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Review Article

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Hydroponics Review and a Proposed Automated Hydroponics System for Urban Family

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A B S T R A C T

The world population is increasing rapidly and will become three billion more in 2050 than there were in 2010. To feed these huge populations sustainably with quality food by 2050, it is necessary to implement new-fashioned technologies in agriculture that would be capable of producing more food with less space and time. To mitigate future food crises, hydroponics farming which is a soilless crop-growing method, could be a possible solution as it requires less space, water, and time compared to traditional soil-based cultivation. Implementation of modern technologies like the Internet of Things (IoT), automation, artificial intelligence (AI), robotics, etc. in hydroponics systems, makes it more effective and robust. In this review article, we have briefly discussed hydroponics farming methods and technologies used in hydroponics cultivation, and the importance of hydroponics farming for sustainable food production shortly to meet the upcoming food crisis. We have also discussed the nutrient management technique and various nutritional and environmental factors that should be considered and handled carefully for successful hydroponics farming. Finally, we have proposed an automated hydroponics system that can be implemented to meet the daily needs of vegetables and leafy greens for urban families, which may assist in solving a small portion of future food crises as 75% of the world's population will live in urban settlements in 2050.

Introduction

The amount of food we produce today is not adequate to feed everyone in 2050. The world population will be approximately ten billion by 2050. We need to feed about three billion more people than there were in 2010. It is necessary to increase food production without extending agricultural land, to feed these huge populations sustainably by 2050 (World resource report, 2018).

The scope for agricultural land expansion is almost impossible throughout the world. Presently, lands used for farming, both arable land and permanent crop fields, are almost 1.5 billion hectares, which is about 12 percent of the world's total land area. Even if substantial amounts of land are possibly compatible with agriculture, much of which is enclosed by forests, preserved for environmental reasons, or used for civic allotments. Also, there is a lagging of spare land for agricultural extension in some regions of the world (Southern Asia, Western Asia, Northern Africa, etc.) (FAO Statistical Yearbook, 2013). Bangladesh is not beyond this situation. According to financial express.com.bd (Shahiduzzaman Khan, 2024), more than 69 thousand hectares of farming land have been shrinking yearly due to swift industrialization, unplanned urbanization, and an increase in rural allotments. With this worse situation, the country's food security is falling at risk.

People face another warning issue with the difficulty of agricultural land expansion, which is the degradation of soil quality of arable land. Soil fertility and quality are reducing due to natural disasters, climate change, periodic production of similar crops, and unrestricted utilization of chemicals and pesticides in agriculture. Also, the rapid growth of industrialization and urbanization causes difficulty in soil-based cultivation.

In this situation, a new alternative farming technique has developed namely hydroponics which is a soil-less cultivation method, where plants are grown in a nutrient-rich water solution. Huge amounts of vegetables and leafy greens can be produced using the hydroponics technique. Usually, hydroponically produced end product quality, yield, taste, and nutritive value are superior to soil-based cultivation. This eco-friendly, pesticide-free, low-cost cultivation technique is achieving growing popularity both in developed and developing countries of the world. This prospective technology can also be implemented for producing food in areas with adverse climate conditions like deserts, Iceland, and even space research stations. Hydroponics is going to be a dominating technology for producing different kinds of crops, grains, fruits, vegetables, and leafy greens to meet the global nutrition demand. Implementation of this emerging technology is increasing day by day for feeding the world properly (Seerat Jan *et al.,* 2020).

Hydroponic farming is easier than traditional farming as it does not require plowing, weeding, soil fertilization, and crop rotation. Also, it is clean and environmentally friendly (Nguyen *et al.,* 2016). Large land requirements, high volume water uses, chemical and pesticides, soil degradation, and some other negative impacts of conventional agriculture can be overcome using the hydroponic farming method (Treftz and Omaye, 2016; Horrigan *et al.,* 2002). Farming in a highly controlled environment makes the quality of hydroponics products better than soil-based farming. Moreover, the unique feature of seasonality independence makes hydroponics farming higher than traditional farming and homogenous all over the year (Okemwa, 2015). Consumers are gradually more attracted to having healthy, echo-friendly, pesticide-free fresh vegetables and leafy greens because of the robust and influential opposite relationship between food ingestion and the risk of various life-long and worsening diseases like stroke, cancer, asthma, cardiovascular, and neurological disorders (Kris-Etherton *et al.,* 2002). Owing to this increasing health-conscious consumer needs, pesticide-free healthy food production is becoming an essential concern for fruit and vegetable producers (Sgherri *et al.,* 2010).

However, the initial investment cost for installing and operating a hydroponic system is generally higher. Also, skilled manpower with deep knowledge of smart information and control systems, plant physiology, chemistry, etc. are required for operating large-scale hydroponics farms (Velazquez-Gonzalez *et al.,* 2022; Saad Khan *et al.,* 2021). On the other hand, hydroponics systems use 5 to 10 times less water than conventional soil-based cultivation (Saaid, 2013). Also, hydroponics gardens require 5 times less space than soil-based gardens to produce the same yield (Sardare and Admane, 2013). With this space-saving feature, it is possible to install hydroponics systems in small spaces like balconies, terraces, courtyards, etc. Hence, it could be a big opportunity for urban people to produce fresh vegetables and leafy greens of their own. Utilizing this major space savings feature of hydroponics any nation can produce more for their people with less space (Saad Khan *et al.,* 2021).

In rural areas, people have adequate land surrounding their homes to produce vegetables and leafy green to meet the daily demand. Due to the shortage of agricultural land, urban people should use progressive technology that can replace traditional soil-based cultivation with less space, less time, and less water usage but with a great increase in production yield.

Hydroponics systems could be the solution for urban people to produce vegetables and leafy green for family use. Moreover, with an automated hydroponics system, it is possible to produce pesticide-free, fresh, and good-quality crops all year round with minimum cost and care.

In this review research work, we are going to discuss about 2. Hydroponics cultivation 3. Types of hydroponics production system with suitable crops 4. Nutrients used for plants 5. Nutritional and environmental parameters affect plant growth 6. Automation used in hydroponics system, 7. Proposed automated hydroponics system for urban family, 8. Conclusion.

