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Automated Hydroponics System for Urban Farming

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Abstract

Hydroponics refers to the process of growing plants without using soil. Instead, a solution of nutrients in water is passed through its roots for their nourishment. We use a vertical, continuous-flow solution culture technique hydroponic system in a controlled environment to grow crops such as spinach. The environmental factors that we controlled include the temperature, lighting, water supply and the pH. We also enabled Internet of Things (IoT) control of the system. This allows for the control of the various parameters in the system from a distance, over the internet. Various crops have various ideal conditions, and these conditions can be changed as required in this system. The system uses the Intel Edison board for its component integration. Furthermore, the system was designed with the aim of allowing for a more efficient use of space, better pest management, and overall increased efficiency with regard to plant growth rate and quality. The system is also meant to be relatively easy to transport, and cost efficiency is a huge bonus, wherein while initial investment may be high, follow up prices are markedly reduced from conventional methods.

Keywords: *Internet of Things, Intel Edison, Soil, Crops, Hydroponic System*

1. Introduction

Hydroponics is the subclass of hydroculture. The process of growing plants by the means of mineral nutrient solutions mixed in a solvent like water without the use of soil is called Hydroculture. It is precisely the cultivation plants in a soilless medium, or an aquatic based atmosphere. Plant nutrients are distributed via water. Hydroponics (or aquaculture) uses pumps, unlike the capillary action used in Hydroculture.

In Hydroponics, plants are grown in an inert growing medium with an absolutely balanced pH adjusted nutrient solution. This solution is delivered to the roots in a form that is highly soluble. This enables the plant for an easy uptake of food unlike the roots searching for the nutrients and extracting them from the soil. This process takes place even with the usage of organic soil which is rich in nutrients. This energy consumed by the roots can be rather spent on the blooming of flowers which results in good production of fruits.

Hydroponic farming involves a growing medium which is the material in which the roots of the plant grow. This includes substances like Rockwool, perlite, vermiculite, coir, gravel, sand etc., This does not allocate any nutrition to the plants. The main source of nutrition is the pH solution. Therefore, everything the plants obtain (including the quantity of pH induced in the nutrient solution) can be controlled easily. This enables the

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plants to receive the right quantity of food. A timer can ensure the scheduled watering of the plants.

The hydroponic fertilizers as well as those used in soil have nitrogen, phosphorus and potassium which are three major nutrients. The way in which hydroponic fertilizers and the fertilizers used in soil differ is that the former has the proper amount of all the essential micro-nutrients which the later does not. The plants predict that these elements can be found in the soil, considering the fact that the trace elements are infact present. The depletion of micro-nutrients from the soil due to excessive planting can result in difficulties for the plants.

The refined form of these fertilizers results in the scarcity of impurities. This increases the stability as well as the solubility of the fertilizers which induces better absorption by plants [1] – [3].

The growth of a healthy plant requires micro-nutrients (trace elements) like calcium, magnesium, sulfur, boron, cobalt, copper, iron, manganese, molybdenum and zinc.

The deficiency in the above trace elements results in the plant being vulnerable to pest attacks, various diseases, substantial stress in the uptake of the N-P-K fertilizer which is being fed to the plants. This results in the plants not living up to their genetic potential, decreased yield and at worst death. But, in food crops the deficiency in nutrients is passed on to the humans and animals who consume them. The over farming in the same fields results in the quality of the food hardly more than that of waxed fruit.

In addition to all of the above, it is important to note that hydroponic units such as the one in this paper are very space-efficient; a single room may yield a field's worth of crop. It is also far more portable than regular harvest, in that the entire growing unit may be transported, in spirit of keeping freshness of the yield. Furthermore, it's independence on climate allows it to be grown even in adverse conditions, as long as it is within the unit.

2. Literature Survey

2.1. Historical Significance and Origin

Francis Bacon's book "Sylva Sylvarum" was the first book on "the growth of terrestrial plants without soil" which was published on 1627 a year after his death. This was the gate way for the popularity of the water culture research technique. Experiments by John Woodward with spearmint was published in 1699. By these experiments he discovered that plants grew better in less pure water than in distilled water. Nine elements that are vital for a plant's growth was listed by 1842. Between the years 1859–1875 the German botanists Julius von Sachs and Wilhelm Knop made discoveries which resulted in the advance of the technique of soilless cultivation. The term "solution culture" was given to the process of growing terrestrial plants without soil, instead in mineral nutrient solutions. It developed rapidly into a typical research and teaching technique which is now widely used. Solution culture is now accepted as a type of hydroponics in which an inert medium is not present [4] – [5].

