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Aquaponics - An Advanced Tech for Land and Water Management

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Abstract

Water, being a critically inevitable resource for agriculture, needs to be managed effectively. Globally, aquaculture is recognized as an essential source for proteinaceous food production in animal food production sector. However, nutrient pollution caused by aquacultural effluent let into rivers lead to amplified growth of certain phytoplankton as a consequence declines the water quality. As freshwater availability is limited, complete utilization of water is necessary to ensure resources for the future. To resolve this, 'Aquaponics' is an efficient technique that ensures a maximum water reuse. Aquaponics integrates ecological cycles by combining fish culture with plant culture and proves to be advantageous in water scarce areas. In this article, media-based aquaponics system is discussed due to its availability of significant surface area for microbes. This paper manifests the likelihood of water and land management engaged by aquaponics in food production. The conclusions are applicable, sustainable and significantly land and water conservative.

Introduction

Due to rapid urbanization, land resources for agriculture have been decreasing. Rapid growth of human population has also increased the demand for food. In 21st century, feeding the developing population is one of the main biggest challenges and search of sustainable and more productive systems are the quest among the researchers. Development and application of innovative technologies for intensification of aquaculture to increase the water and nutrients reuse and minimizing the environmental impacts are the possible solutions to the further expansions of the aquaculture.

Growing population and food demand necessitate the understanding of crop water management in irrigation. Water sustainability in agriculture can be achieved only through appropriate management practices. Water management in agriculture and aquaculture should be coordinated as water is a critically inevitable resource for both. Traditional agriculture methods for growing plants require huge land space, time, and manpower. Consequently, there is an increasing concern for safe and sustainable food sources, which leads to the need for new agriculture methods. Traditional aquaculture has some disadvantages like extreme water usage, extensive land usage and release of nutrient rich effluent water due to the improper feed management and low nutrient accumulation in cultured animals.

The demand for culture fisheries exist in society with concern for marine pollution. In most cases, the effluent water is not treated properly and when it is let into water bodies they affect the good quality water by nutrient pollution. Secondly, the non point sources of pollution such as pesticide runoff from agriculture affect water bodies including groundwater. This effluent needs intense water treatments which are expensive and complex. The potential of aquaponic system is to grow fish at high density, maintain acceptable water quality, limit water exchange, and generate a marketable crop has attracted a lot of interest.

Aquaponics System

The combination of aquaculture and hydroponics is known as aquaponics, in which both the plant and fish species can be cultured at the same time. Aquaponics system converts the fish faecal waste into valuable food products and it is a soilless agriculture system. Nutrients required for plant growth was provided by fish feed and its waste. In the aquaponics system water, energy and fish feed are the three main physical inputs in any type of production system of different sized animals (Love *et al*., 2015). Aquaponics system can be used as an alternate to overcome the disadvantages of the traditional plant and fish culture practices because both agriculture and aquaculture requires huge land space and water resource, manpower, consumes time.

According to FAO (2014), among the three general types of aquaponics systems (media filled bed system, floating raft and nutrient film technique) media filled bed system is majorly successful in growing fruiting plants, as the plant growing media is fixed and bear the weight of these plants on it. There is no requirement of a separate biofiltration system in this technique because the plant bed with large surface area acts as a filtration unit. Hence, the cost of operation can also be minimized. Among these types, media filled aquaponics system is commonly followed in the small scale aquaponics units, because of their low initial cost and efficient space utilization capacity. The available tanks or waste plastic barrels, bath tubs can be used to culture the fish and plants in small scale. In large scale, excavation and HDPE lining must be done which is very much effective and economy instead of constructing the whole tank and plant bed.

Figure 1: Recirculating Aquaponic System

Major Components

1. Plant Culture Unit

Plants in hydroponics and aquaponics grow more rapidly compared to their counterparts, which grow in the soil because the root system is in direct contact with nutrients and nutrient uptake is more efficient in an aqueous phase. The ratio of fish culture unit to plant culture unit was taken as 1:2 (Shete *et al*., 2015). Seasonal plants can be chosen based on the need, demand and the available nutrient concentration of cultured water. According to the statement of Somerville *et al*. (2014), tomato, chilli, brinjal are the high nutritional requirement plants and media beds which provided with right depth (at least 30 cm) are having the capability to grow all the vegetables. Most types of veggies, greens, herbs, fruits and flowers can be cultured under the recommended conditions of the specified species. In terms of the floriculture, ratio of fish culture unit to plant culture unit can be increased to 1:3 and 1:4 because floriculture requires only less amount of nutrients since there is no fruiting.

2. Animal Culture Unit

In aquaponic units, some fish species have shown excellent growth rates. Tilapia, Catfish, Largemouth bass, Asia sea bass, Barcoo grunter, Trout, Char, Grayling, Murray cod, Common carp, Silver carp, Grass carp and Indian major carps are all appropriate for aquaponic farming. Some of these species, which are found all over the world, thrive in aquaponic systems. The ratio of fish culture unit to plant culture unit was taken as 1:2 (Shete *et al*., 2015). Tilapia is known as "aquatic chicken" due to its adaptability to a wide range of environmental conditions, high growth rate and ability to grow and reproduce in captivity like aquaponics system and feed on low trophic level. As a result, the fish became an excellent candidate for recirculating aquaponics system, especially in tropical and subtropical regions. Indeed, tilapia became a versatile species for use in aquaponics system which is now practiced in most of the developed countries worldwide. For hardy fishes the optimum preferred temperature range is 27-30 °C and the preferred feeding rate is 2% of their body weight. The optimum stocking density ranges from 0.5-1.0 fish ft^{-2}.

