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A Review on Plant without Soil – Hydroponics

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ABSTRACT: Open field/soil-based agriculture has faced significant difficulties since the dawn of civilization, chief among which is the decline in the amount of land available per person. Per capita land was 0.5 ha in 1960 when there were 3 billion people on the planet; today, there are 6 billion people. It's only 0.25 ha and will grow to 0.16 ha by 2050. Arable areas under cultivation will continue to shrink as a result of growing urbanization, industrialization, and iceberg melting (a clear result of global warming). Aquaculture is soil-less agriculture practice in which the plants were grown in a medium consisting of nutrients. the "Aquaculture" was first coined by Dr. WF Gerick in 1936. Plants are grown in soilless culture without the use of soil. Improved soilless culture techniques for food production have produced some encouraging outcomes globally in terms of saving space and water.

KEYWORDS: Aquaculture, Soilless-culture, Techniques, Aeroponics, Fogponics, Limitations.

I. INTRODUCTION

For plants, the earth is often the most easily available growth medium. It provides anchoring, nutrients, air, water, etc. for effective plant growth. The presence of disease-causing organisms and nematodes, inappropriate soil reactions, unfavourable soil compaction, poor damage, degradation, due to erosion, etc. are some of them. Soils can also significantly limit plant development. Conventional crop growing on soil, or open field agriculture, is also relatively challenging because it requires a lot of room, work, and water. Furthermore, due to unfavourable topographical or geographic conditions, some regions, such as urban areas, have no soil that can be used for agricultural cultivation at all or only has a limited amount of rich cultivable arable lands. The inability to get workers for intensive open-field agriculture has recently become another severe issue. In these circumstances, soil-less cultivation can be successfully established.

To feed the country's growing population and attain self-sufficiency in agriculture products and food security, the demand for farm products must be raised as much as is practical. In Iran, a disproportionate amount of arable land is plagued by issues with sodium, salinity, and the bilge of soil [31]. Particularly soilless plantation systems or aquaculture of all varieties of ornamental flowers, vegetables, fruits, and medicinal plants are grown in controlled environments (greenhouses) [8,21]. Growers have the choice of having total control over how nutrients are distributed and delivered to the plant thanks to the modern form of agriculture known as the aquaculture plantation. It should also be available for affordable rates [18]. Aquaculture, despite the need for adequate expertise and relatively high investment, in comparison with soil-based plantation has a lot of advantages such as high performance, the need for a low labour force, and simplicity of work [22]. In most cases, soil serves as a plant's primary growing substrate. It offers support, nutrients, air, water, and other elements necessary for effective plant growth [1]. Although soils can occasionally impose significant restrictions on plant development. Some of these include the presence of nematodes and disease-causing organisms, inappropriate soil reactivity, unfavourable soil compaction, poor drainage, degradation brought on by erosion, etc. [2]. Additionally, it might be challenging to cultivate conventional crops in soil (Open Field Agriculture) because it requires a lot of space, labour, and water [2]. Additionally, in other locations, such as urban areas, there is no soil suitable for agricultural growth at all, or there are few fertile cultivable arable lands available due to unfavourable topographical or geographical circumstances in those locations [2]. The challenge of finding a workforce for conventional open-field agriculture is a recent, major issue [3]. Such conditions allow for the successful introduction of soilless

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cultivation [3]. In terms of culture without soil, mostly hydroponics and aeroponics are used [2]. The Greek words hydro, which means water, and ponds, which means labour, are the origin of the phrase hydroponics [2,6,7]. It is a technique for growing plants without soil using mineral nutrition solutions [2,5]. The roots of terrestrial plants can either be cultivated in the mineral nutrient solution or an inert medium like perlite, gravel, or mineral wool [16]. With their roots submerged in the nutritional solution, plants are grown hydroponically—soullessly [4]. This method assists in managing the production system for effective use of natural resources and reducing malnutrition in addition to assisting in addressing the difficulties posed by climate change [3]. Another method, known as aeroponics, is somewhat comparable to hydroponics with the exception that plants are grown using tiny drops (a mist or aerosol) of nutritional solution [1]. An English scientist named W. J. Shalto Duglas constructed a laboratory in the Kalimpong district of West Bengal in 1946 and introduced hydroponics to India. In the later 1960s and 1970s, commercial hydroponic farms were built in Abu Dhabi, Arizona, Belgium, California, Denmark, Germany, the Netherlands, Iran, Italy, Japan, the Russian Federation, and other nations.

Diverse methods for soilless culture are currently available. There are numerous hydroponic and soilless cultivation methods available [20]. However, the following elements are considered while choosing a technique: 1. Room and other resources that are accessible 2. anticipated output 3. Access to appropriate growth media. 4. Expected crop quality, including colour, look, and pesticide-free status.

ABBREVIATION
NFT-Nutrient film technique
DFT-Deep flow technique
CDC-Crop Diversification Centre
LECA –Lightweight Expanded Clay Aggregate

II. HISTORY

1699, John Woodward, a fellow of the Royal Society of England, grew plants in water containing various types of soil, the first man-made aquaculture nutrient solution, and the greatest growth occurred in water that contained the most soil. Since they knew little chemistry in those days, he was not able to identify specific growing elements. He thereby concluded that plant growth was a result of certain substances and minerals in the water derived from enriched soil, rather than simply from the water itself.

