Electronic Hydroponics: Insights and the Case Study of Oman

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Abstract. The Ministry of Agriculture and Fisheries in Oman is taking care of a major role in the field of agriculture by rationalizing the use of water for irrigation, and it has also adopted new initiatives dedicated to the field of agriculture which will enhance crops productivity. Greenhouse systems are considered to be among the technologies that are currently considered, where the vegetables grown such systems have excellent characteristics, thus enhanced productivity becomes vital. In principle, it is possible to grow plants in any season by controlling the plantation environment. In this paper, the concepts of soilless farming equipped with an electronically assisted platforms are investigated with a specific focus in Oman’s context. The soilless farming is also referred to as water farming or hydroponics. This technique is crucially important to the Sultanate of Oman as it optimizes the consumption of water that might be wasted due to evaporation or leakage into the soil. The water used by the electronic hydroponic systems can be recirculated in a closed-loop scenario. This paper also touches on relevant research directions of advanced technologies on the area of electronic hydroponic systems.

1. Introduction

1.1 The concept of cultivation
Cultivation is a source of income for many families and residents in rural areas, and it also seen as one of the most important elements of local development as it represents the essential mainstay of social and economic security in rural areas [1]. Agriculture is a production process based on a regular movement of plants and animals aimed at producing food and goods. The agriculture is a national priority and security for any country as it directly relates to the life of human beings especially during wars or global pandemics such as the current COVID-19. It also relates to the survival of animals and birds. As such, this sector is of a critical importance to any country and it often coordinates with other sectors to provide better operational plans, implementation and control [2]. Other than the reduction of poverty, the growth rates of agriculture can also achieve environmental sustainability. In addition, agricultural is an economic activity that is considered as a direct source of income for farmers and a potential employability for those in environmental and logistic services. Thus, the agricultural sector is considered important for its contribution to the growth and advancement of the economy, and it is an important catalyst in the field of agricultural-related industries.

1.2 Past Civilizations and Agriculture

1.2.1. Sumerian civilization
Sumerian civilization is one of the historical civilizations that began since the sixth lap [3]. It is worth mentioning that it relied on the cultivation of different crops as a primary source, giving them a kind of independence and strength at that stage.

1.2.2. Pharaonic civilization and its achievements in the agricultural field
The Paranoiac civilization is an ancient civilization that was established in the northeastern part of the African continent in the year 3150 BC, and specifically in Egypt, where it sets its borders on the banks of the Nile River [4]. The agricultural activity developed due to the fertility of the land and the availability of the rest of the appropriate agricultural conditions. It is evident by looking at the Egyptian history that the Pharaonic civilization has given this world a lot of achievements in several areas, including the agricultural field, as the social situation in the Egyptian civilization was divided into several classes, but the majority of the people of the Pharaonic civilization are from the class of farmers. In view of the existence of the Nile River, this has a positive effect on the agricultural sector in the Pharaonic civilization due to the fertility of the soil and moderation of the climate, as well as the availability of water in abundant quantities. The ancient Pharaohs were able to predict the coming season of floods and they knew that there were three seasons annually namely: Sister (i.e. the flood season; from June to September), Beret (i.e. the planting season; from October to February) and Shimo (i.e. the harvest season; from March to May). This is what represents an agricultural achievement registered for the Pharaonic civilization.

1.2.3. The Civilizations of Majan and Mazoon in the Old Sultanate of Oman
These two civilizations were established in the Sultanate of Oman and each of these two civilizations existed in Oman for a certain period of time [5]. Perhaps the common link between these two civilizations was that the agricultural activity was very popular, so important and represented the cornerstone of all other activities such as trade and others. All activities were related to agriculture at that time and even worked on developing the agricultural field. This is evidenced by the following: First, by referring to the cuneiform writings, it becomes clear that the other civilizations used to import important agricultural products from Oman. Second, the presence of long lines of cracks that the ancestors made in order to carry out the irrigation process, called aflaj, which are spread in many places and regions of the Sultanate. The aflaj are tens of miles from old irrigation canals with different slopes until they get to a close proximity to agricultural villages and cities, and the water is then distributed for different life purposes.

