Development of an Embedded Circuit and a Prototype Bucket Aeroponic System for Bitter Gourd Production

[1]Gagandeep Kaur, [2]Dilip Kumar, [3]Sukhwinder Singh
[1]Academic and Consultancy Services-Division, Centre for Development of Advanced Computing (C-DAC), Mohali, India
[2]Sant Longowal Institute of Engineering and Technology (SLIET), Longowal, India
[3]Central Potato Research Station (CPRS), Jalandhar, India

Abstract
The critical conditions for Bitter guard growers are pests and diseases. R&D efforts to protect this medicinal value plant were carried out in this research paper. Soil is main platform for pests and diseases to grow. A prototype bucket aeroponic system was developed and an embedded system using sensors were designed for this research work. This embedded system includes monitoring and control system. The prototype system was successfully tested in Central Potato Research Station (CPRS), Jalandhar, Punjab, India.

Keywords
Aeroponic, Monitoring System, Control System, Bitter Gourd

I. Introduction

In vegetable production, China stands first and India second in the world [8]. Many vegetables possess medicinal properties and are considered important and highly desirable for human consumption. Bitter gourd is one of these medicinally important vegetables [18]. This is intensively consumed as part of diet all almost all over the world as it contains many beneficial antioxidants and essential vitamins that cure respiratory disorders, immune system, liver, diabetes, constipation, kidney, bladder, heart diseases and skin infections [2,18]. Bitter guard is reported to be highly effective for managing type2 diabetes [2]. India has the highest number of diabetic patients (31.7 million in 2000 and projected 79.4 million by 2030) [2]. Number of diabetic patients is growing fastest in sub-saharan Africa [17]. Bitter gourd is consumed as a folk medicine for managing type2 diabetes in Asia and some African countries. Studies also suggest that bitter gourd has a role in glycemic control of diabetes [2].

There are many constraints in this vegetable if grown in soil system in open. Growers are engrossed with a number of problems like infectious seed born diseases, insects, pests and high labour inputs etc. A study conducted in Kalliyoor Panchayat in Thiruvananthapuram district revealed that pests and diseases are major constraints in bitter gourd cultivation [8].

An important alternative to avoid soil related and open cultivated crop can be raising crop in soilless culture under covered cultivation system. Out of many methods of soilless cultivation most recent and advance system is aeroponic system [5,6,11]. The term Aeroponics means to cultivate plants without soil in an air mist environment. In this system air dangling roots (in dark chamber) are misted with nutrient rich solution constantly or recurrently and shoot part is exposed to sunlight or artificial light. All the important parameters like pH, EC and temperature of nutrient solution are maintained at desired levels [11]. Similarly environmental parameters temperature and humidity of the green house are also maintained for optimum growth of plants [11].

In March 2013, Tripura Agricultural Graduate's Association [1] had structured a basic premise on which the idea of aeroponics is based. According to this association, the working principle is using minimum amount of input to gain maximum output.

In the last decade, aeroponic research has been conducted on tomato, lettuce, cucumber and potato [9, 11]. Studies on potato minituber production via aeroponic system revealed that, through aeroponics 5-7 times more number of minitubers per plant can be achieved as compared to traditional system [8]. At CPRI potato specific commercial scale aeroponic systems have been designed and developed [5-6].

Existing aeroponic systems need improvements in structure and automation for efficient working. Various pump operations, operation of fans and pad pumps, RH control etc. are presently controlled operated through separate cyclic timers, sensors and switches. Automation of various sub system operations embedded circuits is required for efficient working of this system. Looking into all these points, a prototype aeroponic system suitable for growing bitter gourd and other vegetable crops along with an embedded system for monitoring and controlling was developed jointly by Centre for Development of Advance Computing (CDAC), Mohali and Central Potato Research Station (CPRS), Jalandhar. System was tested at CPRS, Jalandhar on bitter gourd during 2014.

II. Materials and Methods

A. Fabrication of Aeroponic System

As shown in fig.1, two plastic buckets of 20 litre capacity each, two submersible pumps, a multi hole sprinkler, 50mm thick styrofoam sheet, pvc pipes and fittings were used for fabrication of aeroponic system. One bucket covered with styrofoam sheet was used as grow chamber and second bucket was used as reserve nutrient solution reservoir. Both the buckets were wrapped with black polythene sheet of 100 micron thickness to avoid algae formation and increase of temperature due to exposure to direct sunlight.

