PLANTING COLD SEASON CROPS IN WARM CLIMATE SETTING VIA TEMPERATURE-CONTROLLED GREENHOUSE WITH AUTOMATED IRRIGATION, AND SOILD ACIDITY REGULATION

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ABSTRACT: — In this paper an idea of automated green house is introduced, using multiple sensors to monitor and control parameters for optimum growth of cold seasonal crops, with which a microcontroller is programmed to process the data and trigger the irrigation and soil acidity regulation system. The idea is to simulate a natural habitat of the cold seasonal crop inside the greenhouse. Based on the results of this study, the system provides a data that can be used as reference for the production of such plants concerning the future effects of Global Warming.

1. INTRODUCTION

Nowadays, shipment of fresh vegetables became questionable due to its quality when it reaches the market. Especially when there are a lot of transportation problems that cause delays in delivering vegetables which cannot handle being frozen, canned, or dried. Most of these crops are usually from places where they are specifically grown due to its needs in nature like cold seasonal crops. Places where these crops can be planted are just limited and rarely near the cities where large markets are. Moreover, since global warming can already be felt, even cold areas will be affected by it and there might come a time where they could no longer produce the crops they usually do. Therefore, there became a need of a solution where cold seasonal vegetables can stay fresh when it arrives in the market of cities that experiences hot weather. Considering this situation, automated greenhouse has been one of the ideas that can make cold season crops grow in these cities. Devices such as cooling systems, temperature monitoring sensor, humidity monitoring sensor etc., were invented. However, these still has deficiencies that lead for the need to improve and upgrade to adapt more to the necessity of the situation.

Despite the huge number of studies about the improvement of greenhouses, various aspects are still needed to be considered. One of the causes of barren and ephemeral plants is lack of sunlight due to rainy seasons in a tropical country like the Philippines. The most problem is the cold seasonal plants are sensitive when it comes to sunlight, temperature, soil moisture, and soil acidity. And so, to avoid such situation, precise information is needed to create a more reliable device. Hence, the automated and monitoring-based approach is much more appealing than just dealing with detectors that can't provide plant necessities. In most existing greenhouses that uses automation, they either control the temperature, soil moisture, or soil acidity (Walthall, 2013).

The study focuses on the possibility of growing cold season crops in a warm climate. Completion of this study and implementation of this automated greenhouse system would help people secure a stable supply of broccoli, lettuces and/or strawberries. This automated greenhouse system could also help in supplying the said crops in times where their supply is scarce (Godfray, 2010).

This study aims on planting cold-season crops in a warm climate setting with the use of temperature-controlled greenhouse with automated irrigation, and soil acidity regulation. This goal incorporates the following objectives: (1) to construct a greenhouse that grows at least one cold season crop that is geographically outside its natural habitat; (2) to automate the regulation of the soil moisture, and soil acidity needed by our selected crops namely, strawberries, head lettuce, and broccoli (Jairath, 2015) (Gupta, 2002) (Kumar, 2009).

The automation will incorporate soil moisture, and soil pH level sensors to provide the required data needed for the actuators to regulate the desired parameter values inside the greenhouse for it to grow a plant that is geographically away from its natural habitat. With the soil moisture sensor, it helps the automated irrigation system when to perform watering the crops to maintain the needed moisture for each crop (Jones, 2004) (Smith, 2011) (Hanson) (Singh, 2016). As for the soil pH sensor, it monitors the acidity and alkalinity of the soil to meet the optimal pH level of the plants (United States of America Patent No. 34, 1914). On the other hand, there are sensors used to acquire health vegetation using remotely-sensed data (Ballado, et al., 2016).

The study focuses on the possibility of growing cold season crops in a warm climate. Completion of this study and implementation of this automated greenhouse system would help people secure a stable supply of broccoli, lettuces and/or strawberries. This automated greenhouse system could also help in supplying the said crops in times where their supply is scarce.

This paper is presented as follows: section 1 - introduction, section 2 - review of related literature, section 3 - methodology, and section 4 - results and discussion, section 5 - conclusion and recommendation.

