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Using Hydroponic and Aquaponic Systems for Food Production under Water Scarcity Conditions and Climate Change Scenarios: A Review

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Climate change has made it necessary to adapt agricultural practices in novel ways in order to ensure food security, particularly in nations with limited water supplies. There has been a strong trend toward the use of soilless cultivation systems in general to maximize the utilization of available resources due to the scarcity of irrigation water, the high cost of fertilizers, and their limitations. The goal of this review article is to highlight the significance of using hydroponic and aquaponic systems as the best systems for sustainable food production under conditions of water scarcity and climate change. Aquaponics systems in particular to expand intensive fish production to meet the growing needs of animal protein, clean and sustainable vegetable production, which is in high demand with Rising living standards and increasing awareness of clean food consumption. The production of vegetables with the Aquaponics system requires many controls and good knowledge of many sciences, such as intensive Aquaculture, systems of cultivation without soil that can be converted to Aquaponics, and the types of filters used, whether mechanical or biological, and beneficial bacteria, microorganisms, water quality as well as its physical and chemical characteristics required for the growth of all organisms in the system. Thus, have a biological system that must be understood and known as the environmental conditions necessary for its growth in order to obtain a productive and sustainable economic system.

Keywords: Hydroponic, Aquaponics, Climate Change, Food Security, Aquaculture, Filters Biological, Sustainable Vegetable Production.

Introduction

The conditions of arid and semi-arid regions that suffer from problems of drought with limited water resources, always represent a very big pressure on the agricultural sectors, to reduce the consumption of freshwater and unconventional water suitable for use in irrigation purposes (Abdelraouf et al., 2020 b, Hozayn et al., 2016, Marwa et al., 2017). The suffering of limited resources of irrigation water increases with the increase in the rate of population growth, as population growth requires increasing in the production of agricultural crops, which requires increasing in the water requirements required to irrigate larger areas and more water to provide the quantities of food required, and this requires most of the methods and techniques of modern irrigation systems to compete to increase water productivity for all major crops while increasing and improving crop yield and quality properties (Bakry et al., 2012). The main goal under conditions of drought and water scarcity for all those working in irrigation and agricultural production is to increase the water productivity of crops due to the increase in the volume of demand for food production with the turbulent population increase (Eid and Negm 2019, Abdelraouf and Ragab 2018 a, Abdelraouf and Ragab 2018 b, Abdelraouf and Ragab 2018 c, Okasha et al., 2013, El-Metwally et al, 2015). After we have reviewed the importance of providing food under conditions of drought, it is very important to apply the latest and new innovative technologies, as well as most of the technologies related to the provision of irrigation water to provide huge

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volumes of water for irrigation from its various sources, whether traditional or non-traditional, to cultivate other large areas depending on the volumes of water that are provided (El-Habbasha et al., 2014, Abdelraouf and Abuarab 2012). It is very important and very necessary to reduce water losses to the highest degree for irrigation, through the continuous development, modernization, and innovation of multiple and sustainable irrigation techniques (Abdelraouf and Abuarab 2012). One of the most important affected of this change is crop production all over the world (Abdelraouf et al, 2022, Okunlola et al., 2017) and it determines the coming periods, according to experts, increasing trends for the emergence of drought. Almost one-third of the lands suitable for the agricultural process have been defined as arid or semi-arid lands, and the intensity of drought appears to be in an increasing trend in the following years where it appears strongly in the coming periods (Vurukonda et al, 2016, Iglesias and Garrote 2015). The impact of climate change extends to the water resources needed for agricultural production and increased consumption due to higher temperatures, increased evapotranspiration, and decreased precipitation, which causes an increased need for irrigation (Bakri and Abou-Shleel 2013). It is expected that the water need will increase due to water changes to fill nutritional gaps in some crops (Abdelraouf et al, 2020). With the current housing increase, the population is expected to increase between 9.2 and 10.2 billion, between 20% and 30% in 2050, and thus the rate of vegetable consumption is expected to increase to 60% in 2025 (Wada et al., 2016). Also, there has been a global increase in water consumption, reaching 600% in the last century, and it is expected to increase annually at a rate of 1% (Cohen et al., 2018). With the increase in population growth, which is followed by an increase in food consumption, and thus there is pressure on the resources needed to produce food, whether water or nutrients needed for the production process, and most of these resources are limited or their production pollutes the environment, and therefore there is a strong tendency to search for sustainable sources of production. With the climate changes that the world is witnessing and the increasing impact of desertification, an innovative agricultural approach must be adopted to ensure the provision of food, especially in countries of water scarcity, that suffer from permanent drought (Majid et al., 2021). With the effect of climate change on the arid regions, it has become necessary to change the methodology of agriculture in innovative forms to provide food security, especially in countries that suffer from a shortage of water resources. Villarroel et al., (2011) mentioned that the persistent climatic conditions exacerbated the challenges of severe drought and limited water resources, stressing that the continuity of these harsh conditions will seriously harm agricultural production if we rely on traditional water-saving techniques. We must rely on the use of the best and latest innovative and new technologies for the cultivation and production of agricultural crops, which will undoubtedly increase this and support our ability to address and face these challenges.

