International Journal of Agriculture and Environmental Research

Volume:01,Issue:02

www.ijaer.in

MINI REVIEW: HYDROPHONIC GREENHOUSE- THE COMMON PROBLEMS AND SOLUTIONS

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ABSTRACT

Hydroponic greenhouse farming has attracted much attention because of numerous advantages it presents to growers compared to the conventional form of farming, even though hydroponic greenhouse systems are faced by a number of challenges. The main challenges include the high start up and running cost, being skilled-labor intensive and requiring more time commitment, as well as the quick spread of infections to plants in the circulating system. Other key challenges facing this method of farming include the fact that hydroponic greenhouse systems are influenced by power cut, deficiency of some elements such as oxygen can result to low production, and a failure of the system that can result in a rapid plant death since there is no soil to act as a buffer. Moreover, plants in hydroponic greenhouses react quickly to changes in the surrounding with some reactions being almost irreversible such as hot weather or narrow oxygenation.

The challenge of high startup capital is minimized by using homemade greenhouse kits that are constructed using improvised materials that serve similar purposes with the material used in ready-made kits. The issue of high running cost that is primarily caused by the high cost of energy and purchase of readily-mixed solution recipes is minimized by using relatively cheap alternative sources of energy like wood chips and home-made solution recipes. The issue of demanding much commitment and management skills can slightly be minimized by automating the system and by using apps that would enable sensors to send their readings to devices such as phones and computers. These problems among others are discussed in this paper along with the best solutions of managing the challenges.

Keywords: Common problems, common solutions, greenhouse, hydrophonic, sustainable

Hydroponic Greenhouse: The Common Problems and Solutions

Human beings require food, water and living space for them to survive. However, these elements are not available in endless abundance since they are derived from biotic and abiotic sources, a factor that makes man inherently dependent upon the optimization of land area and the preservation of biodiversity [1]. With the world's rampantly increasing population that is anticipated to hit 9.5 billion from the current 7 billion people, the demand for quality food species is increasing at a dramatic rate, hence forcing mankind to adopt agricultural technologies such as greenhouse farming and most recently hydroponic greenhouse farming [2]. This research paper will explore the problems facing hydroponic greenhouse farming, and outline the possible solutions.

Definition and Brief Background Information about Hydroponic Greenhouse Farming

Hydroponic refers to a system of farming that utilizes nutrient laden water instead of using soil for plant nourishment. In simple terms, hydroponic is the art of growing plants on a growing medium without soil [3]. The widely used types of growing medium include coconut fibers, perlite, Rockwool, as well as gravel. Just like the conventional form of agriculture, plants absorb water through their roots with the only difference being that roots of hydroponic plants hang directly in the nutriment solution, either misted by the solution or enclosed in a container with a substrate.

Problems Facing Hydroponic Greenhouses

a) High Initial/Startup Cost

Construction of a hydroponic greenhouse system involves two phases; construction of the greenhouse itself, and secondly equipping it with a hydroponic system. Phase I has been explained above. Phase II involves installation of a large, centralized hydroponic system that could be able to support the number of crops expected to be grown. Experts suggest that a standard hydroponic system should be able to support a minimum of 40 large plants such as tomatoes, banana peppers and belly peppers just to mention a few, and a minimum of 72 small plants such as spinach, lettuce, and strawberries among many others [4]. This calls for the installation of a large and powerful hydroponic system that is capable for supporting a total of 112 plants. Acquiring such a system is expensive and in most cases beyond the ability of most of the ordinary farmers.

Other than equipping a greenhouse with a large and powerful hydroponic system, it is also essential for one to equip it with an arduino based climate control system which is also expensive. According to Hochmuth (2001b), the arduino based climate control system used

should be able to monitor the indoor environment through the various sensors installed (light intensity, temperature, carbon dioxide concentration, and humidity among other atmospheric conditions) [5]. A suitable system should be automatic and efficient in adjusting each variable by controlling the various respective devices such as heaters, exhaust fans, louvre doors, grow lights, solenoid valves, and pumps just to mention a few.