Public promotion of solution culture was started in 1929 by William Frederick Gericke of the University of California at Berkeley who termed it aquaculture only to know later it was the term used for the rearing of aquatic organisms. The twenty-five feet tomato vines grown by Gericke using solution culture created a good impression on this technique. The term "hydroponics" was proposed by W.A. Setchell who was a phycologist. Gericke later introduced this term in 1937.

Gericke's work on hydroponics as the way to revolutionize agriculture provoked a large number of requests for more information. Due to the doubtfulness of the

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administration, he was not allowed to make use of the University's greenhouses for his experiments. He was compelled to release the primary nutrient recipes which he developed at his house. The University agreed when he said he needed greenhouse space and some time to improve them. But, the University allotted two other scientists, Dennis R. Hoagland and Daniel I. Arnon to develop his formula in a way that it had no advantage over soil grown plant's. Gericke published a book called as Complete Guide to Soil less Gardening in 1940, after leaving his academic position. This book later became one of the most vital premature works in the subject. It built attention in a field that was initially rejected by agriculturists who were endangered by its views and effects.

Hoagland and Arnon claimed that hydroponics was not better than good-quality soil. Crop yields were not limited by nutrients but by other factors especially light. This ignored the fact that hydroponics has other advantages namely (i) The roots have round the clock oxygen supply (ii) They have a supply of water to as much or as little they need which is essential as one of the most common errors when growing is over watering and under watering. Since a large quantity of water is available to the plant any water that is not used can be drained away, recirculated or actively aerated. This eliminates anoxic conditions, which results in the drowning of the root systems in soil. Therefore, hydroponics averts this from happening. If plants are grown in soil, the gardener needs to be very experienced to know the quantity of water required for the plant. Extra water results in the plant not being able to access oxygen. If it is scanty the plant loses the capability to transport nutrients, which are usually transported to the roots while it is still a solution. They developed many formulas for mineral nutrient solutions and called it Hoagland solution. Nowadays modified Hoagland solutions are still used.

Wake Island which was a rocky island used as a refueling station for Pan American Airlines. Since airlifting vegetables for passengers is expensive, hydroponics was introduced in 1930 which turned out to be a huge success. This success was the gateway for further investments and research in this field.

Recently NASA did extensive hydroponic research for its Controlled Ecological Life Support System (CELSS). Hydroponics intends to take place on Mars by using LED as a lighting for plants to grow in a different colour spectrum which has less heat. Ray Wheeler, a plant physiologist at Kennedy Space Center's Space Life Science Lab, believes that hydroponics will create advances within space travel. He terms this as a bio regenerative life support system.

2.2. Techniques

There are several different techniques through which hydroponics can be done. Some of these types are:

2.2.1. Static Solution Culture: This technique involves the growth of plants in home applications (such as glass jars, plastic buckets, tubs, or tanks) which contain a nutrient solution. The solution is usually slightly aerated but can also not. If so, the level of the solution must be kept low enough so that the roots which are above the solution get ample oxygen. There can be several plants per reservoir. These reservoirs have holes cut into them. The range of the reservoir can be improved as the plant grows.

2.2.2. Continuous-flow solution culture: This technique ensures the continuous flow of nutrient solution along the roots. This technique can be automated with ease unlike the former. This is due to the testing and changes on the temperature and nutrient concentrations which is made possible in a large tank which can serve thousands of plants.

The nutrient film technique (NFT) is standard variation of this technique in which a shallow stream of water which has the dissolved nutrients vital for the growth of a plant is recirculated the thick root mat with an upper surface. This is developed in the end of the channel. This though moist, is still air bound. Following this, an ample amount of oxygen

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is supplied to the roots. A well designed NFT system depends on the use of a good channel slope, a perfect flow rate and the right channel length. Although it is a vertical type system, we implement this technique in the proposed hydroponics.

2.2.3. Aeroponics: This system includes roots kept in an environment with fine drops of nutrient solution which is present in the form of mist. This method requires no substrate. It involves growing plants with air bound roots in a growth chamber. These roots are regularly moistened with a fine mist of atomized nutrients. Perfect aeration is the chief benefit of aeroponics. NASA has given special attention to aeroponic techniques as mist is way easier to use than liquids in a zero-gravity environment.

