Role of Hydroponics and Aeroponics in Soilless Culture in Commercial Food Production

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ABSTRACT

The technology Hydroponics and Aeroponics plays very crucial role in 21st century in soilless culture in commercial food production. In this technology natural media is helpful to grow the plants. The main principle involving the use of sprayers, nebulizers, foggers to create a fine mist of solution of deliver nutrients to plants roots. Plant roots are suspended above a reservoir of nutrient solution or inside a channel connected to a reservoir. Plants will grow under optimal conditions like nutrient, temperature, aeration, and pH. In this technique oxygen is influenced into the nutrient solution, allowing the roots to absorb nutrients quicker and more easily. This facilitates stimulating the rapid growth, preventing algae formation and resulting high yields.

Keywords: *Hydroponic, aeroponic, greenhouse, NASA, nutrient solution*

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1. HYDROPONICS AND AEROPONICS

The word hydroponics has its derivation from the combing of two Greek words, *hydro* meaning water and *ponos* meaning labor, i.e, "*water work".* The word first appeared in a scientific magazine article (Science, Feb 178:1) Gericke and Setchell, 1937. Hydroponics is a method of growing plants using mineral nutrient solutions instead of soil. Similarly related hydroponic terms are " aqua(water) culture", "hydro culture", "nutriculture", "soilless culture", "soilless agriculture", "tank farming" or "chemical culture". A hydroponicist is defined as one, who practices hydroponics, and hydroponicum defined as a building or garden in which hydroponics is practiced [1].

Hydroponics is a technology for growing plants in nutrient solutions (water containing fertilizers) with or without the use of an artificial medium (sand, gravel, vermiculture, rokwool, perlite, peat moss, coir, or sawdust) to provide mechanical support. Liquid hydroponic systems have no other supporting medium for the plant roots. Aggregate systems have a solid medium of support. It does not harm our environment as runoff from fertilized soil and very little water is lost to evaporation. It is very useful in drought stricken areas. These hydroponic medium are designed to be very porous for excellent retention of air and water. Healthy plant-roots are developed by good breathe. In this hydroponics plants will get perfectly balanced diet [2].

Aeroponic is a form of hydroponic technique. The word aeroponic is derived from the Latin meaning of "aero" (air) and "ponic" (work). Aeroponic growth refers to growth achieved in an air culture. Such conditions occur in nature.

For example, in tropical climates orchids develop and grow freely in trees.

2. AEROPONIS IS AN APPLICATION OF HYDROPONICS WITHOUT A GROWING MEDIUM

Plant roots are suspended mid-air inside a chamber kept at a 100% humidity level and fed with a fine spray of nutrient solution. This mid-air feeding allows the roots to absorb much needed oxygen, thereby increasing metabolism and rate of growth reportedly up to 10 times of that in soil. And there is nearly no water loss due to evaporation. Laboratory research on air culture growing utilizing vapors began in the mid 1940s. Today aeroponics is used in agriculture around the globe [3]. Aeroponic culture differs from both hydroponics and *in vitro* (plant tissue culture) growing. Unlike hydroponics, which uses water as a growing medium and essential mineral to sustain plant growth, aeroponics is conducted without growing medium [4].

3. HISTORICAL PAST

Ancient people such as the Babylonians and Aztecs used growing techniques where nutrients were obtained from sources other than soil. The mineral nutrients solutions used today for hydroponics were not developed until the 1800s [5].The first use of controlled-environment agriculture (CEA) was the growing of off-season cucumbers under "transparent stone" (mica) for the Roman Emperor Tiberius during the 1st century; the technology is believed to have been used little, at all, for the following 1500 years [6]. Greenhouses (and experimental hydroponics) appeared in France and England during the 17th century; Woodward grew mint plants without soil in England in the year 1699. The basic laboratory techniques of nutrient solution culture were developed (independently) by Sachs and Knap in Germany [7].

