120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #7880

Remote Humidity and Temperature Real-Time Monitoring System for the Study of the After-Ripening Process in Seeds

Mr. Thiruparan Balachandran, Middle Tennessee State University

Thiruparn is graduate student at Middle Tennessee State University and pressuring MS degree in Engineering Technology concentration .He has his BS degree in Engineering Physics. He is interested in Embedded system .he has published several conference papers. He can be researched by email at: bt2t@mtmail.mtsu.edu

Dr. Saleh M. Sbenaty, Middle Tennessee State University

Saleh M. Sbenaty is currently a professor of engineering technology at Middle Tennessee State University. He received the B.S. degree in E.E. from Damascus University and the M.S. and Ph.D. degrees in E.E. from Tennessee Technological University. He is actively engaged in curriculum development for technological education. He has authored and co-authored several industry-based case studies. He is also conducting research in the area of mass spectrometry, power electronics, lasers, instrumentation, digital forensics, and microcontroller applications.

Dr. Jeffrey Walck, Middle Tennessee State University

Jeffrey Walck is a Professor of Biology at Middle Tennessee State University. His research interests focus on the ecology of seed germination and on the conservation biology of the cedar glade ecosystem. He has been an Invited Visiting Scientist to Australia, Japan, South Korea, Taiwan, and China.

Remote Humidity and Temperature Real-Time Monitoring System for the Study of the After-Ripening Process in Seeds

1. Abstract

The current paper discusses the design, prototyping, and testing of a remote monitoring system that is used to study seed germination under various controlled conditions. The research will help biologists in determining the optimal conditions for after-ripening in seeds, which are necessary for successful seed storage and germination. The research is being performed through collaborative efforts between two faculty members and a graduate student from the Engineering Technology and Biology Departments at Middle Tennessee State University.

2. Introduction

Seed biology is an important branch of plant science. Many seed germination experiments are carried out under controlled environmental conditions and seed scientists have experienced difficulties in maintaining and monitoring the relative humidity inside closed containers. The common practice is the use of super-saturated solutions of different chemicals to provide and maintain relative humidity. However, these super-saturated solutions require continuous (manual) checking by the researcher to determine their accuracy. The current paper discusses the development of a remote monitoring system that can be used to accurately monitor and measure the relative humidity and temperature of the closed containers used for seed after-ripening. What makes this task especially challenging is that the closed containers are housed in an incubator that maintains a desired temperature. The incubator is not permeable to Wi-Fi signals required for the proper wireless communication with the monitoring system.

3. Background

The need of measuring physical parameters plays an important role in science and technology. In modern days, sensors are used not only for this purpose but also in every day of our lives. Sensors are electronic components that translate physical parameters into electrical signals [1]. In early days, these sensors were normally coupled with complex digital systems or with computers in order to monitor and control the physical parameters of interest. Those systems were complex, expensive, and large in size. Advancement in technology grew rapidly with the introduction of microcontrollers. The fast developments of these devices have made it possible to replace complex electronic systems with simple and cost effective platforms to interface sensors and provide the necessary measurements. A microcontroller is a device that may have a Central Processing Unit, random access memory, read only memory, timers, counters, Analog to Digital (A/D) converters, Input/Output (I/O) ports and/or other peripherals in a single chip [2].

Applications of microcontrollers are numerous and they range from simple applications such as toys to complex applications such as fly-by-wire. The improvement in fabrication technology has led to the manufacturing of microcontrollers at the nano-meter scale, which provides a small footprint as well as efficient power consumption, high speed, and low cost [3].

Advancements in communication modules and protocols have greatly increased the implementation of microcontroller-based remote monitoring systems. These communication modules includes Wireless Fidelity (Wi-Fi), Bluetooth, Radio Frequency (RF), ZigBee and Global System for Mobile Communication (GSM) [4, 5]. These modules have their own advantages and drawbacks. Bluetooth, RF, and ZigBee modules in particular can transfer data to other modules or to a host computer. Furthermore, the use of Wi-Fi and GSM modules allows the direct transfer of data to an internet server, from which it can be accessed from almost any place. A GSM module needs a dedicated phone line to transfer data while a Wi-Fi module can be used with an existing network or in a common Wi-Fi environment. Nowadays, many places are equipped with Wi-Fi services; therefore, using Wi-Fi modules to transfer data to an internet server is the most widely used since it is cost effective and efficient [6].