With the limited irrigation water and the high prices and limitations of fertilizers, there has been a strong tendency to use (1) Improving the efficiency of traditional farming systems, (2) Maximizing the use of non-traditional sources of irrigation (3) Improving the ability of the root spread area to retain irrigation water within it for the longest possible period to reduce water stress on the roots of cultivated plants, such as adding organic fertilizers and biochar and the production of organic mulches for the soil ..... etc., (4) Expansion of the use of advanced agricultural greenhouses, (5) Reliance on intensive vertical farming systems, (6) Expansion of integrated agricultural systems, and finally and the most important of them is (7) Expansion of soilless agricultural systems, including aquaponic systems.

There are many farming systems, with the possibility that soilless farming systems or what is known as liquid farming systems are the best excellent alternatives to farming systems and traditional methods in open fields. The results of current and previous studies helped in this expansion and spread of liquid farming systems, which confirmed, in actual results, the maximization and increase of crop yields per cubic unit of water using liquid culture systems without soil (Tyson et al., 2011). It has become necessary to use soilless farming systems as they are more important for lands located in desert areas to increase the water productivity values of crops. The other reason behind the need to use hydroponic systems or soilless cultivation systems is that the continuity of repeated cultivation leads to poor fertility of the soil, as this repetition leads to poor productivity and quality properties. As mentioned earlier, the traditional cultivation of the main crops in the open soil under conditions of drought is very difficult, given that it requires large soil areas and large volumes of water required for irrigation, with the increase in the total number of workers (Delaide et al., 2016). The soilless farming systems are considered alternative farming systems to traditional ground farming and the most widespread method for growing and producing various crops under greenhouse conditions. Where the crop cannot grow under the conditions of traditional varieties, except in the case of soil sterilization, as well as crop rotation, etc., as this is one of the most costly and extremely difficult treatments. Sterilization by steam is not economical and also very expensive and ineffective, and the use and application of methyl bromide is one of the internationally banned pesticides in many countries of the world and the European Union. However, on the contrary, production will inevitably continue in a sustainable manner upon the transition and transition to adopting new forms of soilless agriculture. The number of users and implementers of soilless culture systems has increased significantly over the past period so far, as contribute and participate in the process of agricultural intensification to maximize the volume of agricultural production, which gives and provides large yields as well as high-quality of this production in areas with arid climate and other factors and adverse conditions for the process of growing plants and crops and their growth (Tyson et al., 2011). Soilless farming techniques are applied in many regions of the world under protected cultivation conditions for easy control of the environmental conditions necessary for the growth of cultivated plants, in addition to ensuring the presence of irrigation water and nutrients in the root spread area. As are these systems do not suffer from the problem of accumulation of salts and are less exposed to pests and diseases, which will increase the demand for the expansion of farming systems without soil in all its forms and it was also confirmed by Abdelraouf and Ragab (2017). According to Coronel et al., (2009) confirmed that the total productivity of lettuce was greater under hydroponic conditions compared to cultivation under open sandy soil conditions. Also confirmed that, the crop productivity was higher when growing lettuce grown in hydroponic systems (220.75 g/ plant) compared to those grown organically in open sandy soil (44.50 g plant^{-1}) or conventionally (63.50 g/ plant).

Therefore, the aim of this article was to introduce and present the importance of using hydroponic and aquaponic systems as the best systems for sustainable food production under water scarcity conditions and climate change scenarios.

2. Body

2.1. Hydroponics systems

2.1.1. Definition of hydroponics

Hydroponics is the technique of growing plants in a soil-free medium, i.e. without soil, with rich irrigation water loaded with nutrients needed for growth and loaded with oxygen.

2.1.2. Types of hydroponics systems

There are many types of hydroponics systems and they are as follows: (1) he Nutrient film technique, (2) Deep water hydroponic, (3) Aeroponics, as shown as in Fig. (1).