Fig. 1: Prototype System for Bitter Gourd

A hydroponic pump was placed in grow chamber and was fitted with a 50-hole garden sprinkler. Grow chamber was covered with

ISSN : 0976-8491 (Online) | ISSN : 2229-4333 (Print)

50mm thick styrofoam sheet and 8 holes of diameter 50mm were drilled in this sheet for inserting net cups to hold plants. Nutrient solution was filled to depth of 15cm in grow chamber itself. Another styrofoam sheet of 30 mm thickness and drilled with 10mm holes was placed over the pump in the grow box (fig. 2). This sheet works as a barrier to avoid dipping of roots into the nutrient solution. Another pump was submerged into reservoir bucket .

Fig. 2: Drilled Styrofoam Sheet

Fig. 3: Temperature Recording Via Thermometer

B. Embedded System Design and Implementation

For controlling operation of pumps in grow chamber and reserve nutrient reservoir, an embedded system was designed. Block level representation of design is shown in fig. 4.

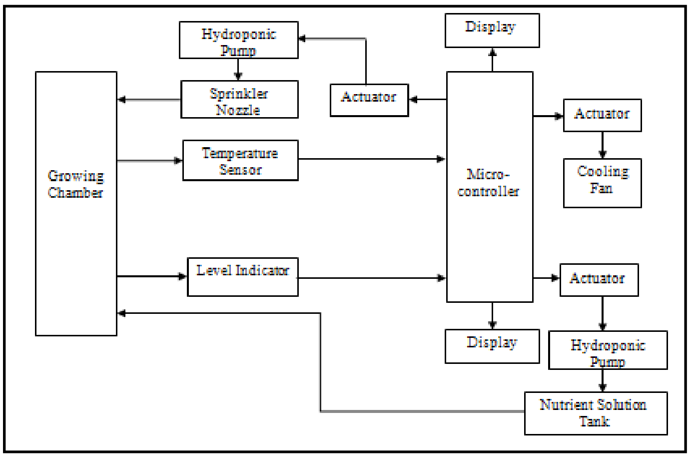

Fig. 4: Block Level Representation of Design

Embedded System is capable of:-

1. Operating grow chamber pump for 20sec followed by 300sec off time
2. Temperature sensing capability for actuating cooling system
3. Operates reservoir pump once the level of nutrient solution in grow box falls below set point

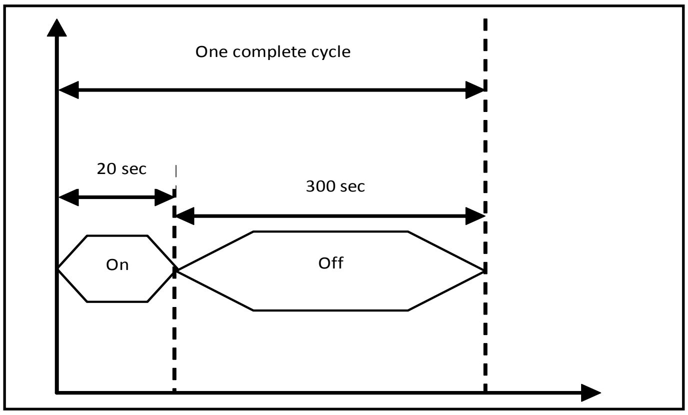

Fig. 5: Timing Diagram of Growing Chamber Hydroponic Pump

The micro-controller used has inbuilt ADC and DAC. There is no requirement of any external signal conditioner. Micro-controller receives input and acts according to set points. There was no provision of manual data entry in system for security reasons. On/off time was mentioned in programming. Resetting of these can be done.