4. Seed After-Ripening Research

To carry out advanced research in plant science, medical, and other fields, real-time and remote monitoring systems are greatly needed. Several instruments have been designed and built to address the needs of researchers in many fields. Seed biology is a major field in plant science, in which biologists have to monitor and manipulate physical environmental parameters in their experiments. These parameters are mainly temperature, light, and relative humidity, which are directly related with seed storage, dormancy break (such as after-ripening), and germination. A dormant seed is one that does not have a capacity to germinate in a specified period of time under any combination of physical and environmental factors [7]. Seed after-ripening is a dormancy break treatment in which seeds are stored for a prolonged period of time, which results in improved conditions that permit germination [8]. Relative humidity (RH) is one of the main parameters that have been shown to significantly affect the rate of seed after-ripening [9]. Seed scientists have been experiencing difficulties in maintaining a specific relative humidity inside closed containers and the common practice is the use of saturated solutions of different chemicals. However, these super-saturated solutions cannot be accepted as an accurate method of control and cannot replace real-time measurements [10].

As shown in Figures 1 and 2, seeds are kept in containers inside incubators for seed after-ripening study. This method maintains the temperature at a desired level. Super saturated solutions that are poured into the bottom of each box are supposed to maintain the relative humidity at a specific level. One such method uses LiCl. By varying the amount of this chemical dissolved in distilled water, various relative humidities can be produced [11]. Alternately, incubators that can control both humidity and temperature might be also used. However, several incubators are needed simultaneously in order to carry out the intended research. This results in increase of cost and required space.

5. Research Aim

In order to better understand seed after-ripening, the current use of super-saturated solutions to control the relative humidity in a sealed box in an incubator is not a reliable method. Therefore, a remote and real time monitoring system that can measure and monitor the relative humidity and temperature should be designed and built in order to help researchers monitor the after-ripening process in seeds.

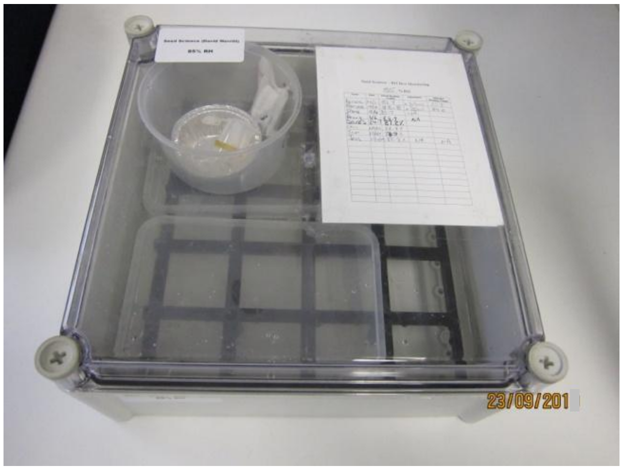

Figure 1. An Air-Tight Container that is Used to Store Seeds Under Study.

Figure 2. Seed Containers Stored Inside an Incubator.

6. Literature Review

Many researchers and engineers have been working on real time and remote monitoring systems. "Low-Power Hybrid Wireless Network for Monitoring Infant Incubators" was published by Shin et al. in 2004. They have designed a wireless network for monitoring infant incubators using Infrared (IR) and RF modules [12]. This system monitors the temperature and humidity of the infant incubators and sends the data to the host computer when the host computer requests for the data through IR communication. It sends the ID of the slave device to a host server and if an ID match is made, the slave device transmits the data back to the host computer through an RF module. In this study, two-way communication platform was used; one is to send a request to slave devices (using IR) and another is to send data to the host (using RF). National instrument LabView software was used to plot the data using a computer. Some of the drawbacks of this system are the use of a host computer and associated LabView software, which increased the cost, limited the range, and provided no alert method to notify the user.

Another system has been designed by Wen-Tsai Sung and Ming-Han Tsai and described in their work "Multi-Sensor Wireless Signal Aggregation for Environmental Monitoring System via Multi-bit Data Fusion." Their system uses ZigBee, a protocol based on the Institute of Electrical and Electronics Engineers 802.15.4 (IEEE 802.15.4). As shown in Figure 3, sensor nodes send the data to ZigBee motherboard that collects the data from all nodes and sends them to the user computer through a Universal Serial Bus (USB). This system uses low power, has a low cost, and is small in size. Some of the disadvantages of this system are low data transfer rate, short distance data transmission, and remote monitoring is not implemented [13].

