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Recent Trends in the Cultivation of Vegetable Crops: A review

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ABSTRACT

As population increases all around the world the food demand increases as well. Humans need to endure water, food and living habitat. What concern is that the existing agriculture system will not be able to meet the food demand soon as this system is facing many challenges. The objective of this review article is to discuss the soilless culture technologies, vegetable crops cultivation, advantages and challenges of hydroponic greenhouse system. Soilless cultivation is better option in the sense of utilization of inputs and improved crop production. Soilless culture systems are modern agriculture techniques that use substrate medias with the nutrient solution or the nutrient solution alone rather than soil for crop production.

Keywords: vegetable crops, soilless culture, technologies, challenges, greenhouse, food requirement

1. Introduction

Soilless culture is to grow plants without the using of soil, those plants feed by a solution made of mixing both water and nutrients. Plants roots grow directly in that solution or in a growing media.

cultivation in substrates is characterized by the way of dealing with the drained solution to two parts, open or close systems, drained solution gets reused in the close system that offers a great way to minimize water resources pollution with nitrates and phosphates resulted from fertigation discharge and help with giving a perceivable reduce to water and fertilizers consuming (Savvas, 2002). Shifting for close cultivation system does not have any negative effect like reducing crops productivity or quality.

Yet, salt ions accumulation in the recycle nutrient solution limits the increasing of using closed cycled growing system in substrate cultivated vegetables crops. This occurs from inlet of salt ions and water at higher ratios than the corresponding ions to water absorbed ratios (Sonneveld, 2002). Although, reusing of discharged solutions in close soilless systems may increase the danger of diseases spreading that need to ensure good solution disinfection system (Wohanka, 2002).

Fast increasing of using hydroponic systems during the few past decades refers to its ability to grow plant without using soil which may have pests of pathogenesis which affect the early growing stage, or poor soils that lost its fertility and composition after long times of continuous use by the same or relative crops. Thus, it became one of the highly recommended ways for producing crops in the greenhouse cultivation facilities

Those methods have a lot of advantages compared with regular soil cultivation for example; it is free from soil borne pathogens, weeds, pests, can have a fool control of plant nutrition, overcome soils difficulties like saline, sodic and poor structured soils, can safely replace soil disinfection, safe the time wasted in preparing land for cultivation and gives a high yield with high quality and possible early yield even in cold winter time duo to controlling solution temperature.

On the other hand, its need for monitoring at all time by very skilled people and its initially high cost, what discourage more people from shifting to use these methods.

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The most important issue for success cultivation using these methods is root aeration. Growers should be aware of growing substrate properties because it controls the air/water ratio which influence O2 availability around root zone. O2 shortage happens in medias that with low air-filled porous, mainly if crop plants exhibiting rapid growth rate joined at the same time by high root respiration, this problem can be solved by filling bags, containers or troughs with substrate in a depth of no less than 20 cm.

Hydroponic systems are mostly closed systems, while substrate systems may be closed or open systems. In the closed ones there is a reuse of solution and it goes in cycle with applying an adjustment to it to restore its initial start nutrient concentrations. However, open systems get a newly solution is introduced on every irrigation cycle. The priority of closed systems over open systems is related to its effectiveness in water & nutrient usage.

Background

Generally, people conceder soilless culture to be a modern plant growing way but truth is cultivating plants in containers separately from ground has done in the past so many times before (Khan *et al.,* 2018).

The Pharos had done it four thousand years ago as shown in Wall paintings in temple of Deir el Bahari (Naville, 1913) it seems to be the first documented try of plants cultivated in container (Fig. 1). They used it for moving mature plants trees from its original countries to the king’s palaces and then keep growing in it because local soil was not suitable for those plants.

The kinds of growing mediums filled the containers is unknown, but it seems to be light materials because people were caring it easily (Jacobs *et al.,* 2009).

By the 17th century, plants were moved around the globe to give a special aesthetic value, and unusual fruits and vegetables to rich people.

The most primitive book on soil-less culture was Sylva Sylvarum published by Francis Bacon in 1627. In 1859-65, German researchers made developments in the soilless culture techniques (Khan *et al.,* 2018). In 1929, William Frederick Gerick promoted the solution culture for agricultural crop production. The word “Hydroponic” was firstly used by the William Frederick Gerick in 1937. In 1946, English scientist W.J. Shalto Duglas introduced the Hydroponics in West Bengal India. English scientist Allen Cooper developed Nutrient film technique in 1960. In 1960-70, commercial hydroponics farms developed in several countries of the world. Later, in eighties several automatic or high-tech hydroponics farms developed all over the globe (George, 2010).

Classification of soilless culture

Soilless cultivation can be divided to two main sections duo to the how it contains plant roots in it; the first section is hydroponic which roots grow directly in nutrient solution, and the second is substrate media that hold the roots inside and give it support.

The used systems have differences among them depending on their shape, size, feeding plants, reuse of solution and if substrates are involved or not Substrate medias can be organic, inorganic or synthetic materials or combinations of some or all of them, they are deferent in shape, size, weight, colure, texture, aeration and water holding ability.

It has to be more water and nutrient amount extra than what plants need to grow, because of the variation differences between crops, its need for water and nutrient at deferent growth stages, variation of the plants consumptions by time, as well as the ways use to add water and nutrients to those crops and the way it used to deal with the extra solution around roots, this extra amount of water and nutrient are essential to ensure that all cultivated plants get equal amounts of water and nutrition and leaching, as well it helps to reduce salt from concentrated around in root zone.

These methods can also be assorted by the way of reusing of the extra drained solution as either open or closed soilless systems.

