Advantages and disadvantages of hydroponics

Growing plants without soil had been known by human for more than thousands year. The fundamental principle of hydroponics relies on fertilized & aerated water which provides both nutrition and oxygen to a plant's root zone. Hydroponics has been recorded back as early as the Aztecs and ancient Egypt (Winterborne 2005). The scientific study of plant fundamental was first recorded in 16th century by Jan Van Helmont, his study found out that plants acquire substances for growth from water (Resh 2004). In 1666, Robert Boyle reported the first experiments on cultivate plants with their roots sank in water. John Woodward proved that plant can be grown in water but soil element had to be added to water in 1699 (Gruda et al. 2006). In 1804, Nicolas de Saussure proposed that plants need nutrition for growing. Mid 1900s, Jean Baptiste Boussingault introduced growing plants in sand charcoal and quartz using dissolved nutrient. Later, in 1860, the earliest typical formula for a nutrient solution that could be dissolved in water and in which plants could be effectively grown was published by Julius von Sachs (Resh 2004). The first proposal for commercial water culture system was made by Dr. Gericke in 1929 (Gericke 1929). The term hydroponics was originated by Dr. William Frederick Gericke of the University of California in 1937 to describe the cultivation of plants in a solution of water and dissolved nutrients. The word hydroponics has its origin from the merging of two Greek words, hydro meaning water and ponos meaning labor (Gericke 1937). In 1938, Gericke's originated system was adopted on Wake island in Pacific ocean to supply passengers and crews of clipper plane that use this island as a way station (Science News Letter 1938). The first large commercial scale implementations for hydroponic growing were the systems established by the U. S. Army in the South Pacific during World War II to supply fresh fruits and vegetables for troops operating in that area (Jones 1985). However, the first deep water hydroponics system described by Gericke was not vastly adopted because they proved to be not profitable and making inefficient use of resources (Schwarz 1968 cited in Gruda et al. 2006). In the 1970s, Allen Cooper created Nutrient film technique to overcome the problem of aeration in Gericke's system (Cooper 1975). At present many researchers is still being carried out to develop hydroponics system.

3. 2 Advantages and disadvantages of hydroponics

There are two main advantages of the hydroponics. First, hydroponics is much greater crop yield (See table 1) (Douglas 1970; Jensen 1990, 1999; Olympios 1998; FAO 2010). Secondly, hydroponics can be used in location where regular agriculture is impracticable (Douglas 1970; Jensen 1990; Olympios 1998). These two advantages are also supported by Resh (2004). Moreover, Resh (2004) pointed out some other main advantages of hydroponics which are more competent nutrition management (Falivene 2005), effective and efficient use of fertilizers and water (FAO 2010).

In addition, if we compare hydroponics or soilless culture with soil culture or ordinary agricultural, we can find that there are many advantages hydroponics over soil culture. Firstly, hydroponics requires less labor needed (Olympios 1998; Maejo Hydroponics Information Centre (MHIC) 2009a). In soil culture, sterilization of growing medium can be labor-intensive and time required is lengthy. In contrast, hydroponics system requires short time to sterilize. The soil preparation processes can result in large cost in soil culture. Secondly, hydroponics system enable grower to totally manage over plant nutrition, on the other words, hydroponics offers the precise control of plant nutrition relative to soil cultures as it is easier to sample, test and adjust because nutrition formula is similar to all plants that share the same tank. Also, enable growers to control over pH and electrical conductivity (EC) which is almost impossible in soil culture (Olympios 1998; Resh 2004). Thirdly, in soil culture, there are many soil-borne diseases (a reduction of biodiversity of soil organisms), crop can be attacked by insects and animal, as a result crop rotation is used to overcome increasing number of insects. Conversely, there is no insects or animals that can attack crop, therefore crop rotation is not necessary (Roberto 2000; Resh 2004). Fourthly, hydroponics is enabling relatively efficient use of water. In soil culture, water is lost as drainage past the vegetable root region and by becoming vapor from soil. In hydroponics system, these problems are eliminated by the layout and functioning design of the hydroponics systems such as nutrient film technique (NFT) (Olympios 1998; Resh 2004). Fifth, large amount of fertilizers drain away from soil past plant root region which is lead to inefficient use of fertilizers in soil culture. In hydroponics system, the use of fertilizers is very efficient since fertilizers cannot leach beyond root region. Moreover, relatively small quantity of fertilizers is used but can be circulated to all plants (Resh 2004). Last, hydroponics system offers almost no time interval between crops, therefore, in the particular growth area, the amount of crops per year is greater than in soil culture (Olympios 1998).