In 1792 the brilliant English scientist Joseph Priestley discovered that plants placed in a chamber having a high level of “Fixed Air” (Carbon Dioxide) will gradually absorb the carbon dioxide and give off oxygen. Ingen-Housz went on to establish that this process worked more quickly in conditions of bright light and that only the green parts of a plant were involved.

In 1856 Salm-Horstmar developed techniques using sand and other inert media. Various research workers had demonstrated by that time that plants could be grown in an inert medium moistened with a water solution containing minerals required by the plants. The next step was to eliminate the medium and grow the plants in a water solution containing these minerals.

From discoveries and developments in the years 1859-1865, this method was proven by two German scientists, Julius von Sachs (1860), professor of Botany at the University of Wurzburg (1832-1897), and W. Knops (1861), an agricultural chemist. Knops have been called “The Father of Water Culture.”

In that same year (1860), von Sachs published the first standard formula for a nutrient solution that could be dissolved in water and in which plants could be successfully grown [21]. This marked the end of the long search for the source of the nutrients vital to all this was the origin of “Nutriculture” [3].

In the 1990s NASA grew aeroponics seedlings in zero gravity aboard the space station opening the possibility of sustainable agriculture in space in the late 1920s and early 1930s, Dr. William F. Gerick of the University of California extended his laboratory experiments and works on plant nutrition in doing so he termed these Nutriculture systems “aquaculture”. The word was derived from two Greek words, hydro, meaning water, and ponos meaning labor _ literally “water –working” [2,14,15]. Aquaculture is defined as the art of cultivating plants without using soil. The first commercial practice was done by Dr. W. F. Gerick for growing tomatoes, lettuces, and some vegetables [2,10].

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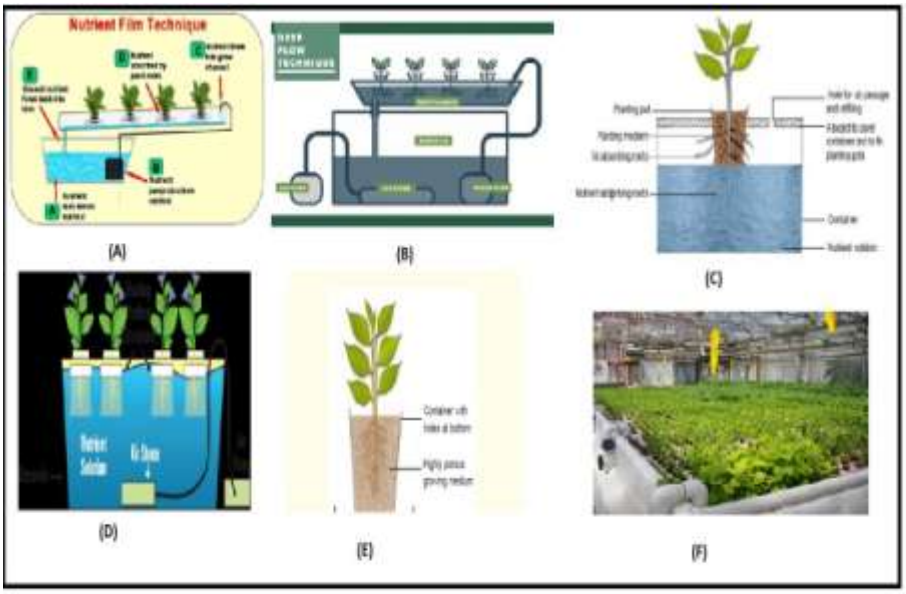

Fig:1 Diagram showing various techniques of hydroponics (A) Nutrient film techniques, (B) Deep flow technique, (C) root dipping technique, (D) floating technique, (E) Capillary action technique, (F) Static solution cultures the deep-water raft tank at the Crop Diversification Centre (CDC) South Aquaponics greenhouse in Brooks, Alberta.

There are two main variations for each medium: sub-irrigation and top irrigation. For all techniques, most aquaculture reservoirs are now built of plastic, but other materials have been used, including concrete, glass, metal, vegetable solids, and wood. To stop algae and fungus growth in the nutrient solution, the containers should be dark.

The method is often referred to as liquid aquaculture. The roots of plants cultivated in solution culture are submerged right into a nutritional solution.
The following categories apply to the techniques:

III. TECHNIQUES OF HYDROPONICS

Liquid hydroponics is another name for the technique. The roots of plants cultivated in solution culture are submerged right into a nutritional solution. Further classifications include circulating techniques (closed systems) and continuous flow solution culture [5,6].

A. Circulating methods (Closed system):
a) Nutrient film technique (NFT)
b) Deep flow technique (DFT)

A. Circulating methods (closed system)/ Continuous flow solution culture

a) Nutrient film technique (NFT)

The N.F.T. system is quite popular with home aquaculture growers as well. Mainly because of its fairly simple design, However, N.F.T. systems are the best suited for, and most used for growing smaller quick-growing plants like different types of lettuce. Along with growing lettuce, some commercial growers also grow different types of herbs and baby greens using N.F.T. [6]. (Shown in Fig. 1 (A))

b) Deep flow technique (DFT)

These systems are among the most frequently utilized kinds of aquaculture systems worldwide, being employed by both domestic and industrial farmers. When you construct your system, it will not constrain your creativity. (Shown in Fig. 1 (B))

B. Non-circulating method (open systems)/ Static solution culture
a) Root dipping technique
b) Floating technique
c) Capillary action technique