Figure (1): Different types of hydroponics techniques

Nutrient film technique: Nutritious film technology (NFT) is one of the technologies that has enormous potential and means for the agricultural production process, under the conditions of semi-arid and arid regions, which means with it low consumption of irrigation water needed to irrigate crops, and also with the possibility of growing most vegetable crops, and there is ease in management It is also characterized by a short growth cycle and an improvement in plant growth, which is reflected positively on yield, quality, and early flowering (El-Behairy et al., 2001). Studies have confirmed that plants produced by NFT technology have a significantly higher vegetative growth rate than plants grown in the traditional way in the soil, as reported by Suzanne et al., (2015) on cantaloupe. In the same regards (Abdelraouf et al., 2016, Abdelraouf et al., 2020). Above Abdelraouf et al., (2021), Abdelraouf et al., 2021, Lester et al., 2006) on cantaloupe. Numerous studies have reported that plants and crops grown with NFT technology gave higher yields and higher quality compared to conventional soil cultivation. Perhaps this is since with this technique, is the result of a continuous and good supply of nutritional fertilizer elements in the available form, through the nutrient solution, which leads to an increase in the absorption of the nitrogen element, which in turn leads to encouraging the vegetative growth of the cultivated plants and increases the absorption of potassium, which is known as a high-quality nutrient with other nutrients (El-Behairy 2003). It may be among the reasons that the roots of lettuce plants are immersed in the nutrient solution continuously and all the time, which makes the temperature buffer during the winter and early spring, as the water collects heat during the day slowly and releases it slowly also during the night period. This makes the roots active most of the day and stimulates the uptake of water and nutrients, which improves and increases vegetative growth rates and thus crop yield (Singer et al., 2009, Abdelraouf et al., 2019). In the same regards (Lennard and Leonard 2006) mentioned that air temperatures inside the cultivation channel on NFT were always higher than the outside in the winter season.

Deep water hydroponic: Deep Water Culture (DWC) is one of the best and most important hydroponics techniques used. DWC where all nutrients are directly supplied to plant roots where DWC technology ensures that plant roots are always immersed in the solution full of necessary nutrients (Vasdravanidis et al., 2022). The simplest widespread hydroponic culture system (DWC) (Jensen and Collins 1985). If the goal is to produce sustainable agricultural food, under harsh, dry environmental conditions while avoiding all negative effects, including the effects of climate change, then soilless farming systems are in these conditions more effective, successful and very strategic to meet this challenge. Therefore, aquaculture systems have been developed and improved with deep water systems, which are considered the most soilless methods of fish farming. This was emphasized by Sabra et al., (2023) in Arizona and Italy. Deep hydroponics (DWC) systems are one of the best and most successful hydroponics methods, as well as effective, and it is economical with the cultivation of lettuce plants, as well as with some types of vegetable crops, especially leafy ones. Barbosa et al., (2015) confirmed that the use of DWC technologies exceeds 75% of the volume of water needed and required for irrigation water and may reach 90% with negligible and negligible impact on the environment. Lettuce is the world's most hydroponic leafy green crop, estimated to be 99% hydroponic, and sells about 40% more expensive than conventionally grown DWC lettuce (Jagath and Kennedy 2010). Some studies have confirmed that the concentrations of calcium, copper, phosphorus, zinc, boron, and magnesium in the leaves of lettuce plants harvested with DWC technology are twice as high as their concentration in lettuce when grown in the traditional way in sandy soil. In the end, it is confirmed to us that the performance of the DWC system is much better through higher yields of lettuce with improved quality and lower irrigation water consumption compared to the traditional sandy land cultivation system (Abdelraouf et al., 2024).

Aeroponics: The process of growing plants in a misty or airy environment is known as aerobic cultivation as the roots are kept permanently or intermittently and saturated with drops of nutrient solution without the use of soil or any medium is an aerobic process (Funmilola Oluwafemi 2022). Aeroponics is a process known as soilless farming that requires very little water for irrigation or humidification. There are many benefits to pneumatic systems as it is a more efficient, cleaner and faster system in the production process for food sources. It is said that farmers who prefer and choose to use the pneumatic system technology can reduce the volume of pesticide use by up to 100%, reduce the use of irrigation water by 98%, use the volume of fertilizers by only 60%, and increase the volume of productivity of different agricultural crops by 45%. % to 75%. Therefore, these systems make cultivated plants grow faster and with less stress and more vegetative health (Genhua and Masabni 2022). Aeroponics are highly efficient in water and nutrient use because they are superior to those of NFT or DWC systems. The biggest advantage of aerobic cultivation is that the roots are exposed to air, thus there is no problem of hypoxia (Chawla et al., 2020). There is a high potential for both aerobatic and hydroponic systems with great and precise control of all environmental conditions for crop growth, which leads to an increase in production and a high improvement in crop quality. Where it is possible to precisely control the properties of the nutrient solution and the volume of nutrients added, the temperature is also controlled, the pH is also controlled, and the degree of electrical conductivity and the volume of the added oxygen content can be controlled according to the needs of the plants. These methods and techniques also have the high ability to produce high-quality foodstuffs in the shortest possible time. The precise supply and control of the nutrient solution and the pH regulation of the growth medium lead to high quality biomass production. This led to an increase and spread of farming methods and techniques, an increase in the yield of agricultural crops, with a decrease in the total cost per unit of production, in addition to achieving many economic benefits. These new systems can also facilitate and provide more water while creating new job opportunities (Endut et al., 2011).