Thus, the approved aflaj system coincides with the so-called canal, meaning the made water pipe that runs underground, and the aflaj have different shapes that can be manufactured, it is possible for the channel to be hidden underground until its arrival point for human use, and it may appear and disappear again. Omani historians and others trace the origin of the aflaj in Oman to the Prophet Suleiman bin Daoud in the tenth century BC, and the naming of some of the aflaj as the Dawudiyya is due to that belief, which represents 40% of the Omani aflaj.

It is clear through the report of the Italian mission on the Aflaj that the new discoveries at the archaeological site of Salut in the state of Bahla indicate that the origin of the aflaj was of Omani origin and dates back to the end of the second millennium BC, when the irrigation system appeared in Oman, and it moved after a large period of time to Iran after its control of the coasts Southern Arabia.

In Oman, there are three main types of aflaj:
• Daudi aflaj (Adiyya) are underground tunnels, reaching a length of 12 km.
• Aflaj (Guelleh), which are open channels found in the valleys, and their length may reach 2 km.
• Aflaj (Ainiyyeh) have their sources in the tops and foothills of the mountains and their waters flow through open channels, tunnels or over bridges, and their channels are prepared to reach villages and cultivated lands.
1.3. Agriculture in the Sultanate of Oman

Oman contains many areas of production and one of the most important productive sectors in Oman is the agricultural sector, which has long been characterized by history [6]. Oman has relied heavily on revenue from oil reserves [7]. The sale of these reserves accounted for 84% of government revenue in 2016. Due to the lower oil prices in the market worldwide, the government of the Sultanate of Oman has sought to diversify its national incomes. In these years, the Sultanate of Oman imports 50% of its vegetable needs. Palm trees, lemon, mango, banana, wheat and gum are considered to be among the most prominent agricultural crops in Oman. The agricultural sector can cover most of Omani society's food needs, and has the largest share in Oman's non-oil exports. The Ministry of Agriculture and Fisheries in Oman has helped to apply the use of soilless agriculture technology to the most important vegetable crops under the closed irrigation system in refrigerated and unrefrigerated greenhouses in agricultural research stations assisted by the technology.

1.4. Modern Mechanisms and Methods of Agriculture

In the past, people worked on the exploitation of animals in leveling the land and preparing it for cultivation [8]. Later on, people worked to do the same by adding tools for plowing to the animals, and with the passage of time the added tools would walk the animals on the ground back and forth in order to turn the soil, ventilate it and convert it from ordinary land to agricultural land ready to use. People needed irrigation, thus worked on extracting groundwater suitable for irrigation of crops. Primitive tools were used to dig wells to extract water. However, after the emergence of the industrial revolution that turned the world upside down, the agricultural processes had to develop with its tools and methods of combating agricultural problems [9]. Pesticides appeared and it became possible with ease to distinguish between good and bad crops and treat problems related to agricultural crops. As the time goes on, advanced machinery and science were used to control all agricultural resources, thus achieving the requirements for their survival but in different forms. Who can imagine the existence of agriculture without the need for soil? By using science and agricultural engineering, farmers were able to create farms with no soil, namely hydroponic farms.

2. Research Directions

In this paper, we explain the most important points associated with controlled hydroponics using electronic to control the entities responsible for providing the needs of the plants that have been cultivated by electronic aquatic farms. Also, research trends and directions on the area of hydroponics are presented.

