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Hydroponics, Aeroponic and Aquaponic as Compared with Conventional Farming

Ali AlShrouf*

Abu Dhabi Food Control Authority, R & D Division, AlAin, UAE
Email: ali.alshrouf@adfca.ae

Abstract

Due to huge demand on water resources and subsequently food supply, many new trends in the farming innovative methods which include a complex agricultural production system have been evolved. Hydroponics is the art of soilless agriculture in which growing of plants in a soil less medium, or an aquatic based environment as aeroponics farming system. Hydroponic growing systems use mineral nutrient solutions to feed the plants in water of using soilless media. While Aquaponics is the integration of aquaculture and hydroponics. Many studies of commercial-scale hydroponic, aeroponics and aquaponics production showed the potential positives role for those new technologies in the sustainable food security. Those agricultural farming systems could be one sustainable alternative to provide different type of produces that it requires less water, less fertilizer and less space which will increase the yield per unit area. The main advantage of those modern cultivation systems is the conservation of water and less or no use of agrichemicals which are dangerous to the human body when applying and especially when eating in the food.

Keywords: hydroponics; Aeroponics; Aquaponics; Geoponics conventional farming; water scarcity; land problem.

1. Introduction

Conventional agricultural (Geoponic) practices can cause a wide range of negative impacts on the environment. “Conventional has been historically defined as the practice of growing crops in soil, in the open air, with irrigation, and the active application of nutrients.

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* Corresponding author.

Some of the negative impacts of conventional agriculture include the high and inefficient use of water, large land requirements, high concentrations of nutrients consumption, and soil degradation [1,2]. The rapid growth of the world population should offset by the same or rather higher rate in the production of the food. To sustainably feed the world's growing population, methods for growing food have to evolve.

The need of large amounts and high quality vegetable products to meet the growing demand of the world population justifies the development of technologies which synchronize the water & nutrient solution demand and supply to greenhouse plants in order to achieve crop yield optimization. The knowledge about water and nutrient uptake by plants is crucial for developing control strategies which increase the possibility to supply the required amounts of water and nutrients for maximum crop growth and development [3].

Conventional agricultural systems use large quantities of irrigation fresh water and fertilizers, with relatively marginal returns [4]. Hydroponics, aeroponics and aquaponics are modern agriculture systems that utilize nutrient-rich water rather than soil for plant nourishment [5]. Because it does not require fertile land in order to be effective, those new modern agriculture systems require less water and space compared with the conventional agricultural systems, one more advantage of those technologies is the ability to practice the vertical farming production which increase the yield of the area unit [6]. The benefits of the new modern agriculture systems are numerous. In addition to higher yields and water efficiency, when practiced in a controlled environment, those new modern systems can be designed to support continuous production throughout the year [7].

Many recent developments in farming system give more possibilities to control all of the agricultural practices along the growing season. One of the greatest innovations in farming technology is the appearance of precision agriculture technology under the green houses. Technology has started to permeate almost everything and in agriculture, which include all of the processes as crop monitor technology and mobile apps to aid farmers in "when", "where", "How" or "what" to plant and precision agriculture. The advantage of those agricultural technology, affording farmers greater control over production, the ability to increase yields, operate more sustainably, and more flexibility as the weather changes.

Most of those technologies could categorized under four key areas: Sensors, Food, Automation and Engineering. Sensors technologies enabling immediate traceability and identification of crop and some self-driven agricultural practices. Food may benefit directly from genetic tailoring and potentially from producing some food directly in a lab. Automation will help agriculture to check and maintain crops at the plant level. Engineering involves technologies that cover the reach of agriculture to new means, places and areas.

In a hydroponic system, plants grow with added nutrients in a certain media or nutrient solution and without soil. Hydroponics uses only water and nutrients fertilizer to cultivate plants. So many advantages could be counted for using of hydroponics to grow plants; soil is not necessary; it's stability and high yields; no nutrition pollution is released into the environment; higher nutrient and water use efficiency due to control over nutrient levels. Hydroponic systems are very useful and can range from simple setups to highly sophisticated ones.