2.1.3. The benefits of hydroponics

- The possibility of using it in places that are not suitable for agriculture or harsh environmental conditions, such as in dry areas or areas with cold climates.
- High control over controlling the content of fertilizer elements and nutrients, as well as the ability to control pH and high control over the growth environment.
- Low total costs of irrigation water and nutrients related to the reuse and recycling of irrigation water and nutrients.
- Plants cultivated with these systems are characterized by rapid growth due to the increase in the availability of more volume and quantities of oxygen within the root spread area.
- The superior ability to eliminate most insects as well as fungi with soil-related bacteria, or at least reduce their impact.
- Significant increase in crop yield.
- It does not require the removal and resistance of weeds and weeds.
- The possibility of giving better and much better working conditions, which reduces the total costs of labor, as it is possible to raise the level of some crops, as happens with strawberry and lettuce crops, where the level of the farming environment is raised to an easier and much better height for the agricultural process and the harvest process.
- Low shock to the crops, as in the traditional ground cultivation method.

2.2. Aquaponic systems

2.2.1. Definition of aquaponics

Aquaponics system: The aquaculture system works on nutrient utilization, efficient water use, and overall environmental sustainability. The liquid wastes from fish farming are rich in the elements of ammonia and phosphorus (Verdegem et al., 2006, Abdelraouf 2019) which is a potential source of environmental pollution. It is also a model for integrated fish farming by recycling the outputs of aquaculture and producing vegetables in closed-cycle soilless cultivation systems (Abdelraouf et al., 2016).

2.2.2. Aquaponic systems component

Aquaponics: It combines the intensive aquaculture system and the soilless culture system into one productive system. In this system, the water is circulated in a cycle from the fish tank to the mechanical filters, then the biological filters, then the soilless culture system, and then returns to the fish again (Goddeka and Körnerb 2019). As a result, we get less input with the advantage of improving crop and aquaculture together (Gichana et al., 2018). Usually, the system consists of 3 main pillars, which are as follows: (1) Aquaculture ponds, (2) Filters unit, and (3) Soilless culture system with plants. First, the aquaculture ponds: Aquaculture is a RAS system. Secondly, the filters: There are two main types; (1) Mechanical filter, To remove solid fish waste from the water and (2) Biofilter, That treats dissolved waste the biofilter provides a continuous supply of nitrozomones and azobacter bacteria to get rid of ammonia and convert it into liters and then nitrites to make it soft for plant consumption. Third, soilless cultivation system: There are many systems used, and each system has advantages and disadvantages. Usually uses one of the closed soilless cultivation systems Fig. (2)

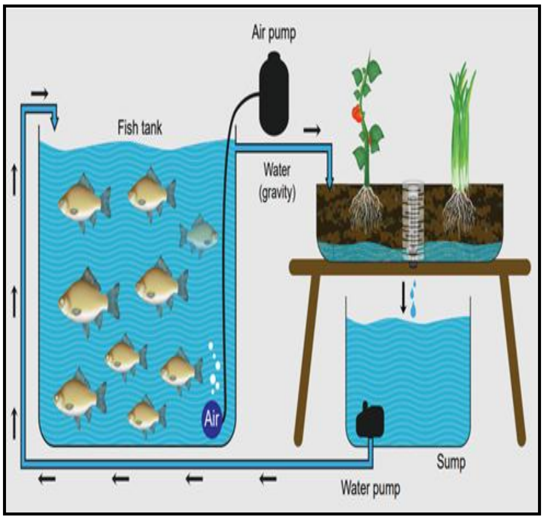

Figure (2): Simple Aquaponic unit

Suitable growth conditions must be provided for the two systems of soilless culture and aquaculture of pH, suitable temperatures and nutrient concentrations, as they both share one ecosystem (Palm et al., 2018, Abdelraouf 2016, Gichana et al., 2018). The water produced from aquaculture is rich in dissolved substances such as nitrogen and phosphorus from fish feces and uneaten forage (Ayman El-Sayed et al., 2023, Schmautz et al., 2016). Aquaculture can be integrated with the current traditional open agricultural systems, as it can increase and raise the productivity of crops, increase the efficiency and productivity of water and overall environmental sustainability (Danaher et al., 2013) and also reduce the use of chemical fertilizers and pesticides (Cerozi and Fitzsimmons 2017)**.**