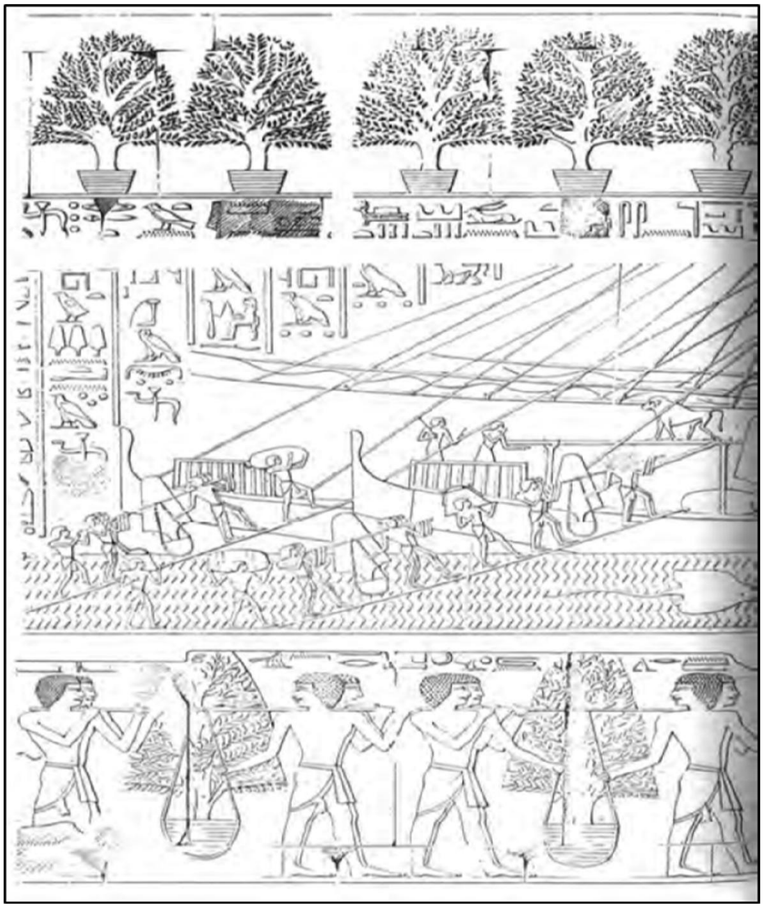

Fig. 1: Early noticed instance for plant production and transportation, showed in the temple of Hatshepsut, Deir El Bahri, Luxor, Egypt (Naville, 1913 and Matkin *et al.,* 1957)

Soilless culture

Substrate systems

Bags (vertical or horizontal), Container, Beds and Trough, Gravel culture and Sand culture.

Hydroponic systems

Wick Systems, DWC, Ebb and Flow, Drip Method, NFT, DFT, Aeroponics

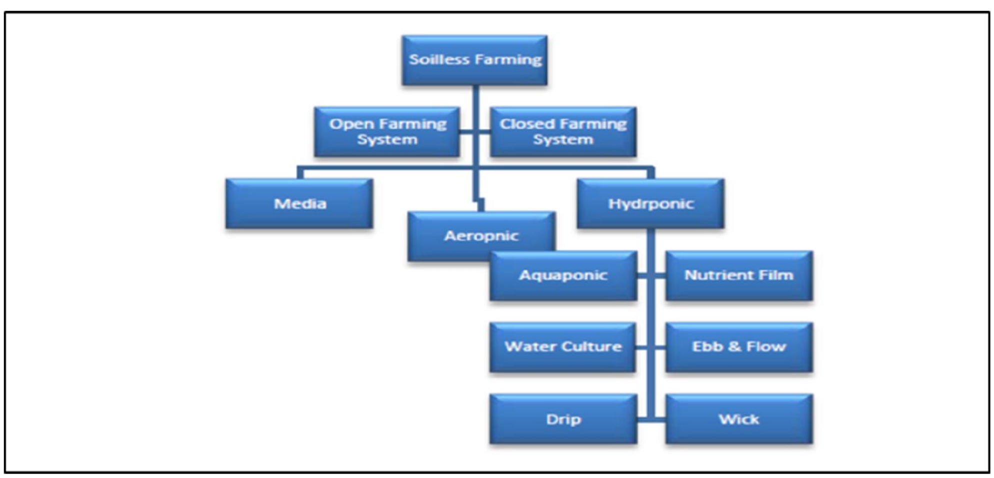

Fig. 2: Classification of the Soilless Farming system (AlShrouf, 2017).

Plants Nutrition in Soilless Culture

Within these methods nutrients and water are joined in one system that supplies both of them together for cultivated plants, in which all the essential nutrients for plants growth and development would introduce using hydro soluble fertilizers.

Highly concentrated solutions prepared by dissolving fertilizers making stock solutions which get added to water to make solution suitable for plant feeding.

There are two fertilizer tanks filled with stock solutions used to detach fertilizers which may react. One of the suggested combinations is a tank "A" having mainly calcium sources and a tank "B" with mainly phosphate and sulphate sources, it allows calcium to be away from phosphorus and sulphate to stop deposition of calcium phosphate or calcium sulphate, because they are niggardly soluble. Anther tank "C" contain a concentrated inorganic acid to be used for controlling pH level for nutrient solution obtains after adding stock solutions to irrigation water, and to clean the irrigation system and stop emitters blocking.

The Plant nutrients which get involved in hydroponic systems get dissolved in water and generally they are from inorganic and ionic forms (Sharma *et al.,* 2018). Whole 17 essential elements for plant growth are supplied using different chemical sources and combinations.

Hoagland's solution is the most used and common nutrient solutions for hydroponic systems. Although, Cooper's 1988 and Imai's 1987 nutrient solutions were used for growing leafy vegetables, tomatoes and cucumber.

pH and EC of the nutrient solution are very essential and must maintained properly for optimum plant performance.

The ideal EC range for hydroponics for most of the crops range among 1.5 and 2.5 dS m-1. If EC level goes above that range will stop nutrient intake because of the osmotic pressure while if it goes down that level will badly affect plant growth and yield. So, convenient control of EC in hydroponics systems play an influential part regarding improvement vegetable yield and quality (Gruda, 2009). As an example, tomato yield in hydroponic system increased as EC of nutrient solution increased from 0 to 3 dSm-1 and decreased as the EC increased from 3 to 5 dS m-1 due to increase of water stress (Zhang *et al.,* 2016). Level of EC @1.5, 2 and 3 dS m-1 at vegetative, middle vegetative and generative stage, respectively had increased plants height, fruit number and pepper fresh weight.