2.2.4. Fogponics: This method is derived from aeroponics in which the nutrient solution is aerosolized by a diaphragm vibrating at ultrasonic frequencies. The size of the solution droplets is way smaller (5-10 µm) than that of aeroponics (which is produced by forcing a nutrient solution through pressurized nozzles). This size enables them to diffuse in the air with ease therefore, delivering the nutrients to the roots without oxygen as the limiting factor.

2.2.5. Ebb and flow: The easier form of this method involves a tray placed on top of a nutrient solution reservoir. There are two ways of implementing this method. The first technique involves the tray being filled with clay granules (which is a common growing medium) and the planted directly. The second technique involves the growing medium standing in a tray. The nutrient solution is pumped up to the upper tray. As soon as the upper tray fills, the water recirculates till the timer turns off the pump and water is again drained down to the reservoir. This can be done at regular intervals with the help of a simple timer. This ensures that the growing medium is soaked with the nutrient solution.

2.2.6. Run to Waste: This method involves the periodical application of nutrient and water solution to the growing medium. This method originated in Bengal on 1946. Therefore, this is popularly known as "The Bengal System". This method has multiple setups in different configurations. The easier way involves the nutrient and water solution being applied manually couple of time a day to a reservoir inert growing medium such as (Rockwool, perlite, vermiculite, coco fiber, or sand). It can be automated using a delivery pump, a timer and irrigation tubing to deliver the nutrient and water solution with a delivery frequency. This is governed by the main parameters of the plant size, the plant's growing stage, the climate, substrate and its conductivity, pH and water content [6].

2.2.7. Deep Water Culture: This method involves the suspension of plant roots in a solution of nutrient-rich oxygenated water. Traditional methods involve the use of large containers (like a bucket). The plant is stored in a suspended net pot in the center of the lid. The roots of the plant are suspended in the nutrient solution. The solution is saturated with oxygen by an air pump with porous stones. Due to the high amount of oxygen received by the roots, the plants grow much faster in this method, compared to that of other methods [7] – [10].

3. Electrical System Design

3.1. Intel Edison (With Arduino)

The Intel Edison is a computer-on-module offered by Intel as a development system for Internet of Things devices. Intel Released an Arduino Uno compatible board that accepts the Intel Edison module. It's very flexible and highly compatible with the sensors being used.

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Figure 1 Intel Edison (In Arduino)

3.2. Base Shield V2

Used for the efficient connection of the various sensors required for connection to the Arduino board. These are used in combination with Grove and Gravity sensors for lossless, uncomplicated wiring. It is also important for securing the wires and connections in order to minimize the chances of short circuitry and other possible failures. It's very important for the simple integration of the various sensors required for a hydroponics set up, and is extremely useful.

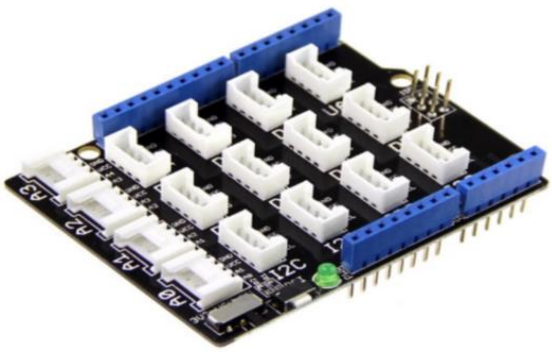

Figure 2 Base Shield V2

3.3. Grove - Temperature and Humidity Sensor

This sensor is used for detecting and regulating the temperature and the humidity of the environment to which it is exposed. Its thresholds are set, and when these thresholds are breached, they trigger a number of fans that are used to cool the system down. This is very important, as plants require very specific temperatures to grow in. Grove is used for it's high compatibility to Arduino compounded with Intel Edison.

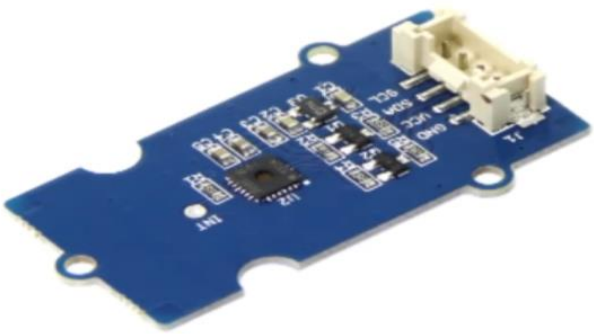

Figure 3 Grove - Temperature and Humidity Sensor

ISSN: 2005-4238 IJAST

3.4. Grove - Moisture Sensor

Plants require a very specific amount of moisture for their growth. For this, a moisture sensor is required. Manufactured by Grove, this too has high compatibility with Intel Edison. When it's thresholds are breached, once again, fans are switched on to vent out excess moisture.