2.1 The Concept of Hydroponics

The development of technology that contributed to the preparation of modern agricultural fields through realizing smart farms by using, for instance, Internet of Things (IoT) technologies and big data, helped farmers reduce the use of natural resources is terms of soil, and this leads to increased agricultural efficiency [9]. Smart agriculture systems monitor the irrigation processes as well as they control the variables involved in growing crops. Such concepts must be taken into account by farmers to reduce the amount of water resources. Hydroponics is defined as the cultivation of plants and crops without soil. The hydroponic system has the potential to reduce water consumption by dripping water onto the roots of the plants. There are many names for hydroponics [10]. The principle of the work of aquatic farms has been used for a long time throughout the ancient history of this world and the traces left by the ancient peoples attest to that, as the hanging gardens of Babylon, the gardens of Mexico and China floating are examples of the use of the hydroponic mechanism from ancient times to hydroponics technology: a sophisticated agricultural mechanism that was named "Hydro pinks" is a term that means the growth of plants in organic and nutrient solutions as shown in ancient Egyptian hieroglyphic writings that demonstrate the existence of this mechanism in agriculture where the development of plants in water rather than soil has been hundreds of years BC. This
principle began to develop after experiments were conducted by Belgian scientists. Hydroponics is cultivation without soil, where the roots of plants are placed in an aqueous solution, thus the plants are nourished. This type of agriculture was not given a specific name until the year 1940, when the Greeks were the first to use this method. They placed the plants in nutritious water so that the plants could benefit from. This technology has been discovered since ancient times in Egypt, India, China and other civilizations. Hydroponics is interpreted as “working water”, which were originated from the Latin words “hydro” which means water and “ponics” which means work. In hydroponics mineral supplements are developed instead of using the soil in order to obtain beneficial and healthy crops.

The hydroponic system uses only 10% of the water resources, and this enables farmers and agricultural workers to control their ability to fully control the transportation of nutrients that represent the cornerstone of the growth and quality of agricultural crops because the nutrient solution is easy to transport, unlike the traditional farming based on soil. The hydroponic system can also limit the exploitation of large areas of agricultural lands. Hydroponics systems can provide accurate monitoring of the nutrition of agricultural crops as the roots of plants are directly connected to the nutrient solutions and they absorb the necessary materials and nutrients to grow and avoid factors not suitable for their growth. The research area of hydroponics is attracting an increased attention over years as can witnessed, for example, by the number of publications upon searching for the keyword “hydroponics” in IEEE Xplore since the past 5 years as shown in Figure 1.

![Figure 1: No. of publications in Hydroponics in IEEE Xplore from 2015 to 2019](image)

2.2 Internet of Things

The field of communication has witnessed a visible progress in developing new smart technologies [11]. Among such technologies, IoT is described as devices connected to the Internet with built-in sensors and data that can be transferred to the cloud or recorded and processed later on [12]. IoT uses the power of the cloud, and it is featured by computing capabilities and data analysis devices. It is expected in the coming years that there will be a great development in the field of artificial intelligence and IoT which will contribute to the development of various engineering applications including smart farming. The use of IoT as a platform to plan, implement, monitor and control the environment of the hydroponic systems is a research hot topic due to its impact on enhancing the productivity and quality of agriculture crops.

2.3 Artificial Intelligence

In his article, Abdullah Hamdy talked about artificial intelligence and its applications in hydroponics [13]. With the development of artificial intelligence research and the abundance of data, artificial intelligence algorithms can play a crucial role in imitating several tasks that
humans perform. As such, the artificial intelligence algorithms can be used in hydroponics to monitor the growth of crops, analyze collected data patterns, and provide an adaptive environment to the crops based on learned experience.

2.4 Nutrient Film Technology (NFT)
This technique allows to control the nutrient solution, which is the primary environment necessary for the growth of roots for agricultural crops in particular [14]. This technique works on the principle that the shallow layer of the nutrient solution moves from the upper end to the lower end of the agricultural crop due to the presence of the gravitational factor. The nutrient solution is in a continuous circular motion, and this leads to direct contact of the plant root with the nutrient solution of the cultivated plants, following the hydroponic system, and this provides an opportunity to supply the plants with quantities of ventilation, nutrition, and water that are suitable with the size of the agricultural crop and the flow channel. A continuous or intermittent fluid supply is often used to solve the problem of discrepancy that occurs between the root's absorption of water and the absorption of oxygen by the root. It is worth noting that the intermittent flow technology can save pump wear and reduce energy consumption by as much as 84%. This technology was emerged very early in 1974 with the cultivation of vegetable crops in particular. The results were stimulating at the time, and the development processes of this technology continued and became clear that it could achieve the best results in the cultivation of aquatic vegetable crops compared with other agricultural techniques.