In a nutrient solution, pH controls the availability of essential elements for plants, PH from 5.5 to 6.5 is the most advantageous range for plants development in most species (Trejo-Tellez and Gomez, 2012).

While plants grow changes in the solution structure will happen duo to consuming some nutrients more than others, absorbing water from it and changing pH level by excretion of either acidity or alkalinity.

Mixture of three (HNO_3, H_3PO_4 and H_2SO_4) acids was more effective than only single acid for maintaining an optimal solution pH of 5.5 to 6.5. The Change in pH will cause nutrient imbalance and plants will show some deficiency or toxicity symptoms (Wang *et al.,* 2017).

Frequent add and amount solution giving depends on kind substrate in use, the crop (species and growing stage), the container size, the used irrigation systems and prevalent weather circumstance (Mamta *et al.,* 2013). Feeding cultivated plants must be every day (Singh and Singh, 2012. The time between 6.00 and 8.00 am is best time for administer the nutrient solution, however water consumption will change a lot during the day, and from one day to another.

While giving solution to plants roots, wetting plants leaves must be avoided to stop its damage and diseases appearance. Plants should not be allowed to suffer from water stress under any circumstances because that will affect their final yield (De Kreij *et al.,* 1999). It is also recommended to do a weekly cleaning by pouring water to get rid of any extra salts remained in the system.

Average from 20 to 50% of solution has to be drained off to stop the accumulation of toxic ions and an extravagant increase of the EC around root zone (Singh and Singh, 2012).

Open and closed systems

Open system: feeding solution will tread the same way in regular soil cultivation by getting rid of the drained amount or using it for feeding other soil cultivated plants (Figure 3).

Closed system: the drained solution will be recovered, collected in solution tank and get adjusted to the same levels of nutrient and given once again to cultivated plants in the system (Figure 4). closed systems require more special monitoring for nutrient solutions, technical know-how is needed because it is sensitive to operational mistakes, for example collected nutrient solution must adjusted to get back its original nutrient element composition.

Decontamination is needed for solution to prevent root diseases from spreading by killing pathogens.

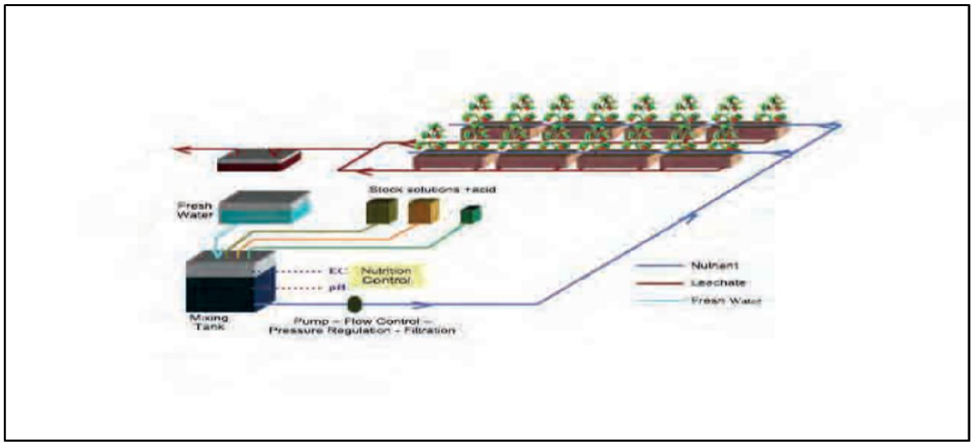

Fig. 3: the open system (FAO, 2013)

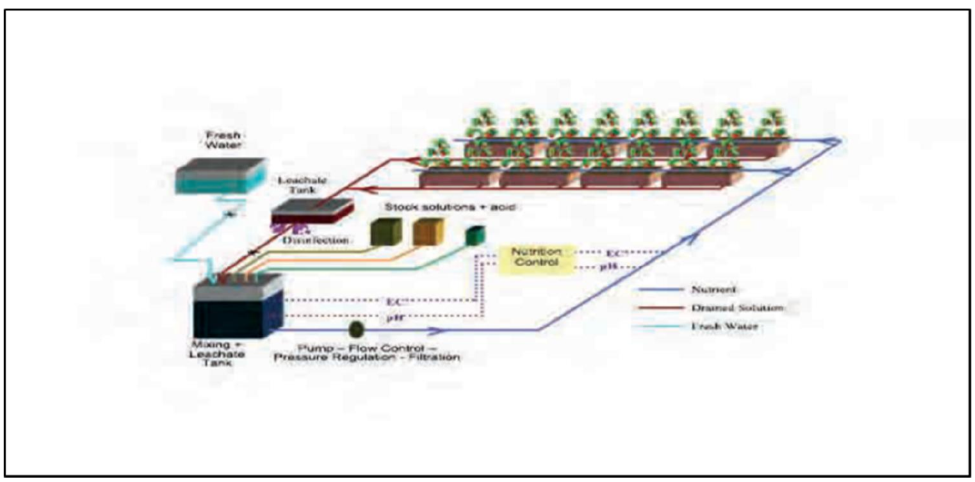

Fig. 4: the closed system (FAO, 2013)

Comparison between both techniques are shown in table below regarding percentage of irrigation water saving, percentage of efficient fertilizer saving, increase in the percentage of productivity, and percentage of water productivity (Table 1) (Van Os *et al.,* 1991) (Van Os, 1995) (Bohme, 1996) (Gul *et al.,* 1999) (Tuzel *et al.,* 1999) (Van Os, 1999) (Dhakal *et al.,* 2005) [18-19-20-21-22-23-24].

Table 1: Comparison between Hydroponic Techniques.