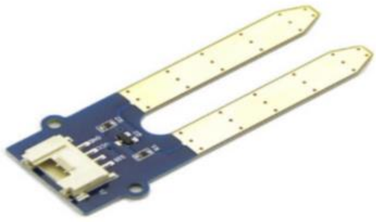

Figure 4 Grove - Moisture Sensor

3.5. Grove - Light Sensor

While plants conventionally grow in sunlight, they mainly require light from a particular part of the electromagnetic spectrum for growth. This can be optimized by isolating those portions of the spectrum, to the point where their growth can occur even at night or when lighting is limited. For this, LEDs can be used, and a light sensor is set with thresholds to trigger the lights to go on and off when the thresholds are breached.

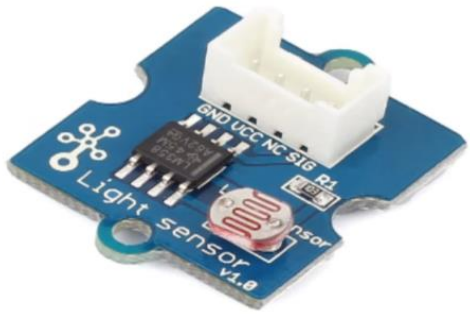

Figure 5 Grove - Light Sensor

3.6. Gravity - pH Sensor Kit

In Hydroponics, the water that is used for the plant's nourishment requires a carefully maintained pH. For this, a pH sensor is used. This sensor detects the pH. According to its thresholds, it either releases some acid or alkali to neutralize the alkalinity or acidity of the water, thus maintaining the pH at a steady level.

ISSN: 2005-4238 IJAST

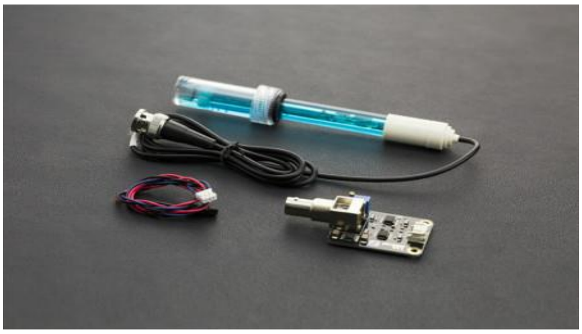

Figure 6 Gravity – pH sensor Kit

3.7. Grove – LCD RGB Backlighted Display

This display is very useful for the calibration of the various sensors involved in the system, as it can be connected to display the various real time values that are being detected by the sensors. This information is also useful for at-a-glance status information of the system.

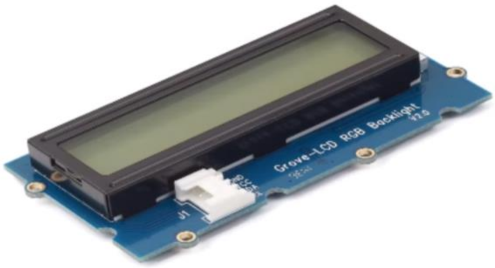

Figure 7 Grove – LCD RGB Backlighted Display

3.8. The Grove Indoor Environment Kit For Edison

Grove Indoor Environment Kit for Edison makes it easy to create complete indoor environment applications with Intel Edison and Arduino Breakout Board. With the Base Shield V2, developer can plug up to 11 different Grove sensors & actuators quickly. It simplifies the wiring process greatly, and comes with demo code for testing.

Fig. 8 The Grove Indoor Environment Kit

3.9. Gravity - Electrical Conductivity Sensor

The salinity of the soil, irrigation water systems or fertilizer solutions is an important parameter affecting the root zone environment of plants. These parameters form

ISSN: 2005-4238 IJAST

electrolytes in water, and hence their quantities can be determined by their electrical conductivity. The EC Sensor level therefore provides a lot of information with respect to the status of the plant.