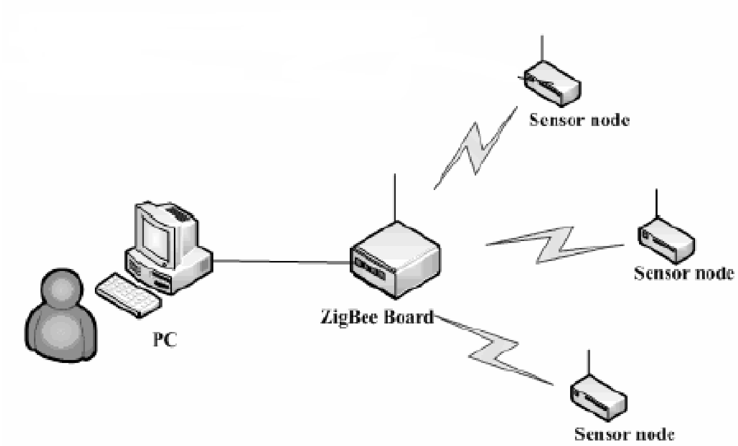

Figure 3. Wireless Sensor Network Using ZigBee Protocol [12].

7. The Proposed System

The system under discussion allows a remote real-time monitoring of the relative humidity and temperature of five (can be expandable to more than five) different closed containers. The system functions as a client that is connected to the internet using Wi-Fi technology. At fixed time intervals, the system reads the sensor measurements that are available and pass them to a Google Spreadsheet. A time and date stamp is provided with each measurement. Application-specific software was created, which allows users to plot the data as a graph in the browser. The data can be also downloaded as a Microsoft Excel sheet and further analysis can be done. The following factory calibrated sensor, SHT 75 from Sensirion, is used to sense the relative humidity and temperature. Its RH response time is 8 sec, power consumption is 80 µW, and has temperature and RH operating ranges from -40 to +125 °C and from 0 to 100% RH, respectively.

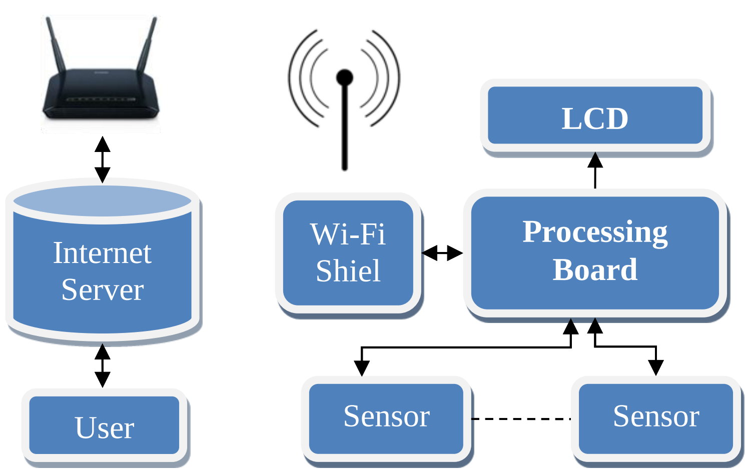

Figure 4.A. Proposed System Design.

The processor used is an Ardunio microcontroller that has an AVR 8-bit microcontroller on it. This device is connected to Internet using Microchip MRF24WB0MA Wi-Fi module using IEEE Std. 802.11b/g/n wireless networks protocol. Figure 4A illustrates the basic block diagram of the proposed system.

8. System Design and Construction

This system consists of sensors, main processing board, a Wi-Fi module and an LCD module. The processing board reads the sensors' measured values and sends them to an internet server. The user can view the date either as numerical values or as a graph. The data can be also downloaded as Microsoft Excel sheet. Figures 4B and 4C show the main processing board and its associated components.

Figure 4.B. Main Processing Board and its Associated Hardware.

8.1. Sensors

The SHT 75 sensor from Sensirion is selected to measure temperature and relative humidity. This sensor consists of a sensing element and a signal processing unit and provides calibrated temperature and relative humidity measurements. This sensor uses capacitive and band gap sensing technology to measure the relative humidity and temperature, respectively. In this system five of these sensors are used and they are connected to the microcontroller through a two-wire serial interface. Each sensor is placed inside the sealed container in which the experiment is carried out and a special USB airproof Coupler is used to make connection to the outside. Figure 5 below shows how the sensor is connected to the closed container.