Parameters	**Hydroponic Technique Solution Culture**	
	Open	**Closed**
Percentage of irrigation water saving	85	90
Percentage of fertilizer saving	68	85
Percentage of productivity increase	200	300
Percentage of water productivity	2000	3500

Substrate growing Medias

During the past decades a lot of new ways and methods got involved in this technology it has been tested and used that includes new materials which used as growing medium from both organic and inorganic sources or the methods which not using substrates (Gruda, 2009).

A wild selection of materials can show up to do its part in this industry to introduce the needed variation which help growers to achieve their goals giving them huge advantages. For example, it works as tank holder for solution, give plants the support they need, offer enough O2 exchange and keep and limit temperature variation better than water cultures. Also, it is better than regular cultivation because its lighter in weight, standard, free of pests and diseases and does not need soil.

However, there are some disadvantages when comparing with regular soil cultivation due to limited volume can used, more expensive and nutrient concentrations must be monitored all time or there will be fast spread of minerals deficiency symptoms
Therefore, to select a growing media, it is important to know of its physical, chemical and biological characteristics due to its effect on plant growth and the production expenses. It must be free of diseases, biologically stable specially when long cultivation cycle is done, or media is reused among growing cycles.

Various standards are used to the examination of substrates such as physical properties which indicate good information about many parameters, for example: water/air ratio and volume weight or bulk density. When using small containers, the physical properties of the used substrate must be very high (Verdonck and Demeyer, 2004).

Particle size, porosity, water / air ratio and the hydraulic conductivity are the Physical properties which should be considered.

The chemical properties: pH, CEC, Salt concentration are important as well for choosing the substrate beside the biological once like phytotoxicity.

The definition of substrate medias and how to choose one:

Different kinds of growing medias have been used over the years, but producers nowadays are moving towards the new kind of medias from natural origin as well as from renewable raw materials (Gruda, 2005).

Growing medias can be divided to two main groups (organic and inorganic) substrates. The chosen substrate media should have a small volume, low weight, good aeration, quick overcome drying by fast rehydration, stable structure, suitable PH for the cultivated crop, free from pest, pathogen and phytotoxic compounds. Also, media cost, reuse ability, container type and volume and the soilless culture system used shall take into consideration.

Inorganic substrate Medias

In the early soilless culture facilities gravels and sand used to improve aeration, while the modern facilities use lighter materials such as rockwool, perlite, tuff, expanded clay granules, Zeolite, Pumice, and vermiculite (Raviv *et al.,* 2002) (Gruda *et al.,* 2006).

Organic substrate Medias

Medias like peat-moos, Coir (coconut fibre), Bark, Sawdust, Woodchips and wood fibre and compost are widely used as substrates to cultivate numerous crops. It's standardized and growth promoting as well as its availability should be considered before using it (Gruda, 2005).

The Reuse of the Media

In substrate culture cultivation, media can be used for many years and several growing cycles with no major negative effect on cultivated plants but sometimes it is possible of some variation in media structure, variation in its air/water capacity ratio, and getting some soil-borne diseases.

The global substrate moving to use the natural and renewable raw materials as medias. The media investments at present and future time are looking for peat-moos alternatives and that invest in new technology will be investing in their future (Gruda, 2012).

Hydroponic Systems

In these growing systems plants grow directly in the nutrient solution, in which their roots are suspended (Khan *et al.,* 2018) (Maharana and Koul, 2011) .It is also known as liquid hydroponics method and It can be further categorized into different subsections as below.

Static Solution Culture

The nutrient solution in this system is not circulated but provided only once while changing the EC. It has three kinds of systems; dipping method, floating method, and capillary action method.

In root dipping method, plants are grown in small pots that have the growing media while about 2-3 cm bottom of pots is dipped into nutrient solution. In floating method, shallow container used to grow the plants, these containers are filled with nutrient solution. Plants are grown in pots that fixed on Styrofoam sheet which is floated on the nutrient solution. In capillary action technique, seedling/seed are planted in pots of different sizes and shape which is filled with inert medium Shallow container having nutrient solution is used in this technique and pots are placed in this shallow container and the nutrient solution reaches the inert medium by the capillary action. Ornamental, flower and indoor plants can be sown by using this technique (Maharana and Koul, 2011).

Continuous Flow Solution Culture

In this system pump is used to circulate the nutrient solution in plant roots and excess solution is collected and reused. Various studies have been conducted on continuous flow solution culture in different countries. This culture has two types of system named as nutrient film technique and deep flow technique.

Wick Systems

Wick system is not a circulating system including of raised garden beds which have a water collector underneath plant root. A pipe supplies solution to a reservoir then drawn upward into the root zone by capillary action that allows plants to absorb the needed solution.
This system suitable for dry areas which suffers technical support like power and water problems. its unit could use for cultivation 3-5 times/year and it’s easy to control. The dark side for it is not being suitable for cultivation larger crops and happening of salt accumulation in media which need to be washed every week to clean extra nutrients around rooting area.

Fig. 5: Wick system
(https://www.nosoilsolutions.com/6-different-types-hydroponic-systems/)

Deep water culture (DWC)

Professor W.F. Gericke created DWC in 1929. It was the first hydroponically system for commercial purpose. Buckets filled with solutions, topped by a net and a cloth then a thin sand layer (1 cm) for plants support while roots are hanged in the solution. Those buckets might cover by lid and plants in net cups and hanged from the cover centre. The major problem in this system is O2 shortage around root area because of the little air-water exchange area compared with solution volume. Using an air pump can solve this issue.

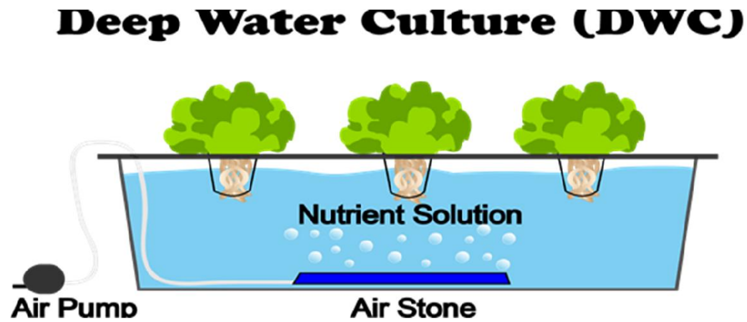

Fig. 6: Deep water culture system
(https://www.nosoilsolutions.com/6-different-types-hydroponic-systems/)

Ebb and Flow

Also called flood and drain, it is widely used because it's low cost, simple and easy to manage. Plants feed by flooding its site with the solution then let it drain back into a reservoir. Cups filled with inert media placed inside a tray or container filled automatically many times a day by a pump connected to timer.