Figure 9 Gravity Electrical Conductivity Sensor

Figure 10 Sensor Assembly and Integration with Kit

4. Mechanical System Design

4.1. Piping

Various PVC Pipes, T-s and Elbows are required to set up the structure of the hydroponics unit, and to provide passage for the water to flow, as will be detailed in the construction.

ISSN: 2005-4238 IJAST

Figure 11 Piping with slots for the plants

4.2. Pump

A Pump is required to draw water and pass it through the system, especially since this is a vertical system. The water needs to be given enough velocity to ascend up the system, after which gravity will provide for its return for drainage. It has to be submersible in the water, therefore a submersible waterproofed pump is used, having a rating of 230V and 16W.

4.3. Bucket

A bucket of known dimensions is required to store the water before pumping. This is very important, as the volume of water held by the bucket determines the height of the system and the rate at which pumping needs to be done.

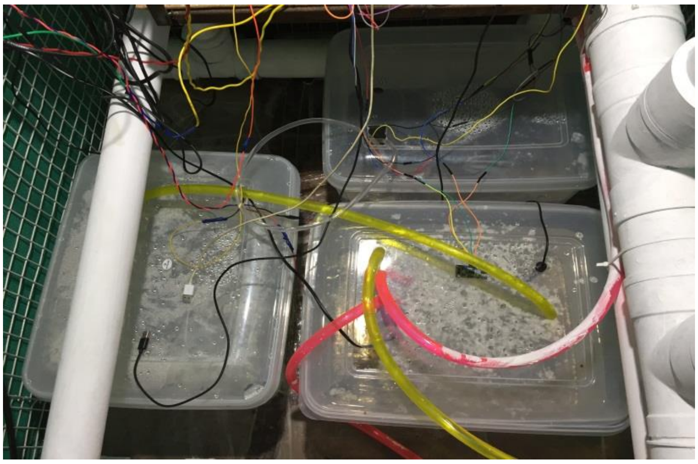

Figure 12 Buckets with submersible pump

4.4. Enclosure

An enclosure of steel is made in order to isolate the hydroponics unit from external conditions, in order to better moderate the various factors that are being controlled. This is done by covering the enclosure using any agreeable material.

5. Proposed Model Realization

The hydroponic system consists of two main aspects with regard to construction and assembly:

ISSN: 2005-4238 IJAST

1. The electronic aspect
2. The mechanical aspect

The Electronic Aspect consists of the following stages:

5.1. Sensor Calibration

First, it is required to calibrate all the sensors that are used in the system. This is done by adjusting their thresholds in their program, and then dumping the program onto the Edison chip, through the Arduino board. This is applied to the relevant sensor, which is then tested at its threshold limits to see if it works. This is done with the help of the LCD RGB Backlighted Display, which indicates the active value being picked up by the sensor. This value is then compared with the threshold given in the program, at the threshold. If the sensor activates the device that it controls at the appropriate value, then the sensor is calibrated. If not, then the sensor's zero value needs to be adjusted to match with the thresholds.

5.2. Assembly

Once this calibration is done, all the sensors are connected as the interface between the Arduino (Edison) and the devices that they operate. This assembly and connection is made very tidy and simple, owing to the Grove Indoor Environment Kit. Once this is done, it is only required to set the various devices at their appropriate positions in the hydroponics system. The mechanical aspect involves the assembly of the various PVC pipes in the system. The following figure is highly indicative of the build of the system, however, instead of using 10 columns, are system, for the sake of compactness, uses just three columns, with three holes in each.

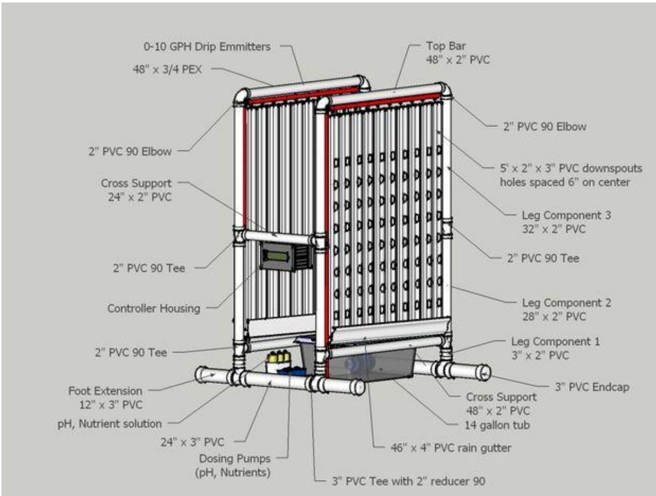

Figure 13 Piping Layout

In these holes, a conical slot is inserted in order to support the roots of the plant to be grown in such a way that their roots are exposed to the water flowing through the system.

