

Access provided by:
Universidad Nacional de Colombia
(UNAL)
Sign Out

Browse

My Settings

Get Help

Advertisement

< Previous | Back to Results | Next >

Conferences > 2012 IEEE Conference on Contr...

Advertisement

Monitoring and control of aeroponic growing system for potato production

<< Results | < Previous | Next >

2

Irman Idris ; Muhammad Ikhsan Sani

Author(s)

View All Authors

2

Paper Citations

675

Full Text Views

Export to
Collabratec

Alerts

Manage
Content Alerts

Add to Citation
Alerts

Related Articles

Design and implementation of a room temperature control system: Microcontroller-based
2014 IEEE Student Conference on Research and Development
Published: 2014

Microcontroller based drip irrigation system using smart sensor
2013 Annual IEEE India Conference (INDICON)
Published: 2013

View All View More

Related Articles

Design and implementation of a room temperature control system: Microcontroller-based
2014 IEEE Student Conference on Research and Development
Published: 2014

Microcontroller based drip irrigation system using smart sensor
2013 Annual IEEE India Conference (INDICON)
Published: 2013

View All View More

See the top organizations patenting in technologies mentioned in this article

ORGANIZATION 4

ORGANIZATION 3

ORGANIZATION 2

ORGANIZATION 1

Click to Expand

Provided by: InnovationQ PLUS
POWERED BY IEEE AND IP.COM
A PATENT SEARCH AND ANALYTICS TOOL

See the top organizations patenting in technologies mentioned in this article

ORGANIZATION 4

ORGANIZATION 3

ORGANIZATION 2

ORGANIZATION 1

Click to Expand

Provided by: InnovationQ PLUS
POWERED BY IEEE AND IP.COM
A PATENT SEARCH AND ANALYTICS TOOL

See the top organizations patenting in technologies mentioned in this article

ORGANIZATION 4

ORGANIZATION 3

ORGANIZATION 2

ORGANIZATION 1

Click to Expand

Provided by: InnovationQ PLUS
POWERED BY IEEE AND IP.COM
A PATENT SEARCH AND ANALYTICS TOOL

Advertisement

Abstract

Document Sections

Download PDF

I. Introduction
II. Aeroponic System
III. Design and Implementation
IV. Testing and Analysis
V. Conclusions
Authors
Figures
References
Citations
Keywords
Metrics
Related Articles

Abstract: Aeroponic is the method of cultivating plants inside a conditioned air environment without the use of soil or water medium. This method grows plants suspended in a closed... [View more](#)

Metadata

Abstract: Aeroponic is the method of cultivating plants inside a conditioned air environment without the use of soil or water medium. This method grows plants suspended in a closed or semi-closed environment (chamber) by spraying the plant's dangling roots and lower stems with nutrient-rich solution. Under this circumstances, controlled environment has a strong potential to improve plants' developmental stages, health, and growth. In the recent decade, aeroponic system is applied intensively for the purpose of growing potato in order to produce disease-free potato seed and in order to have a pesticides-free cultivation environment. It is also predicted that the aeroponic method will be able to lower potato farmers' cost of operation and increase their yields. A monitoring and control system intended for water and nutrients distribution has been designed to support the optimal application of aeroponic cultivation system for seed-potatoes production. The monitoring system was used to monitor the chamber's parameters such as temperature and humidity. meanwhile, the control system was used to manage actuators in delivering water and nutrients. Temperature and humidity data will be displayed on the LCD and be transmitted to computer to facilitate easier monitoring on the plant growing chamber. The overall system has been designed and implemented to receive user-defined setting points by using the keypad. Microcontroller system will automatically regulate actuators for distribution of water (pump and nozzle) and distribution of nutrients (ultrasonic mist maker, fan, and pump). The pH measurement results at various points showed that the nutrient (pH = 5.8) were successfully spread inside the growing chamber. The average measured-temperature and humidity of growing chamber during the water and nutrients delivery process are (View more)

Published in: 2012 IEEE Conference on Control, Systems & Industrial Informatics

Date of Conference: 23-26 Sept. 2012

INSPEC Accession Number: 13372016

Date Added to IEEE Xplore: 25 February 2013

DOI: 10.1109/CCSII.2012.6470485

Publisher: IEEE

ISBN Information:

Conference Location: Bandung, Indonesia

Advertisement

 **Contents**

SECTION I.