Notwithstanding many benefits, there are some drawbacks of hydroponics. First, obviously, hydroponics system requires high capital investment for set up (Olympios 1998; Resh 2004; MHIC 2009a). Second, hydroponics system requires high technical knowledge needed for the management which is mainly from experiencing the complexity of nutrition mixing (Jensen 1990; Olympios 1998; Resh 2004; MHIC 2009a). Third, in hydroponics system, plants are sharing the same nutrition tanks, therefore, some diseases such as Fusarium and Verticillium can spread out very fast to all plants that sharing the same tank (Resh 2004). However, these disadvantages can be overcome; capital cost can be controlled by use of simplified hydroponics technique, diseases can be restrained by use of technical knowledge.

3. 3 Appropriate site for hydroponics

In order to minimize any risks of failure in hydroponics production, the selection of suitable sites for the large commercial hydroponics installation is matter; we must choose the area location that suitable to set up hydroponics site. (MHIC 2009b) suggested some requirement characteristics of the proper location. First, the area should fully exposes to sunlight in east, south and west with barrier against the wind from north. Next, the area should be slightly sloped or can be readily to flatten (Douglas 1985). Next, area should have a good supply of public utility such as electricity, telephone and good quality water (at least 6 litres per square metre of growing area per day). Next, area should have a good action of draining water with penetration at least 1 inch per hour. Next, the area that has a good connection to road and close to high density living area for easy access to the market. Next, the region or district which has maximum supply of sunlight. Finally, North-south oriented layout of growing area. However, it is not specific to have all characteristics but should meet those requirements as much as possible.

3. 4 Type of hydroponics

At each phase of growth, within a speculative hydroponics system, all the oxygen, water and nutrients are provided to the root region of the plant at the strength of a solution and temperature that the plant requires (Rural industries research & development corporation (RIRDC) 2001). There are two main types of hydroponic systems: water or solution culture and medium or substrate culture.

3. 4. 1 Water culture

Water culture, by definition, is classified as true hydroponics. This method does not use solid medium for the root, just only dissolved nutrient solution. Water culture was the method of hydroponics used in large scale commercial crop production and laboratory research (Douglas 1985). Resh (2004) suggested three requirements to be met in order to be successful in operation of water culture; aeration of the roots and darkness of root zone. First, aeration of the roots. Roots should be provided with enough oxygen. This may be attained in two ways. The first way is called forced aeration, by bubbling the air into the nutrient solution using airstone stationed in the tank or at the lowest part of the bed. The second way is using the instrument that regulates flow placed at the bottom of the tank. Second, darkness of root zone. During the daytime, normally, plants can function with their roots opened to the light in the condition that they are at all time 100 percent relative humidity. Nevertheless, algae will be promoted to growth in light. Algae will impede growth of plant by contending for oxygen and nutrients as well as creating toxic though its decomposition. Therefore, in order to eliminate algae growth, beds and cover should be made of non transparent materials.

3. 4. 2 Substrate culture

In substrate culture, the nutrient solution is provided to plants by water supplied through the media which allow the surplus solution to be recirculated or run to waste in some case. The medium is also providing support and surround plants. The medium should not hold back or lock up any nutrient. Therefore, plants will be able to absorb nutrient they need as much as possible and whenever they need. According to Olympios (1998), there are two categories of medium that use in the substrate culture; inorganic and organic media. For example, rockwool, sand, and gravel for inorganic. The later such as sawdust, bark, wood chips, and peat.