Modern hydroponic greenhouses require control systems with sensors that are capable of sending their readings over the internet so that they can be viewed remotely and with immediate effect from any smart mobile device or computer [6]. However, acquiring such a system is a major investment that requires large sums of money. According to Taig (2012), the initial cost of installing arduino based climate control system depends on a number of factors such as the availability of the systems within the locality, the efficiency of the system, transportation cost among other features [7].

Nevertheless, it is estimated that the price of an effective arduino based climate control system for a commercial hydroponic greenhouse ranges between $500 and $2000 [8,9].

Solution

There are a number of ways in which the initial startup cost of a greenhouse can be reduced. Nonetheless, it is essential to note that the initial expense of building a greenhouse must be incurred no matter the way one goes. This is because some inputs such as the lighting gadgets, containers, pump, and solution among others must be bought. Lighting is the most costly item and it is indispensable for the system to be effective [9].

The best approach for reducing the initial cost of acquiring a hydroponic greenhouse involves using PVC and timber for erecting a greenhouse frame rather than using aluminum and steel structures would significantly reduce the initial construction cost of a greenhouse. However, the structure is not likely to be rigid and durable like structures built using steel or aluminum. Coverings of a greenhouse vary from glass to rigid or flexible plastic materials [8]. Growers who are looking for possible ways of reducing the cost can use coverings whose cost matches that of their budget. For the coverings, one can decide to use ultraviolet (UV) light resistant polyethylene plastics which are often installed in two thick layers other than using a glass cover.

Nonetheless, growers should avoid improvising to a level that is likely to jeopardize production of the greenhouse or make it difficult for the environment inside the structure to be regulated. Moreover, other factors such as the local building codes, structural load from its own weight and environmental forces must be considered [10,11]. At the same time, building a greenhouse is a process that is not within the capacity of every grower. Persons who do not have this knowledge should seek advisory services from experts before embarking on the process, or even hire them to do the job for them.

The main problem with improvising some materials include the fact that the constructed structures are often not strong enough, are unable to fully regulate the environmental conditions, and they are not durable compared to structures made from the exact materials. For example, light transmittance is higher for polyethylene compared to that of glass. Moreover, UV lasts for about 4 to 5 years while glass covering lasts for more than 25 years [12].

b) High Maintenance and Running Costs

Maintenance and running costs for hydroponic greenhouse facility are also substantially high. According to Wells (2014); Tavassoli et al. (2010), one of the chief input expenses for maintaining a hydroponic greenhouse in a narrow and precise temperature range in order to attain optimal plant growing conditions [13,14]. This cost depends on oil prices or the cost of electricity with at times becoming extremely high especially when prices of oil have skyrocketed. Another major cost that makes operational cost of hydroponic greenhouse higher is the other resources required to maintain the large concentrations of nutrients in the water in order to feed the plants. The cost of energy required for pumping the water-mixed nutrients, run the fans, as well as the sensors is also considerably high.

Solution

In order to curb the problem of the high maintenance cost incurred while trying to regulate temperature range in a hydroponic greenhouse using the common fuels, farmers have been looking for alternative sources of energy that are relatively cheap. In some parts of the world such as in some areas of Canada, large scale growers have been reported to be using cheap alternative sources of energy such as wood chips. Natural gas and geothermal energy has also been in use in some parts of the world. For example, geothermal energy, which is believed to be a relatively cheap source of energy, is under experimentation in Holland and plans to experiment it in California are underway [15].

Solar energy is the most commonly used alternative source of energy for regulating temperatures in a hydroponic greenhouse facilities. It requires a significant investment that most growers are unable to meet. The main disadvantage with this source of energy is that it is unreliable, particularly in areas along the tropics [16]. Subsequently, growers who are situated in areas that offer an ideal combination of temperature and daylight hours usually have an upper hand in the market because their production cost is low. However, analysis of these possible solutions to the problem of high energy costs confirms that designing more energy efficient systems that can utilize renewable sources of energy could be the best solution to this challenge.