Applicability of aquaponics**:** As mentioned above, agriculture using the aquaponics system combines two important systems in agriculture, namely intensive aquaculture and soilless farming. It was found that soilless culture has become popular recently, not only because it is a farming system that brings many gains, but because it is also a solution to many of the problems that are facing us now, such as climate changes, desertification, lack of water resources and fertile lands for agriculture, so it has become a solution to one or more of these. The problems are that they also face a lot of challenges in providing appropriate nutritional solutions and chemical compounds involved in nutrition, so alternative solutions have been thought of. Aquaculture has also increased interest in it in recent decades to bridge the nutritional gap in animal protein, and the RAS system was one of the most important solutions to that (Cerozi and Fitzsimmons 2017) until the outputs from the production of this system caused a lot of environmental problems from the accumulation of phosphorus in the environment and ways to get rid of it and provide suitable water of high quality for production High-quality fish and abundant production (Abdelraouf et al., 2021). Therefore, the integration of this system was the solution to the previous matters and the production of an integrated and sustainable environmental system, and the combination of the most productive systems in its specialization is a clear example of the optimal exploitation of resources and their sustainability.

A brief history of modern aquaponic technology: The idea of using waste from fish is not new and it was used by early civilizations in Asia and South America. In the modern era in the seventies, studies began to integrate aquaculture and soilless culture, whether in North America or Europe, and an increase in research in this field for the development of aquaponics in the eighties of the last century. This achieved limited development and success. Biological filters were added in the nineties, the required proportions of fish to plants were neutralized, and a closed water circulation system was established to concentrate nutrients for plants. It remained a relatively new and limited method for food production. At the University of the Virgin Islands, James Rakosi in the United States developed calculations and evaluated the vital ratios to maximize production, whether for fish or vegetables and to maintain the environmental balance. Current applications of aquaponics. Wilson Lennard in Australia calculated the proportions and rates of feeding and plans for production and Savidov in Alberta - Canada produced aquaponics units for the production of tomatoes and cucumbers at the University of Bangladesh, Muhammad Abdul Salam made home units for aquaponic cultivation (Goddek et al., 2015).

2.2.3. Understanding Aquaponics

Based on what was previously explained about aquaculture systems, we move here to discuss the vital and biological processes that take place within the production unit of aquaculture. In the beginning, the concepts of basic processes, including the nitrification process, will be explained, with an explanation of the vital role of bacteria as well as their main biological processes. Finally, the importance of balance in the ecosystem of aquaponic technologies, which includes fish farming and plant cultivation with the presence of bacteria, will be discussed, with an explanation of how to achieve the preservation of aquaponic unity over and the continuation of time Fig. 3.

***Important Biological Components of Aquaponics*:** The most important advantages of aquaponics system are the symbiotic relationship between plants and fish in soilless culture systems and Aquaculture systems, which are linked to the water recycling system. The RAS provides the primary nutrients needed for plant growth while the plants in turn filter and clean by absorbing dissolved nutrients that are toxic in high concentrations to fish (Tyson et al., 2008). This reciprocal relationship depends on the work of two main groups of bacteria, *Nitrosomonas spp*. and *Nitrobacter spp*. This works on the oxidation of ammonia, basic waste from fish, to nitrite, then nitrite to nitrate, which is the appropriate form for absorption by plants (FAO 2014) and it allows the growth and breeding of fish, plants, and also bacteria to grow symbiotically, and then all living organisms together create a healthy environment for healthy growth with each other, so that this system is properly balanced.

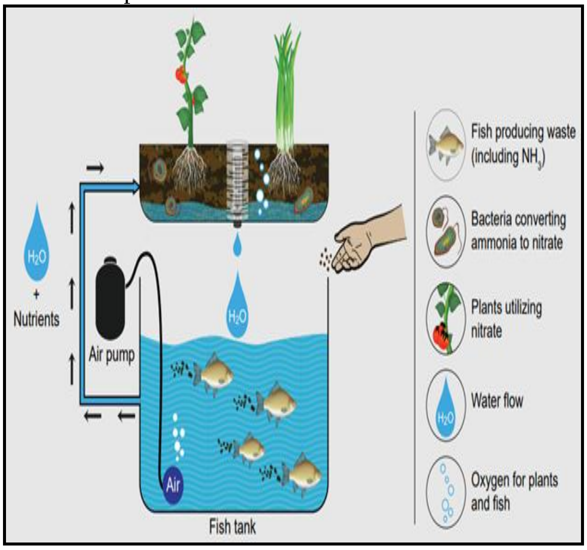

Figure (3): Explain the main biological components of the three aquaculture cultivation and education process: plants, fish and bacteria

