Android-Based Hydroponics System Using Local and Remote Monitoring and Correction of Water pH Scale

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***Abstract*— Agriculture in the Philippines and other parts of the world has been historically beset with many challenges such as agriculture land conversion that resulted to scarce agriculture area, weather, pests, and disease, as well as fluctuating markets and need for capital investments. The pressure for growth leads to the significant conversion of farmland to non-farm use.**

The study was aimed to develop and implement an Android-Based Hydroponics System with pH Scale Correction. The system is composed of a microcontroller, LCD Shield with keypad, 3 pH sensor, 3 pairs of peristaltic motor and an IP-based camera. The microcontroller is an Arduino Yun based on the ATmega32u4 and Atheros AR9331 for its wi-fi connectivity. The LCD shield provides the user interface for local monitoring and control using the I2C pins. The pH sensor is used to measure the water quality for optimal nutrient absorption of the specie. The peristaltic motor serves as a peristaltic liquid pump that presses on the tube to pass the fluid though. The IP-based camera provides a real-time transmission of quality video images for surveillance. The Graphical User Interface (GUI) is installed on a mobile phone for remote monitoring and remote control purposes.

Test conducted on the system showed that it has achieved above 95% reliability. The prototype accurately measured, precisely controlled and successfully monitors the amount of pH scale concentration.

***Keywords*— hydroponics, pH, microcontroller, Android, nutrients**

I. INTRODUCTION

The hydroponics and aquaponics systems are the two major techniques that are being focused nowadays in most agricultural countries like the Philippines [1], to improve the way of living modern techniques are used in agriculture industry [2]. Since more and more agricultural lands are being transformed into commercial establishments, the need for a soil-less culture technique for fruits and vegetables are in felt [3].

The hydroponics system answers the problems in the space and soil requirements needed in culturing fruits and vegetables[4]. Since the water and nutrients are the main needs of these fruits and vegetables, the electronic controlled hydroponics system show a way on how to successfully culture these species by achieving high yield, significant improvements in growth rates and nutrient absorption.

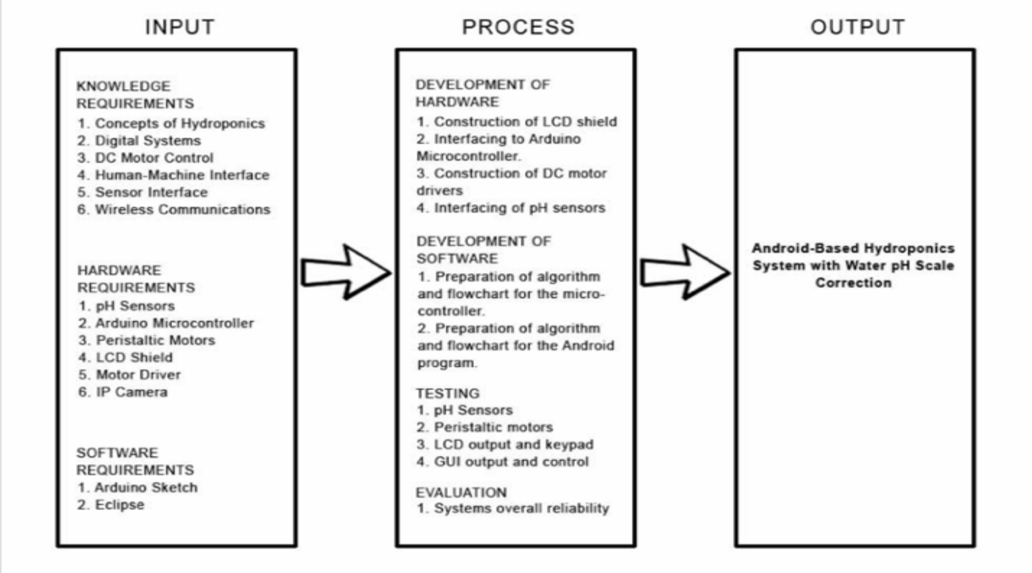


Fig. 1 Conceptual Framework

Figure 1 shows the conceptual framework in the development of the entire research study. The inputs are basically the skills needed, identification of the hardware and software in the development of the system.