B. Non-circulating method (open systems)

a) Root dipping technique

The pots are positioned so that their lower 2-3 cm are buried in the nutritional solution. For nutrition and air absorption, different roots are suspended in the solution while others are dipped in it. (See Fig. 1 (C))

b) Floating technique

A floating raft system is one of the simplest aquaculture systems to build. This method is ideal for raising fast-growing, leafy greens such as lettuce and spinach, and can provide you with a constant source of fresh vegetables for your table. In its simplest form, a floating raft system is not much more than a basin to hold the liquid and a raft to hold the plants. Roots can thrive in a steady nutritional environment with the help of flowing solution culture systems. They are quite adaptable to automatic control, but if the flow of solution ceases for any reason, they are vulnerable to rapid plant desiccation. As a result, constant care is needed. (See Fig. 1 (D))

c) Capillary action technique

Capillary action occurs when the adhesion to the walls is stronger than the cohesive forces between the liquid molecules. The height to which capillary action will take water in a uniform circular tube (picture to right) is limited by surface tension and, of course, gravity. (See Fig. 1 (E))

Static solution culture

Static solution culture is a type of hydroponic farming where your plants and crops are grown in a static container or tubs (in case of a home setup) otherwise big plastic containers have holes on them to put the plant roots in contact with the hydroponic nutrient solution [5]. (See Fig. 1(F))

In static solution culture, plants are grown in containers of nutrient solution, such as glass Mason jars (typically, in-home applications), pots, buckets, tubs, or tanks. The solution is usually gently aerated but may be un-aerated. If un-aerated, the solution level is kept low enough that enough roots are above the solution so they get adequate oxygen. A hole is cut (or drilled) in the top of the reservoir for each plant; if it is a jar or tub, it may be its lid, but otherwise, cardboard, foil, paper, wood, or metal may be put on top. Reservoir size can be increased as plant size increases. A homemade system can be constructed from food containers or glass canning jars with aeration provided by an aquarium pump, aquarium airline tubing, and aquarium valves. Clear containers are covered with Aluminium foil, butcher paper, black plastic, or other material to exclude light, thus helping to eliminate the formation of algae. The nutrient solution is changed either on a schedule, such as once per week or when the concentration drops below a certain level as determined with an electrical conductivity meter. Whenever the solution is depleted below a certain level, either water or fresh nutrient solution is added. A Mariette's bottle, or a float valve, can be used to automatically maintain the solution level. In raft solution culture, plants are placed in a sheet of buoyant plastic that is floated on the surface of the nutrient solution. That way, the solution level never drops below the roots [3].

Continuous-flow solution culture

In continuous-flow solution culture, the nutrient solution constantly flows past the roots. It is much easier to automate than the static solution culture because sampling and adjustments to the temperature, pH, and nutrient concentrations can be made in a large storage tank that has the potential to serve thousands of plants.

In continuous-flow solution culture, the nutrient solution constantly flows past the roots. It is much easier to automate than the static solution culture because sampling and adjustments to the temperature, pH, and nutrient concentrations can be made in a large storage tank that has the potential to serve thousands of plants [19]. The nutrient film technique, also known as NFT, is a well-liked version in which a very shallow stream of water containing all the dissolved nutrients needed for plant growth is recirculated in a thin layer through a bed of bare-root plants in a watertight tube with an upper surface open to the air. A properly designed NFT system is based on using the right channel slope, the right flow rate, and the right channel length. The key benefit of the NFT system over other forms of aquaculture is that the plant roots are exposed to adequate supplies of water, oxygen, and nutrients. NFT, because of its design, provides a system where the althea nutrient film technique (NFT) being used to grow various salad greens three requirements for healthy plant growth can be met at the same time, provided that the simple concept of NFT is always remembered and practiced. The result of these advantages is that higher yields of high-quality produce are obtained over an extended period of cropping. The downside of NFT is that it has very little buffering against interruptions in the flow (e.g., power outages). But, overall, it is probably one of the more productive techniques [28].

The same design characteristics apply to all conventional NFT systems. While slopes along channels of 1:100 have been recommended, in practice it is difficult to build a base for channels that is sufficiently true to enable nutrient films to flow without ponding in locally depressed areas. Consequently, it is recommended that slopes of 1:30 to 1:40 are used. This allows for minor irregularities in the surface, but, even with these

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slopes, pending water occurs. The slope may be provided by the floor; benches or racks may hold the channels and provide the required slope. Both methods are used and depend on local requirements, often determined by the site and crop requirements.

As a general guide, flow rates for each gully should be one litre per minute. At planting, rates may be half this and the upper limit of 2 L/min appears about the maximum. Flow rates beyond these extremes are often associated with nutritional problems. Depressed growth rates of many crops have been observed when channels exceed 12 meters in length. On rapidly growing crops, tests have indicated that, while oxygen levels remain adequate, nitrogen may be depleted over the length of the gully. Therefore, channel length should not exceed 10–15 meters. In situations where this is not possible, the reductions in growth can be eliminated by placing another nutrient feed halfway along the gully and halving the flow rates through each outlet.

IV. MEDIA CULTURE

The media culture method, also known as sand culture, gravel culture, or rock wool cultivation, uses a stable medium for the roots [13]. Sub-irrigation and top-irrigation are the two basic variations for each medium. It is generally categorized as follows:

a) Hanging bag technique
b) Grow bag technique
c) Trench or trough technique
d) Pot technique

Refer Fig. 2 for above mentioned techniques.