Aeroponics is actually a subgroup of hydroponics, except that it uses no growing medium at all, and the plant

grow by misting rich nutrients water. Plant roots in this system are suspended in a dark enclosure, while a nutrient-dense solution is sprayed on the roots at certain intervals. Aquaponics system relies on the integrated relationship between the animals and the plants to maintain a stable aquatic environment that experience a minimum of fluctuation in ambient nutrient and oxygen levels. So aquaponics is the marriage of aquaculture (raising fish) and hydroponics (the soilless growing of plants) that grows fish and plants together in one integrated system. The fish waste provides an organic food source for the growing plants and the plants provide a natural filter for the water the fish live in. The third participants are the microbes (nitrifying bacteria) and composting red worms that thrive in the growing media. Those microbes are converting the ammonia from the fish waste first into nitrites, then into nitrates and the solids into compost that are food for the plants. Due to many debates as to which method of those three new farming system would come out on the top of the battle; hydroponics, aquaponics and aquaponics. This article will look at the main differences between the three new farming systems. So this paper will analyze and compare three types of farming system as compared with the conventional. In this comparison, the goal is to assess the impact and performance of each system and then identify the best method for growing crops.

2. Similarities and differences:

Figure 1 explains the classification of the new soilless culture trend, those system might be open system. The figure shows two main types of hydroponic systems; closed hydroponic systems and open hydroponic systems. Hydroponic systems that do not involve growing media are usually closed systems, while hydroponic systems that involve growing media (container plants), may be closed or open systems. In closed system the same nutrient solution is recirculated and the nutrient concentrations are monitored and adjusted accordingly. While the open hydroponic systems a fresh nutrient solution is introduced for each irrigation cycle. The nutrient solution is usually delivered to the plants using a drip system. The main advantage of closed hydroponic systems, in comparison with open systems, is their efficiency in water & nutrient usage.

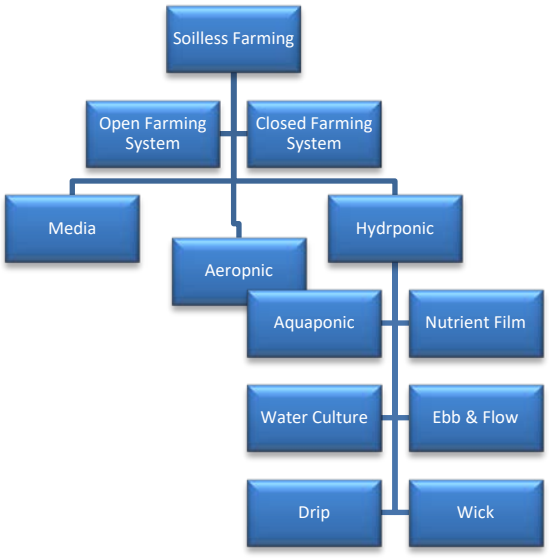

Figure 1: Classification of the Soilless Farming system

There are so much discussions surrounding the three soilless agricultural systems sweeping the globe today. At first glance, the three farming systems; hydroponics, aeroponics and aquaponics have some common similarities since they shared with the elimination of the soil as a medium to grow crops; with the aim being delivering sustainable and profitable food production. However, there are many significant differences where aquaponics improves upon many aspects over the hydroponics as; Cost of fertilizer to supply the plant nutrient in hydroponic system is expensive as compared with the aquaponics system where fish feed is used instead of the nutrients. In term of nutrient solution retention, no need to upload the nutrient solution under the aquaponics system while some times and due to the build-up of salts and chemical where the levels become toxic to the plant uploading and disposing of the nutrient solution is necessary under the hydronic system. Several studies and research conclude the aquaponics farming generally showed a quicker and more efficient results in terms of plant growth compared to hydroponics. In addition to that, aquaponics system is much easier to maintain since there's no need to check the electrical conductivity once every day as would have in a hydroponic system. The natural ecosystem in aquaponics means that elements have a tendency to balance each other out, and you would only need to check pH and ammonia levels once a week, and nitrate levels once a month. Also hydroponics is made up of a sterile man-made environment while aquaponics is a replication of a natural ecosystem, thus making it completely organic.

Aeroponics vs hydroponics they are both equally efficient at growing necessary food production without the use of a soil medium to turn out higher yielding, healthy, fresh produce and vegetables

Although aeroponics and hydroponics are similar in the using of the nutrient-rich water, they are distinctly different. Hydroponics are using certain media other than soil that retains and distributes nutrient rich water to feed the plants, whereas aeroponics uses a misting system to deliver nutrients. Aeroponics succeeds more in vertical growing arrangements and using the space efficiently.

