THE PRACTICALITY AND SUSTAINABLITY OF AQUAPONIC AGRICULTURE VERSUS TRADITIONAL AGRUCULTURE WITH EMPHASIS ON APPLICATION IN THE MIDDLE

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THE PRACTICALITY AND SUSTAINGABLITY OF AQAUAPOINC AGRICULTURE VERSUS TRADITIONAL AGRUCULTURE WITH EMPHAISS ON THE MIDDLE EAST

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ABSTRACT

This thesis examines the practicality and sustainability of growing crops via aquaponic methods as opposed to traditional soil based agriculture. Furthermore it will examine the efficacy of aquaponics in terms of plant production and overall product quality. The goal is to determine whether or not aquaponic agriculture is advantageous to traditional agriculture in certain niches of industrial food production, particularly areas where environmental impact as well as reliable supply of water is an issue. An experiment designed to reliably examine both aquaponic and soil based agriculture will be constructed and monitored over the course of the semester and will be dependent on a final crop harvest once a growing cycle of three months has been completed. Variables such as dried plant weight and overall plant quality will be analyzed in order to quantify the capabilities of aquaponics as opposed to soil based growing techniques.

INTRODUCTION

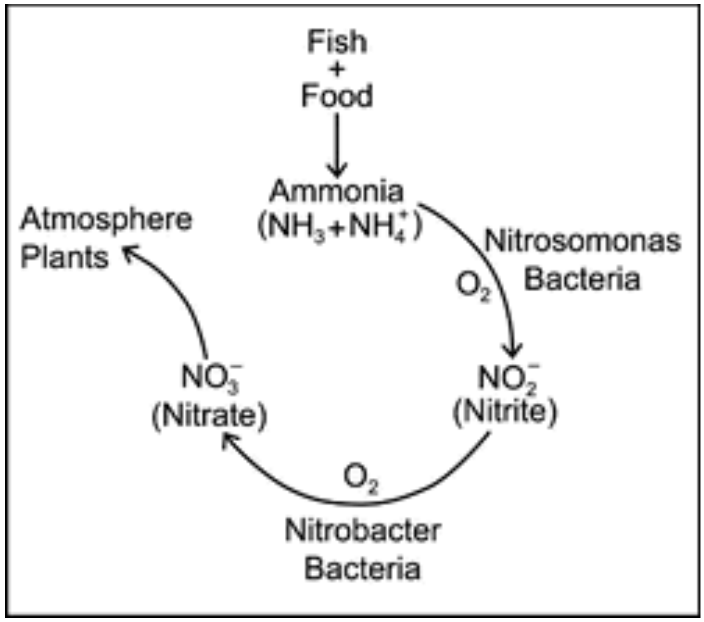
Traditional agriculture is having trouble, water supplies are running out and food demand is only increasing, and there is also a growing demand for crops grown without the use of chemical pesticides and fertilizers. Just because we've always done things one way, doesn't mean that's the best way. This is true of many things in life, and as technology advances many things change. Technological advancements have been very beneficial to the world in terms of food production. The chemical fertilizers and pesticides that came out after World War II led to greater crop yields, use of industrial mechanization led to an increase in the area of land a farmer could work, and genetic modification resulted in significantly increased crop yields as well as various other effects. However, all these improvements were just additions to the age old system of planting crops in dirt, watering them, and waiting on them to grow. Recently though, there has been a radical new approach to growing produce, aquaponics. With aquaponics the need for soil is completely eliminated, and the need for chemical fertilizers is also eliminated (Flavius & Grozea, 2011). Growing plants without soil is almost as strange as growing organs without bodies, but both of these new scientific revolutions, in theory, have the potential to significantly benefit humanity and make the world a better place. If aquaponics can replace a segment of traditional agriculture this could be a turning point in human history, enabling significant increases in food production, as well as reducing environmental impact on an already stressed planet. Furthermore aquaponics would enable things such as growing crops in space stations and on long voyages by astronauts exploring deep into space. The viability of aquaponics must be examined in detail though if we are going to rely on something so radically different to provide something so essential as food.

AQUAPONICS EXPLAINED

Aquaponics is a method of growing pants, particularly vegetables, in a soilless medium where all the nutrients that the plants require to grow are provided via water that is circulated around the plants root systems. This process differs from hydroponics due to its use of fish to provide the essential nutrients instead of manufactured hydroponic fertilizers. The use of fish to grow plants in aquaponics also has the added benefit of providing fish to harvest as well as plants. Aquaponics is essentially the combination of aquaculture (farming fish), and hydroponics (growing plants in a water based medium).