The exact piping requirement is as follows:

5.2.1. Support Frame:

(5) 10' - 2" PVC pipe

(1) 10' - 3" PVC pipe

(4) 2" PVC 90° elbow

(8) 2" PVC tee

ISSN: 2005-4238 IJAST

(4) 3" to 2" PVC tee

(4) 3" PVC endcaps

5.2.2. Towers/Return:

(10) 10' - 2" x 3" PVC downspouts

(1) 10' PVC extruded gutter 4"

(4) PVC gutter end caps (2 left and 2 right)

(2) 1" threaded to 3/4" barbed adapter

(2) 3/4" PVC female threaded connectors

(20) 2" PVC Pipe Hangers ("J" hooks)

(20) #6 Stainless 1 1/2 " machine screws and nuts

5.2.3. Water Supply/Return:

(1) 10' - 1"ID potable water tubing

(3) 1" threaded to 3/4" barbed adapter

(1) 1" barbed tee

(5) 3/4" PEX 90° elbow - barbed

(1) 3/4" PEX tee - barbed

(1) 1" to 3/4" PEX reducer - barbed

(2) 10 pack PEX crimp rings

(1) 10 pack 1 1/2" hose clamps

(1) 25' - 3/4" PEX

(20) Adjustable 0-10GPH drip emitters

(1) Soft plastic bucket

Our system has an overall dimensional matrix of 3’8” x 5’6” x 3’8”, with the largest value being its height.

The post calculation value of the bucket required for a system of this height is found to be 26.994 liters, as detailed below.

The system is then put inside the steel enclosure, that is coated and painted to prevent rusting from occurring. Once the electronic components are put in place, the entire system is enclosed.

5.2.4. Design Calculations: First, it is necessary to calculate the volume of the bucket being used by the system, as this is needed to determine the power of the pump being used. The calculation is given as follows, with the bucket being considered to be the frustum of a cone, i.e. a cone with its peak removed as a part of a smaller cone.

The radii of two circular ends of a frustum shaped bucket are 15 cm and 8cm. If its depth is 63cm, find the capacity of the bucket in liters. (Take $\pi = 22/7$)

Let R and r be the radii of the circular ends at the top and bottom and h be the depth of the bucket respectively. Given R=15cm, r=8cm and h=63cm.

The volume of the bucket (Frustum)

$$= \frac{1}{3}\pi h(R^2 + r^3 + Rr)$$

ISSN: 2005-4238 IJAST

$= \frac{22}{7} * 63 * \frac{1}{3} * (15^2 + 8^3 + 15 * 8)$

= 26994 cu.cm

$= \frac{26994}{1000}$ (1000 cu.cm=1litre)

= 26.994 litres.

Thus, the capacity of the bucket = 26.994 litres

Figure 14 Measurement

With the height of the system being known, and the volume of the bucket being known, it becomes evident the best pump can be determined from the following graph:

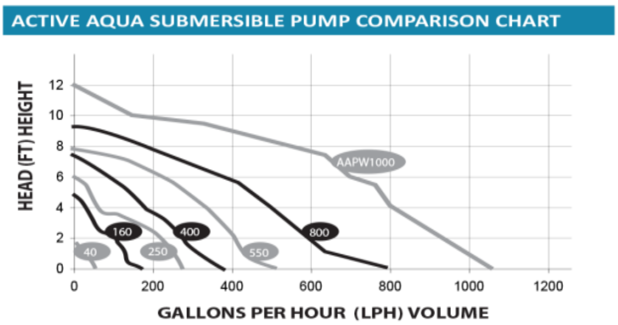

Figure 15 Head vs. Gallons Per Hour Chart for Pump Determination

It is known that 1 Gallon is approximately equal to 4 liters, implying that the bucket contains 7 gallons of water. The flowrate that is being used is taken as the GPH value. It is indicative of the number of times the bucket will be refilled during a flow cycle. The system, having a lesser height, requires a relatively lesser value for GPH, and therefore, the power of the motor required isn't altogether very high.