Both Hydroponic and aeroponics system allow for flexibility and control the quality, health and quantity of the vegetable plants and other produce. Whether a hydroponics or aeroponics system have been chosen, both promote self-sustainability in an environmentally friendly way. Hydroponics uses only 10% of water resources when compared to conventional methods giving the grower complete control over nutrient delivery. With aeroponics there is virtually no grow medium used and a nutrient rich solution is sprayed onto the root system providing for maximum nutrient absorption. Where an aeroponics system will require constant attention, the hydroponics system may be easier for beginners. However, both systems are much more efficient than soil-based agriculture, and both of them have almost the same opportunity for the flexibility to control the irrigation and nutrient applications.

Aeroponics systems can reduce water usage by 98 percent, fertilizer usage by 60 percent, and pesticide usage by 100 percent, all while maximizing crop yields. Plants grown in the aeroponics systems have also been shown to uptake more minerals and vitamins, making the plants healthier and potentially more nutritious

There are a few other advantages aeroponics has when compared to hydroponics. One of these is that the plants can more easily be transplanted, since they don't suffer from transplant shock. This gives you a lot more options

than you might otherwise have.

Aeroponics also allow you to observe the plants directly without disturbing them, which allows you to adjust the nutrient mix that you're using and cut off any problems that you might be having before they actually have a chance to become a problem.

Under the hydroponic system and because the nutrient solution is passed between plants, it is possible for water-based disease to travel rapidly between them. Also, hydroponic systems, including aeroponics, rely on electricity and require costly generator back-ups to cover for power outages. Hydroponic systems can also be expensive to set up due to the nature of the equipment involved. However, once the system set up have been completed, it is cheaper than a conventional farming to operate. Since the plant roots are isolated and there is no planting medium under the aeroponics system, plants that are grown with this suspended, misted system will get maximum nutrient absorption.

Aeroponics are sensitive and require constant attention to pH and nutrient density ratios. Aeroponics systems are favored over other methods of hydroponics because the increased aeration of nutrient solution delivers more oxygen to plant roots, stimulating growth and preventing pathogen formation

The deciding factors in choosing one method over the other are the ancillary benefits. For aeroponics, this includes lower water and nutrient usage. For certain hydroponic systems, this includes greater buffering capacity and room for error.

3. Results & Discussion

A hydroponic uses about 5 percent of the water and a fraction of the land needed to produce an equivalent amount of produce in traditional agriculture. In the San Joaquin Valley of California, the water use efficiency (WUE: kg tomato yield/ m^3 water applied) for tomato production was shown to be 10-12 kg m^{-3} for flood irrigation, 11-19 kg m^{-3} for sprinkler irrigation, and 19-25 kg m^{-3} for drip irrigation [8,9,10]. Many researchers have reported much higher WUE values for greenhouse tomato production. Open hydroponic irrigation systems (no recirculation of unused water by plants) in the Netherlands and France have been reported as 45 and 39 kg m^{-3}, respectively [11]. Closed irrigation systems (recirculated irrigation water) have been shown to achieve WUE values of 66 kg m-3 in the Netherlands, and 25 and 30 kg m^{-3} in the warmer climates of Spain [12] and Italy [13] respectively.

Research on crop water requirement under greenhouse has been carried out in the temperate region. In Netherlands, it has been reported that water consumption for tomatoes is estimated at 0.5–0.9 m^3/m^2 greenhouse area per year [14]. Another study conducted by [15] revealed that plant water consumption of tomatoes ranged from 0.19 to 1.03 l/plant/day at different water salinities. In Mediterranean area, the optimum water requirement for vegetables was still not clearly stated, but pan evaporation method within the greenhouse was used to estimate water consumption use [16,17]. Increasing the irrigation rate up to 120% of pan evaporation increased crop yield but decreased total soluble solids [17]. In another region, the volume of irrigation water will vary depending on the season and the size of tomato plants cultivated in a gutter-connected plastic greenhouse. New

transplants need only about 0.05 l/plant/day. At maturity on sunny days, however, plants may need up to 2.7 l/ plant/day. Generally, about 1.8 l/ plant/day are adequate for fully grown or almost fully grown tomato plants [18].