2. RELATED WORKS

A. Climate Change on Agriculture

According to the research of Charles L. Walthall [3] on “Climate Change and Agriculture in the United States: Effects and Adaptation”, every crop species has a different temperature threshold for its growth and reproduction. Some crops are developed in cold areas, and some are developed in warm areas. Crops also have their own critical period for optimal growth depending on the climate where the plant is developed. The world’s climate is now rapidly and unpredictably changing due to the greenhouse effect. With the temperatures already on the rise, it will result to a decrease in growth and reproduction yield because crop production areas. The change in air humidity and soil acidity are inevitable with the rise of temperature and would affect the optimum parameter threshold of the crops. Like pollination, it is very sensitive to temperature. Exposure of crops at high temperature during this process could result in minimal crop produce and may increase the possibility of the crop dying. The temperature at nighttime may also rise that can affect the productivity and quality of the crops. The rise in temperature speeds up the development stages of the crop, it may affect the feasibility and profitability of the crops. The increase in plant growth may result to smaller plants. In addition, in the aspect of irrigation, the rise in temperature would increase the rate of water use.

B. Growth Parameter

In the study conducted by F.W. Zink and M. Yamaguchi (Zink, 1962) on the growth rate of head lettuce, the growth parameters that could be used for a head lettuce are its number of leaves. Furthermore, in the study of S.A. Shehata, (Shehata, 2011) et al., the crop or vegetative growth parameters used for the plants are the plant height and the number of leaves in each plant. Lastly, for broccoli crops, the number of branches per crop and the plant height are the parameters of growth, which were used in the study of Nadia Gad and M.R. Abd El-Moez (Gad, 2011).

C. Automated Irrigation

In the study of Richard Smith (Smith, 2011), for the development of lettuce, the best irrigation system is the surface drip irrigation. Since drip irrigation can distribute water across plants in a certain area more uniformly, as compared to other irrigation systems, using drip irrigation could help in achieving uniform growth in fields with differing soil textures by maintaining moist soil across the whole area of the field.

According to the study of Ajit K. Pandey (Pandey, n.d.), strawberries are shallow rooted plants. With that in mind, they require frequent but less amount of water for each irrigation. It can be accomplished more efficiently through drip irrigation systems. It increased the fruit weight by 6%, has the highest water use efficiency with a savings of 50-55% irrigation water compared to surface irrigation.

For the development of broccoli, from the study of high frequency water management provided by drip irrigation, the system decreases the possibility of turning the soil as a storage for water. Furthermore, it maintains the daily water requirements of the crops in a portion of the root zone, and also reduces the water stress of the crops by maintaining high soil matric potential in its rhizosphere.

D. Red-Blue Light Source

Constructing a LED lighting system composed of 70% red LEDs and 30% blue LEDs at 500 μmol m-2s-1 promotes plant growth comparable to those found in greenhouses (Sabzalian, 2014).

Table 1. Examples of positive effects of LED lighting on plants and microorganisms' production.

Type of LED illumination	Effects	Plant/organism	Reference
Red—10 % Blue fluorescent light	Higher shoot dry weight, higher seed yield	Wheat	Goins et al. 1997
Red-blue	Higher shoot and root fresh weight	Micropropagated strawberry plants	Nhut et al. 2000
Red-blue	Larger and higher bulblet fresh and dry weight	*Lilium*	Lian et al. 2002
Red-blue	Improved flower induction, higher number of flower buds and open flowers	*Cyclamen persicum*	Heo et al. 2003
Blue	Higher carotenoid production	*Thraustochytrium* sp. CHN-1	Yamaoka et al. 2004
Red-blue	Higher leaf area and photosynthetic rate	Radish and lettuce	Tamulaitis et al. 2005
Blue	Astaxanthin production	*Haematococcus pluvialis*	Katsuda et al. 2006
Red	Better growth	*Spirulina platensis*	Wang et al. 2007
Red	Higher antioxidant activity	pea	Wu et al. 2007
Red	Higher rooting percentage	grape	Poudel et al. 2008
Red-blue	Economic production	Lettuce	Martineau et al. 2012
Red	Increase in volatile molecules	Petunia, strawberry	Colquhoun et al. 2013

E. Soil Acidity Regulation

Soil pH is the measure of the acidity or alkalinity of the soil which is expressed in pH. It is a scale that goes from 0.0 to 14.0 where 0.0 is the most acidic value while 14.0 is the most alkaline value. Additionally, 7.0 pH means that the soil is neutral; it is neither acidic nor alkaline.