3. 5 Hydroponics techniques

There are many hydroponics techniques that developed and in practice nowadays, however, this paper will emphasize on techniques that widely use in commercial production.

3. 5. 1 Nutrient Film Technique

The nutrient film technique (NFT) was pioneered in 1965 at the Glasshouse Crops Research Institute in Littlehampton, UK by Dr. Allen Cooper (Winsor et al. 1979 cited in Jensen 1999). The standard features of NFT consisted of nutrient solution tank, electronic pump to deliver the solution through pipes, and troughs (See Fiqure XX). A variety of types of material can be used to construct a trough; for example, coated metal, PVC pipe, and polyethylene, depending on the crop and size of the trough (van Os et al. 2008). The plants are grown in superficial trough or channel such as PVC pipe which is provided with a very swallow flowing film (1 – 2 centimetres)of continuously recirculated nutrient solution (Marr 1994). The minerals are supplied straight to the root system. The nutrient solution is delivered from nutrient tank to the higher end of the groove at the rate of 2 – 3 litres per minutes, then flows past the plant roots by gravity to drain hole and to nutrient solution tank, the slope should be between 1: 50 – 1: 100 depends on plant crop (Adams 1981). The nutrient solution should be monitored for the relative amount of salt contained within a solution before recycling. The necessities for the managing of recirculating hydroponic growing systems were discussed by Bugbee (2003). The add-on of make-up water, the requirement for restoring the pH and nutrient element constituent, filtering, and sterilization are procedures that need to be adopted. In addition, on condition that the flow speed is too low, the issue is not deficient of water, but insufficient of nutrients, particularly for plants whose roots are moving in the direction in which a nutrient solution flows in the trough and are disclosed to water from which many other plants have obtained some nutrients before. The last plants in the row get the least nutrients, especially potassium. As a result, this can be created the problem of slow growth (van Os et al. 2008). The nutrient film technique is suitable for plant with 120 – 150 days cycle or leafy vegetables such as lettuce (Pardossi and Sciortino 2004). Conversely, regarding to Resh (2004), in the past NFT was used to grow vine crops such as tomato, cucumber and peppers but due to aeration problem of NFT in growing vine crops, rockwool is used to grow these vine crops instead. Significant aspect of NFT is to make sure that adequate oxygen is obtainable to the plant. This may require either aeration of the nutrient within the tank or allowing air to reach the nutrient solution within the channels.

There are many advantages of nutrient film technique. First, an advantage of this system in comparison with others is that the required volume of nutrient solution is a greatly reduced (Jensen 1990). Second, another benefit is conservation of water by the use of recirculated water rather than an open system. Third, it is easier to sanitise roots and hardware compared to other system types. Fourth, pest and disease control is simplified by use of systematic insecticides and fungicides in the nutrient solution to control insects and diseases (Cooper 1975). Fifth, NFT is simple to set up and has relatively low cost of building materials (Jones 2005).

There are some drawbacks that possible come up from the practice of NFT (RIRDC 2001). Firstly, the roots will dry out if the circulation of nutrient solution is interrupted even for short length of time and rapidly become stressed. Therefore, electricity supply to the system is crucial. Secondly, difficult situation can be the immoderate high temperature of troughs in newly planted systems. Thirdly, roots of very healthy growing plants can become an obstruction in troughs which makes movement or flow difficult or impossible.

3. 5. 2 Aeroponics

Aeroponics technique was first researched in 1942 by W. A. Carter and described in his work “ a method of growing plants in water vapor to facilitate examination of roots” (Rajshekhar 2009). Later, the aeroponics technique is the method that requires no medium. Plants are pensile in the supporting holder where root system is freely suspended and enclosed inside a dark chamber (see figure XX.). To inhibit algae growth, that is a reason why chamber has to be dark (Jensen 1990). The nutrient is supplied to plants continuously as a nutrient mist or fog rather than a nutrient solution through a spray jets which regularly, function 24 hours per day (Haddad et al. 2009). This method is suitable for plant that cannot be immersed in water (MHIC 2009c). Recently, this method is vastly using in laboratory studies, but not much as other methods in large-scale commercial production (Resh 2004). However, aeroponics is used by some Italian companies to produce lettuces, tomatoes, cucumbers and melons for commercial scale production.