Fig 2: Different media culture method (a) Hanging bag technique, (b) Grow bag technique, (c) Trench or trough technique, (d) Pot technique

V. TECHNIQUES OF AEROPONICS

In an aeroponics system, roots are maintained intermittently or continuously in a space saturated with tiny drops of nutrient solution (a mist or aerosol) [21]. The process involves growing plants in a deep air or growth chamber with their roots suspended and regularly misting them with a fine mist of atomized nutrients without using any substrate. Aeroponics' main benefit is superior aeration. (See Fig.3 (A))

Aeroponics techniques have proven to be commercially successful for propagation, seed germination, seed potato production, tomato production, leaf crops, and micro-greens [10]. Since inventor Richard Stoner commercialized aeroponics technology in 1983, aeroponics has been implemented as an alternative to water-intensive aquaculture systems worldwide. The limitation of aquaculture is the fact that 1 kilogram (2.2 lb.) of water can only hold 8 milligrams (0.12 go) of air, no matter whether aerators are utilized or not [32].

Any kind of plant can be produced in a real aeroponics system since the microenvironment of aeroponics can be precisely regulated, which is another clear advantage of aeroponics over aquaculture [17]. The limitation of aquaculture is that certain species of plants can only survive for soling in water before they become waterlogged. The advantage of aeroponics is that suspended aeroponic plants receive 100% of the available oxygen and carbon dioxide to the roots zone, stems, and leaves, thus accelerating biomass growth and reducing rooting times. NASA research has shown that aeroponically grown plants have an 80% increase in dry-weight biomass (essential minerals) compared to aqua-culturally grown plants. Aeroponics used 65%less water than aquaculture.

NASA also concluded that aeroponically grown plants require 1⁄4 the nutrient input compared to aquaculture. Unlike aqua-culturally grown plants, aeroponically grown plants will not suffer transplant shock when transplanted to soil and offer growers the ability to reduce the spread of disease and pathogens. Aeroponics is also widely used in laboratory studies of plant physiology and plant pathology. Aeroponics techniques have been given special attention by NASA since a mist is easier to handle than a liquid in a zero-gravity environment.

- **Fogponics:**

A kind of aeroponics known as fogponics uses a diaphragm that vibrates at ultrasonic frequencies to aerosolize the nutritional solution. Solution droplets produced by this method tend to be 5–10 am in diameter, smaller than those produced by forcing a nutrient solution through pressurized nozzles, as in aeroponics. The smaller size of the droplets allows them to diffuse through the air more easily, and deliver nutrients to the roots without limiting their access to oxygen. (See Fig. 3 (B))

- **Passive sub-irrigation:**

Passive sub-irrigation, also referred to as passive aquaculture, semi-aquaculture, or hydroculture, is a technique that involves growing plants in an inert porous medium that transports water and fertilizer to the roots by capillary action from a separate reservoir as necessary. This method saves labor and ensures that the roots always have access to water. The pot is placed on a capillary mat that has been saturated with a nutrient solution or in a thin solution of fertilizer and water for the easiest technique. (See Fig. 3 (c))

The various aquaculture media available, such as expanded clay and coconut husk, contain more airspace than more traditional potting mixes, delivering increased oxygen to the roots, which is important in epiphytic plants such as orchids and bromeliads, whose roots are exposed to them in nature. Additional advantages of passive aquaculture are the reduction of root rot and the additional ambient humidity provided through evaporations.

Hydro culture compared to traditional farming in terms of crops yield per area in a controlled-environment was roughly 10 times more efficient than traditional farming, uses 13 times less water in one crop cycle than traditional farming, but on average uses 100 times more kilojoules per kilogram of energy than traditional farming [29].

- **Ebb and flow (flood and drain) sub-irrigation:**

In its simplest form, there is a tray above a reservoir of nutrient solution. Either the tray is filled with growing medium (clay granules being the most common) and then plant directly or place the pot over medium, and stand in the tray. At regular intervals, a simple timer causes a pump to fill the upper tray with nutrient solution, after which the solution drains back down into the reservoir. This keeps the medium regularly flushed with nutrients and air. Once the upper tray fills past the drain stop, it begins recirculating the water until the timer turns the pump off, and the water in the upper tray drains back into the reservoirs. (See Fig. 3 (D))

- **Deep water culture:**

The aquaculture method of plant production is using suspending the plant roots in a solution of nutrient-rich, oxygenated water. Traditional methods favour the use of plastic buckets and large containers with the plant contained in a net pot suspended from the centre of the lid and the roots suspended within the nutritional solution. The solution is oxygen saturated by an air pump combined with porous stones. With this method, the plants grow much faster because of the high amount of oxygen that the roots receive. The Kratky Method is like deep water culture but uses a non-circulating water reservoir. (See Fig. 3 (E))