Introduction

World Data Products Commodity FAO in 2007 shows that Indonesia is in third place in rice and cassava productions, but did not make the rank in the Top 20 for potato.

TABLE I WORLD COMMODITY PRODUCTS FAO 2007 FOR INDONESIA

Commodity	Production (MT)	Value (x \$ 1000)	Top 20
Rice	659.590.623	130.994.000	3
Wheat	605.994.942	72.917.380	-
Potato	309.344.247	34.821.630	-
Cassava	214.515.149	14.051.950	3

Source : <http://www.fao.org>

In Indonesia, however, potato research has been carried out intensively in Vegetable Research Institute (Balitsa), Horticulture Research and Development Center, Ministry of Agriculture, in collaboration with the International Potato Center (CIP). CIP headquarters is in Lima, Peru, with several regional offices located in Indonesia, India, and Kenya. Since 1992, Indonesia has become the Regional Office for East, Southeast Asia and the Pacific (ESEAP).

In the research area in Lembang, there are greenhouse facilities used for breeding and development of new varieties of potato plants. The problem faced is the complexity of monitoring, the arrangement of equipment, controls, and the huge cost involved in operating a greenhouse system.

One of the urgent need in cultivation of potato, which is the third most important staple food in the world after rice and wheat, is the quality of potato seeds. One technique to increase the production of potatoes, especially potato seeds, recently developed intensively by researchers in the world is an aeroponic system [1] adopted from NASA research. This system shows a number of advantages and a better prospect in encouraging the production of potato in a more efficient, hygienic, and cost-effective. Aeroponic systems have the potential to outperform conventional methods (medium soil), especially in seed production followed by a potato seed cultivation in the fields. By comparison, with the conventional system, a single potato plant can produce approximately 8 bulbs, while in the aeroponic system, up to 70 bulbs can be produced. This technique was also able to reduce production costs and improved the healthcare of quality potatoes from the first generation of field production. One previous study [2] concluded that the aeroponic system is the best system to produce potato seed GO (generation zero). Aeroponic system has proven its ability to increase production of potato tubers up to tentimes more compared to other systems, namely non-circulating solution-culture system and soil-less growth medium system.

One solution to solve the problems of monitoring and controlling the growing conditions in the space environment to grow potatoes is by applying a number of sensors that can detect and monitor a number of parameters such as temperature, humidity, light intensity, O_2 and CO_2 levels, direction and wind speed, etc. Aside of the sensors, there is also a requirement for the actuators to distribute nutrients and waters to potato roots or lower stems.

SECTION II.

Aeroponic System

Precision farming is an agricultural management in a modern concept that aims to control inputs and processes in agricultural activities to obtain optimum production, sustainable and profitable. Keywords appropriate for precision farming are [3]:

- exact dose
- exact time
- exact location

Achievement of these three key objectives requires a number of sensors that can detect and monitor the parameters [3]:

1. environment, e.g. temperature, humidity, light intensity, O₂ and CO₂ levels, direction and wind speed, etc.
2. agricultural media, such as nutrient levels of N, P, K, minerals, water, etc.
3. plants, such as colors and leaf size, plant height, etc.

According to Blackmoore (1994) [4], there are four factors that are inter linked in precision agriculture, namely:

- reduction of input,
- an enhanced control system,
- increased efficiency and,
- information management system

One of the agricultural systems that can be applied to enable precision farming is aeroponic system. Aeroponic is the process of growing plants in an environment without the use of medium soil or aggregate. The basic principle of aeroponic is growing plants in a closed or semi-enclosed environment with equipment necessary for spraying the plant's roots with nutrient-rich solution.