Greenhouse areas began to expand significantly in Europe and Asia during 1950s, and large hydroponic system were developed in the deserts of California, Arizona, Abu Dhabi, and Iran about 1970 [6,8]. In the late 1960s researches at the Glasshouse Crops Research Institute (GCRI) Littlehampton, England developed the Nutrient Film Technique (NFT) along with a number of subsequent refinements [9]. In selecting a greenhouse site, a grower must be aware of several chemical properties that might cause problems for greenhouse growers; PH alkalinity, soluble salts etc. [10]. It was Carter in 1942 that first researched air culture growing and described a method of growing plants in water vapor to facilitate examination of roots. It was Went in 1957 who first coined the air-growing process as "aeroponics" growing coffee plants and tomatoes with air-suspended roots and applying a nutrient mist to the root selection.

4. SOILLESS CULTURE/AEROPONICS AND HYDROPONICS

Gericke originally defined hydroponics as crop growth in mineral nutrient solution, with no solid medium for the roots. The distinction between hydroponics and soil less culture of plants has often been blurred. Soil less culture is a broader term than hydroponics; it only requires that no soils clay or silt is used. Note that sand is a type of soil yet sand culture is considered a type of soilless culture. "Hydroponics is always soilless culture, but not all soilless culture is hydroponics" [11].

5. METHODS

1. Solution culture
(A) Static solution culture
(B) Continuous flow solution culture
(C) Aeroponics
2. Medium culture
(A) Sub irrigation
(B) Top irrigation.

One of the most obvious decisions hydroponicists have to make is which medium they should use. Different media are appropriate for different growing techniques. Dennins, Hoagland and Daniel developed several formulas for mineral nutrient solutions, known as Hoagland solutions. Modified Hoagland solutions are still used today. Knop and other plant physiologists (a history of how the hydroponic concept was conceived is given by Steiner [23], showed conclusively that K, Mg, Ca, Fe, and P along with S, C, N, H, and O are all necessary for plant life. In 1940, Gericke wrote the book, *Complete Guide to Soil less Gardening* [13].

Knop's Nutrient Solution	
Reagent	**(g/L)**
Potassium nitrate (KNO_3)	0.2
Calcium nitrate [$Ca(NO_3)_2 \cdot 4H_2O$]	0.8
Monopotassium phosphate (KH_2PO_4)	0.2
Magnesium sulphate ($MgSO_4 \cdot 7H_2O$)	0.2
Ferric phosphate ($FePO_4$)	0.1

Diahydro, expanded clay-under the trademarks 'Hydroton' or LECA (light expanded clay aggregate), rookwool, and coco peat also known as coir or coco, perliteis a volcanoic rock, vermiculture, sand, gravel, brick shards, polystyrene paking peanuts and nutrient solutions are available as a media for plant growth [14].

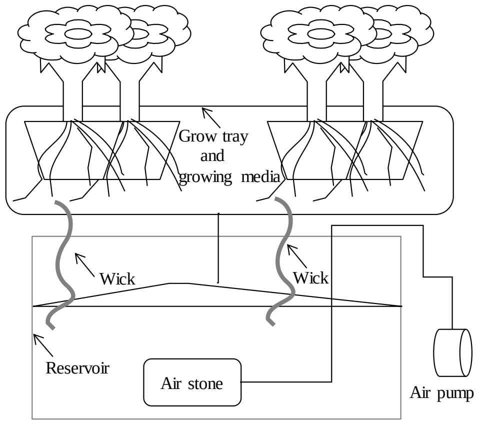

Fig.1: *Simple Hydroponics Wick System.*

6. PRODUCTION OF PLANT ROOTS SECONDARY METABOLITES

Plant secondary metabolites are largely used for anticancer antiviral drugs. Hydroponics has been used to grow entire plant in no sterile conditions and to force root secondary metabolite exudation in order to collect these compounds from the nutrient solution in which the plant has grown. The alkaloids like hyoscyamine and scopolamine can be obtained from living *Datura innoxia mill.* In the production of plant secondary metabolites we considered hydroponics as a system comparable to bioreactors. It is known that hydroponics which can lead to biomass production and this culture method is largely employed for legumes and flowers growth [15].This technology has been called “Plant Milking Technology (PMT)” because it consists of forcing root exudation in order to collect to liquid nutrient solution. An obvious analogy to cow growing and milking thus largely appear Hydroponics plants release their compounds without loose of viability [16].

