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Aquaponics: The Water Conservant Integration of Aquaculture and Crop Cultivation

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Abstract: The advancements in the field of medical sciences have been successfully increasing the gap between the birth and the death rates over the past 10 decades, resulting in a drastic rise in population, in turn triggering the increasing need for food, water and land. To satisfy the need for food various advancements have been made in the fields of Agriculture with very few of them addressing the generated scarcity of land and water. Besides high water requirements current practices also requires a considerable amount of land. Talking about the smaller crops like lettuce, tomatoes, swiss chards, basil, mint, peppers, cucumbers, beans, peas, squash, broccoli, cauliflower, cabbage and other green leafy vegetables with weak stems, these plants are short lived and have an immature root system only upto centimeters in depth. Studies suggest that only 10% of the water supplied to these crops and about 20% 0f fertilizers are effectively absorbed by them, rest percolates into the ground and becomes a part of the ground water. This makes the system ineffective and inefficient in terms of resources and efforts. To combat the challenges in the way of meeting the food demands of the society there was a need to develop a system that would consume fewer amounts of water and land and produce a considerably high amount of food. This was addressed by the development of integrated agricultural and aquaculture practice termed as Aquaponics.

Keywords: Aquaponics, Aquaculture, Hydroponics, Soil less cultivation, Fishes, Agriculture, High yield, Environment, Food security, Food scarcity, Vertical farming, Fish farming, Proteins, Sustainable development, waste management, Energy conservation, Resources management, Recycling of water, Organic food, Bio accumulation, Indoor cultivation, Photo-synthetically active radiations, PAR.

INTRODUCTION

With the increasing need for food in developing country like India, the agricultural industry is trying hard to fulfil the demand for food by using various techniques including grafting, use of chemical fertilizers and so on. Some of these practices pose serious health hazards to the environment and its inhabitants. To combat these challenges aquaponics may be an excellent way to feed the growing population. Aquaponics is basically the the integration of aquaculture and hydroponics and there by the art of maintaining the an equilibrium between the two. In aquaponics the crops with immature root system and weak stems are cultivated soilessly in a vertical manner to reduce the use of land or rather increase the amount of food generated from a particular piece of land, the plant roots are directly supplied with the required nutrients from the processed waste generated form an aquacultural system.An aquaponics system consists of 3 major components viz. fish growing tank, a digester cum filtration unit, and the grow towers topped with a reservoir.

Aquaponics successfully reduces soil borne diseases, parasitic and insect infestations thus increasing the productivity of a plot of land. In developing coastal countries like India, not much emphasis is laid upon the phenomena like bio-accumulation, parasitic infestations and the effects of water and soil pollutants on the live fishes and vegetables which pose serious hazards to the humans consuming them. Besides this the hazards posed by current agricultural practices viz. space, water and losses due to seepage and surface evaporation, maintenance and disinfection are also reduced to a considerable extent

I. BASIC PRINCIPLES

The waste generated by the fishes mostly constitutes of Ammonia (NH3) and Ammonium (NH4), oxidation of these components by the bacteria Nitrosomonas under aerobic conditions gives out nitrites (NO3-) and on further oxidation the formation of nitrates(NO4-) by nitrite oxidizing bacteria of nitrobacter genus. These bacteria require a considerably high surface area to colonise and efficiently complete the nitrogen cycle. This surface area is created provided in the filtration system and the nitrate rich output water is then circulated through the grow towers for the plants roots to absorb the nutrients . Fig. 1 Aquaponics Cycle. Table 1. Ideal parameters for aquaponics as a compromise between all three organisms. The bacterial conversion of ammonia and nitrites to nitrates is the key factor that promotes the absorption of nutrients i.e. the waste generated by the fishes by the plants. The reactions that take place in the filtration unit of the aquaponic system are as follows:

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$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 2H_2O + 4H^+$ (Nitrosomonas)

$2NO_2^- + O_2 \rightarrow 2NO_3^-$ (Nitrobacter)

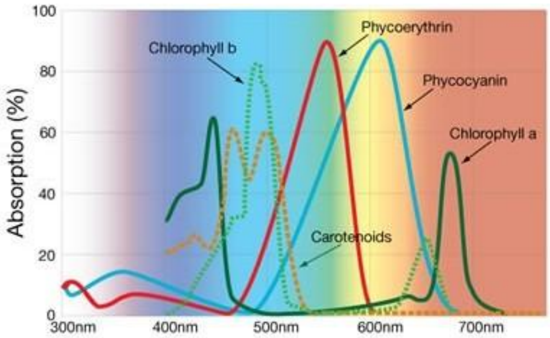

Fig 2. Percentage absorption of various spectrums of light

The light requirements of the crops may be fulfilled with natural sunlight if the setup is out doors or the advanced automated LED based lighting system with PAR(Photosynthetic Active Radiations) can be effectively used to simulate multiple days in 24 hours resulting in up to 4 times faster plant growth.