The process is basically the design, prototyping, assembly and interfacing of the electronic components. This also includes the software development, testing and evaluation of the overall reliability of the system.

The output is the overall packaging, performance, and actual implementation of the system in a conventional hydroponics setup.

II. PROJECT DESIGN METHODOLOGY

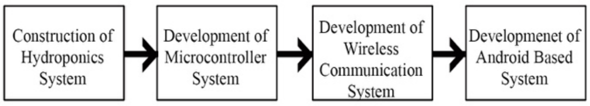


Fig. 2 Project Development

Figure 2 shows the project design methodology of the system. The first part was the indentification and collection of materials in the assembly of a conventional Nutrient Thin Film (NTF) hydroponics system. The second part is the identification, design and assembly of the electronics system [6]. The development of algorithm based on the requirement and actual programming of the microcontroller. The third part is the design, setup and configuration of wireless communications using the IPv4 standards thru YUN Linux Server. The forth part was the development of mobile application using Juno Eclipse for remote monitor and control of the hydroponics system.

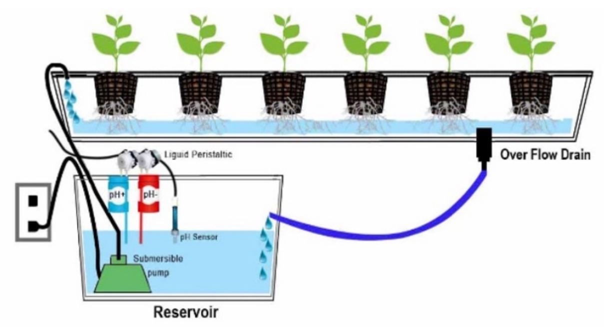


Fig. 3 Illustrative Set-up of NTF Circulating Hydroponics System with pH Correction

Figure 3 is the illustrative set-up of a conventional Nutrient Thin Film (NTF) [7] in a circulating manner with a plus factor of pH monitoring and correction for optimal nutrient absorption.

The actual setup employed three (3) medium scale integration in one (1) controller capable of controlling three (3) different pH level and species for hydro-culture.

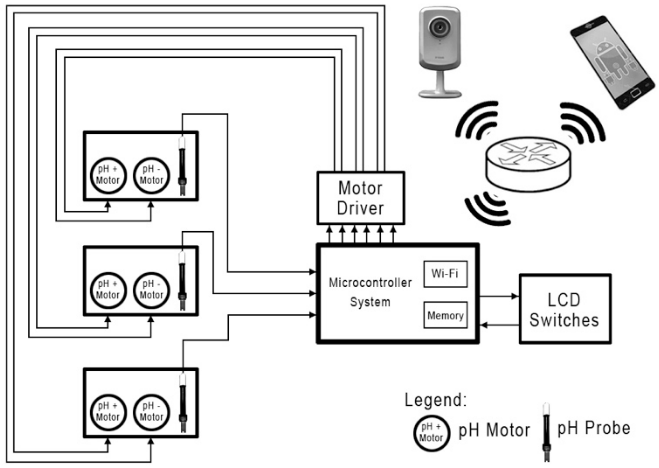


Fig. 4 Pictorial Overview of the System

Figure 4 shows the pictorial overview of the system. An Android program that serve as GUI for remote monitoring, set and reset of pH value. IP camera for remote visual monitoring and a microcontroller with integrated wi-fi module, these three (3) devices are all connected to a wireless router.

A motor driver module to muscle up the three (3) pairs of peristaltic motor. The three (3) pH probe as stimuli on the acidity or basicity of the system reserviour.

III. PROJECT TESTING AND EVALUATION

A. Data Acquition Test

The data acquisition test verified the capability of the microcontroller device to read and display the pH level readings of the three (3) sensors submerge in a common buffer solution. The test was conducted in 5 trials to verified the capability of the system.

Data acquisition test was performed by adding either positive (+) or negative (-) solution in a random manner to the system reservoir. The initial reading of Probe 1, Probe 2, Probe 3 and the pH pen meter are the following 7.95, 7.90, 7.96 and 7.9 respectively.