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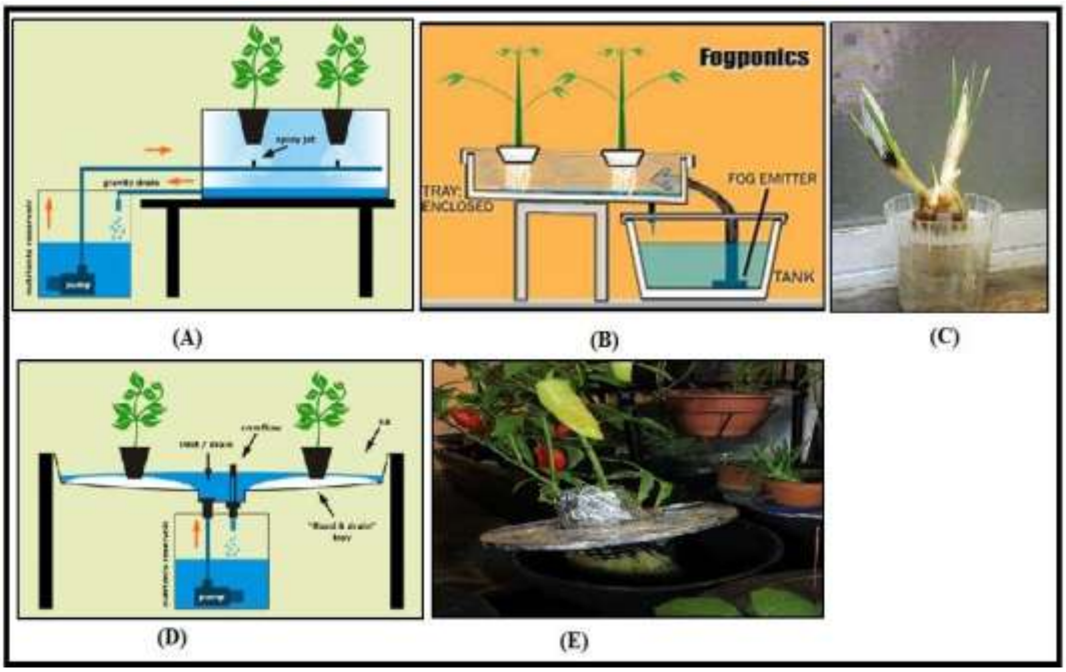

Fig 3:- Diagram of (A) the aeroponics technique, (B) fogponics, (C) Water plant-cultivated crocus, (D) an Ebb and flow and drain aquaculture system, (E) Deep water culture

VI. REQUIREMENTS OF AQUACULTURE SETUP

- **Seeding:**

The seed mix consists of a mixture of the following coconut coir, coco peat, cotton, micro, and macronutrients needed for the plant's growth, and trace amounts of compost to nourish the growth of plants. First, we know the mode of propagation of our plant. In this study we used three plants namely Marigold – Calendula officinal is; Karisalankanni – Ecliptaprostrata; and Siriyananghai – Andrographipaniculata. The seed mix can retain moisture for a long period so that the plant can grow efficiently. It should be watered continuously to prevent drying. Once the plants reach a certain height, they should be transferred to the aquaculture system. Usually, it takes about 10-15 days for a plant to grow to the required range.

- **Aquaculture setup:**

It is made of a rectangle-shaped tank with two openings into which water and nutritional solution are poured. The plants are suspended from the basket at the top. The baskets are provided with large pores for the roots to touch the solution. They are usually filled with some supporting medium. Here we used LECA as a supporting medium. LECA stands for Lightweight Expanded Clay Aggregate. It is made up of expanded clay pellets used for holding the moisture content and they are neutral in pH. The holes are provided through which the air pump is connected externally for aeration. The roots of the plant are dipped into the solution thus they get the nutrients for their Growth [11].

VII. FORMULATION OF NATURAL MEDIA FOR AQUACULTURE

- **Vegetable Waste Extract**: Vegetable waste was collected from the vegetable market in Rajapalayam. The waste contains seeds, pulp, and peels. They were soaked in the water and closed air ties. They incubate for up to 15 days in a dark room. After a period of 15 – 20 days, the solution achieved with the formation of carbon-di-oxide appeared. The solution was filtered to get a concentrated solution. The observed solution is highly viscous and has an acidic odor. The solution was diluted in a ratio of 1:10 (10 mL of solution and 90 mL of water) for implementing aquaculture [12].
- **Vermicompost Extract**: The vermicompost was purchased commercially from a farm in Madurai. The vermicompost was packed in a packed bed reactor and water was passed through it to obtain the extract. For instance, we used a burette as the column for the packed bed reactor. To prevent the flushing out of the

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vermicompost the bottom of the burette was sealed using cotton. The vermicompost was added to it and packed tightly. Water was allowed to percolate through the column to get a concentrated solution. The solution was collected using a beaker. It was slightly yellow in colour. The procedure is repeated for about 20 days to get about 300 ml of extract. Two packed bed reactors were used simultaneously to get a higher yield of solution [9,13].

- **Cattle Shed Soil Extract**: The top layer of the soil from the cattle shed was collected and prepared and extracted. The soil was placed in a muslin cloth and water would percolate through it and the extract was collected. The solution was darkly coloured.
- **Chlorophyll Assay**: Chlorophyll, a green pigment plays a vital role in photosynthesis. The amount of chlorophyll a and b was found out for both the control and the test (Vermicompost Extract {positive control}, Cattle shed soil Extract). First, the leaves were weighed, and then it was ground using mortar and pestle by adding a small amount of methanol. Leave it for some time as the methanol evaporates. Transfer this sample into a tube. Observed the optical density using a spectrophotometer for chlorophyll „a‟ at 663 nm, 645 for chlorophyll „b‟ and methanol was used as blank [2,9].