7. HYDROPONICS IN NETHERLANDS

The Netherlands was formerly one of Europe’s largest users of methyl bromide for soil fumigation. Using this pesticide to control soil borne pests on greenhouse grown crops such as tomatoes, lettuce, strawberries, cucumbers, sweet peppers, eggplants, as well as well as nursery crops and cut flowers (only a small amount was used to fumigate soils in field crops). By using alternative cropping methods, such as hydroponics and soil less culture on artificial substrates, growers in the Netherlands have successfully eliminated the risk of infection of soil borne pests, while increasing crop yield and quality [17]. Hydroponics and soil less on artificial substrates as an alternative to methyl bromide soil fumigation. This method was frequently used in Netherlands.

8. HYDROPONICS IN SPACE

Hydroponics for space, helpful of purifying water, maintaining a balance between oxygen (O_2) and carbon dioxide (CO_2) in space sections and providing food for astronauts is being intensively researched [18–21]. Hydroponics growing in desert areas of the world and in areas such as the Polar Regions [6, 22– 25].

One of the early success of hydroponics occurred on Wake Island, a rocky atoll in the Pacific Ocean used as a refueling stop for Pan American Airlines. Hydroponics was used there in the 1930s to grow vegetables for passengers. Hydroponics was a necessity on Wake Island because there was no soil, and it was prohibitively expense to airlift in fresh vegetables. In the 1960s, Allen Cooper of England developed the Nutrient Film Technique. The land pavilion at Walt Disney World's EPCOT center opened in 1982 and prominently features a variety of hydroponic techniques. In recent decades, NASA has done extensive hydroponic research for their Control Ecological Life Support System (CELSS). Hydroponics intended to take place on Mars are using LED lighting to grown in different color spectrums with much less heat [26].

9. NASA AEROPONICS

Aeroponics is defined as a system where roots are continuously or discontinuously in an environment saturated with fine drops (a mist or aerosol) of nutrient solution. The method requires no substrate and entails growing plants with their roots periodically wetted with a fine mist of automized nutrients. Excellent aeration is the main advantage of aeroponics [27]. The first commercially available aeroponic apparatus was manufactured and marketed by GTi in 1983. It was known then as the "Genesis Machine". The *Genesis machine* was marketed as "Genesis rooting system". At the time, the achievement was revolutionary of terns of a developing (artificial air culture) technology. The *Genesis machine* simply connected to a water faucet and an electrical outlet Aeroponic techniques have been given special attention from NASA since a mist is easier to handle than a liquid in a zero gravity environment [28].

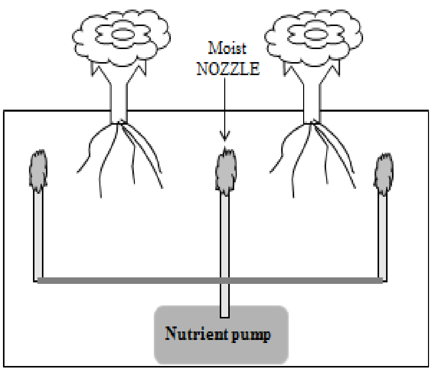

Fig 2. Simple Aeroponics system

10. SPACE PLANTS

Plants were first taken into earth's orbit in 1960s on two separate missions, Sputnik 4 and Discover 17. NASA life support GAP technology has done experiments with beans, wheat, pea, and maize in space. Plant experiments were later performed on a variety of Soviet, American, and joint Soviet–American missions, including Biosatellite 2, Skylab 3, and 4, Apollo-Soyuz, Sputnik, Vostok, and Zond. Some of the earliest research results showed the effect of low gravity on the orientation of roots and shoots [29].

11. BIOCONTROLS IN SPACE

In 1996, NASA sponsored Stoner's research for a natural liquid biocontrol, known then as organic disease control (ODC), that activates plants to grow without the need for pesticides as a means of control pathogens in a closed-loop culture system. ODC is derived from natural aquatic materials. In 1997, Stoner's biocontrol experiments were conducted by NASA. The NASA experiments were conducted to study only the benefits of the biocontrol [30]. NASA low-mas inflatable aoneroponics system (AIS) an inflatable low-mass aeroponic system (AIS) for space and earth for high performance food production is a self-contained, self-supporting, inflatable aeroponic crop production unit with integral environmental systems for the control and delivery of a nutrient/mist to the roots [31].