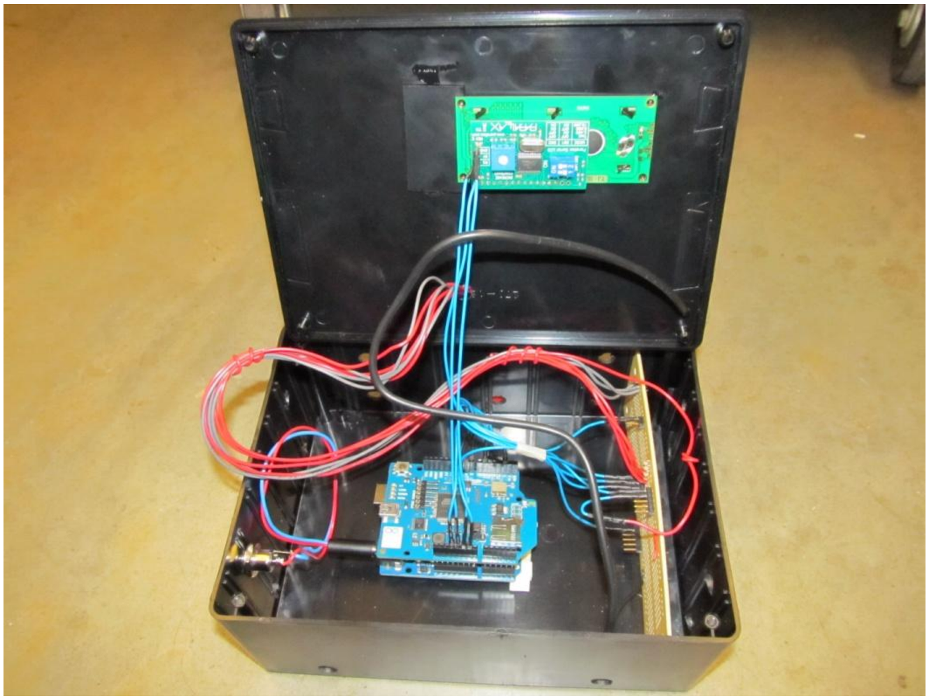

Figure 4.C. Inside the Main Processing Board and its Associated Hardware.

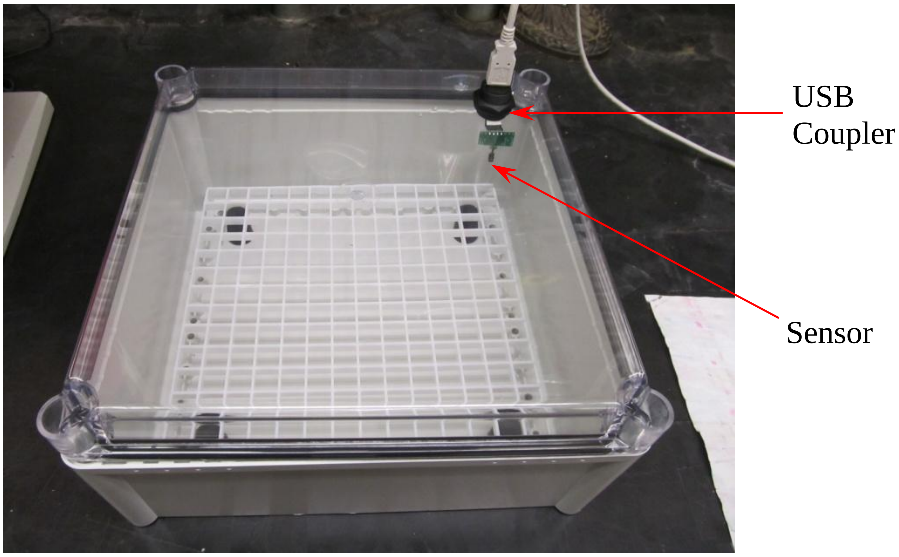

Figure 5. Temperature and RH Sensor Connected Using a USB Airproof Coupler.

8.2. Main Processor Platform

The Ardiuno UNO is used as the main processing board, which has ATmega 328 microcontroller and its supporting components on it. Sensors are connected through a common clock signal line and I/O pins for data transmission, one for each sensor. The microcontroller reads the data from each sensor one by one every 15 seconds and sends the data to the Wi-Fi module with a time stamp. An Arduino Wi-Fi shield is used as a Wi-Fi module. The microcontroller and the Wi-Fi Shield communicate through SPI bus. A Google form is created using Google Apps (please see Figure 6 below) and the Wi-Fi shield acts as a client. The shield enters the data into the form automatically once it is received from the main processing board. By default, Google form is connected to the spreadsheet and all the data being entered is collected in the spreadsheet. A software program is created to view the data as a graph in real time.