There are many advantages of aeroponics system. First of all, environment of root system is well supplied of oxygen as all roots are exposed to the air in the chamber which benefits to the plants. From the study of Kratky (2005) showed that amount of air in the chamber has positive relationship to crop yields. However, to prevent a deficient in oxygen, the chamber should be aerated. Second, an examination of the roots for indications of disease or growth check can be easily done and with minimal disturbance as there is no medium at root region (Kratsch et al. 2006). Third, basically, bacteria that can possible harm crop plants generally grow and become more numerous in a medium. Thus, this can be less of a concern with aeroponics.

On the other hands, aeroponics also has some disadvantages. To begin with, the system is vulnerable to a power outage or pump failure. As a result, exposed roots will rapidly dry out and kill the plant. Next, salt in nutrient can be build up rapidly because water can vapor very fast, unless we can control the evaporation rate in the chamber by sealed the chamber to minimize vapor flow out.

3. 5. 3 Deep Flow Technique

This technique was first developed in Japan in 1973 (Kao 1991). Deep flow technique (DFT) can be described as a method that the roots always exposed to flowing nutrient solution similar to the principal of NFT. The nutrient film is as thin as possible in NFT, in contrast, in DFT method, the uninterruptedly flowing nutrient solution has approximately 5-15 cm deep with constantly depth (van Os et al. 2008) (see figure xx). This system has nutrient solution stagnated in the trough constantly. Therefore, it is suitable for plants that do not need much oxygen and like water such as lettuce and Chinese celery. Trough might be made from PVC 2. 5 to 4. 0 inches in diameter. Plants are fixed in holes on PVC pipe by uses of medium such as polyurethane foam. This system requires air pump to increase oxygen in the nutrient solution as plants roots are submerged in the nutrient solution.

The benefit of this system is that the high circulation rate and large volume of the nutrient solution makes it possible to control total organic carbon of the solution and give the solution a good aeration (Vestergaard 1998). The drawback is that high energy demand for pumping the nutrient solution throughout the system.

3. 5. 4 Floating Technique

A floating system is a variation of DFT. In this technique, plants are grown in large channels or basins. The plants are fixed to a piece of styroform and left floating on the surface of the water which lets the roots to be suspended in the water below (Vestergaard 1998) (see figure xx). This system also called raceway or raft system. The prototype of commercial size raft system was developed by Dr. Merle Jensen during 1981 -1982 (Resh 2004). Plants are grown in the beds of nutrient solution for example; the model of Jensen, a bed dimension is 60 cm wide by 20 cm deep by 30 m long. The floating boards are made of styrofoam which enable them to float on the nutrient solution. The dimension can be; for example, 2. 5 cm deep by 15 cm long by 58 cm wide, that can fit to the bed size. Crop will be hold in the hole on the board with about 3 cm diameter. Plant roots are immersed in the solution and the plant to be supported on a piece of foam above the solution. According to Resh (2004) as the nutrient solution bed is large, the volume of solution per bed (from the example dimension) is 3, 600 litres, therefore, the nutrient solution need to be sterilize before recirculating to prevent bacteria or germ that can cause diseases. The nutrient solution is recirculated through a nutrient tank of approximately 4, 000 – 5, 000 liters. Between the crops cycle, the boards need to be clean and sterilize. Moreover, in high temperature, this system can use chiller unit to cool the water to the suitable temperature.