The second data acquisition was a result of adding 3ml of negative (-) pH to the system reservoir, the reading of Probe 1, Probe 2, Probe 3 and pH pen meter are as follows 6.90, 6.82, 6.94, and 6.8 respectively.

The third data acquisition was a result of adding 5ml of positive (+) pH to the system reservoir, the reading of Probe 1, Probe 2, Probe 3 and pH pen meter are as follows 7.39, 7.30, 7.41, and 7.3 respectively.

The fourth data acquisition was a result of adding 10ml of negative (-) pH to the system reservoir, the reading of Probe 1, Probe 2, Probe 3 and pH pen meter are as follows 4.84, 4.77, 4.88, and 4.8 respectively.

The fifth data acquisition was a result of adding 4ml of positive (+) pH to the system reservoir, the reading of Probe 1, Probe 2, Probe 3 and pH pen meter are as follows 5.77, 5.73, 5.77, and 5.7 respectively.

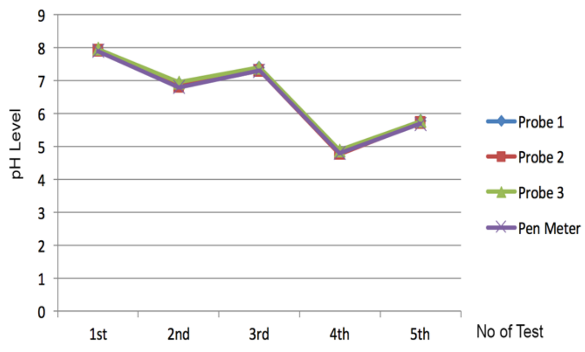


Fig. 5 Chart of the Data Acquisition Test

Figure 5 Shows the line chart of the data acquisition test. It is significant that the readings of the 3 probes and pen meter are closed to each other. The initial reading of the three (3) probes shows a very close result of 0.05 difference between proble 1 and probe 2 while 0.06 difference between probe 2 and probe 3 nearing a pH value of 8.

The second reading of the three (3) probes shows a close result of 0.08 difference between proble 1 and probe 2 while 0.12 difference between probe 2 and probe 3 nearing a pH value of 6.8.

The third reading of the three (3) probes shows a close result of 0.09 difference between proble 1 and probe 2 while 0.11 difference between probe 2 and probe 3 nearing a pH value of 7.3.

The fourth reading of the three (3) probes shows a close result of 0.07 difference between proble 1 and probe 2 while 0.11 difference between probe 2 and probe 3 nearing a pH value of 4.8.

The fifth reading of the three (3) probes shows a close result of 0.04 difference between proble 1 and probe 2 while 0.04 difference between probe 2 and probe 3 nearing a pH value of 5.7.

B. Stability Test

This part is the evaluation of the systems capability to maintain and correct the pH level after setting the desired pH value. The microcontroller device will force to maintain on its acceptable threshold value of +/- 0.3 of the desired pH value.

Probe 1 was set to maintain a pH level of 7.5 with optimal range of value 7.2-7.8 pH scale based on the threshold value of +/- 0.3 of the system, Probe 2 was set to maintan a pH level of 5.5 with optimal range value of 5.2-5.8 pH scale, and Probe 3 was set to maintain a pH level of 6.5 with optimal range value of 6.2-6.8 pH scale value.

The reservoir for Probe 1 was added by a solution in the following volume: +pH 2ml, -pH 4ml, +pH 6ml, -pH 3ml and –pH 2ml after adding different amount of pH solution, an intantenous pH reading was developed in the system reserviour. Upon processing of data the microcontroller force to actuate the peristallic at a number of intervals until the pH level fall within the optimal range of 7.2-7.8.

The reservoir for Probe 2 was added by a solution in the following volume: +pH 2ml, -pH 4ml, +pH 3ml, +pH 2ml and –pH 4ml after adding different amount of pH solution, an intantenous pH reading was developed in the system reserviour. Upon processing of data the microcontroller force to actuate the peristallic at a number of intervals until the pH level fall within the optimal range of 5.2-5.8.