2.5 Aquaponics
It is a method of plant and animal culture [15]. This method was proposed in the late 1990s, and then, attention has become very much focused on using this mechanism in agriculture to obtain very important products from agricultural crops that were grown using the biocultural technique. Aquaponics uses a mechanism for recycling water and adding fish to it to solve the problem of fluctuations of nutrients. The integration of hydroponics and aquaponics enhanced by advanced smart electronic systems is also another research topic that may receive a great attention in the coming years.

A. A Sample System that Aquaponics is running on
The fish plant culture system has three very important components that it consists of sensors, the PLC and the computer as shown in Figure 2 below.

![Figure 2: Sensors and actuators](image)

The value of the desired variable is defined by measuring it using the sensors. As for the PLC, it is responsible for the process of controlling the water circulation process, i.e. renewing and
collecting data through the sensors and enabling the device to operate over long periods. OPC is for the process of communication between the computer and the controller.

B. Actual hardware design

The hardware system mainly consists of two parts; the cropping system and the PLC control system as shown in Figure 3.

![Figure 3: Actual hardware](image)

2.6 Importance of hydroponics for the economy of Oman

The Ministry of Agriculture and Fisheries has also contributed to the application of aquaculture and testing this technique in the climatic conditions that describe the climate of the Sultanate of Oman [16][17]. Some crops have been cultivated in homes protected, cooled and not chilled. This technique also helped raise the economy by reducing from consuming water used for irrigation, as well as reducing the use of fertilizers that inflict damage to the soil. It has been observed that when using modern technologies, many problems have been eliminated, including fungal and bacterial diseases. The problems of soil salinization due to the excessive use of chemical fertilizers in traditional agriculture is also minimized with the use of modern hydroponic systems. More research and feasibility studies must be carried out to investigate the expansion of hydroponic solutions to a larger scale.

2.7 Nutrient solutions suitable for plants

There are many elements that are important to plants when using hydroponics [18]. Therefore, these elements that may be available in the soil must be provided automatically, but there may be other elements harmful to plants. Therefore, workers in the field of aquaculture must investigate the important elements for plants that must be available in large quantities, for example, calcium, carbon, potassium, hydrogen, phosphorous, oxygen and nitrogen. In contrast, they must also know the elements that must be available in a relatively small quantity such as molybdenum, iron, chlorine and Zinc, boron, manganese and copper. The types and concentrations of such elements for hydroponics solutions is also another open research topic. One of the common composition of chemicals proposed by Alan Cooper to produce 1000 liters of nutrient solution is presented in Table 4.
Table 1: The amounts of chemicals to make 1000 litters of nutrient solution

| Food items             | Weight (g) |
|------------------------|------------|
| Di-potassium           | 263        |
| Phosphate              | 583        |
| Potassium nitrate      | 1003       |
| Calcium nitrate        | 513        |
| Magnesium sulfate      | 79         |
| Iron chelates          | 6.10       |
| Manganese sulfate      | 1.70       |
| Boric acid             | 0.39       |
| Copper sulfate         | 0.37       |
| Ammonium               | 0.44       |

| The name of the complex | The ratio                  |
|-------------------------|----------------------------|
| Calcium nitrate ca(no3)2| 40 litters of water/7.6Kg  |
| Chelated iron) Fe)      | 40 litters of water/400g   |

According to ICARDA, there is more than one way to obtain the nutrient solution for hydroponics as shown in Table 2. It is very important to use fresh water.