Hydroponics Cultivation

Hydroponic farming is different from conventional farming in which crops can be grown without soil. Here, natural or man-made substrates are used to grow plants and a previously prepared nutrient solution tank is used to supply necessary nutrients for proper growth of plants. A simple form of a hydroponics system is shown in Figure 1. Major parts of a hydroponics system are reservoir, nutrient solution, growth tray, substrate, aerator, etc. In hydroponics, the nutrient solution contains all essential nutrients for plants except for carbon, hydrogen, and oxygen, which are directly taken from the environment. The nutrient solution is placed inside a reservoir. An aerator is used to ensure adequate oxygen concentration in the nutrient solution. A substrate is a physical medium that holds plant roots together and supports the stem to keep the plant stable. It provides an aseptic environment with improved water retention capability, proper oxygenation, and a sufficient amount of nutrient flow to keep the plant under appropriate growing conditions (Velazquez-Gonzalez *et al.,* 2022).

Types of Hydroponics Cultivation Systems with Suitable Crops

Several hydroponics methods are available for growing crops and their application varies depending on the types of plants to be grown, local climate, applied technologies, and budget. Some hydroponics systems with suitable crops and appropriate media are discussed below, which are successfully adopted by hydroponics farms worldwide (Seerat Jan *et al.,* 2020; Velazquez-Gonzalez *et al.,* 2022; Saad Khan *et al.,* 2021; Modu, Falmata, *et al.,* 2020; Tyler Baras, 2018).

Deep Water Culture (DWC)

This is the most commonly used hydroponics method, where plant roots are submerged in nutrient-rich water, and an air stone is used to provide adequate oxygen-reached air to the roots of the plants. It is built up with very few moving parts and assembly, where plants are grown very quickly compared to a soil-based system with very low maintenance. Suitable locations for growing crops with is system could be indoor, outdoor, or green house. The size of this system could be small to large. Many varieties of lettuce, celery, and other leafy greens and lots of different herbs are grown super-fast with high-quality yield. Also, tomatoes, peppers, and even larger fruits like squash, and cucumber can be grown well just taking a bit more effort. Stone wool, and grow rock could be used as growing media for this system.

Wick Hydroponic

This is the simplest hydroponic farming method where electricity, pumps, and aerators are not required. In this method, coco coir, perlite, vermiculite, etc. are used as an absorbent medium, and a nylon wick runs from a nutrient solution tank to the absorbent medium containing plant roots. With capillary action, the nutrient solution is supplied to plants. Suitable locations for growing crops with is system could be indoor, outdoor, or green house. The size of this system could be small to large. This system works well for herbs, spices, and other small plants. Coco coir, vermiculite, and perlite could be used as growing media for this system.

Drip Irrigation

In the drip irrigation method, a pump is used to supply nutrient solution from a reservoir to the plants apart from the reservoir. Nozzles are used to dispense nutrient solution slowly to individual plant roots, and the extra solutions can be collected for recirculation or can be drained out. Suitable locations for growing crops with is system could be indoor, outdoor, or green house. The size of this system could be medium to large. Leafy greens and large flowering crops like tomatoes, cucumber, capsicum, and peppers can be grown using a drip system. Perlite, clay pellets could be used as growing media for this system.

Flood and Drain Hydroponics

In this method, plants are placed in a grow tray with appropriate substrate, and a reservoir tank is used to contain the nutrient solution. The grow tray is periodically flooded with nutrients using a pump, which then slowly drains away using gravity. Suitable locations for growing crops with is system could be indoor, outdoor, or green house. The size of this system could be small to large. This system is suitable for growing microgreens to large flowering crops. Perlite, extended clay pellets, stone wool, or coco coir could be used as growing media for this system.

Nutrient Film Technique (NFT)

The NFT system was developed in 1960 to overcome the drawbacks of the Flood and Drain system. In this system, the nutrient solution is continuously supplied by a pump from a reservoir through channels in which plants are placed. This is a repeating process, where the nutrient solution is sent back to the reservoir when it reaches the end of the channel. Suitable locations for growing crops with is system could be indoor, outdoor, or green house. The size of this system could be medium to large. The NFT system is popular for growing leafy greens, herbs, and strawberries. Stone wool could be used as growing media for this system.

Aquaponics

The symbiosis of flora and fauna is exploited in this method to establish an effective system, where the nutritional demand of the plants is supplied by fish feces. A balanced micro-ecosystem is formed inside the fish tank when nutrients are absorbed by the plant, and the microbial process of denitrification and nitrification allows the recycling of tank water. Suitable locations for growing crops with is system could be indoor, outdoor, or green house. The size of this system could be medium to large. Vegetables, leafy greens, herbs, fruiting plants, and flowers are best grown in aquaponics systems. Grow stone, gravel, lava rock, expanded clay could be used as growing media for this system.

Aeroponics

In this method, plant roots reside above the nutrient solution inside the reservoir, and a nutrient haze is sprinkled on the roots at regular intervals. This method gets rid of the barrier between the reservoir and the growth tray. Suitable locations for growing crops with is system could be indoor, outdoor, or green house. The size of this system could be small to large. The plants that grow best in aquaponics systems include leafy greens, herbs, strawberries, and other short crops. Perlite or clay pellets could be used as growing media for this system.

Fogponics

Fogponics is the more advanced variant of aeroponics where a fogger is used to produce smaller water droplets than an aeroponics system. Suitable locations for growing crops with is system could be indoor, outdoor, or green house. The size of this system could be small to large. The plants that grow best in aquaponics systems include leafy greens, herbs, strawberries, and other short crops. Perlite or clay pellets could be used as growing media for this system.

Nutrients used for Plants

It is mandatory to provide all necessary nutrients needed by plants, both in hydroponics and soil-based farming. Carbon(C), nitrogen(N), Hydrogen(H), sulfur(S), copper (Cu), oxygen(O), magnesium (Mg), boron(B), calcium (Ca), zinc (Zn), phosphorus (P), chlorine (Cl), potassium(K), manganese (Mn), molybdenum (Mo) etc. are necessary elements for plants to grow properly. Nutrient solutions used in hydroponics systems contain almost all of these essential elements except oxygen, hydrogen, and carbon which are directly taken from air and water (George *et al.,* 2018).

In soil soil-based agricultural systems, basic nutrients in the soil are produced from organic matter by biological decomposition, to feed the plants. On the other hand, in hydroponics farming, nutrient solutions are prepared from immensely soluble inorganic salts, which supply all necessary elements for proper plant growth. Nutrients used in hydroponics systems can be grouped into three categories: primary, secondary, and micro-nutrients.