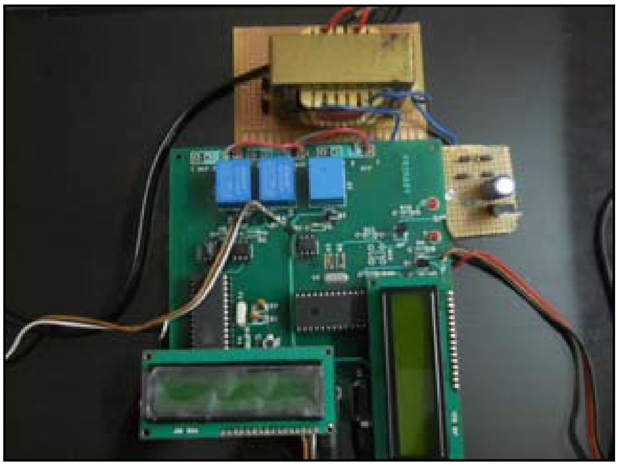

Fig. 6: System Integration

C. Plantlet Preparation

For aeroponic system, plants of 5-6cm stem height are required. Bitter gourd seeds (Karela Chia Tai Seed F1 Unnat CT-108) were placed on filter paper inside petri dish. These seeds were wetted with tap water and were placed inside incubator. These got germinated in 3days. Germinated seeds were planted in net cups using moss grass. These net cups were placed in a plastic tray containing water to depth of 10mm.

Fig. 7: Seedlings Planted in Moss Grass

Cotelydonary leaf started its growth in a couple of days and plants achieved a height of 5-6cm in 7 days after planting. Net cups along with plants were shifted to aeroponic system and system was switched on. pH and EC of nutrient solution was monitored daily by using Hanna made TDS cum pH meter.

Newly developed unit after testing embedded system in lab was placed in net- house for actual testing by growing crop. Temperature of ambience, net-house, soil and grow chamber bucket was recorded hourly after every alternate day with mercury thermometer.

IV. Testing, Analysis and Discussion

A. Embedded Circuit Testing

1. On-Off Testing

Through the embedded circuit, aeroponic system was operated and on-off time was observed using a stop watch for 5 times. As shown in Table 1 system worked as per design parameters.

Table 1: Actuator on-off Time Testing at Different Intervals

No. of events	Actuator time		Stopwatch time	
	On	Off	On	Off
1	20	300	20	300
2	20	300	20	300
3	20	300	20	300
4	20	300	20	300
5	20	300	20	300

2. Testing of Reservoir Pump

Reservoir pump working was tested 5 times. Tap fitted with grow chamber was left on. When the solution level reaches low level, the reservoir pump turned on and it started filling grow box with nutrient solution. When the solution level reached a predefined high level in the grow box, the reservoir pump was turned off in the atomized manner. As evident from table 2 functioning of reservoir pump was accurate as desired.

Table 2: Reservoir Pump on-off Testing

No. of events	Low level	High level
1	Pump on	Pump off
2	Pump on	Pump off
3	Pump on	Pump off
4	Pump on	Pump off
5	Pump on	Pump off

3. Cooling Fan Testing

Cooling fan was tested with respect to temperature. It turned on when temperature reaches above 26°C and turned off at 23°C. This atomized process was recorded 3 times.

Table 3: Cooling Fan Testing at Different Intervals

No. of events	Temperature above 26°C	Temperature below 23°C
1	Fan on	Fan off
2	Fan on	Fan off
3	Fan on	Fan off

Testing of embedded circuit shows that this circuit is suitable for aeroponic system operation and control.

B. Testing of Aeroponic System

Newly developed bucket type system was actually tested by growing bitter gourd. System worked without giving any problem. Crop parameters and performance are indicated in table 4. There was no twisting, loosening or un-holding of stems and roots were covered fully by the nutrient solution sprinkler. Roots assembled over the partition fitted in the grow chamber and partially got submerged into the solution also.

Table 4: Crop Parameters in Aeroponic System

Parameter	Description
Date of planting in net-cups	27 March 2014
Date of shifting cups to aeroponic system	1 April 2014
Root initiation	5days after planting in moss grass
Appearance of flowers	40 days after planting
First picking	50 days after planting
Average no. of fruits per plant	15

C. Temperature Variation

Temperature was recorded at different intervals of time in day to understand the variation with respect to time and condition. Most of the time grow chamber temperature as clear from the fig. 8 was lower than net-house temperature and was below 26 degree C which is considered good for growth of bitter gourd.