Table 2: The nutritional solution for hydroponics

| The name of the complex     | The ratio                    |
|-----------------------------|------------------------------|
| Calcium nitrate ca(no3)2    | 40 litters of water/7.6Kg    |
| Chelated iron) Fe)          | 40 litters of water/400g    |
| Compound Fertilizer NPK 12/12/3 | 40 litters of water/4.8 kg |
| Magnesium sulphate MgSo4   | 40 litters of water/1.6 kg  |
| Minor items (micro plex)   | 40 litters of water/270 g   |

The ratio of acidity is very important for plants. Thus, the acidity must be followed up in a cycle through the devices available in the market where the pH should be in the range from 6.5 to 5.8 [18]. The determination and fine tuning of such ratio requires further investigation. In addition, knowing the concentration of salinity in the nutrient solution is very important so that we can obtain crops with excellent quality and quantity, as well as the amount that the worker expects in this field [18].

2.8 Experimental structure:
The water farming or hydroponic systems used to use a deep flow technology (DFT) via channels that are 6 meters long and have been made from PVC pipes and 0% slope [19]. Other structures of hydroponic systems can be examined to maximize the production gains.
3. Literature Review

This section includes a literary review of the research works in the area of hydroponic systems. The review results are tabulated in Table 3. In [20], attention has been paid to facilitating the cultivation process by making control over it via a mobile phone and the solution has been used to control the concentration of materials or elements the plants need in an easier way. A program has been designed through which it reads the whether the plants require. The sensing cycle is set to 15 minutes and that the temperature is controlled in the summer by operating fans that can reduce the temperature via remote access and control. In [21], an artificial wool was used which helped in the growth of the plant faster due to the heat produced by the wool. Also that this wool has a characteristic that may not be available in the soil; the wool-based system contains no elements that may cause harm to the plants. Thus, the proposed system addressed this issue as it has the ability to produce fruits with high quality and completely free from diseases. In [22], the most important goal was to make agriculture safer in terms of toxins and diseases that may be present in some plants. Also, this project aims to make seasonal plants grow at any time with high quality to cater for people’s desires. In [23], The project works on building water parks for self-cultivation only, and it is characterized by its simplicity in design, limited production, and no electronic control.

In [24], the details of a Herb Box Eco System is presented. It suggests an intelligent agricultural system that reads plant data, contains moisture sensors in the soil, and pipes in an external water tank controlled electronically. In [25], after the tsunami in Japan, large areas of agricultural land became unsuitable for agriculture, thus the use of in-house hydroponic systems was proposed. In [26], hydroponics has been successfully implemented in the Sultanate of Oman which consisted of sixteen greenhouses with high-quality products that supply the local markets and expected to knock the door of global markets. However, the use of smart electronic solutions to monitor and control the farming processes was not taken into account.

Table 3: List of Relevant Past Related Work

| Ref. | Title                                                                 | Description                                                                                                                                                                                                 | Control          | Cost  |
|------|-----------------------------------------------------------------------|                                                                                                                                                                                                          |                  |       |
| [20] | Smart hydroponics                                                     | Smart hydroponic system is proposed to overcome the issues of the traditional agriculture with soil as well as to automate the plantation processes, thus making workers’ life easier. | Automatic control | High  |
| [21] | The use of modern technologies in hydroponics by artificial wool      | This project aims to make vegetables that are harvested free of diseases that can spread when using the soil, as well as aiming to exploit the small places that may be in homes or in buildings. To cultivation aims to grow vegetables that are more consumed in homes. | Automatic control | High  |
| [22] | A device that facilitates hydroponics in the Omani environment and increases the amount of production in all seasons | One of the most important goals of this project is to provide a safe food free of any toxins that may be present in the planted plants in the soil, as well as the ability to produce crops in all seasons. | Automatic control | High  |
|   |       |                                                                 |                                                                 |                         |                         |
|---|-------|----------------------------------------------------------------|----------------------------------------------------------------|-------------------------|-------------------------|
|23| Indoor garden | A work on building private gardens for self-agriculture. Simply stood in design and limited electronic control. | Automatic control | high                    |
|24| Herb box eco system | The proposed system works to make a smart agricultural system that reads plant data and contains moisture sensors in the soil and pipes in an external water tank linked to the Alexa system. The system is controlled electronically. | Automatic control | high                    |
|25| Hydroponics | It is a water farm in which work is done in a precise way. As it has been implemented in Japan, and it has also met a great achievement in crops. | Automatic control | high                    |
|26| Hydroponics | This project was implemented in the Sultanate of Oman in Baraka [18]. It achieved a great achievement in crops, as the owner of the farm opened many greenhouses due to the amount of crops he reaps at the end of each season. | Not automatic control | high                    |