Figure 1. Aeroponic Growing Chamber

The aeroponic system has more advantages than hydroponic in terms of spraying high air content in the nutrient solution to provide oxygen to plant roots, stimulating growth, and help the prevention of pathogen compounds' formations [4]. The focus of attention variables in the aeroponic system research are as follows:

- micro-environment (temperature, humidity, pH), and
- the effectiveness of nutrition (spraying/fogging).

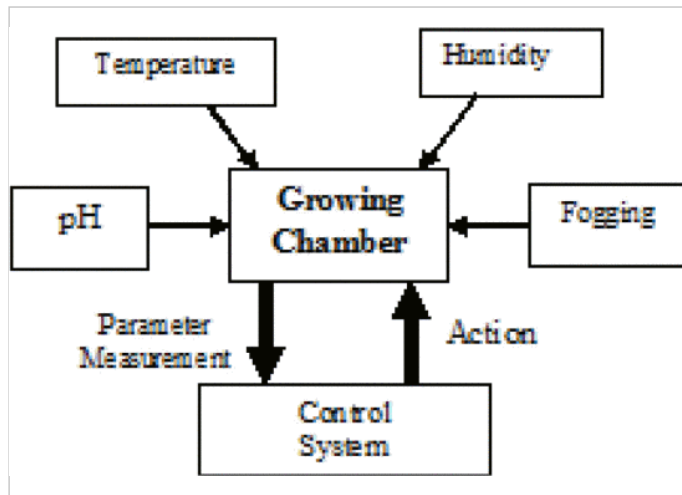


Figure 2. Monitoring and Control System for Potato Growing Chamber Block Diagram.

SECTION III.

Design and Implementation

In general, the task of this system is to maintain the magnitude of temperature, air humidity, and pH in growing chamber box to keep it inside the conditions required by the potato plants to grow optimally. An electronic system using sensors [5] will take measurements of those parameters, then the results were processed and compared with the desired parameter values (set point). If there is a difference, there will be a corresponding action for the environmental conditions leading to the desired state.

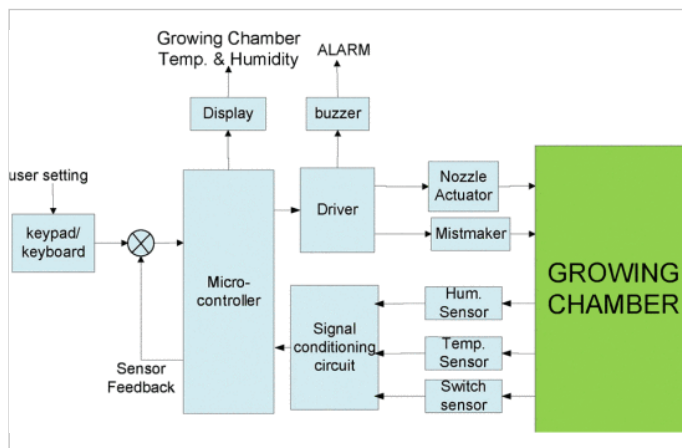


Figure 3. Control and Monitoring Systems Growing Chamber Block Diagram

System divided into two main sections:

- Monitoring system, to obtain the value of the temperature and humidity inside the growing chamber and display it on the LCD and hyper terminal.
- Control system for controlling the water and nutrients actuators inside the growth chamber by using a timer.

System will distribute water and nutrients inside the plant growth chamber with a nozzle and pump system incorporating an ultrasonic

system. In this case, the ultrasonic system is used to provide nutrients, while the pump nozzle systems are used to provide water and wet the plant roots to enable easier attachment of the nutrients fog to the roots. Each plant has its own growing zone of roots and stems. Because the potato is a tuber crop, then the root zone is more important. The root zone should have a humidity between 80% –90% RH, related to the efficiency of nutrient uptake. Meanwhile, to prevent the proliferation of pests and diseases, the air humidity should be maintained in the range of 60–80% RH and air temperature in the range 16–25°C. This information is used as a reference in designing systems for monitoring and control system.

