:

- In hanging bag technique 1m long cylindrical structure, white from outside and black from inside thick polythene bags, filled with sterilized media and sealed at the bottom end and tied at the top small pvc pipe.
- Bags are suspended vertically in nutrient solution.
- Planting material squeezed into holes on the side of hanging bags.



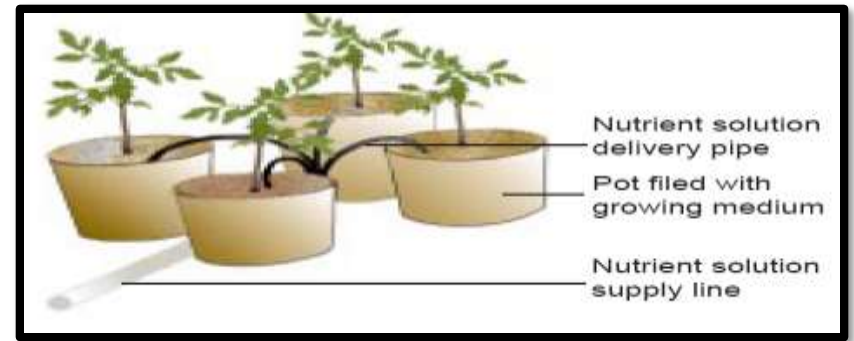
2. Trench or trough technique

- Plants are grown in narrow trenches in the ground constructed with bricks or concrete blocks.
- Trenches or troughs lined with waterproof material.
- Depth of trough at least 30cm.
- Irrigation by drip system or manual application.
- Pipe of 2.5 cm diameter placed at the bottom for drainage.



3. Grow bag technique:

- Growing media is filled in grow bags.
- Nutrient is supplied through drip system.



Characteristics of good soilless culture media

- Should be fairly constant in volume.
- Should be free from weed seeds, nematodes and soil born diseases.
- Should have proper drainage and aeration.
- Should contain sufficient nutrients.
- Should possess adequate CEC and low insoluble salts.
- Should be biologically and chemically stable on sterilization.
- Media pH should be maintained between 5.2 to 6.5.

Classification of soilless culture media

GROWING MEDIA or SUBSTRATES

| Organic media | Inorganic media | |
|---|--|--|
| | Natural media | Synthetic media |
| <ol style="list-style-type: none"> 1. Sawdust 2. Cocopeat 3. Peat 4. Woodchips 5. Pleece 6. Marc 7. Bark | <ol style="list-style-type: none"> 1. Vermiculite 2. Gravel 3. Rockwool 4. Perlite 5. Sand 6. Glasswool 7. Pumice 8. Zeolite 9. Sepiolite | <ol style="list-style-type: none"> 1. Hydrogel 2. Foam mates (Polyurethane) 3. Oasis (Plastic foam) |

Organic substrates

- **Cocopeat:** It is byproduct of coconut husk.
- Coconut peat is used for a wide range of soilless crop production:tomato,cucumber, eggplant, capsicum, etc. with no harmful environmental impact.
- The high water holding capacity of this substrate provides a buffer in high temperatures and high crop load demand without compromising air supply.



PEAT MOSS

- **Peat** : It is remains of aquatic marsh bog or swamp vegetation in partial decomposed state. It has high moisture holding capacity.
- Peat moss is formed by the accumulation of plant materials in poorly drained areas.
- The type of plant material and degrees of decomposition largely determine its value for use in a growing medium.



SPHAGNUM MOSS

- Sphagnum is perhaps the most desirable organic matter for the preparation of growing media .
- Sphagnum moss is light in weight and has the ability to absorb 10 to 20 times its weight in water.
- This is attributed to the large groups of water holding cells, characteristic of the genus.
- Peat substrate may be used in various ways for raising crops the most popular are bags, modules and troughs.