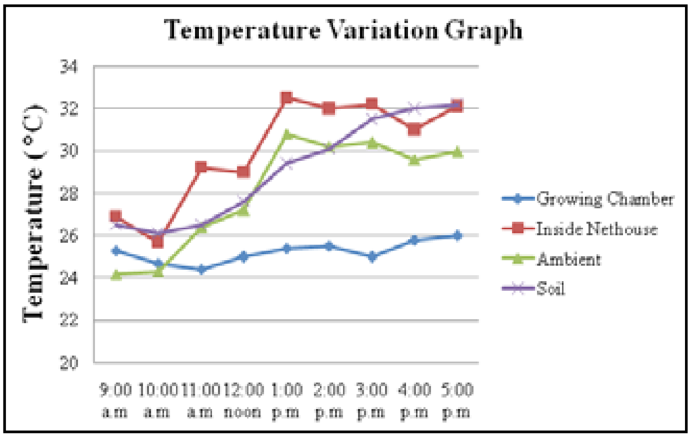

Fig. 8: Temperature Variation

D. Root & Shoot Length Growth

Maximum root and shoot length was recorded regularly. As shown in fig. 9 both root and shoot growth was steady.

In convential growing method, it takes approximately 8-9 weeks [4] to pick the first mature fruit. In present study first mature fruit was picked in 6th week after planting.

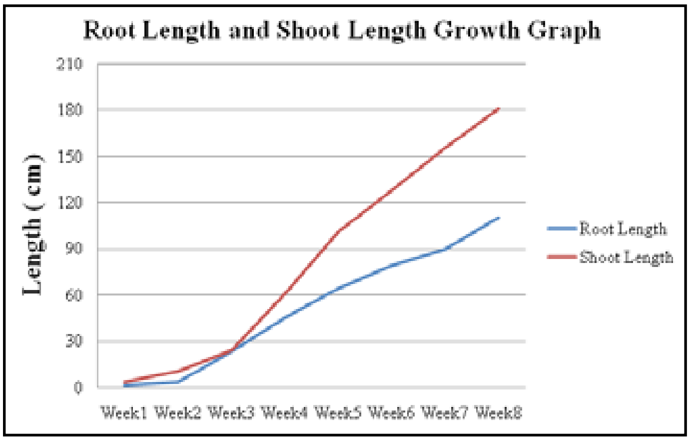

Fig. 9: Root & Shoot Growth fo Bitter Gourd

E. pH and EC Testing

The test was performed manually using Hanna made TDS meter. Test points were established to cross-check the values.

Table 5: pH Values Observed at Different Test Points

Test Point	pH
1	6
2	6
3	6

Table 6: EC Values Obtained at Different Test Points

Test Point	EC
1	2
2	2
3	2

F. Temperature Sensor Testing

Sensor and thermometer were used to measure temperature at different intervals of time. Both worked accurately in the specified manner.

Table 7: Temperature Values at Different Conditions

Condition	Sensor (°C)	Thermometer (°C)
Initial Chamber	27	27
Sprinkler On	24	24
After 2 minutes	24.8	24.8
Polyhouse	24.3	24.3

Fig. 10: Male Flowers on Bitter Gourd Vines

Fig. 11: Mature Fruits of Bitter Gourd

Fig. 12: Root Mass Inside Growing Chamber

Fig. 13: Vegetative Growth and Bitter Gourd of Prototype System

VI. Conclusion

Operation and testing results of this prototype aeroponic system and embedded circuit indicate that system worked efficiently and circuite actuated the actuators as per design parameters.

There seems a good possibility of using this embedded circuit in commercial scale aeroponic systems. This should also be tested on other soilless production systems in future. Further, aeroponic system may be tested for growing other important vegetable and medicinal plants in clean environment. There seems to be good scope of this technology if proper automation and control systems are designed.