Based on the article by Leonard Perry (United States of America Patent No. 34, 1914), soil pH level may be corrected with the use of ground agricultural limestone to raise its pH level. On the other hand, sulfur is used to lower the soil pH level. Tables 2.4 and 2.5 show the amount of ground agricultural limestone or sulfur needed per 100 square feet to raise or lower the soil pH level.

3. METHODOLOGY

A. Conceptual Framework

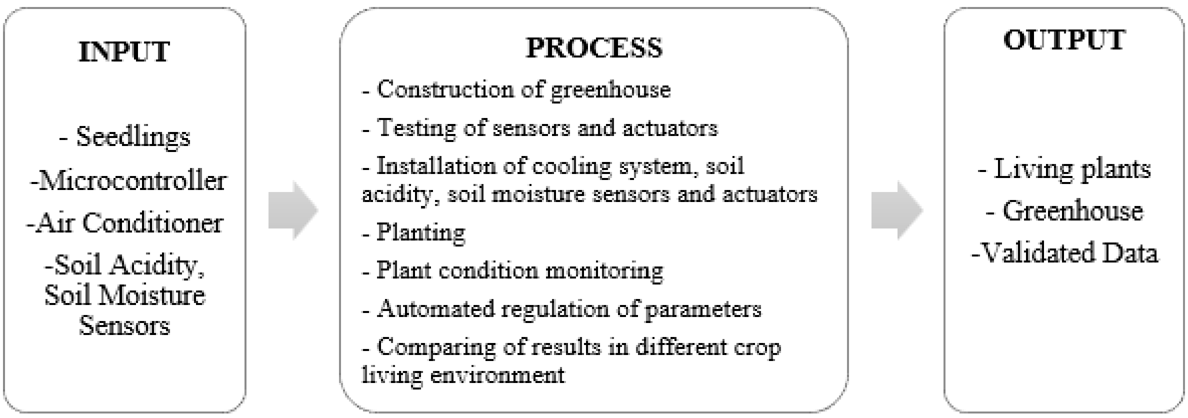

Fig. 1 Conceptual Framework

Fig. 1 shows the conceptual framework of the study. The seedlings, microcontroller, and sensors will serve as the input of the system. It will undergo a controlled environment necessary for the crops' required atmosphere. The time allotted for the crops to grow will determine if the crops can grow inside and outside the controlled environment. The output of this research are the matured plants, the automated greenhouse, and the growth measurements of the planted crops.