### 4. CONCLUSIONS

The hydroponic industry is expected to grow significantly in the future. In particular, in Oman which is characterized by high temperature and low rainfall, smart electronic hydroponic systems can provide a sustainable and feasible agriculture solution. With the emergence of advanced technological solutions such as Internet of Things, big data analytics and artificial intelligence, efforts must be made to exploit these technologies in enhancing the efficiency of hydroponic industry. In this paper, several research directions have been briefly explored and suggested.

**Acknowledgement**

The research leading to these results has received funding from The Research Council (TRC) of the Sultanate of Oman under the Block Funding Program. TRC Block Funding Agreement No. TRC/BFP/ASU/01/2019.

**References**

[1] "Agricultural," *Jordan Journal of Agricultural Sciences*, 2013.

[2] "Development and the Next Generation," oman, 2006-2007.

[3] A. Shahen, "Cultivation and writing, components that distinguished the Sumerian civilization in the ancient world," 10 January 2017. [Online]. Available: https://middle-east-online.com. [Accessed 5 10 2020].
[4] I. Al-Hiyari, "The Pharaonic Civilization and Its Achievements," 13 September 2018. [Online]. Available: https://vistabuzz.com/pharaonic-civilization-and-its-achievements. [Accessed 6 9 2020].

[5] W. Z. Al-Din, "The Ancient Omani Civilization," 16 November 2016. [Online]. Available: https://en.wikipedia.org/wiki/Oman. [Accessed 12 10 2020].

[6] The Statistical book, oman, 2018-2019.

[7] Sana Al-Dweikat, "Agricultural Methods in the Past," 7 May 2017. [Online]. Available: https://mawdoo3.com/%D8%B7%D8%B1%D9%82_%D8%A7%D9%84%D8%B2%D8%B1%D8%A7%D8%B9%D8%A9_%D9%82%D8%AF%D9%8A%D9%85%D8%A7%D9%8B. [Accessed 1 10 2020].

[8] A. K. Telkar and B. Gadgay, "IoT Based Smart Multi Application Surveillance Robot," 2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA), Coimbatore, India, 2020,. [Online]. Available: 2020, pp. 931-935, doi: 10.1109/ICIRCA48905.2020.9183289.

[9] Jose de anda, Harvey shear, "Potential of Vertical Hydroponic Agriculture in Mexico," 20 January 2020. [Online]. Available: https://www.mdpi.com/2071-1050/9/1/140. [Accessed 17 10 2020].

[10] A. Y. R. T. S. T. N. Ambosaidi A, "School gardening in early childhood education in Amman: A pilot project with second-grade students," International science education. 2019; , no. 30 (1): 45--55. Accessed December 3, 2020.https://search.ebscohost.com/login.aspx?direct=true&db=eue&AN=135385010&site=eds-live.

[11] BCS TCI for I, "Internet of Things: Living in a Connected World," BCS, The Chartered Institute for IT; 2017, 4 December 2020. [Online]. Available: https://search.ebscohost.com/login.aspx?direct=true&db=e000xww&AN=1485499&site=eds-live.

[12] S. Singh and N. Singh, "Internet of Things (IoT): Security challenges, business opportunities & reference," architecture for E-commerce," 2015 International Conference on Green Computing and Internet of Things (ICGCIoT), [Online]. Available: Noida, 2015, pp. 1577-1581, doi: 10.1109/ICGCIoT.2015.7380718..