Nutrient solution management can be considered as the basis of successful hydroponics farming (Aviles and Light. 2018). The productivity and quality of hydroponically produced fruits and vegetables are highly dependent on nutrient quality. Hence, the successful implementation of nutrients in a balanced way is significant for determining the ultimate quality of the product (Abou-Hadid *et al.,* 1996).

Depending on plant type, and growing stage, the chemical composition of nutrient solution varies. Macro-nutrient contents of commercially available nutrient solutions are expressed by a three-digit sequence, following the N-P-K values presented in weight percent of nitrogen, phosphorus, and potassium. For example, a 5-15-30 formulation, which is within the recommended level for lettuce, contains 5% N, 15% P, and 30% K. For strawberry crops, a 10-10-10 or 20-20-20 formulation is used. Previous work of Hoagland and Arnon is considered as the basis for nutrient solutions recommendations (Saad Khan *et al.,* 2021). Jensen and Collins published an article in 1985, that provides a complete description of nutrient solution formula, mixing, etc. (Jensen and Collins, 1985).

The nutrient solution lifetime plays an important role in hydroponics farming which depends on appropriate correction of pH, electrical conductivity, and water level. Water lost by evaporation and absorbed by plants should be refilled periodically to keep constant water level in the nutrient tank.

Or else, the salt concentration in the nutrient tank will change and will affect the plant's growth. Depending on crop type, it is recommended by Bosques to change the nutrient solution by cleaning and disinfecting the tank every two to three weeks (Velazquez-Gonzalez *et al.,* 2022).

Nutritional and environmental parameters affect plant growth

Nutritional Parameters

In a hydroponic system, potential hydrogen (pH), electrical conductivity (EC), dissolved oxygen (DO), and temperature are some essential parameters (factors) of the nutrient solution that must be carefully monitored for the proper growth of plants. All these factors play an important role in ensuring a comfortable, and healthy environment for plants to be grown.

pH is the most important chemical property to specify the acidity or alkalinity of nutrient solution and is indicated on a scale from 1 to 14. Solution with pH lower than 7 is acidic, and higher than 7 is basic. A pH value between 5 and 7 for hydroponics solution is accepted by the majority of authors (Lu and Shimamura, 2018).

In the nutrient solution, EC represents the total concentration of ions and is expressed in milliSiemens per linear centimeter (mS/cm). When the EC value of nutrient solution falls below a certain level it indicates scarcity of nutrients. Contrariwise, too-high EC values indicate the presence of salt stress in the nutrient solution which is harmful to plants (Savvas and Gruda, 2018). It is recommended to keep the EC value within the specified range for a particular crop as the growth and quality of the crop are potentially affected by EC (Sonneveld and Voogt, 2009).

Enough dissolved oxygen (DO) levels in nutrient solution should be maintained to ensure healthy and quality crops. In soilless culture, falling DO levels in the nutrient solution may introduce a reduction in ion and water uptake causing poor root growth and an increase in the incidence of diseases and pests, and eventually decreasing crop production (Pezeshki *et al.,* 1993). Also, oxygen deficiency in the root environment causes serious root respiration issues when DO levels fall from a critical value (Lemon and Wiegand, 1962).

Another influential factor that must be considered in hydroponic production systems for quality crops, is the temperature of the nutrient solution (Muthir *et al.,* 2019). The nutrient absorption rate is highly affected by the temperature of the nutrient solution, which in turn affects the physiological process in plant roots (Nxawe *et al.,* 2010). For example, at low temperatures, the uptake rate of Zn, Fe, K, Mn, P, Na, and N was significantly reduced in Jojoba (Reyes *et al.,* 1977).

Environmental Parameters

Environmental factors like light, temperature, relative humidity, carbon dioxide, and air velocity should be properly monitored and controlled for hydroponics farming.

An essential precondition for plant growth is light. It plays a vital role in determining the final yield and quality of hydroponics products, as it affects the growth of plants by influencing plant's physiological activities like photosynthesis, photorespiration, photoperiodism, etc.

Photosynthesis activity is strongly influenced by light intensity and increases with the increasing luminosity until it reaches a maximum value, where a further increase in luminosity does not make any change (Zanon, 1990).

Plant's physiological activities like photosynthesis, respiration, and transpiration are affected by environmental temperature. It affects the light-independent reactions of photosynthesis but not the light-dependent reactions of photosynthesis. For vegetable production in the greenhouse, environmental temperature should be maintained between 21-27 C to obtain maximum activity (Kawasaki and Yoneda, 2019).

It is important to control the relative humidity inside a greenhouse effectively, as it affects the quality of plants. The Rh value is a critical environmental parameter for crop production since it affects the leaf transpiration rate and can influence the water balance in crops. It also affects the photosynthesis rate as well (Jolliet, 1993).

Photosynthesis rate is directly proportional to CO2 concentration. Photosynthesis rate increases rapidly with increasing CO2 concentration, as its atmospheric concentration is very low (about 0.04%). It had reached a plateau when the maximum rate of fixation was achieved.

Air velocity is considered one of the influential environmental variables that affect the growth of plants in controlled environments like a greenhouse and indoor farming (Kawasaki and Yoneda, 2019). Effective control of environmental temperature, CO2 concentration, and relative humidity depends on the appropriate management of air circulation inside a greenhouse (Shibuya *et al.,* 2006).

Automation used in Hydroponics System

Automation is the application of a wide range of technologies in various processes to reduce human effort, electricity cost, material cost, etc. with improvements to quality, accuracy, and precision. In an automated hydroponics system, different factors (Environmental factors, Nutritional factors, and others) that control the growth of plants are managed with sensors (temperature sensor, humidity sensor, pH sensor, etc.) connected with a controlling device such as a microcontroller, Raspberry PI, etc. A camera module can also be included with the system to detect and identify plant diseases automatically. A website or mobile application can be created to send system information remotely to the user as needed.

In Alan Hadinata and Mashoedah (2021), the authors conducted their research work to find out the IoT devices and platforms used for the development of IoT-based hydroponics systems. They have concluded their research work with the indication that the measured variables are Potential Hydrogen (pH), Total dissolved solids (TDS), Water Temperature, Environmental Temperature, Humidity, Carbon Dioxide (CO_2), and Electrical Conductivity (EC) and Devices used are ESP8266, Arduino, and Raspberry PI with MySQL, Firebase, Thingspeak, Wyliodrin, and Domoticz IoT Platforms.