The reservoir for Probe 3 was added by a solution in the following volume: +pH 2ml, -pH 4ml, -pH 3ml, +pH 2ml and –pH 4ml after adding different amount of pH solution, an intantenous pH reading was developed in the system reserviour. Upon processing of data the microcontroller force to actuate the peristallic at a number of intervals until the pH level fall within the optimal range of 6.2-6.8.

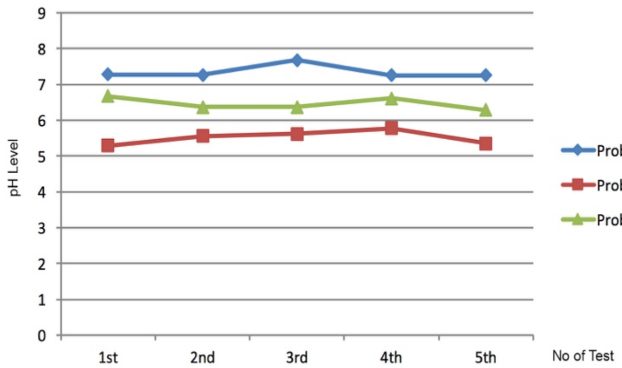


Fig. 6 Chart on the Stability Test of the System

Figure 6 Shows the line chart of the stability test of the system. It shows that after adding 5 different volumes of either negative or positive pH on each reservoir of the 3 probes, the system was able to activate the peristaltic motor and dispense the necessary concentrates to force the pH scale reading to fall in between the optimal range value.

C. Controllability Test

This test determine the systems capability to set and reset locally and remotely the optimal range value of each pH sensor on its acceptable threshold value of +/- 0.3..

Probe 1 was set to 5 different pH level, the values assigned to probe 1 are the following 7.5, 6.7, 4.5, 5.5 and 3.7. The system was able to dispense and maintain the pH level within the optimal range which is +/- 0.3 of the desired value and the results are 7.59, 6.73, 4.43, 5.34 and 3.83.

Probe 2 was set to 5 different pH level, the values assigned to probe 2 are the following 5.5, 6.3, 4.7, 5.2 and 3.5. The system was able to dispense and maintain the pH level within the optimal range which is +/- 0.3 of the desired value and the results are 5.62, 6.31, 4.75, 5.03 and 3.76.

Probe 3 was set to 5 different pH level, the values assigned to probe 3 are the following 7.2, 6.7, 4.5, 5.7 and 7.7. The system was able to dispense and maintain the pH level within the optimal range which is +/- 0.3 of the desired value and the results are 7.11, 6.85, 4.59, 5.61 and 7.5.

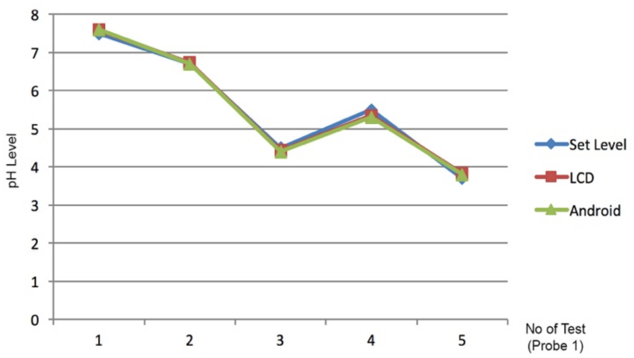


Fig. 7 Chart on the Controllability Test of Probe 1

Figure 7 Shows the line chart of the controllability test of probe 1. This shows that after 5 settings the output on the LCD and Android device was very near on the set pH value.

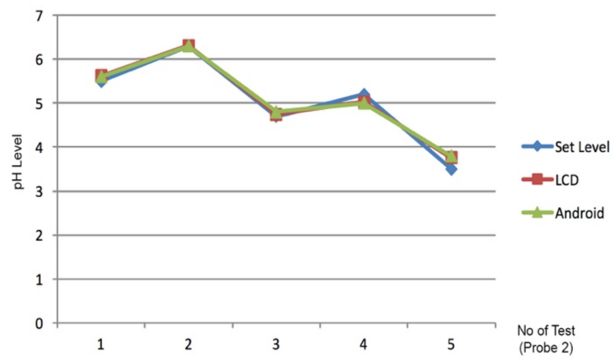


Fig. 8 Chart on the Controllability Test of Probe 2

Figure 8 Shows the line chart of the controllability test of probe 2. This shows that after 5 settings the output on the LCD and Android device was very near on the set pH value.