B. Irrigation System and Soil Acidity Regulation

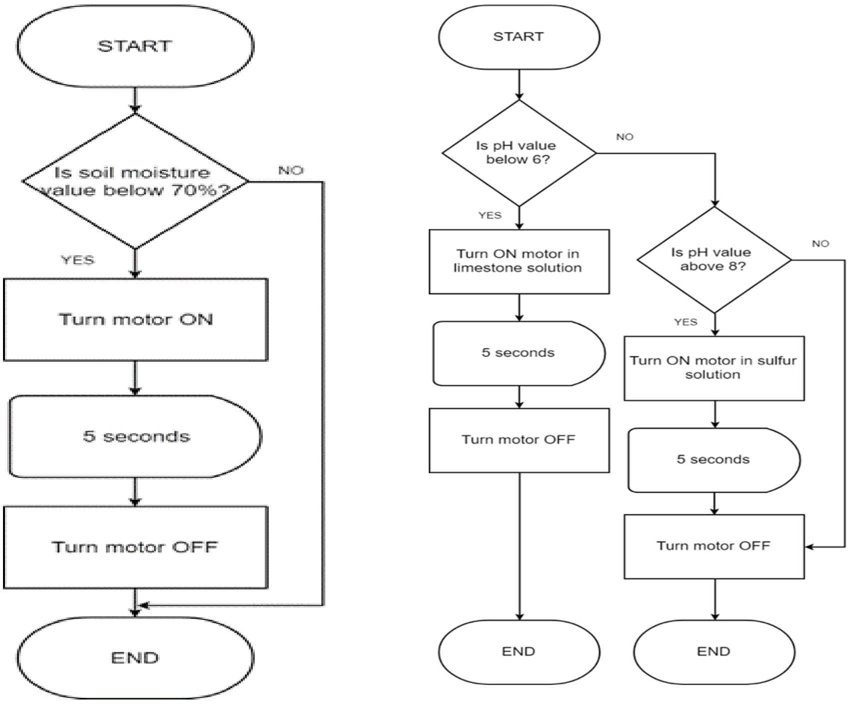

Fig. 2 (a) Irrigation System Flowchart (b) Soil Acidity Regulation Flowchart

Fig. 2 (a) shows the process flow of the irrigation system. To maintain the soil's moisture to at least 70% (OLIVEIRA, 2016), the drip irrigation system will turn on if the maximum allowable depletion fell below 70% and will stop at 85%. Fig. 2 (b) shows the soil acidity regulation. After detecting that the soil acidity is less than 6 pH or greater than 8 pH, the microcontroller would then provide the necessary solution to regulate the acidity of the soil. If the soil is below the threshold pH level, the actuator will provide a solution of ground agricultural limestone to raise its pH level to its desired value. If the soil is above the threshold pH level, a sulfur solution will be provided to lower its pH level to its desired value.

C. System Setup

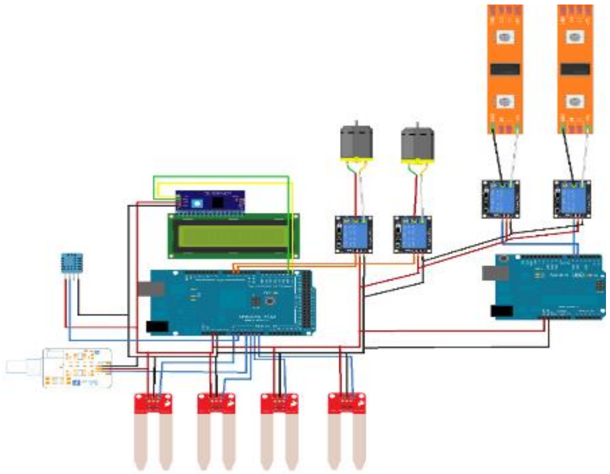

Fig. 3 System Setup

Fig. 3 shows the system setup. The temperature, soil moisture, soil acidity, and humidity sensors are placed on the input of the microcontroller. The actuator such as the dripping system is placed on the microcontroller's output. The actuator would turn ON depending if the input of the sensors does not satisfy the parameters set in the microcontroller. The lighting system is also connected to the output side of the microcontroller. The microcontroller would automatically turn the lighting system ON and OFF. Furthermore, the LCD display would be placed on the output side of the microcontroller which would be used to display the status of the parameters inside the greenhouse. Finally, the microcontroller and air conditioner would be connected to the power supply.

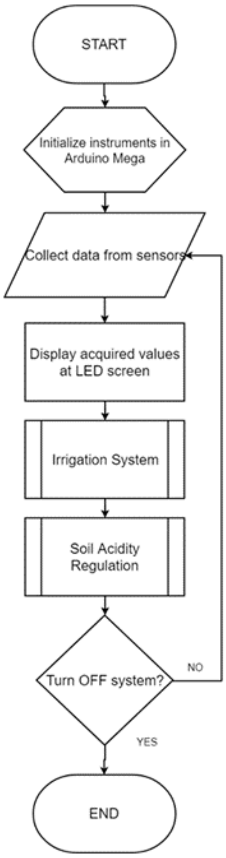

Fig. 4 Flowchart of The Automation Process of The Greenhouse

Fig. 4 shows the general process of automation for this greenhouse starts with the collection of data with the use of the different sensors. Afterwards, the data collected would determine whether the irrigation, lighting system, and/or acidity regulation would turn on.