In this review work, pieces of literature on automated hydroponics systems published in various journals are studied. From this study, it is observed that some authors focused only on the monitoring function of desired factors (e.g. temperature, humidity, pH, etc.). In their design controlling functions of parameters like pH, EC, Temperature, humidity, etc. are absent (Ang *et al.,* 2022; Saputra *et al.,* 2022; Muhammad Syahmi Kamarulzaman *et al.,* 2021; Salvi *et al.,* 2021; Sumaiya Islam *et al.,* 2021; Marques *et al.,* 2019). For example, in Ang *et al.,* (2022), the authors have designed an IoT-based water quality monitoring system that is capable of monitoring pH, DO, and water temperature of nutrient solution remotely. It is also observed that some authors have designed their system for monitoring the majority of parameters with the control of a few parameters of their own design (Safira *et al.,* 2022; Pramono *et al.,* 2020; Dutta *et al.,* 2021; Prince, Imtiaz Ahmed, *et al.,* 2022; Ruengittinun *et al.,* 2017). For example, in (Dutta *et al.,* 2021), the authors have designed an IoT-based indoor hydroponics system that is capable of monitoring pH, humidity, temperature, light intensity, and nutrient tank water level with the ability of automatic pH control.

On the other hand, some authors have designed their system for monitoring and controlling all desired parameters of their own design (Ma-Clarissa Mabitazan *et al.,* 2021; Kaewwiset and Yooyativong, 2017; Caesarendra *et al.,* 2022; Yang, Shi-feng and Daudi S. Simbeye, 2013; Vijayan *et al.,* 2022; Madeira *et al.,* 2019). For example, in (Ma-Clarissa Mabitazan *et al.,* 2021), the authors have designed an automated system for a closed-hydroponic setup that is capable of monitoring and controlling the pH and electrical conductivity of nutrient water automatically. Table 1 summarizes some automated hydroponics systems and their monitoring and controlling functions.

From this literature review, it is observed that monitoring and controlling parameters are different depending on the hydroponics environments (indoor, outdoor, greenhouse, poly house, etc.), local climates, growing methods (DWC, NFT, etc.), system size (small, medium, large, etc.), cost optimization, system complexity, etc. We should consider all the above factors for designing an automated hydroponics system to meet the demands of urban families.

Table.1 Automated hydroponics system and their monitoring and controlling function summarization

Serial number	Article title	Monitoring function		Controlling Function	
		Nutritional	Environmental	Nutritional	Environmental
1	*Design of a water quality monitoring system utilizing IOT platform for hydroponics application [36]*	Temperature pH DO	-	-	-
2	*Microcontroller based of hydroponic monitoring environmental condition [37]*	Temperature pH TDS	-	-	-
3	*Monitoring System of Hydroponic Using Solar Energy [38]*	Temperature pH Water level	-	-	-
4	*HydroIoT: An IoT and Edge Computing based Multi-Level Hydroponics System [39]*	Temperature pH water level	Temperature Humidity Light intensity	-	-
5	*A review on effect of ambient environment factors and monitoring technology for plant factory [40]*	-	Temperature Humidity Light intensity CO2 Air velocity	-	-
6	*Enhanced Hydroponic Agriculture Environmental Monitoring: An Internet of Things Approach [41]*	pH EC Water level	Temperature Humidity Light intensity CO2	-	-
7	*Design of control system for water quality monitoring system for hydroponics application [42]*	Temperature pH DO	-	pH	-
8	*Design of a hydroponic monitoring system with deep flow technique (DFT) [43]*	Temperature pH TDS water level	Temperature	pH	-
9	*IoT based Indoor Hydroponics System [44]*	Temperature pH water level	Temperature Humidity Light intensity	pH	-
10	*IoT Based Monitoring Framework For a Novel Hydroponic Farm [45]*	Temperature pH EC water level	Temperature Humidity	pH Water level	
11	*Applied internet of thing for smart hydroponic farming ecosystem (HFE) [46]*	Temperature pH EC	Temperature Humidity	-	Temperature Humidity
12	*Automated System that Monitors and Controls the pH and Electrical Conductivity of a Closed-Hydroponic Setup [47]*	pH EC	-	pH EC	-
13	*Electrical conductivity and pH*	pH	-	pH	-

	adjusting system for hydroponics by using linear regression [48]	EC		EC	
14	*Hydroponic Box Design with an IoT Monitoring System [49]*	-	Temperature Humidity	-	Temperature Humidity
15	*Computerized Greenhouse Environmental Monitoring and Control System Based on LabWindows/CVI [50]*	-	Temperature Humidity Light intensity CO2	-	Temperature Humidity Light intensity CO2
16	*Smart development in the growth of plants using hydroponics and Internet of Things [51]*	Temperature pH	Temperature Light status	Temperature pH	Temperature Light status
17	*Automated Hydroponics System using NFT System and IOT. [52]*	Temperature pH EC water level	Light status	Temperature pH EC water level	Light status