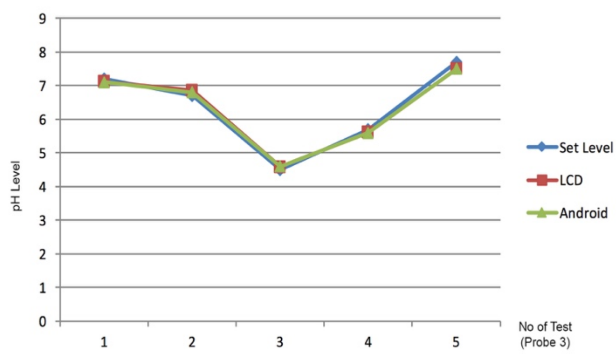
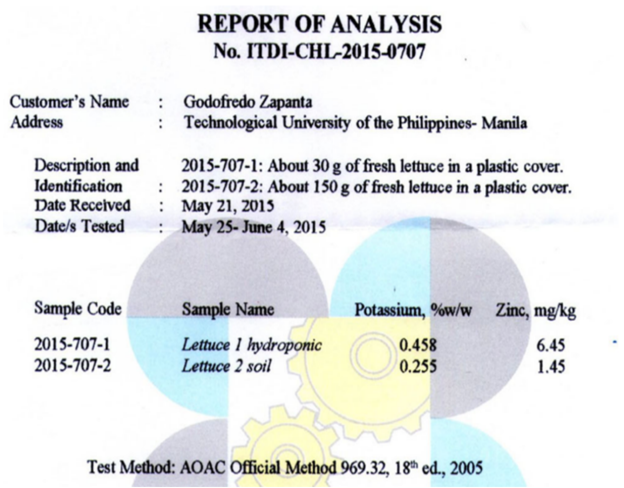


Fig. 9 Chart on the Controllability Test of Probe 3

Figure 9 Shows the line chart of the controllability test of probe 3. This shows that after 5 settings the output on the LCD and Android device was very near on the set pH value.



REPORT OF ANALYSIS
No. ITDI-CHL-2015-0707

Customer's Name : Godofredo Zapanta
Address : Technological University of the Philippines- Manila

Description and Identification : 2015-707-1: About 30 g of fresh lettuce in a plastic cover.
2015-707-2: About 150 g of fresh lettuce in a plastic cover.
Date Received : May 21, 2015
Date/s Tested : May 25- June 4, 2015

Sample Code	Sample Name	Potassium, %w/w	Zinc, mg/kg
2015-707-1	*Lettuce 1 hydroponic*	0.458	6.45
2015-707-2	*Lettuce 2 soil*	0.255	1.45

Test Method: AOAC Official Method 969.32, 18th ed., 2005

Fig. 10 DOST-ITDI Chem Lab Report Analysis

Figure 10 shows the chemical laboratory report analysis conducted by the Department of Science and Technology. Due to expensive rates of mineral extraction on the sample the author decided to choose the minerals Potassium and Zinc.

The report shows that Lettuce 1 that was cultured in a hydroponics setup has a Potassium, % w/w of 0.458 compare to Lettuce 2 that was soil cultured which has a Potassium, % w/w of 0.255. The report also shows that Lettuce 1 has a Zinc, mg/kg of 6.45 compare to Lettuce 2 which has a Zinc, mg/kg of 1.45.

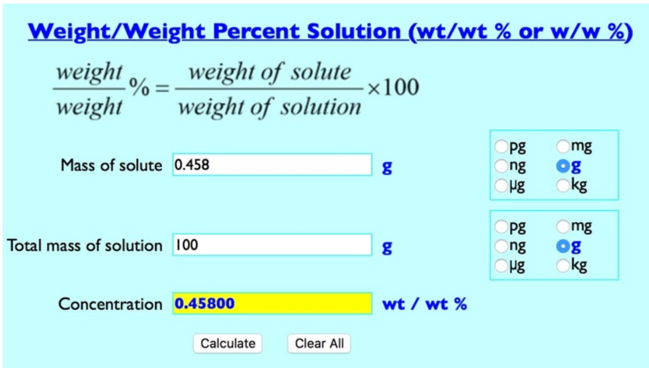


Fig. 11 Online Percent Solution Calculator
http://www.physiologyweb.com/calculators/percent_solutions_calculator.html

Figure 11 shows that the online percent calculator[11]. It shows that a mass of solute 0.458g in a total mass of solute of 100g has a concentration of 0.458 wt/wt %, this is the amount of concentrates found in sample lettuce 1.