***The nitrogen cycle*:** One of the most important processes for the key to success of the aquaponic system is the cycle of the nitrogen element, as failure in it is a failure of the mutual vital system between fish and plants, as nitrogen is an essential element for life in nature, and it is a chemical element that is a basic component of all amino acids, which form proteins and thus affect enzymes and the vitality of the organism Neighborhood, It is one of the most abundant elements in the atmosphere as the most abundant gas, N_2, and it is stable and inaccessible to plants in this picture. And changing it to a palatable form of the plant is called the process of atmospheric nitrogen fixation it appears as Fig. 4 (Zala et al, 2022). The nitrogen element in its gaseous form is the most important, abundant and present element in the Earth's atmosphere, as it is about 78 percent of it and oxygen constitutes only 21 percent despite the fact that the nitrogen element is very abundant, but not as nature shows about the nitrogen cycle. It is a very stable triple bond of several nitrogen atoms and is inaccessible. This is why nitrogen must be converted into the N2 form before plants can be used for growth. This method or process is called the composition of the element nitrogen with the addition of other nutrients such as oxygen or hydrogen and thus the formation and creation of new chemical compounds such as nitrate (NO3) and ammonia (NH3). In short, the fixation of nitrogen by bacteria is by converting it to add oxygen or hydrogen and convert it to ammonia (NH_3^+) or to nitrate (NO_3^-), which is the form used by the plant (Lennard and Goddek 2019) (Fig. 4).

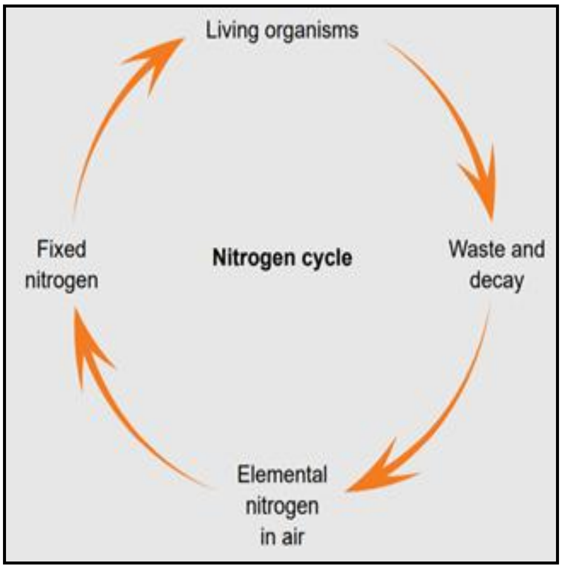

Figure (4): The nitrogen cycle (simplified)

The animal shown in Fig. (5) excretes waste, primarily ammonia (NH3), in the form of feces and urine. Other naturally occurring organic matter that is decomposing, such as dead plants or animals, is converted to ammonia by fungi and various bacterial species. A particular type of bacteria known as nitrifying bacteria, which is crucial for aquaponics, breaks down this ammonia. These bacteria first transform ammonia into nitrite compounds (NO2-), then into nitrate compounds (NO3-), and lastly into nitrate compounds. Both ammonia and nitrates can be used by plants to fuel their growth processes, however, nitrates are more readily absorbed by roots.