Many studies describe the quantitatively the differences between the three most common soilless farming system as compared to the conventional farming system, in term of the irrigation water, fertilizer consumption, crop productivity and the productively of the unit of irrigation water. Table 1 shows the average values which have been collected from many of the research review which have been implemented in different locations. The results showed the highest water productivity could obtained under the aeroponics farming system, also the closed system always showed a higher water productivity over the open system. The values shown in table 1 were obtained from analyzing many previous UAE statistics and some other author personal communications.

Table 1: percentage of water and fertilizer consumption, vegetables yield percentage and the percentage of water productivity for different new farming systems as compared with conventional farming system.

Parameters	Hydroponic system				Aeroponics	Aquaponics
	Media Soilless system		Nutrient solution system			
	Open	Closed	Open	Closed		
% Irrigation water saving	80	85	85	90	95	%85-80
% Fertilizer saving	55	80	68	85	85	%99-85
% Productivity increase	100	150	200	250	300	%150-100
% Water productivity	1000	1600	2000	3500	8000	1000-1600

However, on average, hydroponic systems use 5-20 times less water than soil agriculture. Many studies showed a significant differences between the open and the closed hydroponic system. The yield of closed system increased by almost 5 % as compared for closed one [19,20,21,22]. Author of [23] reported that the total crop yield of the closed system of fertigated greenhouse was almost similar to that of open system greenhouse.

Regarding the plants water consumption as function for the tested hydroponics systems, results shows that the average water consumption of the plants grown in the open system was 15 to 17 % higher compared to the closed systems [24,25]. Generally, the open system results in higher evapotranspiration than closed one [21].

Cultivating plants without soil, open the door for the researcher for the evaluation and popularization of alternative growing media. There are probably hundreds of different kinds of growing media; basically, anything that a plant can grow in is considered a growing medium. Among the many substrate now available are rockwool, perlite, coco peat, and sand, Each alternative has positives and negatives, and the choice between aggregates will depend on many variables as porosity, water holding, cation exchange capacity and some others. Table 2 shows the major characteristics of the some commercial hydroponic media, those analysis was done in Abu Dhabi Food Control Authority

Table 2: physical characteristic of some hydroponic soilless media found in UAE market

Substrate	Total Porosity (V/V)%	Air Porosity (V/V)%	WHC (V/V)%	CEC (cmol/kg)	Bulk density (g/cm3)	C/N %
Perlite	66.3	41.1	25.2	0.0	0.13	0.0
Sand	35.6	24.6	11	12	1.45	0.0
Peat	90	13.2	76.8	110.5	0.11	40.12
Rockwool	94.1	10.3	83.8	0.0	0.06	0.0
Coco peat	92	12.2	79.8	138.7	0.16	48.47

The Media porosity is critical physical characteristic which influences water and nutrient absorption and gas exchange by the root system. Since each these materials have individual properties, so these materials must have high water holding capacity (WHC), sufficient aeration (porosity), suitable drainage and high cation exchange capacity (CEC). In addition to those characteristic the following properties might be considered as well; cost, density, decomposition rate and some time the capillary ability.

As the choice of soilless growing medium for plant nutrition, growth and support is crucial for improving the eco-sustainability of the production in horticultural systems. Regarding the effectiveness of substrate, Table 3 shows directly the average percentage of the some vegetables crops hydroponically grown under different substrate media considering the sand substrate as a control.

Table 3: The percentage potential yield for different hydroponic soilless media as compared with sand as control substrate

Substrate	Potential Yield (%)
Perlite	112
Sand	100
Perlite and Peat (1:1)	106
Sand and Peat (1:1)	106
Sand, peat and perlite (1:1:1)	109
Rockwool	107
Coco peat	105

4. Conclusion

The main advantage of these modern cultivation systems is the conservation of water and increase productivity per unit area. While all three can be implemented in a raised garden, all three are very similar in every way

except hydroponics and aeroponics requires the addition of fertilizer and there's no fish in the nutrient solution. In aquaponics, plants and fish live a symbiotic life with the fish feeding the plants, and the plants cleaning and filtering the fish's environment. Hydroponics is the base for all these methods and would be the easiest to set up. It could be later adapted to create an aquaponics setup. However, the aeroponics requires more maintenance and care in creating a semi-enclosed to fully-enclosed environment. Aeroponics, hydroponic and aquaponics systems reduce water loss and increase water use efficiency compared to the conventional agriculture.

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