The advantage of floating system is that the temperature is absorbed by the large volume of water, making the technique practical in regions where the oscillation of nutrient solutions temperature possibly a problem (Ikeda, 1985; Ito, 1994; Park et al., 2001; Both, 2005 cited in van Os et al. 2008). Another advantage is the utilization of area as this technique can provide high planting density. Third advantage is less catastrophic conditions in case of circulation pump failure due to high volume of nutrient solution in direct touch with the plant roots (Resh 2004). Althrough, disadvantage is the requirement of high cost of capital as well as the technical expertise required is high (Tyson et al. 1999).

3. 5. 5 Dynamic Root Floating Technique

In 1986, the dynamic root floating technique (DRFT) was developed in Taiwan by Dr. T. C. Kao at The Taichung District Agricultural Improvement Station. The objective in developing this system is to find a hydroponics technique which suitable for the tropics. The problem that found in this region is that high temperature of weather which leads to high temperature of nutrient solution that plants roots are submerged. This will cause less oxygen dissolved in the nutrient solution as a result crops productivity is decreased and the development of roots is not good enough because insufficient oxygen for plants to grow especially in summer. The concept of this technique is to induce plants to develop aero roots to solve the problem of lack of oxygen, particularly, at high temperature. The important part of the system is ridged culture bed. The bottom of the bed is in wave shape (see figure layout). The concave holes (No. 3 in see figure layout) below the floating boards provide extra space which enable aero roots to grow above the nutrient solution and therefore receive more oxygen. Instead of a non interruption flowing nutrient solution system like in the NFT, the water pump is frequently turned on and off to adjust the depth of the water. As an alternative, the pump can stay on at all times and a drainage system can be installed to vary the depth using nutrient solution level adjuster. However, this system can be adapted using PVC pipe instead of culture bed by adjusting solution level. (see figure xx)Moreover, different techniques are used to limit the temperature of the nutrient solution. For example, when temperatures rise above 30 degree Celsius, some sunlight is block out by semi-transparent polyethylene sheets that are hung over the roof. In addition, the DRFT channels can be are lined with insulating material to hinder heat transfer from the actual surroundings (Kao 1991).

The main advantage of this technique is that it can retain the temperature of the nutrient solution. Since oxygen is less soluble in warm water, the DRFT is compatible for hydroponic farming in tropical and subtropical climates such as those found in Taiwan, Singapore and Thailand (Kao, 1991).

3. 5. 6 Flood and Drain

This technique can be called Ebb and flow technique. It is a fundamentally subirrigation technique. The system is formed of a water-repellent flood and drain tray, tray containing an inert rooting medium, such as gravel, sand, and rockwool, a nutrient solution reservoir, an electric pump for deliver the nutrient solution from the tank to the flood and drain tray, and a piping system to assist the delivery of the nutrient solution from the reservoir to the flood and drain tray and its return (see figure xx). Nutrient solution is delivered into a superficial flood and drain tray by electric pump to about 1 inch depth for approximately 20 minutes and afterward allowed to drain back to the nutrient reservoir (Resh 2004). However, Jones (2005) suggested that the timing for inundation of the growing tray will be conditional on the atmospheric demand and phase of crop’s growth, as well as the water absorbability of the growing medium. It is very essential that the water be allowed to drain away thoroughly so as to avoid root diseases. If soaked spots continue to exist around the plant, algae growth, root diseases and inconsistent watering will occur (van Os et al. 2008).

The flood and drain technique has advantage over other systems. One of the most significant advantages is that this system is able to withstand high temperatures because the roots are only occasionally soaked in nutrient solution. For instance, if the nutrient solution becomes higher than a particular temperature the plant can become more vulnerable to diseases and root damage due to low oxygen around the roots in some hydroponic techniques (Resh 2004).

Jones (2005) pointed out some disadvantages of the flood and drain system. First, periodically substitute of the rooting medium is essential. Next, the inefficient use of valuable water and chemical as the nutrient solution need to be completely replaced every 2 – 3 weeks. Last, in the large system that has one nutrient solution tank, if there are any diseases infected one plant, the result will be the entire crops infect with disease.