Figure.1 A simple hydroponics system

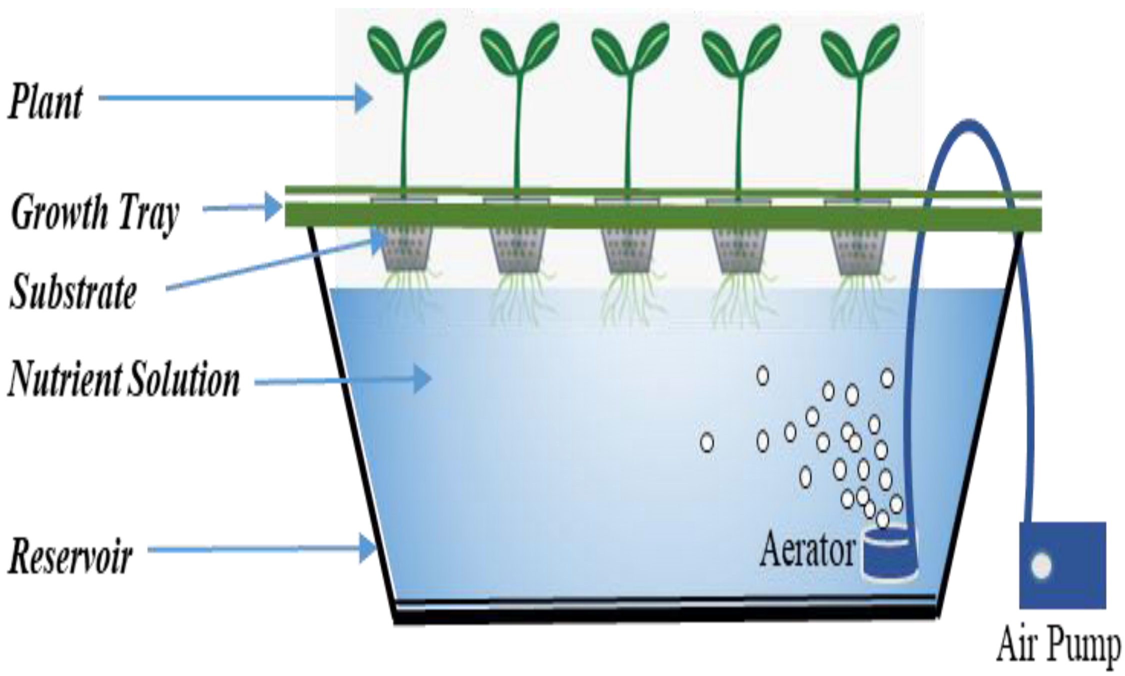


Figure.2 Block diagram of nutrient management unit (NMU)

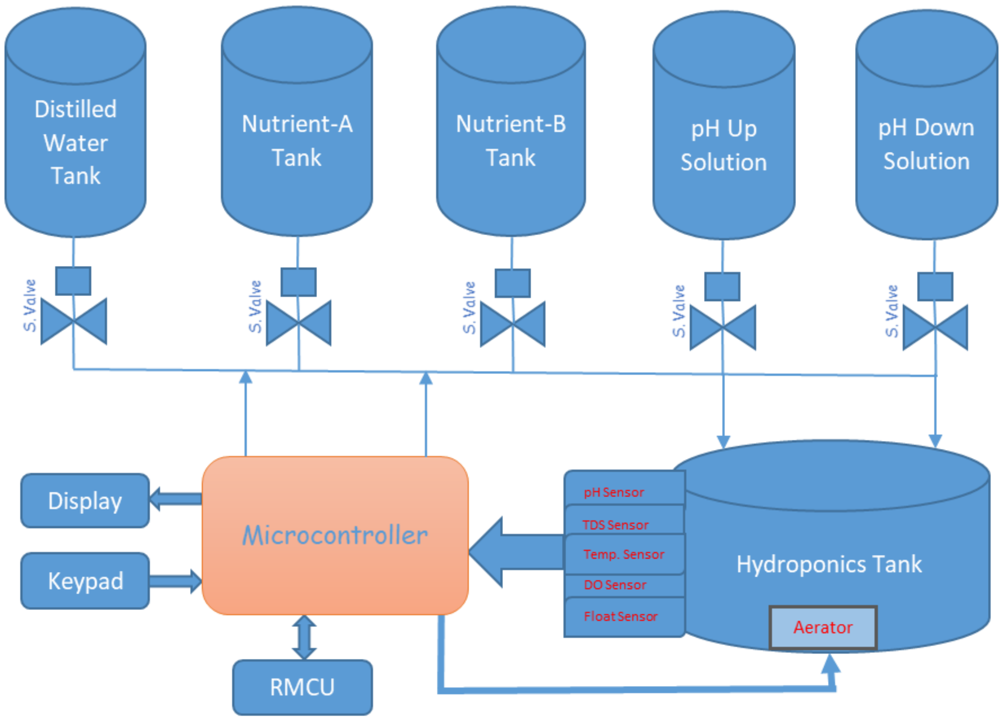


Figure.3 Block diagram of environment management unit (EMU)

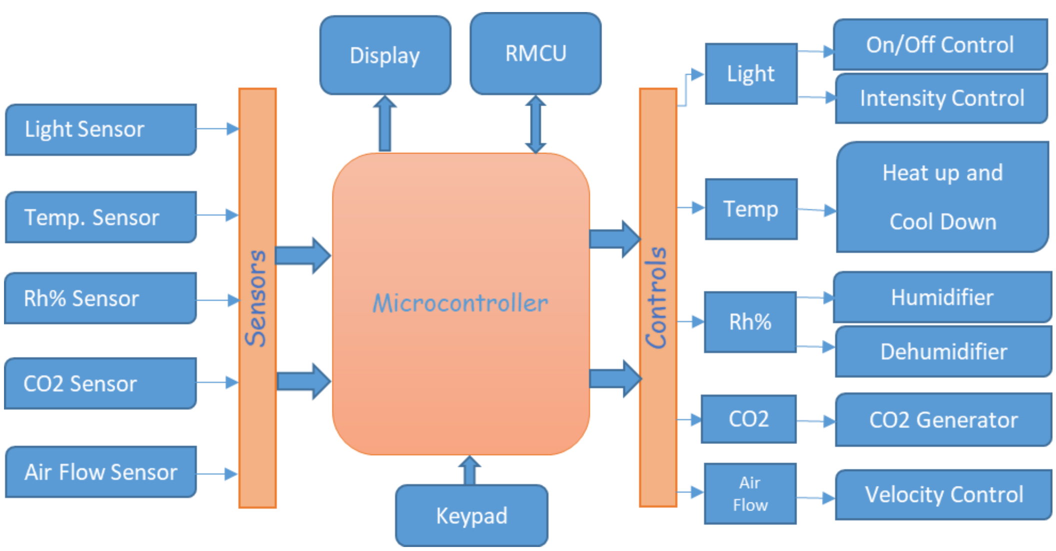
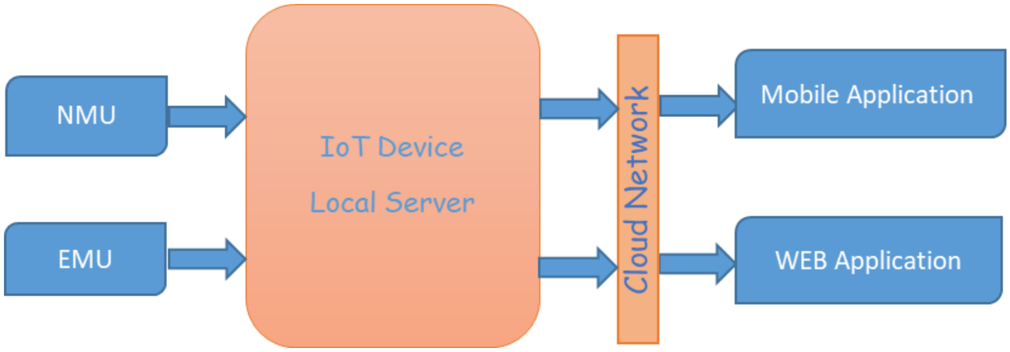