References

[1] Aeroponics in Potato Seed Prodiction. [Online] Available: http://taga.co.in/writeups/4.html (accessed 4 December 2014).
[2] AVARDC. Diabetes.Bitter Gourd Project. [Online] Available: http://www.bitter-gourd.org/project/ (accessed 27 May 2014).
[3] AVARDC. The World Vegetable Center. [Online] Available: http://avrdc.org/ (accessed 27 May 2014).
[4] Bitter Melon. [Online] Available: http://www.rain.org/greennet/docs/exoticveggies/html/bittermelon.htm (accessed 26 May 2014).
[5] Central Potato Research Station, Shimla,"Annual Report", 2011-12.
[6] Central Potato Research Station, Shimla,"Annual Report", 2012-2013.
[7] Chiipanthenga, Margaret, et al.,"Potential of aeroponics system in the production of quality potato (Solanum tuberosum l.) seed in developing countries", African Journal of Biotechnology 11.17 (2012), pp. 3993-3999.
[8] FAO Statistical Yearbook 2013. World Food and Agriculture. [Online] Available: http://www.fao.org/docrep/018/i3107e/i3107e.PDF (accessed 27 May 2014).
[9] Howard M. Resh, Plant culture,"Hydroponic Food Production", 7th revised edition, 2012.
[10] Farran, Imma, Angel M. Mingo-Castel,"Potato minituber production using aeroponics: effect of plant density and harvesting intervals." American Journal of Potato Research 83.1 (2006), pp. 47-53.
[11] Idris, Irman, Muhammad Ikhsan Sani,"Monitoring and control of aeroponic growing system for potato production", Control, Systems & Industrial Informatics (ICCSII), 2012 IEEE Conference on. IEEE, 2012.
[12] Jayapalan, Manjusha, NP Kumari Sushama,"Constraints in the cultivation of bitter gourd (Momordica charantia L.)", Journal of Tropical Agriculture 39.1 (2001).M. King and B. Zhu, "Gaming strategies", In Path Planning to the West, vol. II, S. Tang and M. King, Eds. Xian: Jiaoda Press, 1998, pp. 158-176.
[13] Nugaliyadde, M. M., et al.,"An aeroponic system for the production of pre-basic seed potato", Annals of the Sri Lanka Department of Agriculture 7 (2005): pp. 199-288.
[14] Ritter, E., et al.,"Comparison of hydroponic and aeroponic cultivation systems for the production of potato minitubers", Potato Research 44.2 (2001), pp. 127-135.
[15] Rolot, J. L., H. Seutin,"Soilless production of potato minitubers using a hydroponic technique", Potato Research 42.3-4 (1999), pp. 457-469.
[16] Tsoka, O., et al.,"Potato seed tuber production from in vitro and apical stem cutting under aeroponic system", African Journal of Biotechnology 11.63 (2012), pp. 12612-12618.
[17] Wild, S., Roglic, G., Green, A., Sicree, R., King, H. 2004. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. Diabetes care 27(5), pp. 1047-1053.
[18] 22 Amazing Benefits And Uses of Bitter Melon/Bitter Gourd For Skin, Hair And Health. [Online] Available: http://www.stylecraze.com/articles/amazing-benefits-of-bitter-melonbitter-gourd/ (accessed 23 May 2014).

Gagandeep Kaur received her B.Tech. (Electronics and Communication Engineering) degree from Sant Baba Bhag Singh Institute of Engineering and Technology affiliated to Punjab Technical University, Jalandhar in 2012, and presently she is pursuing her M.Tech (Embedded Systems) degree from Centre for Development of Advanced Computing (CDAC), Mohali and working on her thesis work.

Dilip Kumar received his PhD in Engineering and Technology from Maharishi Markandeshwar University (MMU), Ambala, India in 2010, ME in Electronics Product Design and Technology from PEC University of Technology (formerly Punjab Engineering College), Chandigarh in 2003, and BE in Electronics and Telecommunication Engineering from Army Institute of Technology, University of Pune, India in 2000. He is currently an Associate Professor at Sant Longowal Institute of Engineering and Technology (SLIET), Longowal, India. His research interests include wireless sensor networks, fault tolerance and embedded system. He has published more than 90 papers in international journal/conferences.

Sukhwinder Singh received his B.Tech (Agricultural Engineering) degree from Punjab Agricultural University, Ludhiana, India, in 1988. He worked as Process Engineer with Oswal Agro Furane Limited, Ludhiana, India from 1989 to 1993. He joined Indian Council of Agricultural Research (ICAR) in 1993 as Scientist. After initial project management training he joined Central Potato Research Institute (CPRI), Shimla (India) in 1994. He was Scientist-SS and Scientist-SG at CPRI in 1999 and 2006 respectively. Areas of his research interest include soilless cultivation, hydroponics, aeroponics and vertical farming. At present he is engaged in designing and commercializing commercial scale soilless systems for seed potato production.