II. EXISTING TECHNIQUES

Aquaponics systems have been implemented in various forms and dimensions. The basic components of most aquaponics systems include a fish tank and a soil less plant bed. The plumbing components, aeration, filtration components, the type of plant bed and the amount and frequency of water circulation are the variable components. Filtering out the solid wastes increase the efficiency of the Aquaponics system. The most commonly used aquaponics practices are:

1. NFT
2. Media-filled beds
3. Raft

Each of these methods is based on a hydroponic system design, with accommodations for fish and filtration. Nelson and Pade, Inc.®'s Clear Flow Aquaponic Systems® utilize the original raft system designs with enhancements to increase productivity

Parameters	Range
Temperature (^{o}C)	18-30
pH	6-7
Amonia (mg/litre)	<1
Nitrite (mg/litre)	<1
Nitrate (mg/litre)	5-150
Dissolved oxygen	>5

I. Raft

A raft system (also known as float, deep channel and deep flow) utilizes the polystyrene boards (rafts) suspended(floated) on top surface of water and the plants are grown above the rafts with the roots being suspended in the water. These tanks may of may not contain fishes. If the bedding tanks do not contain fishes the water is continuously circulated through the fish tanks passing through the filtration components of the system.

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Fig 3. Raft Culture

The bacteria which are important for the system are cultivated in the filtration unit and even in the rafts. This increases the volume of water held in the tank and there by act as a buffer to the change in water parameters, reducing stresses on the life stock and rapid alterations in the water quality. This is one of the major benefits of the raft system. In addition, the University of the Virgin Islands and other research programs refined this method during 25 years of research. Nelson and Pade, Inc.® utilizes the raft method as the base of their highly In a commercial system, the raft tanks can cover large areas, best utilizing the floor space in a greenhouse. Plant seedlings are transplanted on one end of the raft tank. The rafts are pushed forward on the surface of the water over time and then the mature plants are harvested at the other end of the raft. After the harvest harvested, the rafts can be replanted with seedlings and placed at the starting end of the tank. This optimizes floor space utilisation, which increases the productivity of any commercial greenhouse set up to a considerable extent.

2.NFT

In Nutrient Film Technique(NFT) the plants are grown in shallow depths of water circulating through the roots continuously within a channel. A thin film of water containing nutrients and oxygen continuously flows through the plant roots, providing the plant roots with oxygen, nutrients and water. Similar to what happens in the Raft system the water is circulated through the channels via filtration unit and then back to the fish tanks. There is a compulsory need of a filtration system in Nutrient film technique as the amount of water utilized is competitively less as compared to the raft system, thus the amount of surface area available for bacteria culture is not Fig 4. Nutrient Film Technique
sufficient and the plumbing used in an NFT system is usually not large enough because the organic nature of the system and "living" water can clogg the pipes and tubes of small nature. NFT aquaponics shows potential but, at this time, it is used less than the other two methods discussed here.

3. Media-filled bed

The media-filled bed system utilizes container or a tank filled with perlite, gravel or another media as the medium for the plant roots. This bed is flooded and drained in periodic cycles with water contaminated in the fish tank. The fish waste, is decomposed and reduced to plant consumable nutrients in the grow beds. Often worms cultivated in the grow beds to speed up the decomposition of the solid waste there by maintaining a healthy environment within the media bed. Media filled bed system has lesser components and it eradicates the need of a filtration system there by making it convenient for use and setup.

There is a limitation in the productivity of this system and the yield of crops is a bit low as compared to the other two methods thus the application of this method is limited to micro scale to hobbyists.Although aquaponics has the promise, there are also potential challenges that may limit its progress as a widespread food production technology. The highly technical nature of aquaponics is often overlooked: a balanced system must match the demands of the plant and fish species, plus the crucial nitrifying bacteria (Tyson, Simonne, White & Lamb, 2004). Aquaponics practitioners shall be comfortable with the design and construction of systems, with the never ending scope of developing new techniques and integrating various techniques together.