Figure.4 Block diagram of remote monitoring and control unit (RMCU)



Proposed automated hydroponics system for the urban family

The concentration of population density is increasing in urban areas. According to the United Nations (UN 2010), 800 million people occupied urban areas in 1950 and will come to 6.3 billion in 2050 (Schnitzler, 2012). Demand for vegetables and leafy greens in urban areas is increasing day to day. In most cases, these products for urban people are transported from distant rural areas and sometimes from abroad. Long-distance transportation adds additional costs to consumers and at the same time reduces food quality and freshness. Unquestionably, people desire fresh, pesticide-free locally produced vegetables and leafy green in their kitchens.

Due to the shortage of agricultural land, urban people should use progressive technology that can replace traditional soil-based cultivation with less space, less time, and less water usage but with a great increase in production yield. Hydroponics systems could be the solution for urban people to produce vegetables and leafy green for family use. Moreover, with an automated hydroponics system, it is possible to produce high-quality, pesticide-free crops all year round with minimum cost and care. Urban people can install hydroponics systems on their roof-top, terraces, balconies, etc. for growing vegetables and leafy green. This is going to be the future.

Urban families are not similar in terms of educational qualifications, monthly income, technology adoption, and other capabilities required to maintain hydroponics systems properly. This work aims to provide hydroponics system solutions for all categories of urban families. In this work, we suggest three types of hydroponics systems- fully automated, semi-automated, and manually operated- that could be used by urban family depending on their need and capabilities. To avoid complexity, our proposed system consists of four parts, so that, the end user can optimize their system according to their need and capability.

Part-1: Hydroponics System Type Selection
Part 2: Nutrient Management Unit (NMU)
Part 3: Environment Management Unit (EMU)
Part 4: Remote Monitoring and Control Unit (RMCU)

Part-1: At first growers should select what they want to grow, how much they want to grow, and where they want to grow. Based on their demands growers should select the appropriate hydroponics system (DWC, NFT, Aeroponics, etc.), then design and build the system. For selecting their desired systems growers should consider several things, such as cost, complexity, local climate, place of installation (rooftop, terrace, balcony, or indoor), etc.

Part 2: The block diagram of the proposed nutrient management unit (NMU) is shown in Figure 2. The nutrient management system consists of necessary sensors, actuators, and input/output devices with data communication interfaces, all are connected to a controlling device, in this case microcontroller. Growers would be capable of supplying the perfect nutrient solution for their desired plants automatically by using NMU.

For perfect nutrient solution pH, TDS, DO and temperature of nutrient solution should be kept within the desired limit for specific plants. NMU consists of pH sensor, TDS sensor, DO sensor, and temperature sensor with the necessary controlling equipment to provide a perfect nutrient solution for plants. Initially, NMU fills the hydroponics tank with nutrient-enriched water that will be used by plants. This is done by opening the solenoid valves attached to the nutrient-A tank, nutrient-B tank, and distilled water tank to mix them in appropriate proportions (Figure 2). NMU utilizes a float sensor to keep hydroponic tank water at a desired height. After that NMU periodically monitors the pH, TDS, DO, and temperature of hydroponic tank water utilizing a pH sensor, TDS sensor, DO sensor, and Temperature sensor to keep these factors within the desired limit.

To keep the pH value within the desired limit, NMU opens the solenoid valves attached to the pH-up solution tank and pH-down solution tank as needed. To keep the TDS value within in desired limit, NMU opens the solenoid valves attached to the distilled water tank, nutrient-A tank, and nutrient-B tank as needed. To keep the water temperature within the desired limit, NMU switched on/off the heating or cooling system as needed. To maintain an adequate oxygen level, NMU switched on an aerator as needed. All these functions are performed automatically by nutrient NMU, to ensure the supplying of perfect nutrient solution for plants. Liquid crystal display (LCD) and keypad switch are attached with NMU for initial parameter setting. NMU system is also connected with RMCU for remote monitoring and control by growers.

Part 3: The block diagram of the proposed environment management unit (EMU) is shown in Figure 3. Environmental factors, such as light, temperature, relative humidity (Rh%), CO2, and airflow, that influence the development of plants (and their quality) in a hydroponic system could be monitored and controlled by EMU. EMU utilizes a light sensor, temperature sensor, Rh% sensor, CO2 sensor, and airflow sensor for monitoring these influential environmental factors. Based on the measured value of various environmental factors, EMU performs similar functionality to NMU by taking necessary steps for controlling these factors within the desired value for specific plants. EMU is also connected with RMCU for remote monitoring and control.

Part 4: The block diagram of the remote monitoring and control unit (RMCU) is shown in Figure 4. RMCU consists of an IoT device such as ESP8266, Arduino, Raspberry PI, etc. that uses IoT platforms such as MySQL, Thingspeak, Firebase, Domoticz, Blynk, etc. to build user interfaces such as mobile applications, web applications for monitoring and controlling functionality of NMU and EMU remotely.

Urban growers can optimize their hydroponics system for producing pesticide-free fresh vegetables with the help of above mentioned four units of our proposed system. Part 1 of our proposed system is mandatory for implementing manual, semi-automated, and fully automated hydroponics systems.

If end users want to install a manually operated hydroponics system, they can go through part 1 of our proposed system. This is the cheapest system affordable for most people without any automation parts. Growers who want to install a semi-automated hydroponics system can customize part 2 and part 3 by including or excluding various sensors and controlling equipment according to their needs.

They can also incorporate part 4 into their design if they want to monitor and control their designed system remotely. For installing a fully automated hydroponics system, growers should install part 1, part 2, and part 3 of our proposed system with or without part 4 depending on their need.