Minor Components

1. Media

Media provides support and surface area for plant growth, promotes bacterial growth for nitrification, aerates the roots by voids and purifies the effluent water. The selection of media was based on the diameter, specific surface area, cost, availability and weight per unit volume. Commonly available, any small media like river sand, crushed stones, granite grit and fine gravels can be used as a media for plant growth, recommending particle sizing ranging from 2-4 mm was highly preferable. Large sized media provides more voids space comparatively which do not retain the water for longer periods.

2. Pump

Submersible pumps are best suited for aquaponics. This lifts the effluent water from the fish culture unit to the plant culture unit. The main advantage of this type of pump is that it prevents pump cavitation. Submersible pumps are more efficient than jet pumps. The selection of pump horsepower is based on the head and discharge.

3. Aerator

Air pumps inject air into the water through air pipes and air stones that lie inside the water tanks, thereby increasing the DO levels in the water. Air stones are located at the end of the air line, and serve to diffuse the air into smaller bubbles. Small bubbles have more surface area, and therefore release oxygen into water better than large bubbles; this makes the aeration system more efficient and contributes to saving on costs. It is recommended that quality air stones be used in order to obtain the smallest air bubbles. Quality air pumps are an irreplaceable component of aquaponic systems, and many systems have been saved from catastrophic collapse because of an abundance of dissolved oxygen.

4. Test Kit

Simple water tests kits are a requirement for every aquaponic unit. Colour-coded freshwater test kits are readily available, fairly economical and easy to use, and thus these are recommended. These can be purchased in aquarium stores or online. These kits include tests for pH, ammonia, nitrite, nitrate, general hardness and alkalinity hardness. Other methods include digital meters or test strips. If using digital meters for pH or nitrate, be sure to calibrate the units according to the manufacturer's directions. A thermometer is necessary to measure water temperature. In addition, if there is risk of saltwater in the source water, a cheap hydrometer, or a more accurate but more expensive refractometer, is worthwhile.

5. Others

Polyvinyl Chloride (PVC) pipelines are best suited for water transfer. Timer's application in water supply regulates the recirculation period, whereas control valve at inlet and outlet promotes recirculation flow rate.

Water Quality Parameters

Water quality parameters are essential for fish growth and survival. The change in water quality parameters affects the plant and fish growth, feed efficiency, leading to pathological changes and even mortality under extreme conditions. Water quality monitoring is substantially less for an aquaponics system than a recirculating aquaculture system. Fish reared in aquaponic systems require good quality water in terms of dissolved oxygen, temperature, ammonia, nitrate, nitrite, alkalinity and pH within permissible species-specific limits. The concentration of dissolved oxygen less than 2 mg L^{-1} retard the growth of nitrifying bacteria and thereby decreases the nitrification rate in nitrifying filters. The optimum range of pH for nitrification can generally between 7 and 9. The optimum water quality parameters to maintain all the three groups of organisms (fish, plant and bacteria) are temperature: 18-30 °C, pH: 6-7, DO: 5 mg L^{-1}, Ammonia: <1 mg L^{-1}, Nitrite: <1 mg L^{-1} and Nitrate: 5-150 mg L^{-1}.

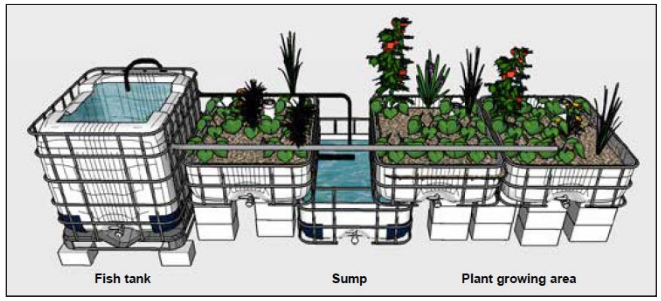

Figure 2: Small Media Bed Aquaponic System

Conclusion

The world is getting urbanised and there is no room for agriculture and aquaculture with space and resources being limited. Therefore aquaponics is considered to be a better alternative among the upcoming technologies. Aquaponics is not only restricted to its betterment but also it reduces the impacts of traditional agriculture and aquaculture practices quadruply. The system described above have the following advantages *viz*.

• During the operation of aquaponic systems, 90-95% of the water is recycled on average.

• Aquaponic utilizes less water; reduce agricultural waste and pollution compared to conventional agriculture systems.

• No synthetic fertilizers and slight pesticides.

• Multiple crops and fish can be developed from the same system.

• Relatively small spaces required.

• Utilization of non-arable land.

Hence the aquaponics system is an emerging technology to address the water and land management in a sustainable way. It not only minimizes the environmental impacts, but also maximizes the economy of the people within the limited space.

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