Wood residues

- Wood residue includes sawdust and bark.
- These materials are generally byproducts of the lumber industry and are readily available in large quantities.
- Nitrogen depletion by soil microorganisms, during the decomposition process, is one of the primary problems associated with these materials.
- However, supplemental applications of N to the growing media can make most wood residues valuable amendments.



Rice hulls

- Rice hulls are a by-product of the rice milling industry.
- Although they are extremely light in weight, rice hulls are very effective at improving drainage.
- The particle size and resistance to decomposition of rice hulls and sawdust are similar.
- However N depletion is not a serious problem in media amended with rice hulls.



Inorganic substrates

- **Perlite:** It is grey white silicate material of volcanic origin, neutral in pH and expands from four to twenty times its original volume when it is quickly heated to a temperature of approximately 1600-1700° F.
- This expansion is due to the presence of two to six percent combined water in the crude perlite rock, which causes the perlite to pop in a manner similar to that of popcorn.
- The surface of each particle is covered with tiny cavities, which provide an extremely large surface area.
- These surfaces hold moisture and nutrients and make them available to plant roots.
- In addition, because of the physical shape of each particle, air passages are formed which provide optimum aeration and drainage. Because perlite is sterile, it is free of diseases, seeds, and insects.



Sand

- Sand is a basic component of soil, ranges in particle size from 0.05mm to 2.0mm in diameter. Fine sands (0.05mm to 0.25mm) do little to improve the physical properties of a growing media and may result in reduced drainage and aeration.
- Medium and coarse sand particles are those, which provide optimum adjustments in media texture. Although sand is generally the least expensive of all inorganic amendments it is also the heaviest.
- Sand is a valuable amendment for both potting and propagation media. But washed sand should be purchased since it is nearly free of clay and organic matter.



Vermiculite

- **Vermiculite** :Chemically, it is hydrated magnesium aluminium silicate. Vermiculite is a micaceous mineral produced by heating to approximately 745°C the expanded, plate-like particles, which are formed, have a very high water holding capacity and aid in aeration and drainage.
- Vermiculite has excellent exchange and buffering capacities as well as good ability to supply potassium and magnesium.
- Although vermiculite is less durable than sand and perlite, its chemical and physical properties are very desirable for container media.



Rockwool

- **Rockwool** : Rockwool is prepared by melting mixture of basalt, limestone at a temperature of 1600 °C.
- The molten mass is then spun at a high speed into thin fibers of 0.005mm diameter, treated with certain additives (a resin) to bind the fibers together and pressed into slabs of various sizes.
- Rockwool is also produced as a loose flock, which is used as a growing medium in pots, in a similar way as peat, or as an additive to other media.
- On average 95% of the volume of dry Rockwool slab is air space and only 5% is fiber.



Calcined clays

- Heating montmorillonitic clay minerals to approximately 690°C forms calcined clays.
- The pottery-like particles formed are six times as heavy as perlite.
- Calcined clays have a relatively high cation exchange as well as water holding capacity. This material is a very durable and useful amendment.



SALIENT FINDINGS

| Crop | Place | Salient finding | Reference |
|---------------|--------------|---|----------------------------------|
| Tomato | Iran | Stem diameter of tomato with sawdust higher than in those supplemented with perlite. | Delshad, (2006) |
| Tomato | China | Addition of maize in perlite and pumice could improve inorganic substrates properties for tomato soilless culture, leading to higher yields and better fruit quality. | Tzortzakis N.G.(Hort. Sci.) 2008 |

Soilless culture for nursery raising

- High quality seedlings can be obtained using soilless media. Usually, mixture of cocopeat, vemiculite and perlite is used.
- Early maturity.
- Reduces seed mortality due to sterilized growing media.
- Provides good mainfield establishment and crop stand.