[13] Obaidly Al-Obaidly, "About artificial intelligence," 3 Dec 2019. [Online]. Available: https://omaninfo.om/topics/101/show/276248 . [Accessed 3 10 2020].

[14] Wei, Yaoguang & Li, Wenshu & An, Dong & Li, Daoliang & Jiao, Yisha & Wei, Qiong, "Equipment and Intelligent Control System in Aquaponics: A Review," 2019. [Online]. Available: IEEE Access. PP. 1-1. 10.1109/ACCESS.2019.2953491.

[15] Joe Masabiny, "Explanation of Fishy Vegetable Production Methods Through Aquaponics," 20 Oct 2014. [Online]. Available: https://ara.sdv3tutorials.com/fishy-vegetable-production-methods-explained-through-aquaponics-324164 . [Accessed 2 8 2020].
[16] W. Wang, Y. Jia, K. Cai and W. Yu., "An Aquaponics System Design for Computational Intelligence Teaching," [Online]. Available: in IEEE Access, vol. 8, pp. 42364-42371, 2020, doi: 10.1109/ACCESS.2020.2976956.

[17] Muhammad Abdullah Al-Qudhat, "Land and Agriculture in Oman through the Book of the Book," 14 May 2016. [Online]. Available: http://alwatan.com/details/113113 . [Accessed 25 9 2020].

[18] Muhammad Ismail, "Cultivation without soil," 11 may 2017. [Online]. Available: http://www.israelagri.com/?CategoryID=484&ArticleID=1269 . [Accessed 8 10 2020].

[19] "food & agriculture," Emirates journal of food & agriculture (effa), no. https://www.ejfa.me/index.php/journal, Apr 2020.

[20] Melchizedek alipio, allen madia dela cruz, jess David asebo doria. rowena maria S.fruto, " A “smart hydroponics farming system using exact inference in Bayesian network,” no. [online], 2017Available at:https://www.researchgate.net/publication/322003465_A_smart_hydroponics_farming_system_using_exact_inference_in_Bayesian_network .

[21] Warood al wahsh, "Modern technologies in hydroponics," 2 dec 2018. [Online]. Available: athttps://www.qou.edu/ar/viewCmsContentDtl.do?contentId=56970 . [Accessed 30 9 2020].

[22] Majid bin Obaid Al Busaidi, Mohammed Al-Anqoudi, 12 Feb 2018. [Online]. Available: athttps://www.omandaily.om/?p=614290 . [Accessed 3 10 2020].

[23] Mega Das, "Arduino Indoor Park," 16 July 2017. [Online]. Available: https://create.arduino.cc/projecthub/mega-das/arduino-indoor-garden-5d975c. [Accessed 5 11 2020].

[24] Walter Heger, "Herb Box Eco System," 13 Jan 2018. [Online]. Available: https://create.arduino.cc/projecthub/walwode/herb-box-eco-system-7c51b3. [Accessed 6 9 2020].

[25] Mohammed amin, " planting water in japan," 8 Oct 2018. [Online]. Available: https://www.youtube.com/watch?v=nC49aQ7oXl8. [Accessed 17 10 2020].

[26] H.E. Dr. Hamad Bin Saeed Al-Oufi, "Agriculture and Fish Wealth in Barka," 12 Feb 2020. [Online]. Available: https://bawaba.org/news/118816 . [Accessed 5 10 2020].

[27] Gaza, "Hydroponics as an alternative to soil." 20 5 2004. [Online]. Available: https://gpnmag.com/article/alternative-hydroponic-substrates/. [Accessed 20 8 2020].

[28] Pamela Kesrouani, "Hydroponics is a profitable and effective alternative to traditional," 13 Feb 2016. [Online]. Available: https://www.albayan.ae/2016-11-29-1.2779423. [Accessed 19 10 2020].