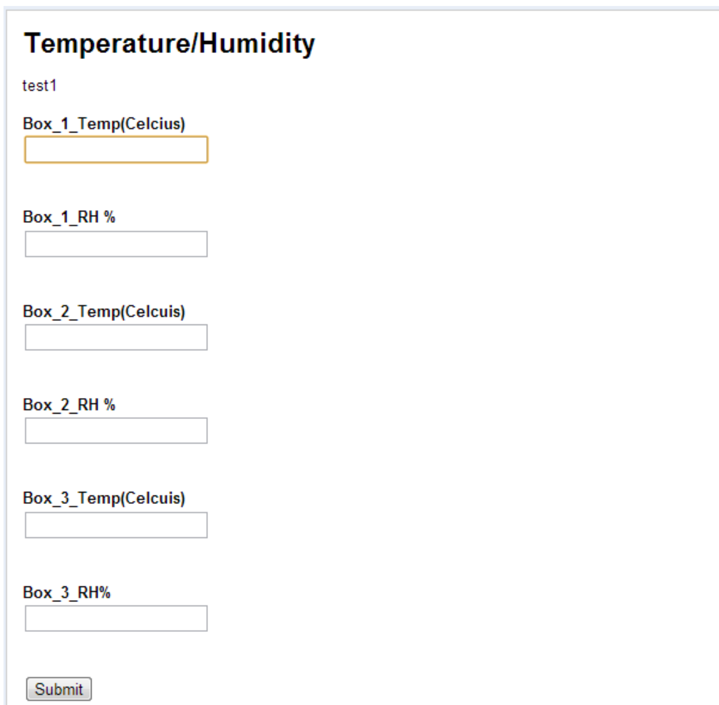
Temperature/Humidity
test1
Box_1_Temp(Celcius)
Box_1_RH %
Box_2_Temp(Celcuis)
Box_2_RH %
Box_3_Temp(Celcuis)
Box_3_RH%
Submit

Figure 6. Google Form in Which the System Enters the Measured Values.

8.3 Plotting the Data

Google Chart Tools are used to draw the graph. This is an open JavaScript library where one can define the data sets and populates the graph. Packages:["corechart"] method is used to import the Google chart API. Since Google Spreadsheet is used to store the data, Google query method is used to retrieve the datasets; arguments for that method are the URL of the spreadsheet and the range of the column to be populated as data.

In order to plot a graph using Google API, the horizontal and vertical axes have to be created first and then method AreaChart is used to define the html division names for the graph. The draw method plots the graph by taking the real-time data and the options as argument. Another requirement is that the spreadsheet data should dynamically change its content, to make sure that a populated graph refers to the spreadsheet dynamically. Set interval (drawChart, 30000) method is used to call the drawChart every 3 seconds. This makes sure that data is plotted in real-time.

9. Results

The sensor system was tested using closed polyethylene containers with various RH and containing seeds to simulate an after-ripening experiment. A gradient in RH was created across three containers: Box 1 with a 75 gram LiCl + 200 ml water solution (predicted 50% RH, cite Gold and Hay paper), Box 2 with 200 ml water, and Box 3 with no solution (control). The containers were placed in a temperature- and light controlled incubator set at constant 20 ^{o}C with a 14 hour photoperiod. Nine green gram (*Vigna radiata*) seeds, which are used in a variety of food dishes in many countries [14], were placed in each box. .

It was observed that the system successfully updated the temperature and RH of each box in the Google spreadsheet and the software plots the graph in real time. It was also possible to download the data as a Microsoft Excel sheet. Average temperature in Box 1 and 2 3 was 20.21 and 20.19 ^{o}C, respectively, and RH was 49.06 and 96.87, respectively (Figures 7-9).