VIII. MEDICINAL PLANTS GROWN IN AQUACULTURE

- **Aloe vera:** -This simple house plant has a lot of use in healing cuts or scrapes and other kinds of small skin injuries. In an aquaculture system, nitrate and ammonium forms are used in nutrient solutions. A balance between ammonium and nitrate favours plant growth, while the degree of benefits varies among crops. (See Fig. 4 (A))
- **Saffron**: - This plant can be hard to grow but for those aquaculture growers who can fit it into a garden except on holistic remedies have shown that saffron can be used in treating a range of conditions like fever and digestive difficulties. Saffron grows best in water that is maintained at a PH level between 6.0 and 6.25, which is slightly acidic. Within the soilless aquaculture context, the individual saffron corms are planted in 2-inch plastic mesh pots that are filled with an inert substrate. Aqua Culturally grown saffron exhibits an unusual morphology of its roots. then, this may well be related to mechanical resistance resulting from the plastic tubing. Roots whose growth has been mechanically impeded are seen to be shorter and thicker than soil-growth plant roots and more frequently exhibit irregular or even bizarre shapes. (See Fig. 4 (B))
- **Garlic:** -Garlic is a superfood that has many health benefits and has been known to help with certain health conditions, as well as to increase overall health and well-being. Some people take a supplement in the form of garlic, but adding it to a natural diet can promote good overall health. Aquaculture garlic is intended to place the plants just below the surface of some growing media such as coir or vermiculite from rock wool. Experts suggest temperature ranges ranging from 2 ° C to 10 ° C and estimate growth time at 45-60 days. (See Fig. 4 (C))
- **Parsley: -**Parsley is a well-suited herb to aquaculture systems. Since it has a long taproot, the aquaculture container must be at least 12 inches deep for the best results. Parsley is an herb that has the potential to aid digestion. It is another culinary green herb that many cultivators like to use in the kitchen. It is a voracious grower in aquaculture systems and if you have local market demand for it, it can be in high demand from grocery stores. Put in a flat and shallow bowl, the rock wool develops cubes mixed. Plant the seeds in the box about one inch apart, making sure that each rock wool cube contains 2 to 3. Sprinkle a thin, 0.25-inch-high layer of moist soil over them. Hold the soil temperature moist at around 21° C. Water them frequently and the sprouts should start appearing about 2 weeks after planting. (See Fig. 4 (D))
- **Lemongrass: -**This exotic herb is a bit successful in the treatment of some conditions. Some people claim it can be useful as a pain reliever. In the aquaculture method, the benefit of growing Lemongrass is that the process is safe, with faster growth and edible roots. Whereas when grown in soil, plant roots are always cut off; the entire plant roots can be consumed [24]. (See Fig.4 (E))

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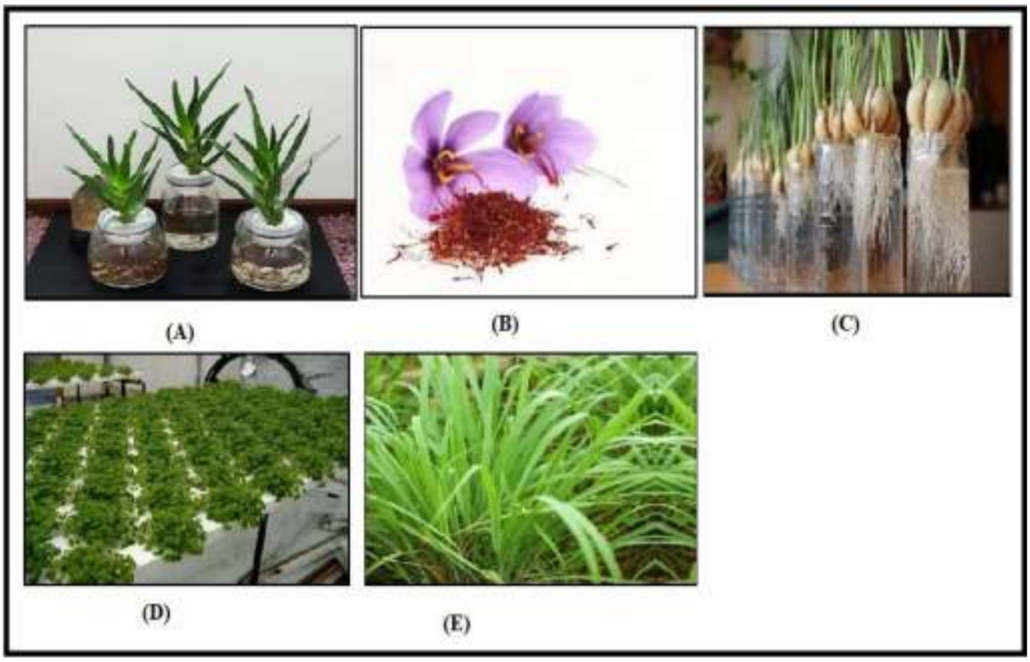

Fig 4: - (A) Aloe Vera, (B) Saffron, (C) Garlic, (D) Parsley, (E) lemongrass

IX. LIMITATIONS

Though there are many merits of aquaculture over conventional agriculture, there are some limitations too:

- Higher set-up cost
- Growers require skill and knowledge to maintain optimum production in commercial applications
- Because each plant in an aquaculture system is sharing the same nutrient, diseases, and pests can easily affect each plant.
- Plants react quicker to changes in the environment, however, if this change is for the worse, plants will quickly react to it; showing signs of deficiency or trouble.
- Hot weather and limited oxygenation may limit production and can result in the loss of crops.