Fig 5. Media Filled Bed

The knowledge physics of water flow, testing and troubleshooting water chemistry and the biology of both fish and plants in order to sustain a system in the long-term should be considered. Additionally, running a profitable commercial aquaponics system requires knowledge in business, finance and marketing. The rise of aquaponics systems is also threatened by external factors such as the wild versus farmed fish debate, strict regulations, cultural ignorance of tilapia (a fish commonly used in aquaponics because of its hardiness) and food safety issues (Graham, 2003). For aquaponics to overcome these roadblocks, there is a growing need for more rigorous preparation in a variety of subjects and increased public awareness.

III.BENIFITS OF AQUAPONICS

The integrated practice of aquaculture and hydroponics is quite new to the market and the scope of utilizing this technique to grow high quality food around the world is tremendous. Some of the many advantages of aquaponics system for food production are:

- The waste water is utilized and recycled within the system, thus the waste water production and costly treatment of waste water is avoided.
- The chemical ingredients used for the dosing of nutrients in hydroponics are eliminated thus the system produces organic foods.
- Aquaponics provides nutrients to the plants through a natural source thus the chemical contaminants in the system are almost zero.
- Since there is no soil used the major threat to the agriculture i.e. the soil borne diseases are minimized.
- The loss of water through evaporation and seepage is prevented.
- There is almost zero weed production thus the water and nutrients are used and utilized effectively.
- There is no space restrictions in Aquaponics due to the abundant availability of the nutrients thus more number of crops can be cultivated over a smaller stretch of land.
- With the real-time utilization and production of nutrients the stocking density of both fishes and plants can be increased to a considerable extent.
- There is no need of pesticides and other in organic harmful chemicals thus the produced goods are safer for consumption.

IV. PROPOSED MODEL

Most existing models focus on horizontal where as the proposed model focuses on the utilization of space in vertical manner. The model includes a set of vertical grow towers placed on top of a grow tank and a filtration unit which holds the filter media. An illustration of the model is shown in Fig 5. This technique can be implemented as a domestic indoor setup or on a commercial scale in a green house or even on the unutilized dead walls of buildings. This farming technology can ensure crop production all year-round in non-tropical regions. 1 indoor acre is equivalent to 4-6 outdoor acres or more, depending on the crop. For strawberries, 1 indoor acre may produce yield equivalent to 30 acres. A building 30 storey high with a basal area of 5 acres (2.02 ha) has the potential of producing crop yield equivalent to 2,400 acres (971.2 ha) of traditional horizontal farming. Expressed in ratio, this means that 1 high-rise farm is equal to 480 traditional horizontal farms. This will not only utilize the unused wall of the building but will also generate a

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handsome amount of capital out if it. Besides the commercial benefits the system will also help in the maintenance of considerable amount of oxygen there by reducing the effects of greenhouse gases thereby contributing to a greener environment.

Fig 6. Illustration of the aquaponics model.

V. RESULTS AND CONCLUSION

Perhaps because challenges to aquaponics in education may be intrinsic to the technology or the educational setting, every aquaponics in education situation seems to be unique. This quality makes it difficult to suggest exact, concrete solutions to every challenge. However, it seems likely that possessing a passion for aquaponics in education and cultivating a supportive community will assist educators in acquiring expertise and uncovering individualized solutions. Nevertheless, the findings of this study can provide some helpful guidelines to educators who are interested in implementing educational aquaponics systems. Broad guidelines emerged from this study that may be useful for establishing the foundations of an aquaponics in education project:

1. Reflect on passion for aquaponics in education and the factors motivating implementation of the educational aquaponics system.
2. Reach out and develop a supportive community, including other educators, administrators, local businesses, government-run fish hatcheries, universities and the aquaponics industry.
3. Cultivate aquaponics expertise, especially through community connections.
4. Establish a plan and desired goals for implementing aquaponics in education but remain flexible.
5. Explore solutions for summer or holiday care early in the process and planning.

VI. ACKNOWLEDGEMENT

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VII. DECLARATION

We hereby declare that the Project titled "**AQUAPONICS:The Water Conservant Integration of Aquaculture and Crop Cultivation**" submitted by us is based on actual and original work carried out by us. Any reference to work done by any other person or institution or any material obtained from other sources have been duly cited and referenced. We further certify that the research paper has not been published or submitted for publication anywhere. We cede the copyright of the research paper in favour of Sayed Mohammed Hadi.

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