The amount of zinc you need each day depends on your age. Average daily recommended amounts for different ages are listed below in milligrams (mg):	
Life Stage	**Recommended Amount**
Birth to 6 months	2 mg
Infants 7-12 months	3 mg
Children 1-3 years	3 mg
Children 4-8 years	5 mg
Children 9-13 years	8 mg
Teens 14-18 years (boys)	11 mg
Teens 14-18 years (girls)	9 mg
Adults (men)	11 mg
Adults (women)	8 mg
Pregnant teens	12 mg
Pregnant women	11 mg
Breastfeeding teens	13 mg
Breastfeeding women	12 mg

Fig. 12 Zinc Fact Sheet for Consumers by the National Institute of Health. https://ods.od.nih.gov/pdf/factsheets/Zinc-HealthProfessional.pdf

Figure 12 shows the recommended daily intake of Zinc base on the life stage by the National Institute of Health[10]. It shows that the minimum recommended amount is for a baby up to 6 months old which is 2mg per day, while the highest recommended amount is for the breastfeeding teen which is 13mg/day.

LENNTECH		
Minerals	**Recommended Daily Intake**	**Over Dosage**
Phosphorus	1000 mg	Contradiction: the FDA states that doses larger than 250 mg may cause stomach problems for sensitive individuals
Potassium	3500 mg	Large doses may cause stomach upsets, intestinal problems or heart rhythm disorder
Selenium	35 µg	Doses larger than 200 µg can be toxis
Sodium	2400 mg	No information found
Vanadium	< 1.8 mg	No information found
Zinc	15 mg	Doses larger than 25 mg may cause anaemia and copper deficiency

Fig. 13 Recommeded Daily Intake of Vitamins and Minerals by Lenntech http://www.lenntech.com/recommended-daily-intake.htm

Figure 13 shows the summary of recommended daily intake of all vitamins and minerals by Lenntech [8]. It shows that the daily of intake of Potassium is 3500 mg.

World Health Organization (WHO) [9] recommends an increase in potassium intake from food for reduction of blood pressure an risk of cardiovascular disease, stroke and coronary heart disease in adults (strong recommendation). WHO suggests a potassium intake of at least 90 mmol/day or equivalent to 3510 mg/day for adults. WHO suggests an increase in potassium intake from to control blood pressure in children. The recommended potassium intake of at least 90 mmol/day should be adjusted downward for children, based on the energy requirements of children relative to those adults.

Summary of Findings on the Hydroponics System and Results of its By-Product

1. The microcontroller was correctly programmed and served as the brain of the whole system.
2. The three (3) pH sensor was able to send the correct stimuli from the system reservoir for processing based on the required algorithm.
3. Signals from the pH sensors was quantified and properly map by the meter interface
4. The motor driver circuit was able to actuate the six (6) peristaltic motors based on its required action. The circuit effectively isolate the electrical noise produce by the DC motor.
5. The Android-based program was developed in precise algorithm. After 15 successful trials of data acquisition test, 15 successful trials of stability test and 15 successful trials of local and remote controlling test. The system has achieved 100% reliability, exceeding the target of 95% reliability.
6. The application was able to Log the pH level in following format <Month><Day><Year><Time><pH1,pH2,pH3> for the purpose of storage and retrieval of pH level data.
7. Summary of finding on the by-product are stated below:
    a. The certificate of analysis report performed by the Department of Science and Technology with ITDI-CHL-2015-0707 shows that the by-product of the Android-Based Hydroponics System using Water pH Scale Correction was able to meet the optimal nutrient absorption compare to vegetables production on soil.
    b. The potassium level of Lettuce 1 cultured using the hydroponic system is 0.458%w/w is less than twice the level of Lettuce 2 with 0.255%w/w cultured via soil. The potassium level of Lettuce 1 is interpreted as 0.458g of Potassium on the total mass of 100grams of Lettuce 1. Based on the Food and Nutrition Series of the Colorado State University the amount of Potassium intake each day depends on the age. As for an adult the adequate amount is 4700mg per day, while the Nutrition and Dietetics of Lenntech recommends 3500mg of Potassium for daily intake. By ratio and proportion a total mass of 1.0262Kg of Lettuce 1 contains 4700mg of Potassium [8].
    c. The Zinc content of Lettuce 1 using the hydroponics system is 6.45 mg/Kg which is significantly high compare to Lettuce 2 with 1.45 mg/kg cultured via soil. Based on the National Institutes of Health under the Department of Health and Human Services of the USA the