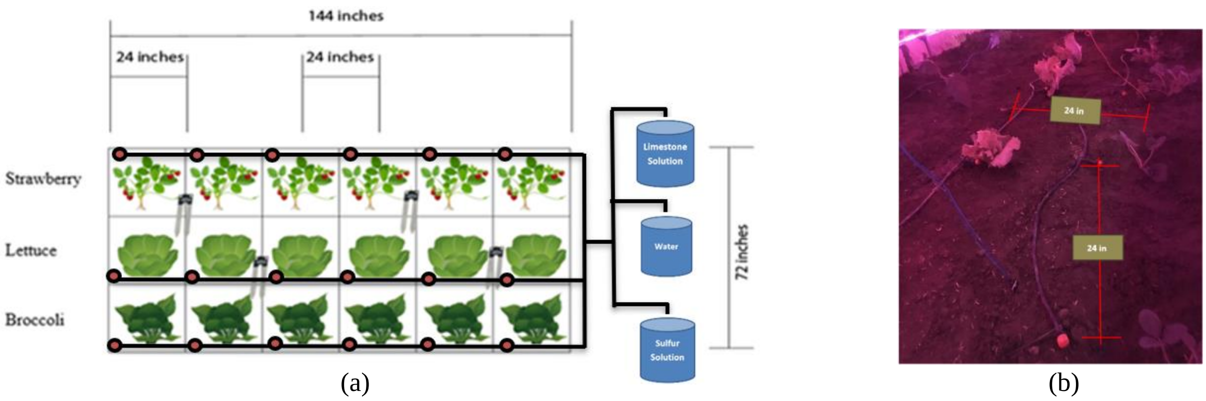

Fig. 5 Setup Diagram (a) Setup Diagram (b) Crop Spacing

Fig. 5 represents the setup diagram of the greenhouse. The crop spacing, sensor placement, and drip system can be seen from the diagram. The required spacing in planting broccoli is 24 inches (MF, 2011), while in another study of Sale, P.J.M (Sale, 2015) it is stated that the required spacing for planting lettuce is 12 inches apart from each crop.

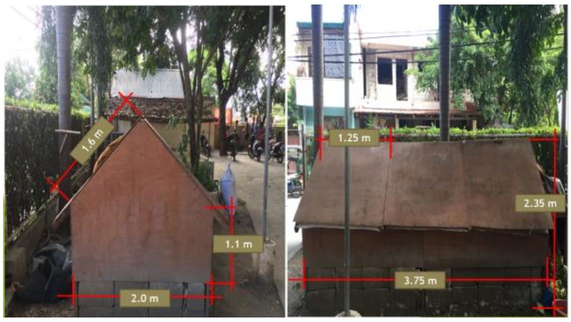

Fig. 6 Dimensions of the Greenhouse

Fig. 6 shows the dimension of the greenhouse. Moreover, in this design it is already considered on how the planting will be made easy. The design of the roof will serve as the access of the farmer in planting the crops.

(a) (b)

Fig. 7 (a) Lighting System and (b) Air-Conditioner Setup

Shown in Fig. 7 (a) and (b), is the installation of lighting system and air-conditioner inside the greenhouse. Since the design of the roof is a slanted surface, a beam is added so that the light will be directly above the crops and it could maximize the range of its rays. The lighting material that is used is LED strips which are going to be alternating with red and blue color and with a spacing of 5 inches apart from each other. Also, in the same figure it is shown where the air conditioner will be installed.

Fig. 8 Testing Location

Fig. 8 shows the testing location at a basketball court in Phase 3 West Urban Farm, F Dela Cruz corner Margie Moran, BFRV, Talon Dos, Las Pinas City.

4. RESULTS AND DISCUSSION

This part will tackle all the results and gathered data by the researchers. This is composed of the results for the test done throughout the study.