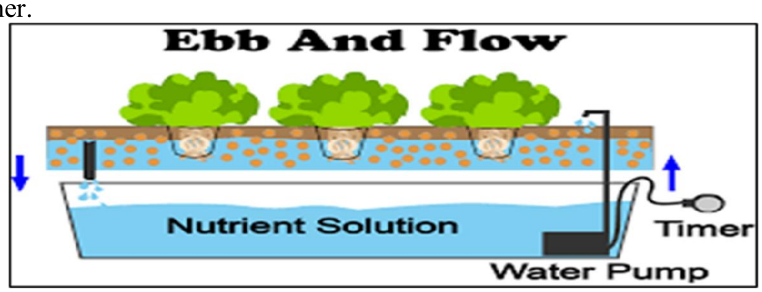

Fig. 7: Ebb and Flow system with substrate (https://www.nosoilsolutions.com/6-different-types-hydroponic-systems/)

Drip Method

The drip system is like drip irrigation as solution delivered to plants through drip emitters which drip the solution instead of spray or run it. After solution goes through growing cup it returns to a reservoir then gets recycled once more. This method needs electricity to power its pump for mixing water in the reservoir with air and.

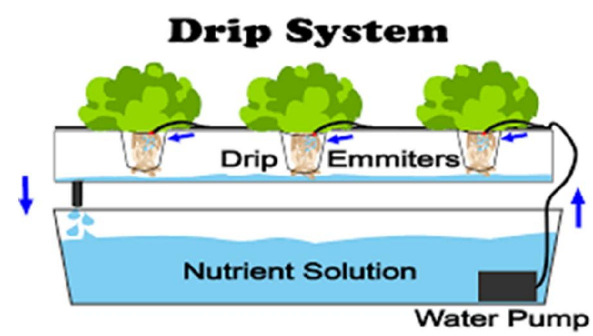

Fig. 7: Drip Method
(https://www.nosoilsolutions.com/6-different-types-hydroponic-systems/)

Nutrient film technique (NFT)

A thin layer of solution goes across tight channels in which plants bare roots lie. Using a slope of 1.2–3.0 to move solution by adding it at the high end of the channels so it goes down inside the channel and wetting the root area.

Slope can be done as well by floor itself or benches or racks for caching channels and give the necessary levelling height.

This thin layer of the solution gives both wet and aeration for plants roots as top part of the root mat gets needed oxygen and the bottom part gets the wetness and nutrient from the solution.

At the lower end of the channels, solution gathered and moved to large collecting pipe then go back to the tank to be reintroduced. Depressions in channels bottom levels have to be contaminated due to pond of immobile solution leads to oxygen shortage and growth impediment.

The channel size and solution flow rate are deferent from crop to another ranging from 1 to 3 L/min. its low for lettuce and high for fruiting crops. It depends also on growth stage, as it is 2 to 4 L/m-2 /h for young crop, it jumps to 5 to 9 L/m-2 /h mature crop. If Flow rates goes up previous levels it causes oxygenation or nutritional problems: for example, too fast and solution becomes too deep and poor root oxygenation. While, too slow causes nutrients shortage particularly for plants by the end of channel which get nationalized from solution too many other plants have already extracted nutrients from. Channel length must not be more than 12 to 16 m to avoid solution depletion.

To fix that issue nozzles added all along growing channels to supply fresh solution, it called super nutrient film technique (SNFT).

Solution delivery for plants could be continuous all day or intermittent, and it could be continuous at daytime and stop for night time.

NFT has less buffering against for interruptions in water and nutrient supplies, and a risk to spread of root diseases is considered. Most crops can grow using NFT, but it is better for short growing circle crops (30–50 days), like lettuce, due to these crops will be ready to harvest before its roots fill the channel.

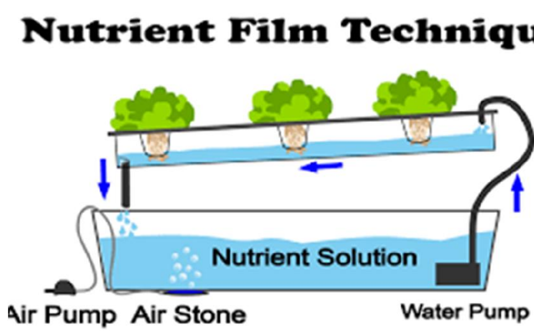

Fig. 9: Nutrient film technique (NFT)
(https://www.nosoilsolutions.com/6-different-types-hydroponic-systems/)

Deep flow technique (DFT)

In this method plants roots are exposed to moving solution at all time. The main difference between DFT and NFT is that the continuously flowing solution is deep (50–150 mm).

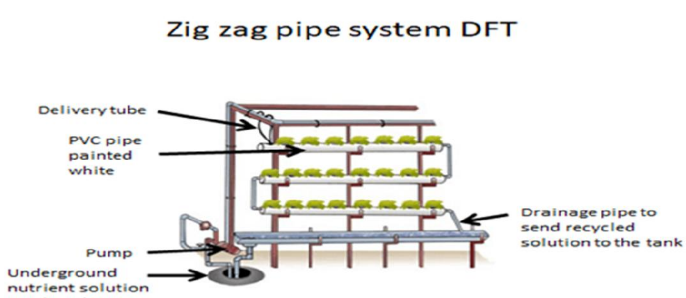

Fig. 10: Deep flow technique system
(https://lifeandagri.com/hydroponics/)

The large water volume simplifies the control of the nutrient solution and buffers the temperature, so the system good for areas suffers from temperature fluctuation in the nutrient solution which might cause troubles. Its channel width usually around 1 m. Plants grows on polystyrene trays floating on the solution or lie down on the channel sidewalls.