By default, the system will run according to the timing diagram illustrated in Fig. 4 below. Initially the plant will be given water by using a pump nozzle system. After that the plants will be given the opportunity to absorb the water for 60 seconds. For 60 seconds of this, some water will be absorbed by roots and some are still left on the plant roots, which makes plant roots a little wet. Next, the plants will be given nutrition using a mist maker. Because of the wetness of the roots, it will be easier for the nutrients particles to attach to the roots. Plants will be given nutrition for 2 minutes, and then the mist maker will be shut down for 10 minutes. Ten minutes is an appropriate time to provide opportunity for the plants to absorb nutrients. This cycle is continuously repeated.

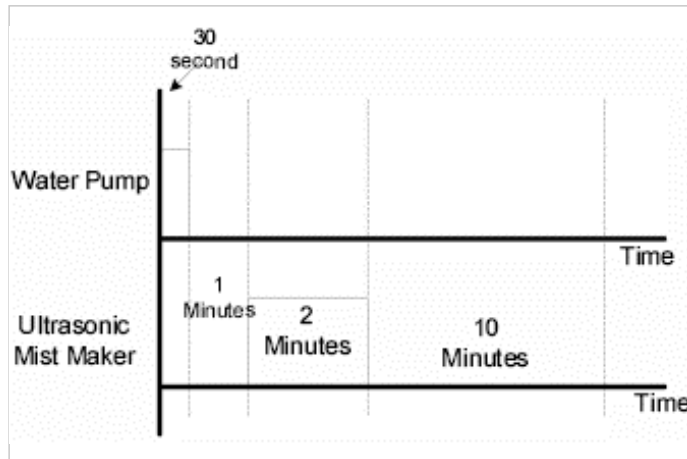


Figure 4. Timing Diagram

A. Monitoring System

The sensor system will be responsible for measuring the values of environmental parameters and then it will send information to the control system. Sensor system consists of:

1. temperature and
2. humidity sensor.

Because the sensor output voltage at the maximum temperature is 55 mv, while the ADC reference voltage used was 4.6 V, then the sensor output must be amplified. This is done by using operational amplifiers with the non-inverting configuration. With a gain of 8x, the output voltage range became 0.16 to 4.4 V. 8 mV/0.1°C. Sensor sensitivity improved to 80 mV/°C Because 8 mV > 4.5 mV (ADC resolution), the selected temperature sensor resolution became 0.1°C. A gain of 8 times can be obtained by using 2 resistors with a ratio of 70/10 in order of kilo ohm value. Because of the differences in the initial values of components, the necessary resistors of 70 k Ω are broken down into fixed and variable resistors of 68 k Ω and 10 k Ω

respectively. By implementing this configuration, the sensor can be calibrated through these resistors.

For the humidity sensor data processing, signal conditioning is required in the form of modifier capacitance value which can be calculated through the pulse wave frequency using TLC555 timer IC. By using such settings, the relationship between humidity and the pulse wave frequency can be calculated. Change of $\Delta RH1\%$ in humidity will result in a change of $\Delta f = 14$ Hz. By using a crystal oscillator of 11.0592 MHz (1 clock period = 90.4 ns) on the microcontroller, the changes are accounted for.

B. Control System

1) Microcontroller System

Control system receives the results of measurements taken by each sensor, then the results are compared with the set point, i.e. the value of the desired parameters in the environment. If there is a difference, the value will be processed into control signals and then sent to the actuator sub-system. This sub-system was built using a microcontroller.