capsicum

Healthy nursery of some vegetable crops



cucumber



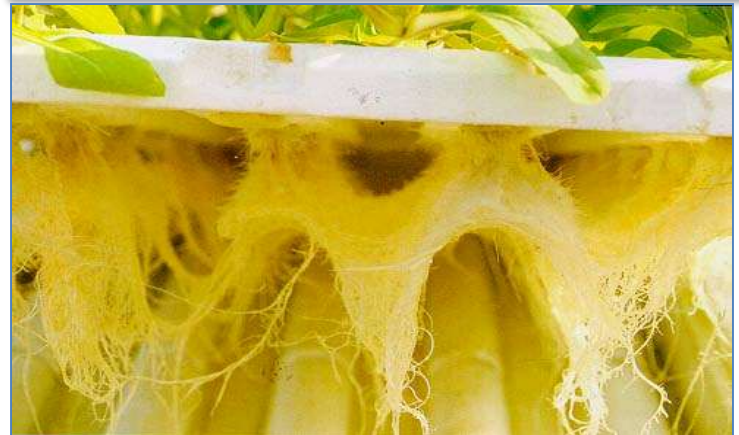
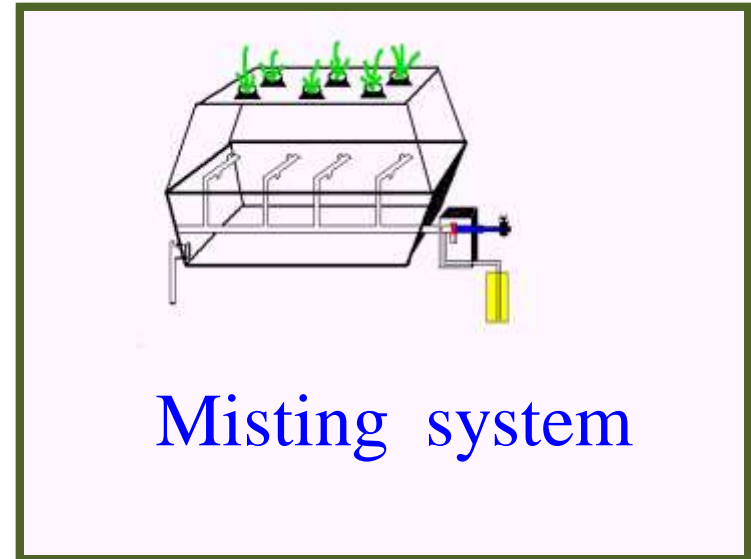
Tomato

World soilless culture system/media and crops grown

| Country | Year | Area (ha) | Media/System | Major Crop Grown | Reference |
|-------------|------|-----------|----------------------------|--|---------------------------------|
| Netherlands | 2001 | 10,000 | Rockwool | Tomato, Lettuce, Cucumber Muskmelons, Cauliflower, Carnation, Gerbera , Chrysanthemum, Strawberry | Hassall <i>et al.</i> (2001) |
| Spain | 2001 | 4000 | Perlite, Sand, Rockwool | Tamato, Lettuce, Cucumber, Capsicum | Hassall <i>et al.</i> (2001) |
| Canada | 2001 | 2000 | Perlite, and Rockwool | Tamato, Cucumber, Capsicum | Bradley <i>et al.</i> (2001) |
| China | 2005 | 1250 | NFT, DFT, Rockwool | Tamato, Cucumber, Lettuce, Roses, Chrysanthemum, Carnation | Jiang <i>et al.</i> (2007) |

Aeroponics

- Method of growing plants where they are anchored in holes of styrofoam panels and their roots are suspended in air beneath the panel.
- The nutrient solution is sprayed in fine mist form to the roots of plants.