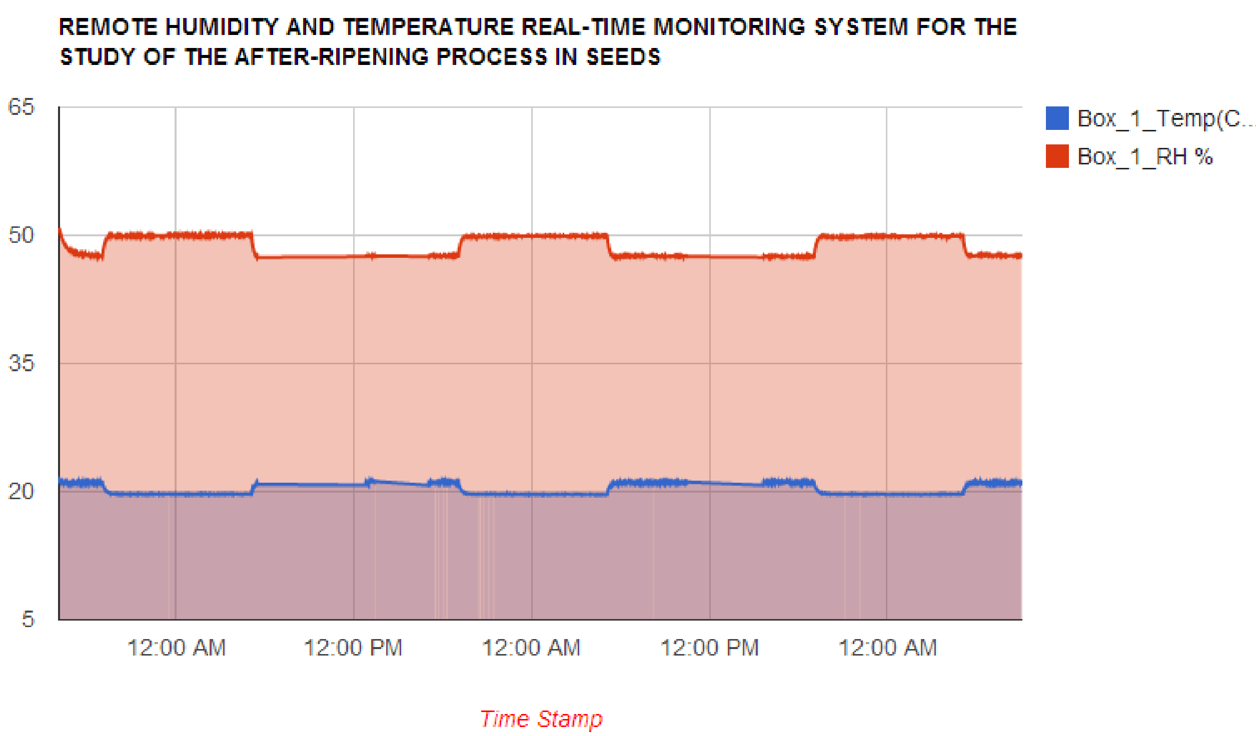

Figure 7. Temperature RH Measurements in Box One, Which Has the LiCl Solution.