5.3. Crop Selection and Ideal Growth Conditions

In addition to calculating the pump requirement, the parameter setting for the various sensors is required. This varies from crop to crop. In this case, the crop being grown is spinach. Spinach requires the following conditions to be set for ideal growth

5.4. Temperature

Spinach grows best at temperatures between 5 degrees Celsius to 50 degrees Celsius, and is quite flexible. Optimally, the crop grows at temperatures between 40 and 50

ISSN: 2005-4238 IJAST

Celsius. Therefore, in the event of temperatures exceeding 50 degrees Celsius, the temperature sensor should send a signal activating the fans in the system, as it might lead to excessive bitterness in the crop.

5.5. Light

Spinach grows best in full light, but can also grow well in partial shade. However, it doesn't grow well in partial lighting conditions, and therefore the luminosity of the system should be high enough to always provide enough light. The lights should come on in the event of the system becoming too dimly lit. Specifically the intensity of light is maintained between 1000 and 1700 lumens Lumens on average. If it is to drop below 1000 lumens, the lights attached to the system will come on.

5.6. pH Levels and Nutrients

Spinach grows best at pH levels between 6.4 and 6.8 (mildly acidic), however, this is best moderated after the spinach has reached a certain stage of growth. Once it has shown some growth, the pH sensor should be allowed to work using the threshold of 6.4 to 6.8.

5.7. Electrical Conductivity

For this crop, we used hydroponic fertilizer at a strength of 1/8 to 1/4 or about 250-350 ppm concentration with a maximum Electrical Conductivity of 0.5. After a degree of growth, this is increased to 900ppm and Electrical Conductivity of 1.2, and later on reduced to 700 ppm, or Electrical Conductivity of 1.0, to prevent it from gaining a bitter taste. Therefore, in general, we average the electrical conductivity to stand between 0.8 and 1.2.

5.8. Humidity

This crop requires a very careful humidity level, as it represents the amount of moisture (or water vapor), that a crop is allowed). In the case of spinach, a humidity of fifty-five to sixty percent is preferred.

5.9. Water Level

The water level in the bucket has to be maintained at a certain level in order for the rate of flow of water through the system to match the plant's watering requirement. We use an ultrasonic sensor in detecting this, utilizing the resonating frequency of the water. The water level preferred ranges from 0cm to 3cm, but with a maximum of 10cm, or even above, depending on the requirement of the plant, at the volume indicated by the prior calculation (a different volume is used by the rate).

6. Implementation

With all the apparatus set up, the implementation can now be done. The implementation itself requires some set up, and can be considered twofold:

1. Software and coding
2. Hardware

The software and coding portion is required in order to upload the various programs to the Intel Edison, in order to run the sensors, regulate the water flow etc. The hardware portion involves the setting up of the pump, testing the flow rate and checking the Electrical Conductivity and Water Quality, and ultimately, the planting of the crop, moderation and control of the nutrients.

In addition to this verification of the software implementation is done, by using external sensors and comparing them with the inboard sensors. Once all this is done, the system can be allowed to work by itself, entirely controlled by software.

ISSN: 2005-4238 IJAST

With IoT implementation, there will be no need to adjust parameters using the source code, and can be done on a user friendly interface instead.

All the parameter breaches will be recorded by the program and control the working of the unit as a result. Ultimately, the primary requirement for the planter is to monitor the growth of the plant itself – all the other work is doable by the software.

The software and hardware set up is given in detail in the following pages.

6.1. Computer Based System Preparation

The essential principle that must be understood while coding the software is that the basic requirement is to provide idealized outdoor conditions in an indoor environment. This requires control over the various sensors involved in the code, followed by their integration and implementation from the various output devices that will enforce the necessary conditions.

6.2. Algorithm and Implementation

As this project is an exercise in automation, a lot of coding is required. The code is passed on to the system in the following steps:

- First, the Edison Image File has to be written onto the Intel Edison Processor. This is done in order to complete its set up.
- On the computer, the preferred IDE (Integrated Development Environment) is run. Putty is used for this purpose.
- While the Intel Edison can understand a wide variety of languages, the language used in this case is C.
- The specifications of the Intel Edison need to be inputted into the Putty Configuration box in order to connect the IDE to the Edison.
- The programming itself consists mainly of recursive loops, wherein, a condition must be satisfied for the loop to end. This maintains a constancy of the program outcome over averaging values of external conditions, while simultaneously dramatically simplifying the code.
- A lot of the aesthetics for the interface come prepackaged for use, making the preparation of the IoT aspect much simpler.
- The various limits for the sensors have been given in a previous section; therefore, using those values, conditional loops are applied on each of the sensors in use.
- As a result, for instance, the light sensor will detect the light intensity, and if it is found to be below 4500 Lumens, then it will switch on the light being used.
- Similarly, the various values for pH, moisture, electrical conductivity are implemented as threshold values in their individual conditional loops.
- Finally, each of these individual loops are used as individual modules and integrated into a package, that is ultimately dumped onto the Arduino board holding the Intel Edison via the cloud, that is published onto a secure net based backend.
- Next, the various buttons and objects present in the IoT interface are labelled and purposed to interact with the programming.
- The most important thing that the IoT interface is required to do is to change the threshold values present in the program as is required by the user. This can be done quite easily with the prepackaged interfaces present for use with the Intel Edison board.
- With that, the program is done, and can be implemented to work with the hardware.