In this manuscript, we describe the theoretical and technological aspects of the hydroponic-based food production process and its sultriness in solving global food demand in 2050 by implementing this system in urban areas, where arable land is inadequate.

Our proposed hydroponics system provides an appropriate solution for selecting a suitable hydroponics system for every urban family depending on their need and capability, for producing high-quality, pesticide-free crops all year round with minimum cost and care.

Author Contributions

M. Atiar Rahman: Investigation, formal analysis, writing—original draft. M. A. A. Mamun: Validation, methodology, writing—reviewing. Sabiha Sattar:—Formal analysis, writing—review and editing. Mist. Toma Khatun: Investigation, writing—reviewing. M. Shohel Rana: Resources, investigation writing—reviewing. Mohaimina Begum: Validation, formal analysis, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

References

Abou-Hadid, A. F., E. M. Abd-Elmoniem, M. Z E. Shinawy, and M. Abou-Elsoud. 1996. Electrical conductivity effect on growth and mineral composition of lettuce plants in hydroponic system. Acta Horticulturae 434 (434): 59–66. https://doi.org/10.17660/ActaHortic.1996.434.6.

Alan Hadinata and Mashoedah "Internet of Things-based Hydroponic: Literature Review", 2021, J. Phys.: Conf. Ser. 2111 012014

Ang, H. N., M. W. Lim and W. S. Chua "Design of a water quality monitoring system utilizing IOT platform for hydroponics application", 29 August 2022, AIP Conference Proceedings

Aviles, J. J. S., and G. Light. 2018. Embedded Controlled Gardening: An Academically Based Service Course. In IEEE Integrated STEM Conference (ISEC), Canada, 149–53

Caesarendra W and Y R Ramadhan and Harmailis and K A Pranoto and G D Wijaya," Hydroponic Box Design with an IoT Monitoring System", 2022, IOP Conference Series: Earth and Environmental Science, https://doi.org/10.1088/1755-1315/1097/1/012047

Dutta, A., I. Nag, S. Basu, D. Seal and R. K. Gayen, "IoT based Indoor Hydroponics System," *2021 5th International Conference on Electronics, Materials Engineering & Nano-Technology (IEMENTech)*, Kolkata, India, 2021, pp. 1-8, https://doi.org/10.1109/IEMENTech53263.2021.9614730.

FAO Statistical Yearbook 2013, "World Food and Agriculture". Available online: https://www.fao.org/3/i3107e/i3107e.pdf (Last accessed on 01 February, 2024)

George J. Hochmuth and Robert C. Hochmuth "Nutrient Solution formulation for Hydroponic (Perlite, Rockwool, NFT) Tomatoes in Florida".

Horrigan, L., Lawrence, R.S. and Walker, P. 2002. How sustainable agriculture can address the environmental and human health harms of industrial agriculture. Environmental Health Perspectives, 110:445-456.

Jensen, M. H., and W. L. Collins. 1985. Hydroponic vegetable production. Hort. Review 7:483–558.

Jolliet D O 1993 Modelling of Water Uptake, Transpiration and Humidity in Greenhouse, and of Their Effects on Crops Acta Hortic. 328 69–78

Kaewwiset T. and T. Yooyativong, "Electrical conductivity and pH adjusting system for hydroponics by using linear regression," 2017 14th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), Phuket, Thailand, 2017, pp. 761-764, https://doi.org/10.1109/ECTICon.2017.8096350.

Kawasaki, Y., and Y. Yoneda. 2019. Local temperature control in greenhouse vegetable production. The Horticulture Journal 88 (3):305–14. https://doi.org/10.2503/hortj.UTD-R004.

Kris-Etherton, P.M., Hecker, K.D., Bonanome, A., Coval, S.M., Binkoski, A.E., Hilpert, K.F., Griel, A.E. and Etherton, T.D. 2002. Bioactive compounds in foods: Their role in the prevention of cardiovascular disease and cancer. The American Journal of Medicine, 113:71-88.

Lemon ER, Wiegand CL. Soil aeration and plant root relations II root respiration. Agronomy Journal. 1962;54:171-175

Lu, N.; Shimamura, S. Protocols, Issues and Potential Improvements of Current Cultivation Systems. In Smart Plant Factory: The Next Generation Indoor Vertical Farms; Kozai, T., Ed.; Springer: Singapore, 2018; pp. 31–49.

Ma-Clarissa Mabitazan, Raul Mabitazan, "Automated System that Monitors and Controls the pH and Electrical Conductivity of a Closed-Hydroponic Setup", American Academic Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS) (2021) Volume 83,No 1, pp 113-131

Madeira, Malcolm Andrew and Tjprc. “Automated Hydroponics System using NFT System and IOT.” *International Journal of Computer Science Engineering and Information Technology Research* (2019): n. pag.

Marques, G., Aleixo, D., Pitarma, R. (2019). Enhanced Hydroponic Agriculture Environmental Monitoring: An Internet of Things Approach. In:, *et al.,* Computational Science – ICCS 2019. ICCS 2019. Lecture Notes in Computer Science(), vol 11538. Springer, Cham. https://doi.org/10.1007/978-3-030-22744-9_51

Modu, Falmata, *et al.,* "A survey of smart hydroponic systems." *Advances in Science, Technology and Engineering Systems Journal* 5.1 (2020): 233-248.

Muhammad Syahmi Kamarulzaman, Siti Amely Jumaat, Muhammad Nafis Ismail, Ahmad Fateh Mohd Nor, “Monitoring System of Hydroponic Using Solar Energy”, 30 June 2021, Journal of Electronic Voltage and Application, DOI: https://doi.org/10.30880/ijie.2021.02.01.004

Muthir SA, Salim AA, Yaseen AA, Saleem KN. Influence of nutrient solution temperature on its oxygen level and growth, yield and quality of hydroponic cucumber. Journal of Agricultural Science. 2019;11(3):75-92

Nguyen, N.T., Mcinturf, S.A., Mendozacózatl, D.G. 2016. Hydroponics: A versatile system to study nutrient allocation and plant responses to nutrient availability and exposure to toxic elements. Journal of Visualized Experiments, 10: 3791-54317.

Nxawe S, Ndakidemi PA, Laubscher CP. Possible effects of regulating hydroponic water temperature on plant growth, accumulation of nutrients and other metabolites. African Journal of Biotechnology. 2010;9(54):9128-9134

Okemwa, E. 2015. Effectiveness of aquaponic and hydroponic gardening to traditional gardening. International Journal of Scientific Research and Innovative Technology, 2:2313-3759.