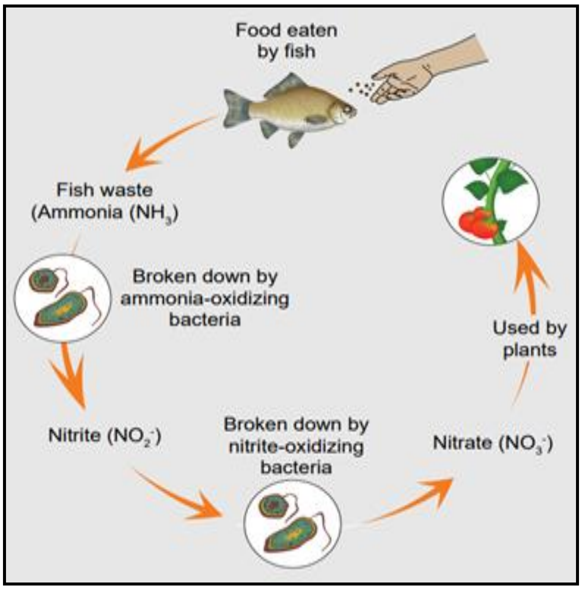

Figure (5): Nitrogen flow chart in an aquaponic system

Feed rate ratio: Feed is the main source of nutrients in aquaponic systems, as it provides fish, bacteria, and plants with the nutrients necessary for their growth (Naylor et al., 2009). Usually, the source of protein in them is soybeans and fishmeal (Mansour et al., 2023, Turchini et al., 2009). There are studies based on mathematical models to study plant requirements of the required nutrients. I suggested that for leafy plants such as lettuce and others, nutrients need between 20-50 grams of fodder per 1 square meter of green, and for green plants 50-80 grams for highlands, flat green, eggplant and pepper (Benjamin et al., 2020). Fish used in aquaponics systems can be fed to insects, as they contribute to enhancing the respiratory capacity of aquaponics products (Francesco et al., 2022). One of the insects used in this is the black soldier fly (Abdelraouf et al., 2020), which is one of the most promising species in this field (Gasco et al., 2018, Mancini et al., 2018).

Water movement: After achieving an appropriate balance between the quantities of fish that produce waste and the number of plants required to absorb nutrients, the rate of water consumption is reduced to the minimum required only to compensate for losses, whether from plant transpiration or evaporation (Abdelraouf and Anter 2020). Fish farming is generally concentrated around cities and areas that have high population densities to increase demand and consumption and the use of open systems for open fish farming in areas where water is well available, but due to the strictness of environmental regulations and laws regarding water discharge, which contains a lot of natural pollutants from fish feces, high concentrations of nitrogen, phosphorus, and undigested food residues (Martins et al., 2010). This forced farmers to use the RAS system because this system also sometimes needs to get rid of 10% of the volume of water in the system, and this is also not environmentally acceptable (Badiola et al., 2012). The use of aquaponics systems reduces the discharge of harmful waste into the environment and promotes the reduction of resources consumed in plant production by employing waste as raw materials and production inputs in another system, thus achieving the goals of the circular economy (Hamza et al., 2022). A crucial part of the nitrification process, which transforms plant and animal waste into readily available nutrients for plants, are nitrifying bacteria, which can be found in a variety of settings, including soil, sand, water, and air. A more intricate flow chart outlining every phase of the nitrogen cycle was shown in Fig. (6).

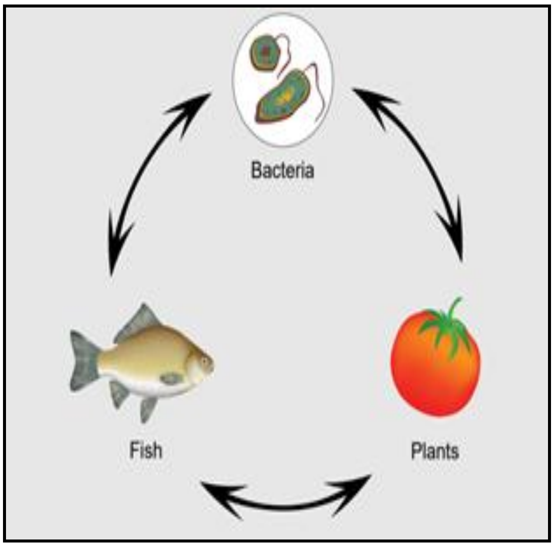

Figure (6): The aquaponic ecosystem

For practical and commercial applications, the ponds are usually built from a galvanized iron structure and are covered with 1 ml thick insulation plastic to be used for breeding fish. Aquaculture is carried out for fish such as bassa carp and tilapia. The deep water system is used to grow leafy vegetables and is the most popular (Figs. 7)

Fig. (7): Growing lettuce plants in a deep water aquaponics system

2.2.4. The benefits of aquaponic

Aquaponics is one of the strongest of these solutions as it is considered a sustainable source of food, it is also an integrated source for the production of fish protein and vegetables with one input and preventing the depletion of available resources or pollution of the environment by using intensive fish farming systems. Aquaponics can be considered a new approach that helps recycle inputs from nutrients and waste and helps achieve sustainable development, especially in arid regions (Conijn et al., 2018).