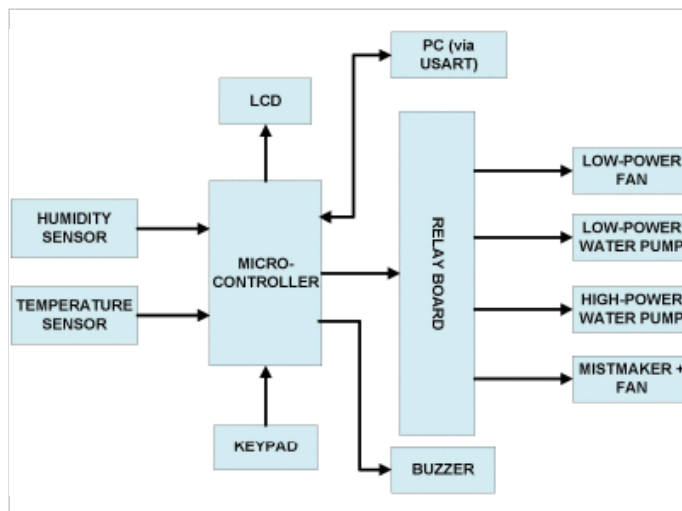


Figure 5. Control System Block Diagram

Microcontroller receives user input of data via the keypad or keyboard settings. Furthermore, to provide water and nutrients to the plants, the microcontroller will send a signal to the driver to activate the relay which in turn will turn the actuator on. Parameters in the growing chamber will be read by the sensor and signal conditioning circuit.

An alarm system has been added to see if the actuator actually functioned. If the actuator does not perform its function properly, the alarm will be set. Temperature and humidity data will be displayed through the LCD and on-screen computer monitor through HyperTerminal.

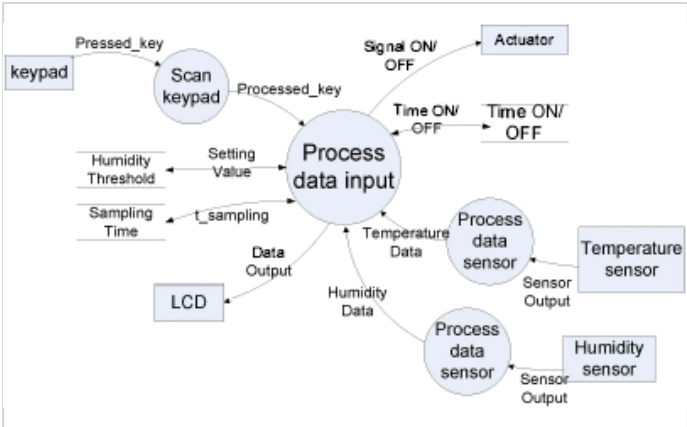


Figure 6. Control Algorithm

2) Actuator

In two-pipe system which is used in every hole drilled and given a specific blockage, called nozzle. Nozzle is useful for creating water droplets that come out of the pipe becomes more subtle. The nutrients is distributed using a high-pressure pump (0.78 KW). The comparison is shown at Table II.



Figure 7. Nozzle Pump Implementation

TABLE II NOZZLE PUMP AND ULTRASONIC MIST MAKER COMPARISON

	Advantages	Disadvantages
Nozzle Pump	- Low heat generation - Nutrition easily attached to plant's root	- High power consumption - High nutrient requirements (100 L/day)
Ultrasonic Mist Maker	• Efficient nutrient (100L/3-4 days) • More power efficient	• Generated fog is difficult to attach to plant roots, so that most seed potato plants became drought and then died. • Heat generation due to ultrasonic vibration

The control system is integrated into one unit and packed as shown in the Fig. 8.

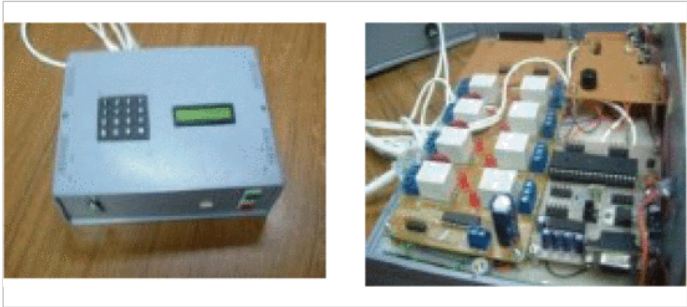


Figure 8. System Integration

SECTION IV.