Aeroponics

In this system plant roots are suspended and sprayed with fine mist of nutrient solution spraying could be continuous or intermittent.

Plants will be secured in holes on polystyrene panels which put in horizontal position or with a slope and then put on a metal frame making closed room shaping a square or triangular portion. nutrient solution is sprayed the plant's roots from misters or forgers. Spraying time is about 30–60 seconds, depending on crops, growth stage, season and time of day. Nutrient solution collected at the bottom of the system and recirculated.

This method allows a huge save in both water and fertilizer consumption and ensure enough aeration and O2 of the roots.

But plants which are growing in aeroponic system might suffer from hard thermal stresses particularly in high temperature times and if there are power outages the system will be inability to supply in the flow of nutrient solution.

Aeroponics used to be suitable for just little vegetables such as lettuce and strawberries or medicinal plants.

Nowadays, it could be used as well for fruiting vegetables such as tomato, cucumber and cantaloupe.

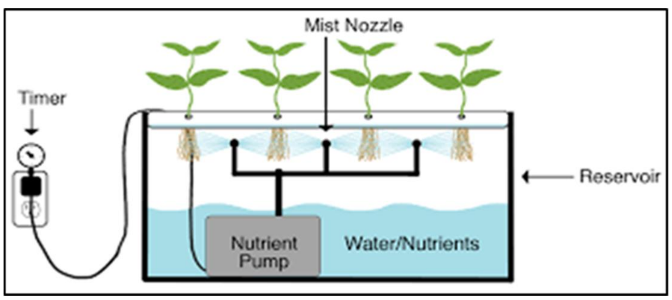

Fig. 11: Aeroponic system
(https://aquaponictrend.blogspot.com/2018/09/hydroponics-aquaponics-aeroponics.html)

Main Greenhouse Vegetables grown in Soilless techniques
Fruiting vegetables

Tomato, cucumber, sweet pepper and melon have long growing times and it can be cultivated from 1 to 3 times yearly. With a little number of plants per square meter 1 to 6 plants cultivation is in 2 to 4 rows each raw with 3.2 to 4 m long (Van Os *et al.,* 2008) . These crops recognized by a special physiology because the vegetative growth, flowering and the fruiting stages nip up and it need to be continuously balanced.

Its transplants raise in advanced and then plants either on medias fed with solution or directly in the solution itself if hydroponic system is used.

Tomato

Tomato is the main cultivated crop produced by soilless culture techniques. The availability of deferent kinds of tomato make it easy for producers to use the new fresh tomato types producing tomato fruits at off seasons of outdoor cultivation so it will achieve the highest yield price combined with high fruit quality.

Cultivating tomato in rockwool media fed with solutions using drip irrigation is the most used soilless culture system for tomato production beside the use of other substrates like perlite and pumice. Whereas, NFT system is not popular for tomato production.

Table 2: Summary of Crops for Hydroponic Greenhouse Cultivation (Singh and Singh, 2012).

Type of Crops	Name of Crops Common Name	Botanical Name
Cereals	**Rice**	*Oryza sativa*
	Maize	*Zea mays*
	Wheat	*Triticum aestivum*
	Oat	*Avena sativa*
	Soybean	*Glycin max*
	Peas	*Pisum sativum*
Vegetables	**Tomato**	*Lycopersicon lycopersicum*
	Chilli	*Capsicum frutescens*
	Brinjal	*Solanum melongena*
	Green bean	*Phaseolus vulgaris*
	Bell pepper	*Capsicum annum*
	Beet	*Beta vulgaris crassa*
	Potato	*Solanum tuberosum*
	Cabbage	*Brassica oleracea var.*
	Cauliflower	*Brassica oleracea*
	Cucumber	*Cucumis sativus*
	Onion	*Allium cepa*
	Radish	*Raphanus sativus*
	Lettuce	*Latuca sativa*
Fruits	**Strawberry**	*Fragaria ananassa*
	Melons	*Cucumis melo*
Fodder crops	**Sorghum**	*Sorghum bicolor*
	Alfalfa	*Cynodon dactylon*
	Barley	*Hordeum vulgare*
	Bermuda grass	*Cynodon dactylon*
	Carpet grass	*Axonopus compressus*
Flower	**Marigold**	*Tagetes patula*
	Roses	*Rosa berberifolia*
	Carnations	*Dianthus caryophyllus*
	Chrysanthemum	*Chrysanthemum indicum*
Condiments	**Parsley**	*Petroselinum crispum*
	Mints	*Mentha spicata*
	Sweet basil	*Ocimum basilicum*
	Oregano	*Origanum vulgare*
Medicinal crops	**Aloe**	*Aloe vera*
	Coleus	*Solenostemon scutellarioides*

Tomato can grow with total salt concentrations up to from 2.5 to2.9 dS m^{-1} in root area with no yield loose (Sonneveld and Voogt, 2009).

Using deferent EC value depends on the cultivation area for example under Mediterranean conditions could be as high as 3.5 dS m^{-1} in root area to get high standard fruit quality but it should be dropped under 3 dS m-1 in summer season, while in northern Europe it could go up to 5 dS m^{-1} due to the cold cloudy climate.

Regarding the N:K ratio in solution, the average N:K uptake ratio was 2.40 for as fruit sets in the first cluster of tomato in February this ratio dropps to 1.12 with the increase of the fruit load then raise up slightly to 1.40 after some weeks (Adams and Massey, 1984).

Tomato growth and yield increase if 5 % to lower than 15 % of total N is performed as NH4 + (Sonneveld, 2002).

The potassium needs to increase during fruit load stage and the opposite happen to calcium (De Kreij *et al.,* 1999). However, the solution Ca amount must be at high level in the reproductive stage to decrease fruits BER.

Cucumber

Cucumber comes in second after tomato regarding its importance in greenhouse soilless growing crops industry.