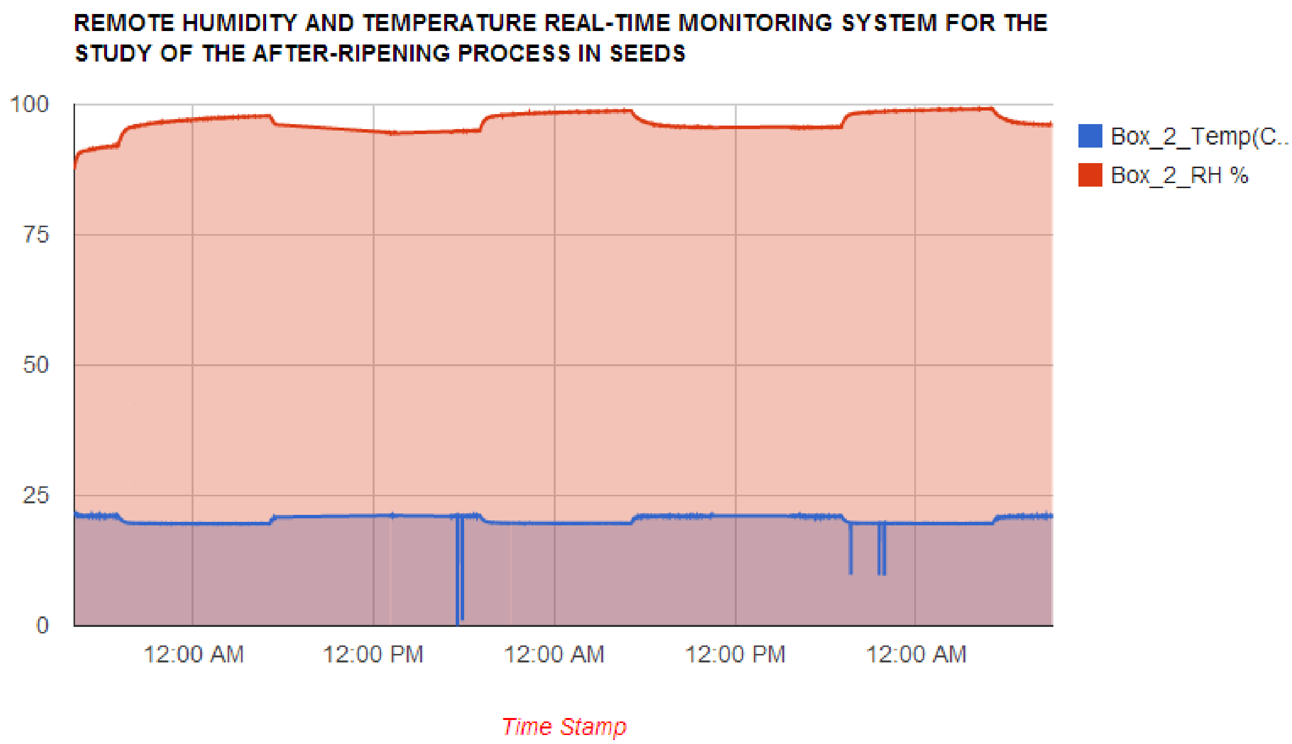

Figure 8. Temperature RH Measurements in Box Two, Which Has Distilled Water Only.

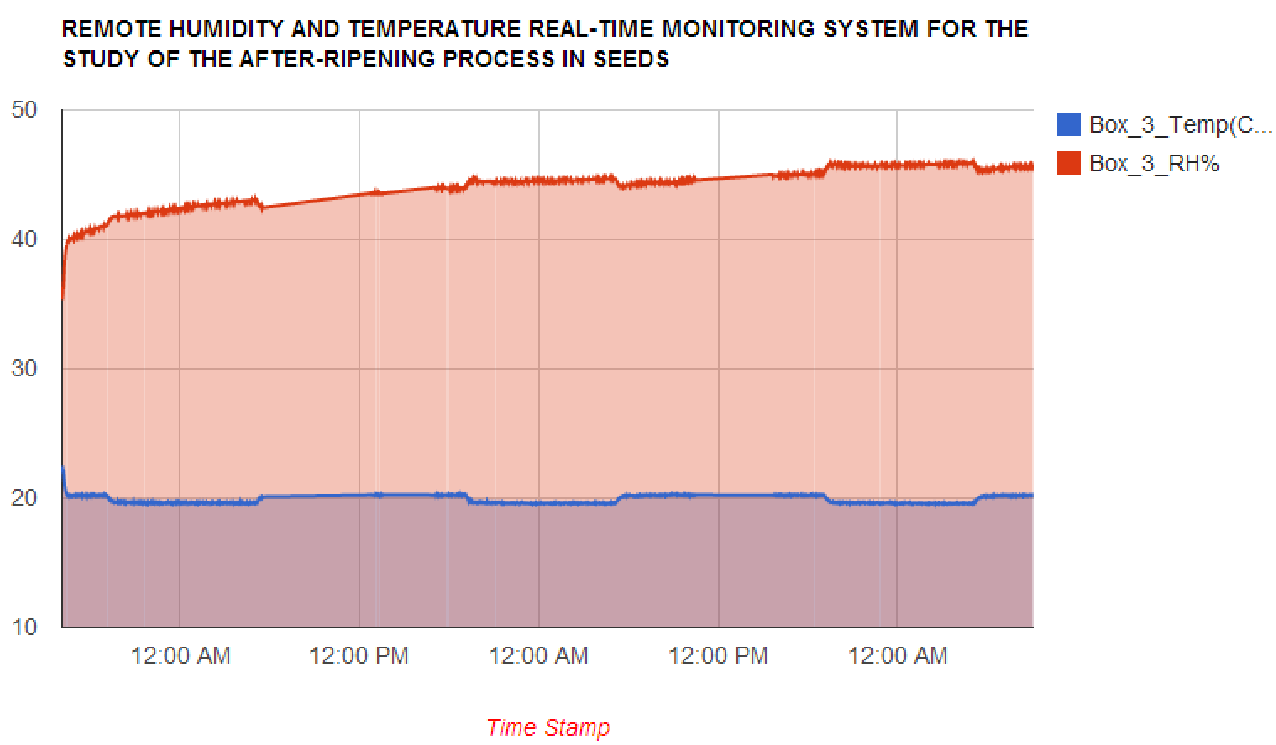

Figure 9. Temperature RH Measurements in Box Three, Which Has no Solution.