X. ADVANTAGES

1. An extended growing season: Cold climates with chilly winter temperatures and shorter day lengths prohibit plant growth. But with an aquaculture system, Aquaculture allows for year-round plant growth since the grower has complete control over the environment's temperature, light, and nutrient levels.
2. Increased yield and growth: Plants grown in aquaculture systems often grow more quickly and produce more. This is probably because of the elevated oxygen levels in the nutritional solution and the well-regulated ambient conditions. Increased oxygen levels in a plant promote root development and improve nutrient uptake. These ideal growing circumstances result in less plant stress and a more abundant crop.
3. Higher plant density: Soil-grown plants have strict spacing requirements that must be adhered to in order to give every plant an equal opportunity to utilise the soil's somewhat constrained supply of water and nutrients. Plants in aquaculture systems can be grown closer together without competing for root space because they give a more nutrient-rich solution to the root zone.
4. Plants can grow anywhere. Unlike traditional gardens that require outdoor space for plants, aquaculture systems are easily incorporated into many homes, regardless of their size or location.
5. Less water consumption Even though aquaculture systems depend primarily on water to grow plants, they use between 80 to 90% less water than plants grown in the ground. In traditional gardening, a large amount of water is applied to the soil to allow adequate moisture to reach the root zone. When moving through the soil, the water evaporates and only a percentage of it reaches the roots.

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With little water lost to evaporation, the water reaches the roots right away in aquaculture. To further increase water efficiency, the nutrient solution is frequently recirculated before being rendered useless and dumped.

6. Fewer pest problems Because aquaculture systems are indoors, pests are not as prevalent and have controlled entrances. Insects find it more challenging to infiltrate the system and attack plants. Plus, fewer pest problems mean little to no need for pesticides.
7. Easier to harvest mature plants grown in aquaculture systems are typically grown on counters, benches, tables, etc., which puts them at waist height for most growers. At this height, mature plants are easier to harvest since there is no need to bend down or kneel to reach the plants. This is an important advantage for growers with limited mobility or physical ailments that prevent them from gardening at ground-level.

XI. DISADVANTAGES

1. Expensive to set up: Compared to a traditional garden, an aquaculture system is more expensive to acquire and build. Costs range depending upon the type and size of the system purchased, and whether it is prefabricated or built with individual components to create a customized design.
2. Vulnerable to power outages: Both passive and active aquaculture systems depend on electricity to power the different components such as grow lights, water pumps, aerators, fans, etc. Therefore, a power outage will affect the entire system. In active systems, a loss of power can be detrimental to plants if it goes unnoticed by the grower.
3. Requires constant monitoring and maintenance: Compared to conventional plant cultivation, aquaculture necessitates a higher level of monitoring and micromanagement. All system components—lights, temperature, and numerous facets of the nutrient solution, such as pH and electrical conductivity—need regular attention to create a meticulously controlled growing environment. In order to avoid accumulation and clogging, the nutrient solution must also be flushed and changed on a regular basis [27].
4. Waterborne diseases: Because aqua culturally grown plants are grown in water instead of soil, waterborne diseases are considerably higher. With the water circulating continuously through the system, infections can spread quickly throughout the growing system, affecting the whole collection of plants. In extreme cases, a waterborne disease can kill all the plants in an aquaculture system within hours [33].
5. Problems affect plants quicker: Soil protects the roots from extreme temperature changes, slows diseases and pests from attacking, and regularly releases and absorbs nutrients. Without soil to act as a buffer, plants grown in aquaculture systems react negatively to problems like nutrient deficiencies and disease much quicker.

XII. LIST OF CROPS THAT CAN BE GROWN IN SOIL-LESS CONDITION

Everything starting from flower to fruit crops to medicinal plants can be grown using soilless culture [25,19]. (Refer Table 1 for the list of crops that can be grown on commercial scale using soilless culture)

Table 1. List of crops that can be grown on commercial level using soilless culture.

Types of crops	Name of the crops
Cereals	Oryza sativa (Rice), Zea mays (Maize)
Fruits	Fragaria ananassa (Strawberry)
Vegetables	Lycopersicon esculentum (Tomato), Capsicum frutescens (Chilli), Solanum melongena (Brinjal), Phaseolus vulgaris (Green bean), Beta vulgaris (Beet), Psophocarpus tetragonolobus (Winged bean), Capsicum annum (Bell pepper), Brassica oleracea var. capitata (Cabbage), Brassicaoleracea var. botrytis (Cauliflower), Cucumis sativus (Cucumbers), Cucumis melo (Melons), Raphanus sativus (Radish), Allium cepa (Onion)

Leafy Vegetables	Lactuca sativa (Lettuce), Ipomoea aquatica (Kang Kong)
Condiments	Petroselinum crispum (Parsley), Mentha spicata (Mint), Ocimumbasilicum(Sweet basil), Origanum vulgare (oregano)
Flower/Ornamental Crops	Tagetes patula (Marigold), Rosa berberifolia (Roses), Dianthus caryophyllus (Carnations), Chrysanthemum indicum (Chrysanthemum)
Medicinal Crops	Aloe vera (Indian aloe), Solenostemonscutellarioides (Coleus)
Fodder Crops	Sorghum bicolor (Sorghum), Medicago sativa (Alfalfa), Hordeum vulgare (Barley), Cynodondactylon (Bermuda grass), Axonopuscompressus (Carpet grass)