Table 2. Data gathered on the growth parameters of lettuce, strawberry, and broccoli inside and outside the

Number of Leaves of Lettuce at Day 41			
Crop	**Inside**	**Outside**	**Normal Growth**
1	8	7	9
2	8	6	8
3	8	7	8
4	7	7	9
5	7	7	8
6	8	6	7
Number of Leaves of Strawberry at Day 41			
Crop	**Inside**	**Outside**	**Normal Growth**
1	8	8	10
2	9	8	10
3	9	8	7
4	8	7	7
5	8	7	9
6	9	8	9
Plant Height of Strawberry (in mm) at Day 41			
Crop	**Inside**	**Outside**	**Normal Growth**
1	108	103	120
2	113	105	115
3	110	102	100
4	112	110	116
5	116	101	115
6	112	102	119
Number of Leaves of Broccoli at Day 41			
Crop	**Inside**	**Outside**	**Normal Growth**
1	10	-	11
2	9	-	9
Plant Height of Broccoli (in mm) at Day 41			
Crop	**Inside**	**Outside**	**Normal Growth**
1	250	-	260
2	236	-	250

Table 3. (a) Statistical Data of Number of Lettuce Leaves Inside the Greenhouse vs Outside the Greenhouse, (b) Statistical Data of Number of Lettuce Leaves Inside the Greenhouse vs Natural Habitat

a. Statistical Data		b. Statistical Data	
Null Hypothesis	μ=0	Null Hypothesis	μ=0
Alternative Hypothesis	μ>0	Alternative Hypothesis	μ≠0
Level of Significance	0.05	Level of Significance	0.05
Level of Confidence	0.95	Level of Confidence	0.95
Number of Samples	6	Number of Samples	6
Degree of Freedom	5	Degree of Freedom	5
Mean Difference	1	Mean Difference	-0.5
Standard Deviation	0.894	Standard Deviation	1.049
t-statistic	2.739	t-statistic	-1.168
t-critical	2.015	t-critical	2.571
p-value	0.0204	p-value	0.2956

Table 3 (a) shows the statistical data between the values obtained on the 41st day of lettuce crop inside and outside the greenhouse. In this t-test, there are two sets of data that were analyzed with a 95% level of confidence and 5% level of significance. Based from the values obtained, the p-value resulted to a lesser value compared to the significance level. While the statistical value resulted to a greater value compared to the critical value. Herewith, it shows full support to the alternative hypothesis which indicates that there is significant difference between the data inside the greenhouse to the data outside the greenhouse. While in Table 3 (b), the p-value resulted to a greater value compared to the Significance Level. While the absolute statistical value is less than the critical value. Based from the results gathered, it shows full support to the null hypothesis which indicates that there is no significant difference between the data inside the greenhouse to the data in its natural habitat.

Table 4. (a) Statistical Data of Number of Strawberry Leaves Inside the Greenhouse vs Outside the Greenhouse, (b) Statistical Data of Number of Strawberry Leaves Inside the Greenhouse vs Natural Habitat

a. Statistical Data		b. Statistical Data	
Null Hypothesis	μ=0	Null Hypothesis	μ=0
Alternative Hypothesis	μ>0	Alternative Hypothesis	μ≠0
Level of Significance	0.05	Level of Significance	0.05
Level of Confidence	0.95	Level of Confidence	0.95
Number of Samples	6	Number of Samples	6
Degree of Freedom	5	Degree of Freedom	5
Mean Difference	0.833	Mean Difference	-0.167
Standard Deviation	0.408	Standard Deviation	1.472
t-statistic	5	t-statistic	-0.277
t-critical	2.015	t-critical	2.571
p-value	0.0021	p-value	0.7926

Table 4 (a) shows the statistical data between the values obtained on the 41st day of strawberry crop inside and outside the greenhouse. Based from the values obtained, the p-value resulted to a lesser value compared to the significance level. While the statistical value resulted to a greater value compared to the critical value. Herewith, it shows full support to the alternative hypothesis which indicates that there is significant difference between the data inside the greenhouse to the data outside the greenhouse. While in Table 4 (b), the p-value resulted to a greater value compared to the Significance Level. While the absolute statistical value is less than the critical value. Based from the results gathered, it shows full support to the null hypothesis which indicates that there is no significant difference between the data inside the greenhouse to the data in its natural habitat.