Testing and Analysis

A. Sensor Testing

1) Temperature Sensor Testing

Referring to the table, temperature sensor output data is relatively the same with thermometer reading. This proves that the temperature sensor and temperature sensor data readings have been working as specified.

TABLE III SENSOR TESTING RESULTS

Condition	Thermo-1 (°C)	Thermo-2 (°C)	Sensor (°C)
Initial chamber temp.	26	27	27
Nozzle turned on	24	25	25
Mistmaker turned on	23	24	24
3 mins after mistmaker turned off	22	23	23
8 mins after mistmaker turned off	22	23	23
Greenhouse temp. (raining)	21	22	22

2) Humidity Sensor Testing

The test method is the same with temperature sensors test. By using this method, some of the implemented sensors inside of the growth chamber is being extensively compared to the reference hygrometer to test their functionality and accuracy.

TABLE IV HUMIDITY SENSOR TESTING RESULTS

Condition	Hygrometer	Humidity Sensor
Initialization	70	60
Nozzle ON	>100	80
Mist maker ON	>100	85
3 min. after mist maker off	>100	85

Humidity readings from hygrometer 1 and implemented sensors show different value. When the nozzle is on, water droplets rushed into the hygrometer, and contributes to the reading of > 100% in reference hygrometer. In addition, the reference hygrometer applied were specified only for measuring humidity in room conditions, so that in extreme humidity, the corresponding hygrometer is unable to perform well on the measurements. From this test it can be concluded that the humidity sensor made for the system has been able to measure the ambient humidity quite well. Unfortunately it is not known whether the reading accuracy is sufficient or not, because there is no proper reference.

B. Actuator Testing

In this test, a tissue was used as a substitute for the plant roots. These tissues are placed in some points in a growing chamber (Fig. 9). With the assumption that if a tissue was able to absorb nutrients from the nutrients-filled fog, the roots of potato plants would also be able to absorb these nutrients too. A pH papers are used to detect pH changes on every test points.

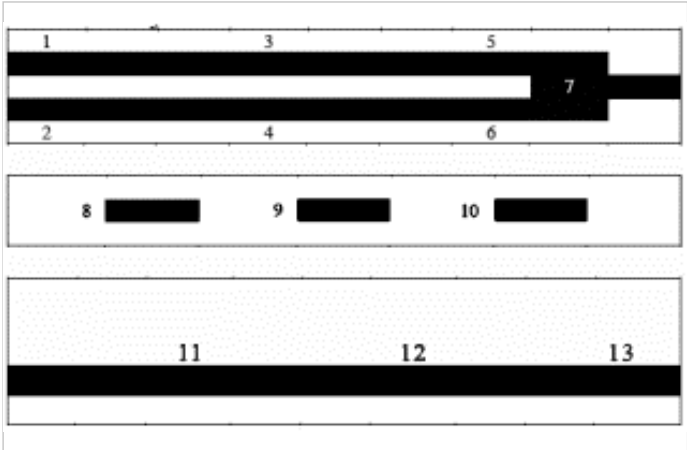


Figure 9. Test Point on Growing Chamber for Actuator Testing

From this observations, it can be concluded that the nutrition requirements has been fulfilled at the specified test points. In other words, the actuator has managed to send nutrients to the tissues that acted as a proxy for the roots of potato plants.

TABLE V ACTUATOR TESTING RESULTS

Test Point	pH	Test Point	pH
1	6	8	6
2	6	9	6
3	6	10	6
4	6	11	6
5	6	12	6
6	6	13	6
7	6		

C. System Testing

Overall system testing is done by defining the ON-OFF timers of the mist maker and pump, and then it was observed if all actuators worked well and was lit in accordance with the specified time. Obtained the following results as a timing diagram for the four actuator nodes.