The secret to aquaponics is bacteria. An aquaponic system is an almost entirely closed loop system where the only inputs to the system are fish food and sunlight (Bernstein, 2014). When the fish feed they produce waste which is primarily ammonia which is water soluble and begins to cycle through the aquaponics system (Flavius & Grozea, 2011). This ammonia is toxic to the fish and useless to the plants (Bernstein, 2014). This is where bacteria come into play, naturally occurring nitrosomona bacteria use oxygen to convert ammonia into nitrite and then nitrobacter bacteria convert the nitrite into the nitrate that the plants need in order to thrive (Nitrogen Transformations in Aquaponic Systems, 2015). This nitrate is harmless to the fish and required by the plants and the key to the success of aquaponics (Nitrogen Transformations in Aquaponic

Systems, 2015). This nitrate is what functions as the plants source of nitrogen and thus what eliminates the need for fertilizers to be added.



There are several types of aquaponic systems, each has its own advantages and disadvantages but media filled beds tend to be the most popular for home gardeners, and nutrient film technique and deep water culture tend to be used more in commercial operations (Bernstein, 2014). Media filled beds are the easiest to build and maintain, they use containers filled with expanded clay known as Hydroton or ¾ inch gravel rock. Water from the fish aquarium is pumped into the media beds where the plants are grown. These beds can either be set up to flood to a set level, drain, and then repeat, or as a constant flow which holds the water at a steady level and fills at the same rate it drains. Media beds are useful due to their ease of operation, they rarely need to be monitored and as long as the water pump functions properly they are completely automated (Bernstein, 2014). The benefits of media beds that other forms of aquaponics lack are mainly the ability of the system to support much greater levels of beneficial bacteria and decomposition of nutrients which result in higher levels of potassium and phosphorous that fruiting plants require (Bernstein, 2014). Disadvantages of media beds are difficulty harvesting whole plants due to plant roots that become entangled in the gravel media. Things that are routinely harvested such as lettuce are easiest grown in other systems but large plants such as tomatoes require the structure and high nutrient profile available in media beds (Bernstein, 2014).

Nutrient film technique (NFT) systems are constructed of small pipes that run horizontally with holes every foot or so that plants are planted into. The nutrient rich water is trickled down the pipes and the plant roots dangle down and absorb nutrients out of the thin film of water that moves down the pipe. This system is really only suited for small plants that have a low nutrient requirement such lettuces (Bernstein, 2014).

The final option is deep water culture. This method uses large volumes of water pumped from fish aquariums into long troughs that are kept at a constant level and plant are suspended above the water, usually in Styrofoam rafts with the root systems dangling down into the water absorbing nutrients. This method is most commonly used by commercial growers due to its ability to produce large volumes of plants in a relatively small space and ease of harvest due to the roots not clinging to anything (Bernstein, 2014).

IMPORTANCE OF THE NITRIFICATION PROCESS

The nitrogen cycle is the heart and soul of aquaponics. In order for it to be running at its peak there are several variables that must be adjusted in order to keep bacteria happy. Nitrifying bacteria occur naturally but in order for them to thrive in a system they need lots of space. The bacteria colonize the surfaces in an aquaponics system so any method of maximizing surface area translates directly to more bacteria and a stronger biological filter to convert ammonia to nitrates and purify the water (Bernstein, 2014). Expanded clay (Hydroton) is porous much like a sponge and all of that internal surface area is colonized by bacteria. The nitrifying bacteria do best at temperatures between 77-86°F (Nitrogen Transformations in Aquaponic Systems, 2015). When temperatures fall below 32°F or rise above 120°F these bacteria start to die off and system nitrification is halted (Nitrogen Transformations in Aquaponic Systems, 2015). Another factor that must be accounted for is ph of the water. Nitrifying bacteria thrive at a ph between 7.3 and 7.5, when ph falls below 6.0 nitrification ceases and the system can become toxic (Nitrogen Transformations in Aquaponic Systems, 2015). Nitrifying bacteria are aerobic and dissolved oxygen in the systems water is important, if dissolved oxygen is too low the bacteria are unable to fix oxygen molecules to the nitrogen and convert ammonia into nitrate (Nitrogen Transformations in Aquaponic Systems, 2015).