Nutrient solution formula for closed system

| Fertilizer and grade | Tomato solution | | Cucumber solution | |
|--|------------------------|------------------------------|------------------------|------------------------------|
| | A | B | A | B |
| | Seedlings to fruit set | Fruit set to harvest of crop | Seedlings to fruit set | Fruit set to harvest of crop |
| | g/1000litre | g/1000 litre | g/1000 litre | g/1000 litre |
| Magnesium Sulfate | 500 | 500 | 500 | 500 |
| Potassium Nitrate (13.75-0-36.9) | 270 | 270 | 270 | 270 |
| Monopotassium Phosphate (0-22.5-28.0) | 270 | 270 | 270 | 270 |
| Potassium Sulphate (0-0-43.3) | 100 | 100 | – | – |
| Calcium Nitrate (15.5-0-0) | 500 | 680 | 680 | 1357 |

Charles, (2002)

Case Study

■ **Aeroponics for potato seed production**

- At CPRS, Shillong studied the relative performance of Kufri Megha, Kufri Himalini and Kufri Himsona for mini-tuber production in the NE region under an aeroponics system.
- Although all the three varieties were able to produce mini-tubers under aeroponics culture in the NEH region, the performance was far from satisfactory in Kufri Himalini and Kufri Himsona in 2014.
- From this study, it can be concluded that aeroponics system can be successfully utilised for the production of tissue culture based disease free quality seed potato in the NE regions all the three varieties were able to produce mini-tubers.

SOURCE : Bag T.k. *et al*, **2015**
Indian Journal Of Agricultural Sciences

High tech seed potato production using aeroponics

- CPRI SHIMLA(HP) under a project compared performance of six potato cultivars viz. Kufri Himalini, Kufri Lauvkar, Kufri Sindhuri, Kufri Girdhari, Kufri Jyoti and Kufri Khyati in aeroponic system.
- The first harvesting of aeroponic minituber was carried out after 55 to 59 days of planting while in Kufri Jyoti about 90 days.
- The aeroponic minituber weight varied from minimum of 2.3 g in Kufri Himalini to maximum of 3.8 g in Kufri Khyati. The maximum no. of leaves & plant height per plant were observed in Kufri Sindhuri while minimum in Kufri Himalini.

SOURCE: K. K. Pandey
Division of Seed Technology
CPRI, Shimla

Disease incidence in soilless culture

Soilless culture is no guarantee for disease free cultivation. Preventive sanitation and plant hygiene is of prime importance for disease and pest prevention and maintaining plant health. This can be accomplished by:

1. Regulating the growth factors.
2. Controlling spreading of pests and diseases.
3. Removal of all infected materials.

Important pathogens of soilless culture

| Culture | Virus | Bacteria | Fungi | Nematodes |
|-----------------|---|---|---|---|
| Tomato | Tomato mosaic virus, Tobacco necrosis virus | <i>Pseudomonas corrugata</i> <i>Pseudomonas viridiflava</i> <i>Erwinia chrysanthemi</i> | <i>Alternaria solani</i> <i>Fusarium oxysporum</i> <i>Phytophthora infestans</i> <i>Phythium ultimum</i> | Globodera sp. And meloidegyne sp. |
| Cucumber | Cucumber necrosis virus,Cucumber mosaic virus | <i>Pseudomonas syringae</i> <i>pv. lachrymans</i> | <i>Fusarium solani</i> <i>Olpidium brassicae</i> <i>Phythium spp.</i> | <i>Meloidogyne incognita</i> Pratylenchus sp., longidorus sp. |
| Lettuce | Lettuce mosaic virus | <i>Pseudomonas sp.</i> | <i>Pythium tracheiphilum</i> <i>Pythium ultimum</i> <i>Rhizoctonia</i> <i>solani</i> <i>Sclerotinia sclerotiorum</i> | <i>Meloidogyne hapla</i> <i>Meloidogyne incognita</i> |
| Pepper | Tobacco mosaic virus Tobacco necrosis virus Tomato mosaic virus | | <i>Diporothea rhiohilia</i> <i>Fusarium solani</i> <i>Phytophthora capsici</i> <i>Pythium sp.</i> | |