Table 5 (a) Statistical Data of Plant Height of Strawberry Inside the Greenhouse vs Outside the Greenhouse
(b) Statistical Data of Plant Height of Strawberry Inside the Greenhouse vs Natural Habitat

a. Statistical Data		b. Statistical Data	
Null Hypothesis	μ=0	Null Hypothesis	μ=0
Alternative Hypothesis	μ>0	Alternative Hypothesis	μ≠0
Level of Significance	0.05	Level of Significance	0.05
Level of Confidence	0.95	Level of Confidence	0.95
Number of Samples	6	Number of Samples	6
Degree of Freedom	5	Degree of Freedom	5
Mean Difference	8	Mean Difference	-2.333
Standard Deviation	4.427	Standard Deviation	7.501
t-statistic	4.426	t-statistic	-0.762
t-critical	2.015	t-critical	2.571
p-value	0.0034	p-value	0.7926

Table 5 (a) shows the statistical data between the values obtained on the 41st day of strawberry crop inside and outside the greenhouse. Based from the values obtained, the p-value resulted to a lesser value compared to the significance level. While the statistical value resulted to a greater value compared to the critical value. Herewith, it shows full support to the alternative hypothesis which indicates that there is significant difference between the data inside the greenhouse to the data outside the greenhouse. While in Table 5 (b), the p-value resulted to a greater value compared to the Significance Level. While the absolute statistical value is less than the critical value. Based from the results gathered, it shows full support to the null hypothesis which indicates that there is no significant difference between the data inside the greenhouse to the data in its natural habitat.

Table 6. (a) Statistical Data of Number of Broccoli Leaves Inside the Greenhouse vs Natural Habitat
(b) Statistical Data of Plant Height of Broccoli Inside the Greenhouse vs Natural Habitat

a. Statistical Data		b. Statistical Data	
Null Hypothesis	μ=0	Null Hypothesis	μ=0
Alternative Hypothesis	μ≠0	Alternative Hypothesis	μ≠0
Level of Significance	0.05	Level of Significance	0.05
Level of Confidence	0.95	Level of Confidence	0.95
Number of Samples	2	Number of Samples	2
Degree of Freedom	1	Degree of Freedom	1
Mean Difference	-0.5	Mean Difference	-12
Standard Deviation	0.707	Standard Deviation	2.828
t-statistic	-1	t-statistic	-6
t-critical	12.706	t-critical	12.706
p-value	0.5	p-value	0.1051

Table 6 (a) shows the statistical data between the values obtained on the 41st day of broccoli crop inside and its natural habitat. Based from the values obtained, the p-value resulted to a greater value compared to the Significance Level. While the absolute statistical value is less than the critical value. Based from the results gathered, it shows full support to the null hypothesis which indicates that there is no significant difference between the data inside the greenhouse to the data in its natural habitat. While in Table 6 (b), the p-value resulted to a greater value compared to the Significance Level. While the absolute statistical value is less than the critical value. Based from the results gathered, it shows full support to the null hypothesis which indicates that there is no significant difference between the data inside the greenhouse to the data in its natural habitat.

5. CONCLUSION AND RECOMMENDATION

Given the results of the study, the researchers were able to successfully provide an alternative habitat for a cold seasonal crop to survive. An automated greenhouse controlled via Arduino Mega Microcontroller served as the alternative habitat, in which it maintained the parameters and triggered systems providing the needs of the crops as they grow.

The cold seasonal crops that were selected for this study are as follows: strawberry, lettuce, and broccoli. Each sub-system which comprised of Irrigation System, Soil Acidity Regulation, Soil Moisture Regulation, and LED Lighting System worked properly making the overall system fully functioning without errors. Thus, with a working system, all the selected cold seasonal crops grew despite being outside its natural habitat.

This study can be continued by incorporating an IoT-enabled system that features real-time monitoring of the greenhouse parameters as well as image processing of plant growth. Furthermore, the data gathered can be stored and accessed through the cloud via mobile application and/or Graphical User Interface (GUI). Alternative solutions other than limestone/sulfur solution for maintaining the pH content for the crops is also recommended.

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