ISSUES WITH STANDARD AGRICULTURE

Traditional agriculture has been around for thousands of years, but since the 1950's agricultural food production has seen a shift away from local growers on a small scale to the invention of the industrial farm which has transformed the landscape as well as the food itself. Industrial agriculture has done an excellent job at supplying massive amounts of food at a low cost but it is not without problems. The pollution created by the use of massive amounts of chemical fertilizers significantly degrades not only the soil quality, building up toxic salts in the soil, but also increases nitrogen levels in local water bodies which can harm natural ecosystems. The use of chemical pesticides also has negative effects on local wildlife, harming crucial insects such as bees and predatory insects. Another trouble with traditional agriculture, whether industrial farms or even local organic farming, is use of water; soil grown crops require large amounts of water to grow. Much of this water is lost to runoff as well as evaporation during application. As water is becoming a precious commodity and groundwater levels are dropping rapidly due to farming this is a serious issue for farmers as well as the average person (Hawkes, 2014).

Most of the U.S. doesn't receive adequate rainfall to grow agricultural crops solely off of rainfall, so underground aquifers are tapped and used to irrigate millions of acres of farmland (Hawkes, 2014). While this has been good method to grow large amounts of crops on land which would typically be too arid to farm, it depletes these aquifers faster than they can recharge and this leads to a deficit. Dropping aquifer levels are a serious issue; in the San Joaquin Valley in California groundwater levels have dropped so significantly that the ground itself is subsiding by as much as a foot per year (Kreiger, 2014). The Ogallala Aquifer, which supplies water to a large portion of the central U.S., where a significant amount of the countries farming is done, is dropping at an alarming rate (Hawkes, 2014). While the use of these water resources is only going to increase, the water itself is running out. This practice of depleting groundwater to farm is unsustainable and is a serious issue that must be addressed.

PRACTICALITY OF AQUAPONIC AGRICULTURE

While aquaponics is not a perfect answer to every agricultural challenge, it does present a very useful and effective solution to a number of the flaws in standard agriculture. The delivery of nutrients to plants through a liquid substrate that allows their roots to absorb all the nutrients they need without having to go out and compete with other plants in the soil allows plants to be planted in much closer proximity to each other (Rakocy, Masser, & Losordo, 2006). This allows structures such as greenhouses to be much more effective as the number of plants per square feet is drastically increased

(Savidov & Hutchings, 2005). One of the benefits of greenhouses is reduction of pests due to isolation from the natural environment; this allows plants to be grown without the large-scale use of harmful pesticides. The issue of water consumption is also solved by aquaponic agriculture; aquaponics uses approximately 10% of the water that commercial agriculture uses (Flavius & Grozea, 2011). Water in the aquaponic system is never lost to runoff and only leaves the system through absorption by the plants and a small amount of evaporation from the aquarium, which can be eased by covering the water reservoir with a lid. The water savings of aquaponics is particularly evident in the long run, initial amounts of water to fill the systems as well as water used in industrial manufacture of parts for the systems and greenhouses is negligible due to the fact that it is only needed once as opposed to traditional agriculture that requires constant water in large amounts. Once an aquaponic system is set up, all the water that is needed is a minor amount to keep the tanks full. Fish food can also be produced in house using recirculated aquaponic water to grow aquatic plants such as duckweed to feed fish such as Tilapia (Bernstein, 2014). The need for chemical fertilizers as well as fertilizers in general is eliminated completely and environmental impacts due to these are eliminated as well. The use of aquaponics in an enclosed greenhouse, which aquaponics is particularly suited for, eliminates the need for large scale use of pesticides and eliminates the negative environmental impacts from this aspect of commercial farming. Vastly reduced water consumption, and reduced amount of land required to grow the same amount of produce are major advantages of aquaponic agriculture (Savidov & Hutchings, 2005).

EXPERIMENT

In order to compare and study the use of aquaponics versus traditional organic agriculture I have elected to build two systems, an organic dirt based garden, and an aquaponic system. My goal in this experiment is to compare the toted benefits of aquaponic agriculture in against traditional agriculture as well as examine the overall effectiveness of aquaponic agriculture in the area of product quality, which is a driving force behind consumer choice and thus industry movement, and supply.