10. Summary and Conclusions

It was demonstrated that a relatively inexpensive system (approximately $250) can be designed and built for the purpose of seed research. This system is very useful for the real-time measurement and monitoring of the RH and temperature in a closed environment. It can be used to compare the capabilities of different chemical solutions, provides an easy and reliable method for monitoring the study of the after-ripening process, and is user-friendly and is easy to setup without much effort. The user can set up different experiments and check the temperature and RH of each box remotely in real-time, and the data can be downloaded as a Microsoft Excel sheet for further data analysis. Since this system uses Google spreadsheet, the user does not need to buy server space for implementation.

During the system evaluation, the system adequately monitored the temperature and RH of the three containers. RH Moreover, the temperature and RH in the containers were maintained (with little variations) over the test period. The variations in temperature and relative humidity observed were due to the slight heating/cooling of the incubator to maintain the desired temperature. Thus, this system also could detect very fine variations in these parameters which could lead to better understanding of the environments inside containers and incubators and their role in seed dormancy break. Finally, this system can be very easily extended to monitoring a broader range of RHs among several to many containers.

11. References

1. Wilson, J. S. (editor), *Sensor Technology Handbook*, pp 1, Elsevier (UK)., 2005.
2. Dhananjay, G. V., *Programming and Customizing AVR Microcontroller*, pp 22, McGraw-Hill (USA)., 2001.
3. Kwong, J., Ramadass,Y. K., Verma, N., Chandrakasan, A. P., "A 65 nm Sub-V_t Microcontroller With Integrated SRAM and Switched Capacitor DC-DC Converter", *IEEE Journal of solid-state circuits*, 2009, 44, 115-126.
4. Brennan, T.M., Ernst, J. M., Day, C. M., Bullock, D. M., Krogmeier, J.V., Martchouk, M., "Influence of Vertical Sensor Placement on Data Collection Efficiency from Bluetooth MAC Address Collection", *ASCE Journal of Transportation Engineering*, 2009, 136, 1104-1109.
5. Jasemian, Y., Nielsen, L. A., "Design and implementation of a telemedicine system using Bluetooth protocol and GSM/GPRS network, for real time remote patient monitoring", *Technology and Health Care, 2005,* 13, 199–219.
6. Forlano, L., "WiFi Geographies: When Code Meets Place", *The Information Society*, 2009, 25, 344–352.
7. Baskin, J. M., Baskin, C.C., "Effect of Relative Humidity on Afterripening and Viability in Seed of the Winter Annual *Draba verna*", *Botanical Gazette*, 1979, 140, 284-287.
8. Bazin, J., Langlade, N., Vincourt, P., Arribat, S., Balzergue, S., El-Maarouf-Bouteau, H., Bailly, C., "Targeted mRNA oxidation regulate sunflower seed dormancy alleviation during dry after ripening", *The Plant Cell,* 2011, 23, 2196-2208.
9. Turner, S. R., Merritt, D. J., Renton, M. S., Dixon, K. W., "Seed moisture content affects afterripenig and smoke responsiveness in three sympatric Australian native species rom fire-prone environments", *Austral Ecology* , 2009, 23, 866-877.
10. Sweetman, H. L., "Studies of chemical control of relative humidity in closed spaces", *Ecology*, 1933, 14, 40-45.
11. Kate Gold and Fiona Hay, Equilibrating seeds to specific moisture levels, Technical Information Sheet_09, Millennium Seed Bank Project, www.kew.org/msbp .
12. Shin, D. I., Shin, K. H., Kim, I. K., Park, K. S., Lee, T. S., Kim, S. I., Lim, K. S., Huh, S. J., " Low-power hybrid wireless network for monitoring infant incubators", *Medical Engineering & Physics*, 2005, 27, 713-716.
13. Sung, W. T., Tsai, M. H., "Multi-Sensor Wireless Signal Aggregation for Environmental Monitoring System via Multi-bit Data Fusion", *Applied Mathematics & Information Sciences*, 2011, 5, 589–603.
14. http://en.wikipedia.org/wiki/Mung_bean