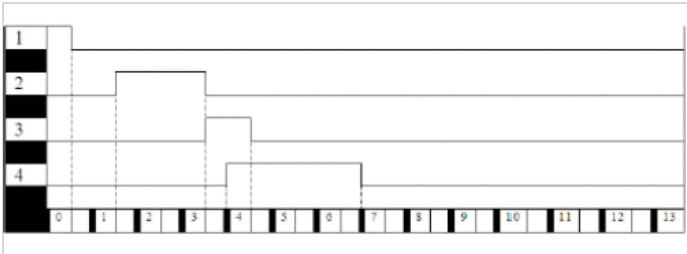


Figure 11. System Timing Diagram in 1 Cycle (1: High pressure pump; 2: Mist maker + Fan; 3: Low-Pressure Pump; 4: Low Power Fan)

D. Resulting Go Potato Plant Cultivated in Aeroponic Growing Chamber

Fig. 12 shows that potato plant actually grows in aeroponic growing chamber. The timing for water and nutrition spray has been through some evaluation to determine the optimal time and dose in its operational. Typical required period for a potato seed to grow into a ripe bulb is around 3 months, in which various methods and timing was also evaluated. Further study is still necessary to consider nutritional balance, but the basic concept regarding automated water and nutritional provision has proven to be working as expected.



Figure 12. Potato Plant in Aeroponic Growing Chamber

In Table VI, there is comparison between aeroponics and other methods.

TABLE VI COMPARISON OF DIFFERENT METHODS OF POTATO PRODUCTION

PARAMETER	CONVENTIONAL [6]	HYDRO- PONIC[7]	AERO- PONIC
Controllable	No	No	Yes
Nutrition usage	High	Medium	Low
Nutrition recirculation	Not Possible	Not Possible	Possible
Land usage	High	Medium	Low
Yield/Plant	3-5	5-15	Up to 30
Use of Pesticide	Often	Occasionally	Never
Energy-Dependent	No	Yes	Yes

The table shows that aeroponics system have more advantages from the other methods mainly in term of controllability and nutrition usage. Aeroponics system also produced more tuber than the other method. However, the system needs further and complete evaluation in terms of profitability and sustainability. Also, a comparative cost-benefit analysis is required between aeroponics and the other methods to determine optimal cost per seed.

SECTION V. Conclusions

The monitoring and control system for distribution of water and nutrients in aeroponic growing chamber for potato cultivation have been successfully designed, implemented, and field tested. The system features:

1. It can measure and monitor the in-situ chamber parameters, i.e. temperature and humidity.
2. It is able to control the actuator (nozzle pump, mist maker, fan, and reservoir pump) which supplies water and nutrients on aeroponic growing system for potato production.
3. User can control system operation with customized-user settings.
4. The developed system was able to provide growing chamber monitoring parameter by sending the temperature and humidity data in real time from sensor to the display.

ACKNOWLEDGMENT

This work was funded by Ministry of Research and Technology, Republic of Indonesia under Hibah Insentif (Insentive Grant) 2010 program and was done in collaboration with Vegetables Research Institute, Horticulture Research and Development Center, Ministry of Agriculture in Lembang, West Java.

Authors

Figures

References

Citations

Keywords

Metrics

IEEE Account

Profile Information

Purchase Details

Need Help?

Other

A not-for-profit organization, IEEE is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity.
© Copyright 2018 IEEE - All rights reserved. Use of this web site signifies your agreement to the terms and conditions.

US & Canada: +1 800 678 4333
Worldwide: +1 732 981 0060

IEEE Account	Purchase Details	Profile Information	Need Help?
» Change Username/Password	» Payment Options	» Communications Preferences	» US & Canada: +1 800 678 4333
» Update Address	» Order History	» Profession and Education	» Worldwide: +1 732 981 0060
	» View Purchased Documents	» Technical Interests	» Contact & Support

[About IEEE Xplore](#) | [Contact Us](#) | [Help](#) | [Accessibility](#) | [Terms of Use](#) | [Nondiscrimination Policy](#) | [Sitemap](#) | [Privacy & Opting Out of Cookies](#)

A not-for-profit organization, IEEE is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity.
© Copyright 2018 IEEE - All rights reserved. Use of this web site signifies your agreement to the terms and conditions.