For the traditional organic garden I have chosen to build a 3ft x 6ft raised bed which I've filled with organic garden soil and amended with volcanic sand, rock phosphate, coffee grounds, and compost in order to ensure the soil is healthy and has an adequate supply of nutrients. I've chosen to plant a variety of popular agricultural produce in order to examine their growth in this system and the aquaponic system. I've elected to plant 2 cabbage, 2 broccoli, 3 kale, and 3 Swiss chard plants at the recommended spacing 14" in order to ensure optimum growth. I have installed a soil moisture monitoring device in order to ensure that soil moisture is kept at adequate levels. Organic fertilizer in the form of fish emulsion and liquid seaweed will be applied at planting, and halfway through the growing season as is standard practice in traditional organic farming.

For the aquaponic system I have decided to build a media filled bed due to its simplicity and versatility as well as being the best system for a limited space and small number of plants. I have chosen a 100 gallon aquarium stocked with approximately 100 small gold fish in order have a ratio of approximately 1 inch of fish per gallon of water. My grow bed is a 4ft x 4ft injection molded plastic trough with a bell siphon installed in the center in order to drain the system once an adequate water level is achieved. The system uses a 400 gallon per hour pump to cycle the water up into the reservoir. The grow bed is filled with lava rock and Hydroton at a ratio of 1:2 in favor of the smaller hydroton. I have chosen to plant the aquaponic system at roughly twice the density of the organic dirt garden to test its ability to supply adequate nutrition to plants in a smaller area than traditional farming. The aquaponic system will consist of 4 cabbage, 4 broccoli, 3 kale, and 6 Swiss chard plants. There will be no additional inputs to the aquaponic system in the form of fertilizer or growth accelerators. Fish will be fed in the morning and at night with standard National Geographic brand goldfish food. Water ph will be adjusted up with crushed oyster shells and down with lemon juice. Water temperature will be maintained at 70°F using a pond heater. The variables of water consumption, visual plant quality, and at the end dried mean weight per plant, will be recorded and analyzed. My goal here is to analyze whether or not the claims surrounding aquaponics are easily replicable and are of a significant magnitude.

APPLICATION OF AQUAPONICS

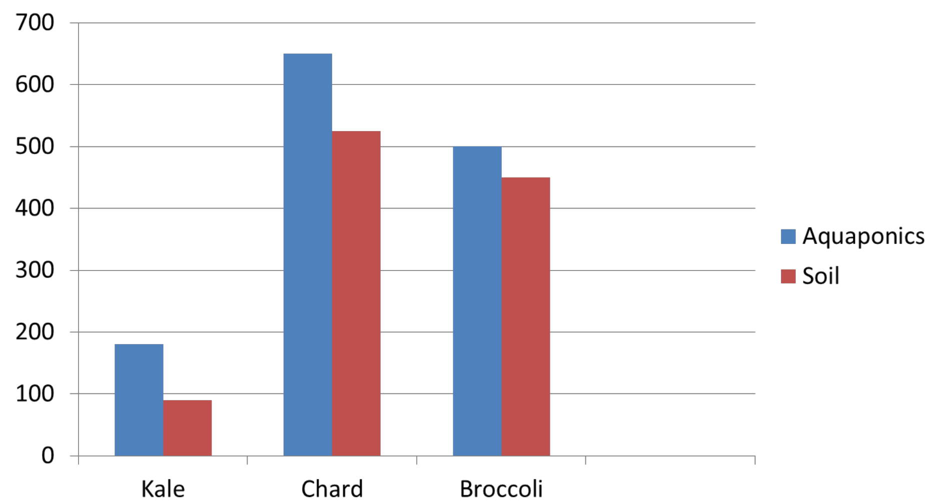
Aquaponic agriculture can be used in any area of agriculture but it is most effective at leafy vegetable production, such as lettuce, kale, chard, and spinach (Bernstein, 2014). These crops traditionally need lots of watering and thus transitioning to an aquaponic farming method would save vast quantities of water. Areas such as southern California and the Midwest could grow a majority of their vegetables with aquaponics and ensure that groundwater is used at a much slower and more sustainable rate than it is currently being used. The reduced size of aquaponic farming allows that much smaller areas of land can be used and the lack of a need for soil allows systems and greenhouses to be placed in urban areas that wouldn't traditionally be farmable. This allows produce to be grown closer to market, which in turn uses less energy in order to transport it.