There are many benefits from aquaponic farms (1) Healthier, more recent, and genuinely organic food is grown in aquaponic gardens. (2) Plants and fish are not harmed by pesticides or weed killers. (3) Everything used to grow plants that produce vegetables and fruits is natural and chemical-free, including fertilisers designed to enhance the overall performance of an aquaponic system. (2) *Food is Grown Year-Round:* Aquaponics farmers do not have to rely on weather conditions to cultivate organic food because they can control temperatures year-round. (3) *Lessens Water Usage:* Water waste is greatly reduced as compared to backyard gardens and industrial farms. There is no need to utilize more water to support the growth of plants and fish because the water used for maintaining an aquaponics system is continuously recycled and reused. (4) With no soil or air seed dispersal, weeding is practically eliminated. Some plants may occasionally produce undesirable sprouts that need to be eradicated. (5) *Accelerated Plant Growth:* When plants have constant access to abundant nutrients and organic fertilisers, they naturally develop more quickly. Plant growth is also aided by a source of water that is constantly controlled, (6) *Commercial Aquaponics Farmers Earn Two Incomes Larger aquaponics enterprises can benefit from two revenue streams:* the fish that can be sold to food producers as well as the vegetables and fruit that they generate. (7) *Lessens the Carbon Footprint of the Planet:* Aquaponic farming does not require acres of acreage to grow food. Indeed, maintaining an aquaponic system is a practical alternative in regions with rocky, unstable, nutrient-poor, or drought-prone soil. (8) *Supports a Self-Sufficient Way of Life:* Because of the unstable economy and rising food prices, a growing number of people are choosing to live off the grid. An aquaponics food cultivation system would greatly benefit a fully self-sufficient lifestyle that includes solar power, well water resources, and raising livestock (Alhashimi et al., 2023).

2.2.5. The Disadvantages of hydroponic farming

- *High Set-Up Cost:* A hydroponic system's setup costs are high. This is particularly valid for a large-scale system with a carefully designed architecture. The initial installation of the water treatment plant, nutrient tank, lighting, air pump, reservoir, temperature controller, EC, acidity control, and plumbing systems can require a significant initial budget, depending on the automation and technology being used for the hydroponic system setup.
- *Reliance On Constant Power Supply/System:* Electricity is essential to the hydroponic farming system's ability to operate all of its parts continually. The entire system is vulnerable to failure in the event of a power outage, which could have detrimental effects for the plants. Even though Bowery Farming and other modern farms use solar-powered hydroponic systems and indoor vertical hydroponic gardens where solar energy serves as the primary power source, initial operating costs remain a concern in order to guarantee the continuity of the electrical source. Although the usage of renewable energy is undoubtedly increasing, reliance on fossil fuels is still a drawback.
- *High-Level Maintenance & Monitoring:* A hydroponic system's various parts cooperate to enable the plants to get nutrients smoothly. Growing people must exercise extreme caution to prevent any of these parts from failing. To ensure that the temperature and light levels are suitable, as well as that the pumps are operating as intended, continuous observation is necessary.
- *Susceptibility to Waterborne Diseases:* The constant flow of water via a hydroponic system increases the danger of some waterborne infections for the plants, even while cultivating plants in this manner helps lower the risk of soil-borne illnesses. These illnesses can occasionally spread from one plant to the others by water solutions. This may lead to the extinction of every plant within the system.
- ***Requires Special Expertise:*** A hydroponic system involves a lot of technical details. The system's tools and procedures require someone with the right training and experience to operate. Without the necessary knowledge, the plants are unlikely to flourish, which could have a detrimental effect on the output and result in significant loss.
- ***Debatable Nature of Organic Labels:*** Can hydroponic plants be certified as organic just because they are grown without the use of pesticides? Given that organic farming entails enhancing the fertility and quality of the soil, some organic farmers are opposed to this notion.

Conclusion

Climate change has become one of the biggest challenges facing food security and production in the agricultural sector, as it represents a direct change in agricultural production processes. Under suffering from a water shortage that threatens the sustainability of the agricultural sector and food security. Since the vegetable crop is one of the sectors that consume water in a high quantity or quality, it was the most affected. Therefore, the thinking was in the cultivation system without soil to overcome water problems, land desertification, and the lack of fertilizer use. The trend towards sustainability and reducing carbon emissions. Thinking about the aquaponics system was one of the practical solutions to this challenge to solve many problems, including: (1) Water shortage and reducing its consumption by 60-80%. (2) lowering the amount of synthetic mineral fertilizers used.(3) Reducing emissions of ammonia and phosphorus that are detrimental to the environment and originate from the fish industry. Since aquaponics relies on the operation of an integrated environmental system, it is an integrated production system that combines fish farming and soilless growing for plants. Consequently, one of the most significant sustainable agricultural production methods that enables the production of vegetables and animal protein from fish through clean, sustainable agriculture is the use of aquaponics. Hydroponics, which involves growing crops in water, and aquaculture, which involves raising fish, are combined to create aquaponics. Microorganisms are added to fish wastewater to convert organic materials into mineral nutrients by biological means. The water is cycled back into the fish tank after the plants have taken up the nutrients. Aquaponic systems can provide up to 20 times the yields of field crops in the same amount of space, using typically only 10% of the water needed to grow comparable crops outside.

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