Cucumber can be grown two or three times a year. One of the most popular way is to grow it in rockwool followed by perlite and pumice medias. bags and slabs filled with media can be used with 15 or 30 cm wild.

Cucumber is sensitive for salt so the EC in the around roots should be kept at 2.7 and not to go up 3 dS m-1 or it will cause yield losses (Sonneveld and Voogt, 2009). Within early plant growth stage EC must be of 2.5 dS m^{-1} then goes up to 2.7 dS m^{-1} with plant size getting bigger (Savvas, 2012).

The pH shall be between 5.3–6.4, this can be done by adding 10 % of the total N in ammonia form.

Cucumber prefers high relative humidity; therefore, irrigation is an essential factor under low relative humidity conditions, at the same time big amount of water may cause oxygen shortage which may affect the growth of cucumber. NFT and other water culture system must consider an additional means to improve oxygenation of the nutrient solution (Papadopoulos, 1994)].

Pepper

Sweet pepper is the third most important cultivated crop in soilless culture systems. It can grow in many soilless culture methods and various medias. it must fertigate with an appropriate nutrient solution. pH should be between 6–6.7 at harvesting time.

High level of ammonia form within reproductive stage may cause BER due to decreasing Ca uptake. EC range can be from 2.7 to 3.0 dS m^{-1}, relying on cultivation time and the mineral composition of available water.

Melon

Melon can grow up to 3 times a year using rockwool, perlite, pumice and by NFT. Melon plants did grow in containers with different kinds of medias and fed with a solution includes: 50 N, 23 P, 44 K, 5 Mg, 0.2 B, 0.5 Cu, 0.1 Fe, 0.5 Mn, 0.005 Mo and 0.005 Zn (mg/litre) (Rodriguez *et al.,* 2006). EC in the root zone should be 2.9 but it can be useful to raise it to 3.2 dS m-1 specially in the ripening stage to improve fruit quality. All tested techniques [aeroponics, NFT, perlite in horizontal bags] gave better results than the regular soil cultivation and NFT introduced the best vegetative growth, yield and fruit quality among all (Singer *et al.,* 2012).

Once over-harvested crops

It includes the leafy vegetables crops like lettuce, rocket and spinach, it has the same growing behaviour with high plant density and short growing period. The seedlings usually raise in peat-moos or rockwool cubes. limited companies produce these kinds of crops using soilless technologies in Europe because of the hard competition from tradition cultivation and the high costs (Van Os *et al.,* 2008).

Lettuce

Farmers can get about 8 harvests from lettuce per year duo to its short growing period. It can grow using floating hydroponic and NFT systems. Lettuce uptakes a high amount of K and P but it is sensitive to Mn toxicity. It should have low nitrate content in the edible leaves, this can be controlled by changing the nitrates supply in the solution just before its harvest time (Schnitzler and Gruda, 2002).

Other leafy crops

Crops like radish, spinach and rocket can be cultivated by using soilless culture systems by the same systems used for lettuce. EC level should be below the one for lettuce (1.3 & 1.6 dS m^{-1} for kohlrabi and lamb's lettuces). While the Fe concentration in the solution must be higher than lettuce specially with lamb's lettuce to be about of 4mg / litre (Göhler and Molitor, 2002).

Table 3: Yield Comparisons between hydroponic and open field cultivation (Singh and Singh, 2012).

Type of Crops	Name of Crops	Hydroponic Yield (kg per ha)	Open Agriculture Yield(kg per ha)
Cereals	**Rice**	13,456.56	841.03- 1.009.25
	Maize	8,971.0	1,682.07
	Wheat	5,606.9	672.83
	Oat	3,364.14	953.18
	Soybean	1,682.07	672.83
	Peas	15,699.32	2,242.76
Vegetables	**Tomato**	403,335.81	11,203.75-22,407.47
	French bean	47,097.96	-
	Beet	22,427.6	10,092.42
	Potato	156,852.29	17,925.98
	Cabbage	20,184.84	14,577.94
	Cauliflower	33,641.4	16,820.7-11,213.8
	Cucumber	31398.64	7,849.66
	Lady's finger	21,306.22	8,971.04-5,606.9
	Lettuce	23,548.98	10,092.42

Global Hydroponic Market and Commercial Hydroponic Production

The international Hydroponics market income nearly crossed 21203.5 million USD in the year of 2016. Tomato leads other crops by the highest production value with about 30.4% share of the international market, during 2018 (Sharma *et al.,* 2018).

Hydroponically production of tomatoes, lettuce and other leafy vegetables is going to be increased soon due to the increase of people awareness of its high-quality production. therefore, the demand for it is rising in Europe and Asia- Pacific which are largest and the second largest markets that inquire advanced techniques of hydroponics.

Leading countries in hydroponic technology are Netherland, Australia, France, England, Canada and USA.

Dutch are the world leader in commercial hydroponic having total area of 13000 ha under tomato, capsicum, cucumber and cut flowers (Netherlands Department of Environment, Food and Rural Affairs, NDEFRA) and this account 50% of the value of all fruits and vegetables produced in the country. Australian hydroponic production of vegetables, herbs and cut flowers of system valued about 300- 400 million dollar which is approximately 20% of the total values of vegetables and cut flower production in Australia reported by Rural Industries Research and Development Corporation (RIRDC). Australia is the largest hydroponic lettuce producers in the world and having strawberry cultivation is larger than USA and cut flower production is almost equal to USA.

Canada and Spain are also expanding the area under commercial hydroponic system. Japan has started to use hydroponics technique system to produce rice for feeding its people (De Kreij *et al.,* 1999).

There is a huge increase in both developing and developed countries regarding the use of hydroponics cultivation systems (Trejo-Tellez and Gomez, 2012).

Nowadays in India people in various big cities like Delhi, Chandigarh, Noida and Bangalore are growing some leafy greens and small herbs and spices on their roof tops and balconies for fresh consumption.