Pezeshki SR, Pardue JH, Delaune RD. The influence of soil oxygen deficiency on alcohol dehydrogenase activity, root porosity, ethylene production and photosynthesis in Spartina patens. Environmental and Experimental Botany. 1993;33(4):565-573

Pramono, Subuh, Arif Nuruddin, and Muhammad Hamka Ibrahim. "Design of a hydroponic monitoring system with deep flow technique (DFT)." *AIP Conference Proceedings*. Vol. 2217. No. 1. AIP Publishing LLC, 2020.

Prince, Imtiaz Ahmed, *et al.,* "IoT Based Monitoring Framework For a Novel Hydroponic Farm." *2022 IEEE Region 10 Symposium (TENSYMP)*. IEEE, 2022.

Reyes DM, Stolzy LH, Labanauskas CK. Temperature and oxygen effects in soil on nutrient uptake in Jojoba seedlings. American Society of Agronomy. 1977;69:647-650

Ruengittinun, S., S. Phongsamsuan and P. Sureeratanakorn, "Applied internet of thing for smart hydroponic farming ecosystem (HFE)," *2017 10th International Conference on Ubi-media Computing and Workshops (Ubi-Media)*, Pattaya, Thailand, 2017, pp. 1-4, https://doi.org/10.1109/UMEDIA.2017.8074148.

Saad Khan, Ankit Purohit & Nikita Vadsaria, “Hydroponics: current and future state of the art in farming”, Journal of Plant Nutrition, 2021, VOL. 44, NO. 10, 1515–1538

Saaid, M. F., N. S. M. Fadhil, M. Ali, and M. Z. H. Noor. 2013, “Automated indoor aquaponic technique”, In Conference on System Engineering and Technology, 19–20 Aug IEEE, 285–289.

Safira, M R., M W Lim and W S Chua, “Design of control system for water quality monitoring system for hydroponics application”,2022, Conf. Series: Materials Science and Engineering, https://doi.org/10.1088/1757-899X/1257/1/012027

Salvi, S., S. Savitha, S. Sawargaonkar, B. Vishwas, T. K. Harshitha and S. A. Pramod Jain, "HydroIoT: An IoT and Edge Computing based Multi-Level Hydroponics System," *2021 IEEE International Conference on Computation System and Information Technology for Sustainable Solutions (CSITSS)*, Bangalore, India, 2021, pp. 1-6, https://doi.org/10.1109/CSITSS54238.2021.9683621.

Saputra, W. J., Muttaqin, F., & Indrianti. (2022). Microcontroller based of hydroponic monitoring environmental condition. International Seminar of Research Month 2021. NST Proceedings. pages 273-276. https://doi.org/10.11594/nstp.2022.2441

Sardare, M. D., and S. V. Admane. 2013. A review on plant without soil –Hydroponics. IJRET 2 (3):299– 304.

Savvas, D.; Gruda, N. Application of soilless culture technologies in the modern greenhouse industry—A review. Eur. J. Hortic. Sci. 2018, 83, 280–293

Schnitzler, W. (2012). Urban Hydroponics for Green and Clean Cities and for Food Security. Acta horticulturae. 1004. 13-26. 10.17660/ActaHortic.2013.1004.1.

Seerat Jan, Zahida Rashid, Tanveer Ahmad Ahngar, Sadaf Iqbal, M. Abbass Naikoo, Shabina Majeed, Tauseef Ahmad Bhat1, Razia Gul and Insha Nazir, "Hydroponics – A Review", International Journal of Current Microbiology and Applied Sciences ISSN: 2319-7706 Volume 9 Number 8 (2020)

Sgherri, C., Cecconami, S., Pinzino, C., Navari-Izzo, F. and Izzo, R. 2010. Levels of antioxidants and nutraceuticals in basil grown in hydroponics and soil. Food Chemistry, 123:416-422.

Shahiduzzaman Khan, "Worries over farmland depletion". Available online: https://thefinancialexpress.com.bd/views/worries-over-farmland-depletion-1605105883 (Last accessed on 01 February, 2024)

Shibuya T, Tsuruyama J, Kitaya Y, Kiyota M. 2006. Enhancement of photosynthesis and growth of tomato seedlings by forced ventilation within the canopy. Scientia Horticulturae 109(3):218-222.

Sonneveld, C.; Voogt, W. Nutrient Management in Substrate Systems. In Plant Nutrition of Greenhouse Crops; Springer: Dordrecht, The Netherlands, 2009; pp. 277–312.

Sumaiya Islam, Md Nasim Reza, Milon Chowdhury, Sun-Ok Chung, Il-Su Choi, "A review on effect of ambient environment factors and monitoring technology for plant factory", September 2021, Precision Agriculture Science and Technology

Treftz, C. and Omaye, S.T. 2016. Hydroponics: Potential for augmenting sustainable food production in nonarable regions. Nutrition and Food Science, 46:672-684.

Tyler Baras, "DIY Hydroponics Garden", 2018, Quarto Publishing Group USA Inc.

Velazquez-Gonzalez, R.S.; Garcia-Garcia, A.L.; Ventura-Zapata, E.; Barceinas-Sanchez, J.D.O.; Sosa-Savedra, J.C. A Review on Hydroponics and the Technologies Associated for Medium- and Small-Scale Operations. *Agriculture* 2022, *12*, 646. https://doi.org/10.3390/agriculture12050646

Vijayan, K., G. Shanthi, K. S. R Radhika, L. Raja, "Smart development in the growth of plants using hydroponics and Internet of Things", May 2022, AIP Conference Proceedings

World resource report on, "Creating a Sustainable Food Future" (synthesis report, 2018). Available online: https://files.wri.org/d8/s3fs-public/creating-sustainable-food-future_2.pdf (Last accessed on 01 February, 2024)

Yang, Shi-feng, and Daudi S. Simbeye. "Computerized Greenhouse Environmental Monitoring and Control System Based on LabWindows/CVI." *J. Comput.* 8.2 (2013): 399-408.

Zanon, I. M. 1990. Synergy between plastics research and protected agriculture. In Proceedings of the XI International Congress F on the Use of Plastics in Agriculture. New Delhi, India, F31–F39

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