amount of Zinc you need each day depends on your age [10]. As for an adult (men) the recommended amount is 11mg per day, while the Nutrition and Dietetics of Lenntech [8] and Government of Tamil Nadu recommend 15mg dosage of Zinc for daily intake. By ratio and proportion a total mass of 2.326Kg of Lettuce 1 contains 15mg of Zinc.

IV. CONCLUSIONS

The pH of the systems reservoir determines the availability of nutrients will take for plant absorption. On a slightly acidic system at about 5.8pH, minerals are soluble and available on most of the plants for intake, a strong acid level can be excessive in presence and therefore can be toxic to plants, and on the other hand alkaline level may contain a higher level of bicarbonate ions that may affect the optimum growth in plants. This prototype will eliminate the manual strip and manual meter of getting the pH level of the system that results to manual correction of the pH scale. This research project can be use to avoid more human efforts. It allows the user to have a real-time monitoring and control of not only one (1) variety of fruits or vegetable but up to three (3) varieties. It is an effective and economic way to reduce human effort, money and wastage of time to time visitation in a conventional hydroponics setup. The prototype can help not only in terms of local and remote real-time monitoring and controlling but also a remote real-time visual monitoring thru a local IP-based camera that transmits high quality video images to be aware to the crop condition and surveillance as well. The capability to store and retrieve data can be useful to further analyze the effect of environment to the system. Apart from hydroponics field, this system can be useful in a controlled environment thru sensor replacement controlling humidity and temperature in a greenhouse climate.

REFERENCES

[1] P. J. Santos, & T. M. Ocampo, *Snap Hydroponics: Development & Potential for Urban Vegetable Production*, Philippine Journal of Crop Science (PJCS) August 2005, 30(2): 3-11 Copyright 2005, Crop Science Society of the Philippines Released 19 June 2005.

[2] TWG *Vegetable Plantation Livelihood for Persons with Disability* Tahanang Walang Hagdanan Inc. 2012

[3] *Growing Potatao without Soil,* Bureau of Agrarian Reform, August 2005

[4] R. Dela Cruz. *Hydroponics Veggie Farmer Captures Local Market* Philstar.com, Business Agriculture. 14 December 2003.

[5] Xirlynx Innovations *On easy pH testing with Eutech's pH testers and Meter.* ThermoFisher Scientific, Eutech Instrument Pte Ltd. Copyright 2005

[6] S. N. Boris, K. Gajan. Y. Thushyanthan, S. Mukherjee, & P. Vasuthas. *Android Based Farm Automation Using GR-SAKURA*, SONA College of Technology, GR Sakura Design Contest 2013.

[7] Hydroponic University. *Simply Hydroponics and Organics.* Copyright 2008

[8] Lenntech BV. *Recommended daily intake of vitamins and minerals.* Copyright 1998-2016.

[9] World Health Organization (WHO). *Photassium intake for Adults and Children.* WHO Library Cataloguing in Publication Data, ISBN 978 924 1504829 Copyright 2012.

[10] National Institute of Health (NIH). *Recommended Dietary Allowances (RDAs) for Zinc.* Office of Dietary Supplements. February 2016.

[11] Physiology Web. *Percent (%) Solutions Calculator.* August 23, 2015

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