Another strategy of managing or counterbalancing the high maintenance running expenses is the idea of planting high value crops. Tomatoes and specialty crops such as yellow and red peppers and basil, as well as high-priced herbs often deliver profits that support greenhouses

[16]. Growers are advised to avoid crops that can do well in the open field and those that have low market value such as grain crops. Growing plants close together is another strategy that growers apply in order to maximize their profits that would cover the high maintenance and operational cost [17].

According to Steiner and Goodwin (2011), growing plants closely together make the greenhouse more lush and oasis-like on top of saving land since plants need less space to grow [18]. As a result, more produce is attained from a less space (Brown-Paul and Ross, 2014). A combination of high priced crops and the concept of growing plants closely in a hydroponic greenhouse help in soothing the pain resulting from the high cost of establishing and running a greenhouse with the potential for higher profits [19].

c) Demands Labor and Require a High Level of Management

Hydroponic greenhouses require a high level of management that often demands trained and experienced managers, especially if a project is undertaken for commercial purposes. Shaw et al. (2001) assert that commercial production of any crop using hydroponic greenhouses requires a high level of management skills [20]. However, it is crucial to note that the level of management highly depends on the sophistication of the system. For example, though commercial growers require experienced and trained personnel to be closely monitoring the systems, most of their systems are fully automated; hence require very little management of the hydroponic part of the system [21].

According to He and Ma, (2010); Cantliffe and Vansickle, (2012), hydroponic greenhouses are highly exacting and demanding systems that require management to have a greater amount of production knowledge, technical skills as well as adequate experience than any other greenhouse system [22,23]. For the production to be successful, growers must be committed to meeting all the demands in a timely and effective manner [24].

If the system is not fully automated, growers are expected to be regularly checking and regulating environmental conditions inside the greenhouse. For greenhouses located along the tropics where there is extreme seasonal change, the facility should be able to provide enough heat during the winter period and chilling or shading during the summer months [25]. The management should also ensure that the water used is of high quality and not contaminated since using low-quality water can put crops at a risk of attracting diseases. For example, AI-Amri (2007) suggests that the best sources of water include digging wells or using county water. AI-Amri further argues that surface water should always be avoided unless it is confirmed to be free from contaminations that may put the planted crops at a risk for getting diseases [26].

Another area that requires specialized training and experience is the germination area for seedlings production as well as cultivar and plant selection. Hydroponic greenhouses have some sections specifically meant for seedling germination [27]. However, most growers prefer having

a special room that is separate from the facility which has controlled environment, benches and artificial lighting that involves cool white fluorescent or high-pressure sodium lamps [28]. If the management is not able to control this environment so that the seedlings cannot get the most suitable environment, they are likely to die off, a misfortune that may lead to high loses and inconveniences.

Growers are also advised to allow experts choose crops for them especially if they are beginners. According to Alexander and Parker (2010), growers should plant crops that are specifically developed for greenhouse production and those considered as high value crops depending on the location of the farm. Failure to choose the right crop may result to losses considering the high start up and running cost of a hydroponic greenhouse [29]. Planting high value crops that have demand in the market depending on the market trend help in counterbalancing the high cost incurred during the production.

Production of the crops also requires commitment and a high level of know-how in order to get the best quality of produces. There are numerous techniques that are used in hydroponic greenhouse systems which largely depend on whether the system is closed or open, active (continuous flow) or passive (static); aggregate or liquid [30]. Growers are expected to apply a technique that is most suitable for them depending on the type of crop and other factors such as the type of system as highlighted above. Nonetheless, nutrient film technique (NFT) and the floating raft technique are the most widely used production methods for closed systems (systems that allow for recovery of surplus nutrient solution after use through the system).

Other areas that are labor intensive and require special management include adding nutrients to the water, pest management as well as harvesting and storing. There are numerous recipes available for hydroponic greenhouse systems which growers can purchase as a ready-to-mix product [31]. Alternatively, they can prepare their own modified formula depending on the type of crop being grown. Most growers prefer modifying their own nutrient recipes though this requires a lot of experience and knowledge because it has to be done without any room for errors. It is crucial to note that the pH of the solution is likely to change during the production because hydroponic nutrient solutions do not have the buffering capacity of the soil [30]. As a result, the pH together with the temperature, oxygen levels as well as soluble salts must be closely monitored by an expert.