XIII. FUTURE PROSPECT

The science of aquaculture opens a "new" door for increased food and ornamental crop production. In addition to improving yield quality, it can lessen greenhouse and nursery environmental impact [8]. In overpopulated areas, aquaculture can provide a high production of native crops like green vegetables or flowers. Aquaculture might be modernised to allow for the global cultivation of all types of plants and crops. In regions of Africa and Asia where there is a lack of water, land, and crops, aquaculture can feed millions of people. Aquaculture thus offers a glimmer of hope for managing crop and food production. To feed its citizens, Japan has started producing rice using aquaculture technology. Due to its dry and arid climate, Israel produces a lot of berries, citrus fruits, and bananas. It is a suitable tool for supporting biological research and examining relationships between various biotic and abiotic elements that affect plant growth. To tell the truth, understanding of aquaculture techniques can be useful in both high-tech space stations and rural or urban settings. This is a useful technique for growing food in habitats with challenging conditions, such deserts, mountainous areas, or polar settlements. The need for aquaculture farming has recently increased in both developed and developing nations. Therefore, the government should establish public regulations and provide subsidies for these types of manufacturing systems [30].

The annual output of the aquaculture method is 1,000 times larger than what the same amount of land could generate. The procedure is entirely automated and is run by robots utilising an assembly line-style system like those found in factories, which is the best part. In places of Africa and Asia where water and crops are scarce, aquaculture can feed millions of people. The future of the space programme also depends on aquaculture. NASA has ambitious goals for aquaculture research that will advance both the long-term colonisation of Mars or the Moon and ongoing space exploration. Aquaculture may hold the key to the future of space travel because we have not yet discovered dirt that can support life in orbit and the practicalities of transferring soil via the space shuttles appear unfeasible. Aquaculture in space has two advantages: It provides a biological component known as a bio-regenerative life support system and the opportunity for a wider variety of food. This merely means that the plants' natural growth process will allow them to absorb carbon dioxide, stale air, and deliver fresh oxygen as they expand. Long-term settlement of both space stations and other planets depends on this [6].

DESIRABLE pH RANGE OF NUTRIENT SOLUTIONS

As a plant grows in hydroponic systems, the pH is continually changing. Less than 0.1-unit changes in pH are not considered significant. Controlling pH is so essential in hydroponic solutions. For most species, the pH range of 5.5 to 6.5 is ideal for the availability of nutrients from nutrient solutions, but species differ substantially and some can thrive outside of this range [23].

CONTROL OF CONTAMINANTS

In a soilless culture, maintaining a sterile root-zone environment is crucial for healthy plant growth. It is crucial to reduce the number of plant pathogens in the root zone, despite how

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challenging this is to do. Wilt is a disease that frequently affects hydroponic systems and is brought on by the fungi Fusarium and Verticillium. Pythium and Phytophthora species obliterate all save the primary roots. There are no reliable fungicides that can be utilised in hydroponics.[26] For the management of Pythium on vegetable crops, only Metalaxyl has been found to be extremely effective, however it is not approved for usage. It has also been discovered that heating fertiliser solutions effectively prevents infections from growing in the root zone. The Pythium-caused root mortality of tomatoes was defeated by heating nutrient solutions to 20–22 o C. The roots of ginger plants grew more quickly and generated slightly more fresh rhizomes in an aeroponic system with heated nutrient solution than they did in the same medium with no bottom heat.

At average speed i.e., the valve opening or closing time is 40ms

For 1 sec 25 openings and closings is possible

For 1 min for one valve 25*60=1500

With a force of 1.31N the inlet valve opens for 1500 times and the exhaust valve opens for 1500 times.

SL.NO	TIME TAKEN FOR ONE OPENING OR CLOSING IN MILLISECONDS	NO OF OPENINGS OR CLOSINGS IN ONE SECOND	NO OF OPENINGS OR CLOSINGS IN MINUTE
1	71.4	14	840
2	55.5	18	1080
3	45.45	22	1320
4	40	25	1500
5	35.7	28	1680
6	30.30	33	1980

XIV. CONCLUSION

Future industry growth is anticipated to be exponential as soil conditions for growing become more challenging.

- There is no other choice but to embrace soilless culture to help improve the production and quality of the products so that we can ensure the food security of our nation, particularly in a country like India where an urban concrete conglomerate is rising every day.
- The deployment of this technology can, however, be accelerated by government action and research institute interest.
- Herbs with medicinal and aromatic properties are in high demand.
- Intensive cultures and traditional agriculture are challenging in practice.
- Soilless cultures and protected environment facilities may be implemented anywhere and are not reliant on climatic considerations.
- Harvesting from the spontaneous flora is detrimental for biodiversity.
- The most intensive kind of production is aquaculture, which also produces larger yields than regular agriculture.
- Aquaculture is becoming increasingly popular and widely used around the world.
- The most intensive kind of production is aquaculture, which also produces larger yields than regular agriculture.
- Aquaculture substrates are sterile, neutral, and have a high capacity to hold wet and nutritious solutions. They also have effective drainage of surplus solution.
- Growing medicinal and aromatic plants in aquaculture systems requires careful monitoring, knowledge of plant biology, and cultivation technology in order to have the best relationship between the type of system and plant.
- Medicinal plants grown in aquaculture systems produced higher concentrations of bioactive substances than those grown in soil.

The flavour and scent of fragrant herbs grown in aquaculture systems are much higher than those grown in soil.

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