Aeroponic bio-pharming is used to grow pharmaceutical medicine inside the plants. The technology allows for completed containment of allow remain inside a closed-loop facility. As recently as 2005, GMO research at South Dakota State University by Dr. Neil Reese applied aeroponic to grow genetically modified corn. Aeroponically grown biopharma corn in 2005. Reese says aeroponics buffer the ability to make biopharming economically practical [32]. In 2006, the Ag University of Hanoi Vietnam in joint effort with Stoner established the postgraduate doctoral program in aeroponics. Vietman joined the World Trade Organization (WTO) in January 2007. The impact of aeroponics in Vietman will be felt at the farm level.

12. ADVANTAGES

Hydroponics is an indoor horticulture. It is best to adapt hydroponics in areas where the soil is not suitable for plant growth like Antarctica and Space colonies. Hydroponics is incredible amount of water; it uses as little as 1/20 the amount of as a regular farm to produce same amount of food. Nutrient solutions may be re-used in other areas such as potted plants and turf management. Growing medium can be reused and recycled. Culture and technique requires less space. When removing the crops, it can be packed and sold. When alive to retain its freshness for a longer time [33].

Due to rising awareness of chemicals and contaminants in the food supply, people are looking for safer alternatives. Fortunately, Hydroponics is an exact fit for the consumer's new requirements. Plants will develop strong resistance. There are also much more consistent results when using Hydroponics, because it is much a CEA. Because hydroponics systems are inside greenhouses, crops can by grown year-round, without being effected by the weather. "Hydroponics gives the farmer precise control of the plants and often even the seasons" [2].

Growing smaller hydroponics gardens for personal enjoyment and consumption is a trend right nowdays. Home growing Hydroponics kits are presently available that start at about fifty dollars No soil means no weeds or soil borne pets and disease. The root systems stay smaller on hydroponically grown plants, so the plant can concentrate its growth energy on producing plant mass, rather that roots. This can result in up to 30% faster growth [34].

13. DISADVANTAGES

High setup costs initially, necessary skills, and knowledge and the fact that not all plants can be grown hydroponically. The failing of the timers or pumps or clogging of the system can lead to a quick death of plants. No doubt, hydroponics is a promising technique but there are still many problems left unresolved ,e.g., you can achieve great biomass increases compared to "Normal" culture methods, but unfortunately at the expense of concentrations of secondary metabolites or/and resistance against pathogens [35].

13. 21st CENTURY AEROPONICS

Aeroponics is an improvement in artificial life support for non-damaging plant support, seed germination, environmental control, and drip irrigation techniques that have been used for decades by traditional agriculturalists. Advantages are excellent aeration is the main advantage of Aeroponics. These techniques have been given special attention from NASA; since a mist is easier to handle than a liquid in a zero gravity environment. One of the main disadvantages was expensive [27].The technology of Hydroponic systems is changing rapidly with systems today producing yeilds never before realized. The future for hydroponics appears more positive today than any time over the last 50 years. I sincerely believe hydroponics will be fashionable again.

14. CONCLUSION

Hydroponics was method of growing plants using mineral nutrients solutions instead of soil. Aeroponic was a form of hydroponics technique. Hydroponics and aeroponics plays very important role for the commercial food production. Hydroponics grown plants will get perfectly balanced diet. In recent decades, NASA has done extensive hydroponics research for their Control Ecological Life Support System (CELSS). NASA sponsored Stoner's research for natural liquid biocontrol, known then as ODC, that activates plants to grow without the need for pesticides as a means of control pathogens in a closed-loop culture system. Aeroponic bio-pharming is used to grow pharmaceutical medicine of plants. The use of CEA was the growing of off-season cucumbers under ‘’transparent stone’’ (mica). Greenhouses are expanding significantly in France, England, Europe, and Asia during 1950s, and large hydroponics system were developed in deserts of California, Arizona, Abu Dhabi, and Iran. Today hydroponics and aeroponics are used in agriculture around the globe [3].

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