Harvesting as well as storing also demand a lot of labor both skilled and semi-skilled. The exercises also require adequate knowledge and experience because most of the produces harvested from hydroponic greenhouse systems are highly perishable and are needed in the market being of the highest quality possible [32]. Each type of crop grown in the systems requires its own specialized form of harvesting and storage. For example, lettuces are often harvested with the roots still attached though excessively long roots are wrapped around the lower stem for packing, or even trimmed.

All these activities processes are labor intense and they need to be supervised by experts. According to the Ohio State University, 3,000 square foot hydroponic greenhouse used for growing lettuce requires approximately 140 hours for production, as well as 1,500 hours for harvesting, packaging and marketing. Vollebregt and Brantford (2014); Rathinasabapathi (2011) stress that this modern type of farming requires a high level of responsibility and diligence for one to be successful [33,34].

Hydroponic gardening requires regular and special attention regardless of whether it is automated or not. One must oversee the whole operation and head off major trouble at the pass [35]. Persons who first put forth a reasonable amount of time to learn how the system operates, how to commune with plants, as well as how to make the system work often get great rewards with those unwilling to commit this noble effort getting frustrated [32].

Solution

The problem of needing high level management skills can be obtained in a number of ways. The first and most vital technique is attending a course that offers specialized training on how to manage hydroponic greenhouses. Nowadays, the number of institutions offering this training has significantly increased as this ingenious technology is continuously being embraced by the society. Interested persons can get the training from firms manufacturing these kits, as well as from institutions of higher learning whereby hydroponic is treated as a special branch of agronomy [30].

The second strategy that helps in controlling the problem of hydroponic greenhouses requiring specialized and high level management skills include the use of mobile apps as well as automating the whole system [36]. Most of the modern hydroponic greenhouses are installed with control systems that have sensors, which are capable of sending their readings over the internet so that they can be viewed remotely and with immediate effect from a smart phone or a computer among other devices. However, growers should note that automating and using sensors in the system cannot substitute the necessary management skills for effective management of a hydroponic greenhouse if high and quality produce are to be reaped from the system.

d) Spread of Diseases and Pest Management

Management of pests and controlling spread of disease is another major challenge facing hydroponic greenhouse systems. According to DeKorne (2009), hydroponic greenhouses require careful management in order to prevent and detect diseases in advance because failure to do so can result in a quick spread of the diseases to other plants because they share same mixed-water solution as the source for their nutrients [37]. Puri and Caplow (2009); Jensen (2007) assert that a disease free system can only be achieved by maintain a high degree of sanitation [38,39].

Most of the devastating diseases occur in hydroponic greenhouse systems when water borne pathogen is introduced into the system or when water molds such as *Phytophthora* and *Pythium*. Water molds swiftly spread to all crops within the circulating system because they have motile spores [40]. Unfortunately, there is no any registered fungicide that can control these pathogens on greenhouse crops, meaning that an outbreak of this disease automatically lead to a complete loss of the planted crops.

Solution

Nichols and Lennard (2010) suggest that the best approach for preventing an outbreak and spread of diseases in a hydroponic greenhouse is by maintaining a high level of sanitation [41]. In addition, experts urge growers to drain all solution tanks and clean all the equipment used using a bleach solution or any other suitable disinfectant prior to planting subsequent crops. In case of an outbreak of an infection in the germination area, benches and systems used for germination must be cleaned and disinfested. It is crucial to note that most of the diseases that can spread to all other crops in the circulating system can be prevented by maintain a high level of sanitation, even though some infections require adoption of special approaches [42].

Another effective strategy of preventing outbreak and spread of infections in hydroponic greenhouses include adopting appropriate measures to prevent mites and insects such as aphids, whiteflies and trips, from entering the greenhouse. One of the most effective ways of preventing insects from entering the greenhouse is by the use of insect screening on the sidewalls of the structure in case sidewall ventilation is used. Insect screening should also be used on any other entry point [43].