Nowadays the hydroponics future seems to be more favourable than any time in the past 50 years. The start-up costs to implement a hydroponic farm can vary widely but, they are usually higher than soil-based farming costs. Therefore, to foster the hydroponics industry’s growth, it is important to implement technologies that reduce dependence on human labour and lower overall start-up costs (Trejo-Tellez and Gomez, 2012).

Future of Hydroponic Greenhouse Cultivation

Hydroponic greenhouse system can play an important role for the food production soon (Butler and Oebker, 2006). The future of this technology is very bright due to world population increases while agricultural land come under colonies so to overcome such situation, people will need a system which produce food with limited inputs, hydroponic greenhouse system is only system which could meet the food requirement according to our needs (Khan *et al.,* 2018). Rice can be harvested four times annually in hydroponic technique, instead of single harvest in open field agriculture (Van Os *et al.,* 2002).

Soilless culture systems can feed millions of people in future in third world countries because water and crops are rare and threaten in those regions although installation cost is high but in the long run all cost will decline, that will make this technology more feasible and convenient (De Kreij *et al.,* 1999) (Maharana and Koul, 2011) (Raviv *et al.,* 1998). This technology also has future in space and NASA started working on this technology (Van Os *et al.,* 2002).

Because of its adaptation anywhere in the world it can be assumed that this technology has a bright future ahead.

Aquaponics

Aquaponics is a system in which fish and plants grow together at the same time. Plants feed on fish waste after modifying it and work as a biofilter for fish production.

Water from the fish tank goes through mechanical filter to remove solid wastes then pushed through a biofilter to get rid of dissolved wastes, this biofilter contains nitrification bacteria to convert ammonia (which is toxic to fish) to nitrate which is suitable for plants nutrition. Then, this water includes nitrate and other nutrients goes to plants beds to feed the growing crops which purify water from most of its nutrients. After that water goes back to fish tanks (Braungart *et al.,* 2007) (Kumar and Putnam, 2008) (Thorarinsdottir, 2015). This system introduces sustainable food production for both fish and plants, environmentally friendly with low water waste, no need for soil or water or fertilizers or pesticides, suitable for arid areas and those with soil problems and produce high yields with good quality.

On the other hand, it is too expensive in the start costs compared with both soil and hydroponic vegetable production, needs care and monitoring all time and fish and plant requirements are not always the same.

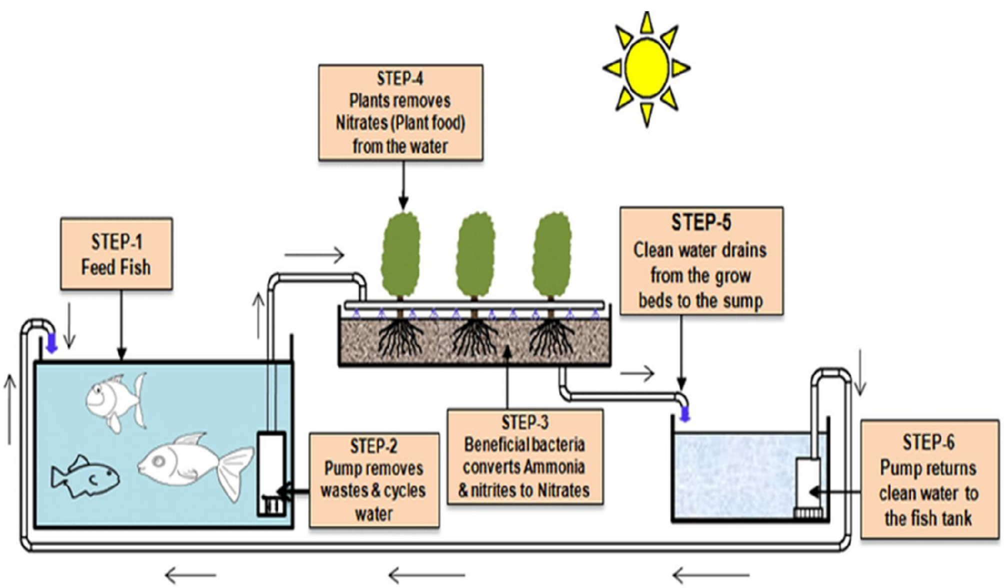

Fig. 12: Aquaponic system (Jena *et al.,* 2017)

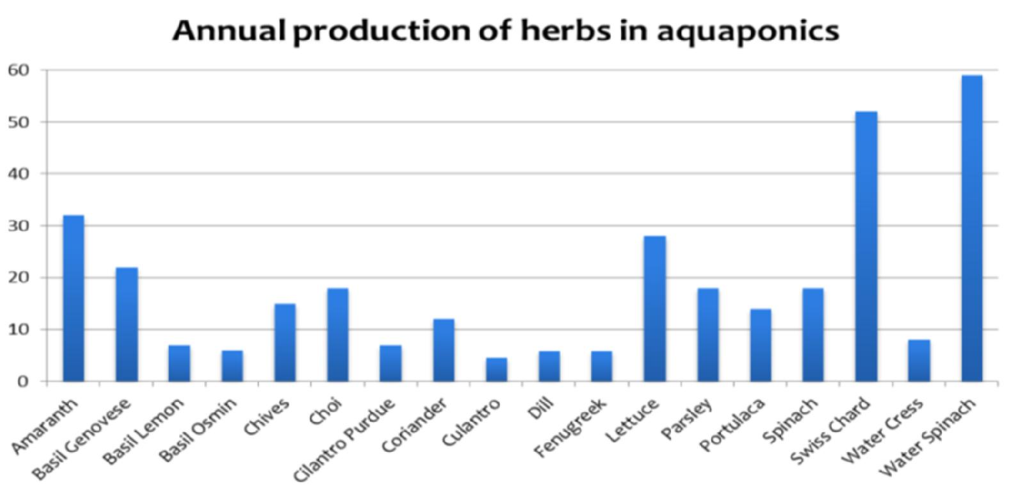

Fig. 13: Annual production kg per square meter of leafy greens in aquaponics (Savidov, 2010).

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