APPLICATION IN THE MIDDLE EAST AND NORTH AFRICA

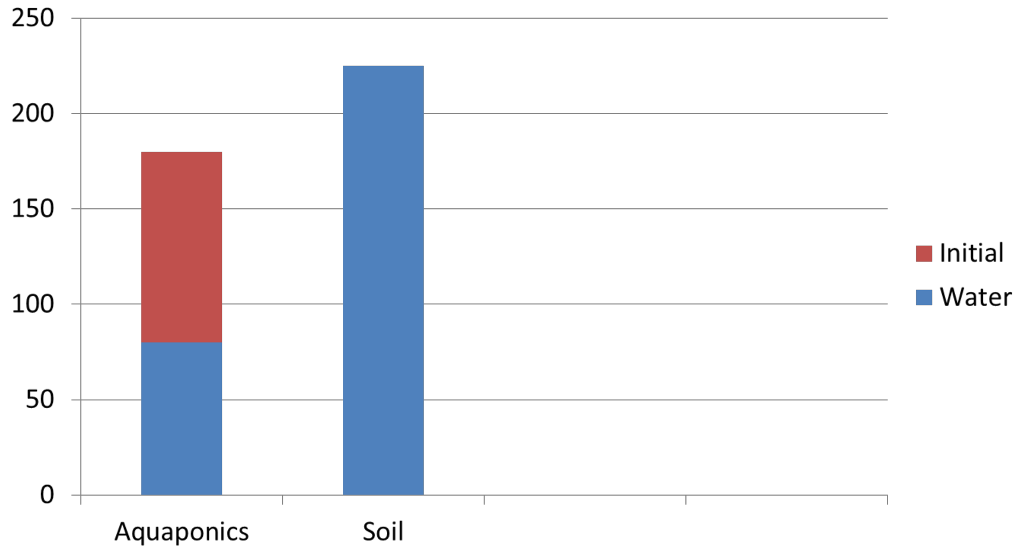
The Middle East as well as North Africa are particularly well suited for aquaponic agriculture. With the exception of the Nile River Valley, there is very little rich fertile farmland that receives adequate rainfall in this region of the world. Average rainfall totals are quite low and the region is extremely arid. These variables require that any crops gown be heavily irrigated and in an area where water is already scarce, this poses a serious issue. As populations in these areas continue to expand and grow there are more and more mouths to feed. Traditional farming practices in these regions struggles to keep pace and food must be imported or else famine is a serious threat (Katkhuda, 2015). The use of aquaponic agriculture in these regions could be greatly beneficial to public good, environmental quality, and economic stability.

RESULTS

After allowing the plants to grown for 16 weeks they have reached maturity and are ready for harvest. The cabbage plants in the soil and aquaponics were both heavily damaged by cabbage moths and I chose to exclude them from all of the testing as they were too heavily damaged. After harvesting and collecting the kale, chard, and broccoli plants, making sure to keep the soil grown specimens separate from the aquaponically grown ones, I chose to dehydrate them in order to get a more exact weight without water weight skewing any results. Plants were then placed on a digital scale and weighed in grams. The final results were as follows.



Water consumption was also a key factor in my comparison between aquaponic agriculture and traditional agriculture. In order to accurately measure the water consumption of both systems I installed a soil moisture gauge in the garden and a flow meter onto the watering hose. I only watered the garden when the moisture gauge indicated that soil moisture was not at optimum levels and I only added enough water to the aquaponics to keep the water level at a weekly maintained fill level. The initial filling of the aquaponic system required 100 gallons to fill the reservoir so I recorded that 100 gallons as an initial allotment of water in the aquaponics water consumption. Results are as follows.



The visual plant quality was a challenging variable to examine as it is not scientific and numerically based, but a matter of opinion, that said, it is a very important factor as most produce that's grown for market must be visually appealing or consumers will not purchase it. Pest damage, coloration, and overall appearance were closely examined and as a whole the aquaponically grown plants had significantly less pest damage and were over all much more evenly colored and had significantly thicker and larger leaves than the soil grown counterparts.

CONCLUSION

In conclusion it is evident that while both the organic soil grown crops and aquaponically grown crops grew well and produced a good harvest, the aquaponically grown crops were quantitatively larger and were able to grow in a much denser environment. The water consumption of the aquaponic system was also significantly lower than that of the traditional soil grown system. Aquaponics does indeed appear to be a viable and even advantageous method of producing plants for human consumption; particularly in regions were water availability is an issue. The ability for aquaponic systems to produce higher yields in a smaller growing space is a huge advantage over traditional agriculture as well as the lack of a need for fertile land. This makes things like urban crop production a viable alternative to traditional methods of trucking produce massive distances and having to devote millions of acres of land to food production.

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