Moreover, plants should be inspected on daily bases in an attempt to detect signs of insects, diseases and mites. In case there is any sign that shows likelihood of an infestation, swift and appropriate measures should be adopted in order to prevent it from reaching adverse levels. Immediate removal of the infected plants once they are discovered is among the most effective methods of preventing spread of diseases[43]. Other measures include use of greenhouse labeled pesticides.

According to Takashima (2007), there are very few pesticides that are labeled for greenhouse production particularly for some crops such as lettuce [44]. This calls for adoption of preventative management as well as early detection of disease measures in order to curb the problem in a timely manner. Nutrient solutions used for feeding the plants provide ideal conditions for growth of algal. However, shading solution-tanks can prevent their growth because algae thrive in well-lit and wet sites [45].

e) Other Mild Problems Facing Hydroponic Greenhouse

Other problems associated with hydroponic greenhouse include the fact that they are influenced by power cut; deficiency of some elements such as oxygen can result to low production, thus losses; and the fact that a failure of the system can result in a rapid plant death since there is no soil to act as a buffer. In addition, plants in hydroponic greenhouses react quickly to changes in the surroundings, with some reactions being virtually irreversible such as hot weather or narrow oxygenation [23].

Nevertheless, these are mild and foreseeable challenges that can be prevented if proper measures are put in place in advance. For example, the problem of power failure can be prevented by ensuring that there is always an alternative source of energy or there is a power backup[46]. The problem of system failure can be avoided by ensuring that regular check and maintenance of the system is done. According to Weiner (2009), hydroponic greenhouse should be checked preferably on the daily basis so as to ensure that everything is serving its purpose [47].

Any malfunction spotted should be addressed with immediate effects. Moreover, automating the system plays a leading role in detecting any malfunctioning since it results into changes in the environment inside the greenhouse that can be detected by sensors. Nonetheless Nicholls (2013); Brown-Paul (2013) suggest that growers should not absolutely rely on the sensors because they can at times fail to detect the changes. Instead, they should be inspecting the system manually as much as possible [48,49].

Despite these challenges facing hydroponic greenhouse farming, this ingenious and modern method of farming is among the most productive techniques of crop production. It results into higher production; plants can be grown anywhere and during any time of the year regardless of seasons; the system conserves water by more than 90%; it prevents soil borne diseases; and plants grows two times faster than in the open field [50].

Other advantages include the aspect of requiring lesser space than the conventional method of farming and produces harvested from hydroponic greenhouses are reported to be of higher nutritional value than those from the open field [51]. In general, the benefits accrued as a result of using this method highly outweigh its disadvantages [52]. However, there is need for carrying out further research in order to introduce lasting and economical solutions to the problems discussed in this paper.

Conclusion

The main problems facing hydroponic greenhouse systems include the high startup and running cost, being skilled labor intensive and requiring more time commitment, and as well as the quick spread of infections to all plants in the circulating system. Other challenges facing this method of farming include the fact that hydroponic greenhouse systems are influenced by power cut; deficiency of some elements such as oxygen can result to low production, thus losses; and the

fact that a failure of the system can result in a rapid plant death since there is no soil to act as a buffer. In addition, plants in hydroponic greenhouses quickly react to changes in the surroundings with some reactions being almost irreversible such as hot weather or narrow oxygenation.

The problem of high startup capital can be minimized by using homemade greenhouse kits that are constructed using improvised materials which serve similar purposes with the material used in ready-made kits. The issue of high running cost that is primarily caused by the high cost of energy and purchase of readily-mixed solution recipes can be minimized by using relatively cheap alternative sources of energy like wood chips and home-made solution recipes. The issue of demanding much commitment and management skills can slightly be minimized by automating the system and by using apps that would enable sensors to send their readings to the devices such as phones and computers. However, growers should note that automating and using sensors in the system cannot substitute management skills necessary for effective management of a hydroponic greenhouse.

Acknowledgments

This study was presented as a full text report at international conference BIOENG2015.

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