Source: Alsanius B.W.
and Brand T. Acta Hort.,
ISHS ,2004

Substrate and nutrient solution disinfection methods

| CHEMICAL METHODS | PHYSICAL METHODS |
|----------------------------|------------------------|
| 1.Ozone | 1. Heat treatment |
| 2. Hydrogen peroxide | 2.U V radiation |
| 3. Sodium hypochloride | 3.Membrane filtration |
| 4.Chlorine dioxide | 4.Slow sand filtration |
| 5.Copper silver ionization | |

CONT.....

| Disinfection method | Dose | Advantages | Disadvantages |
|---------------------|--|---------------------------------------|---|
| Heat treatment | 95°C for 30 s 85°C for 3 min | High efficacy | High investment and running costs (only for farm > 1 Ha). |
| UV-C radiation | 100-250 mJ/cm ² UV-C | Moderate efficacy and investment cost | Sometimes unreliable results; needs pre-filtration. |
| Membrane filtration | Pores size: 0.05 µm for <i>Fusarium</i> ; 0.1 µm for <i>Verticillum</i> | High efficacy | Very expensive; low lifetime of filter membrane. |
| Ozone | 10 g m ⁻³ h ⁻¹ | High efficacy | Expensive; needs preventive filtration and acidification. |

| Cont..... | | | |
|-------------------|--|---|---|
| Chlorine | 2 ppm di cl per 1' For <i>P. cinnamomi</i> | High efficacy; used for sanitation of greenhouse structure and devices | Difficulties to establish the efficacy doses; acidity affects efficiency. |
| Hydrogen Peroxide | 100 ppm for <i>Fusarium spp.</i> | Low investment costs | Do not kill nematodes completely. |
| Slow filtration | Flow rate of 100–300 L m ² h ⁻¹ Sand grain size: 0–2 mm | Low investment costs; Suitable for low technology, small-size greenhouse operations | Eliminates completely Zoosporic fungi and eliminates Fusarium, Viruses And nematodes partially. |

SOURCE : The advantage and disadvantage of most popular nutrient solution disinfection methods (from Van Os et al., 2003; Runia, 1996, Van Os 2011; Stewart-Wade, 2011).

SALIENT FINDINGS

| CROPS | Salient finding | REFERENCE |
|---------------------|--|--|
| Tomato and cucumber | Investigation on heat disinfection of nutrient solution was carried out. Heat exchangers work well at 95 °C for 30 sec., e.g. To control <i>phytophthora cryptogena</i> and <i>pythium aphanidermatum</i> | Runia et al. (1988) and McPherson <i>et al.</i> (1995) |
| Pepper and cucumber | The application of non-ionic surfactants works very well where mobile zoospores are the sole source of disease spread. In this case, the addition of 20 µg.Ml surfactant to the nutrient solution effectively controls the spread of <i>pythium</i> in cucumber and <i>phytophthora</i> in pepper without phytotoxicity. | (Stanghellini <i>et al.</i> ,1996) |
| lettuce | Ultra-violet radiation found to be effective against <i>pythium</i> rot . | Benoit and Ceustermans, 1993). |

Limitations

- Slight mistake can end up the crop.
- High initial capital investments.
- require technical knowledge.
- Energy inputs are necessary to run the system (Van Os *et al.*, 2002).
- Soil-less culture is limited to high value crops on sustainable basis.
- Less awareness among people.

CONCLUSION

- Soiless culture has many advantages over geponics like efficient utilization of inputs, high production and quality produce. Thus, soiless culture is becoming popular to meet the international standards of quality produce, especially in commercial production of vegetables. Soiless culture could well dominate food production in the future. As the population increases, arable land declines due to poor land management, people will turn to new technologies like soiless culture of crop production Although, more literature on soiless culture is available but standard, precise and authentic information's are still lacking. Since the soiless culture industry is still rather small, and there are not sufficient marketing. For popularization of soiless culture, it is very important to provide scientific proven technology of soiless culture to gardeners and create mass awareness in potential areas at national level.

THANK YOU