ISSN: 2005-4238 IJAST

6.3. Hardware Adjustments

The most basic principle of hydroponics is that plants can be grown without the use of soil. As a result, there is a need to understand the nutrient requirements of the plant, as well as the conditions that it requires. There is an additional need to understand how these conditions can be maintained without outside interference, and without disruption by external organisms such as pests.

6.4. Methods and Implementation

This work, while programming heavy, requires some thought regarding the operation of its physical properties:

- For one thing, the necessary nutrients required for Spinach must be understood.
- The fertilizer used must contain Ammonium Calcium Nitrate, Potassium Nitrate, Iron EDTA, Copper EDTA, Manganese EDTA, Sodium Molybdate, Sodium Borate and Zinc EDTA, as well as Potassium Phosphate, Potassium Nitrate and Magnesium Sulfate.
- Next, the environment needs to be properly insulated from the external conditions, through the use of sheeting the steel cage that is being used.
- Once this is done, the seeds can be placed in their conical placeholders.
- The water, mixed with the nutrients and pH stabilizer solution is allowed to flow through the seeds via the piping system that has been set up, as presented in a prior section.
- The software then takes care of the conditions involved in causing the seedlings to sprout and grow; therefore, the next imperative to study the efficacy of the system.
- Furthermore, there is a need to protect the system from pests, although most likely the sheeting that is done to the steel cage enclosure will be enough.

With that, both the hardware and the software implementation of the hydroponics system is completed, and the plant is grown without trouble.

Some points of importance during the implementation stages worth noting include:

- Ratings of the various fans, lightbulbs and the pump must be considered when giving the supply. It is easy to acquire these items at appropriate ratings, so that no regulators are required.
- As there will be water, as well as fluids of various pHs, it is important to make sure all the material being used is corrosion resistant, even to rust.
- There should also be an understanding of the nature at which plants grow; such as the importance of transpiration, respiration, photosynthesis as well as photoperiodicity.
- When programming, there will be a requirement for several library files that are necessary to operate the sensors with ease. In the event of these files not being available, they may require individual designing, although this is rarely necessary.
- The debugging of the program must be done carefully, as any bugs present will result in improper implementation. This in turn will lead to non-ideal conditions, which will cause the plant to grow at a slower rate, or not grow at all.
- Spinach shouldn’t be exposed to too much heat, as it will become very bitter.

ISSN: 2005-4238 IJAST

Figure 16 Completed setup

7. Conclusion

Hydroponics is a historically successful farming method, and of all the techniques in agriculture, it is the most easily enabled by technology. The lack of dependence on soil enables for a lot of flexibility when it comes to farming crops. It allows for the plants to be grown in layers, vertically, and in any way as long as a pipeline can be made for water to flow through. This leads to exciting possibilities when compounded with a control system that controls the environment required for efficient plant growth. The concept that a plant can be grown without soil or sunlight, and instead with the use of water, nutrients and artificial lighting, in a chemically moderated system, allows for far greater control when it comes to farming. It also allows in better space utilization, portability and pest management.

Our system strove to implement these concepts, and succeeded. The result was a miniaturized crop growth system that is fully controllable by a computer. It can be made even smaller, and other control features can easily be added. It can be transported, which is something that cannot be done in conventional farming. In the case of several units being used, they can be stacked one on top of the other, and generally placed in any desirable manner, allowing for total spacial control. By virtue of it being a closed environment, the problem of having pests or natural disasters are eliminated. The system also requires less water than a conventional farm, allowing it to be less threatened by the prospect of a drought.

In conclusion, the hydroponic system makes the process of growing crops highly efficient, and could very likely be the future of farming.

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