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A Computer-Based Monitoring System to Maintain Optimum Air Temperature and Relative Humidity in Greenhouses

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ABSTRACT

The present study is concerned with the control and monitoring of greenhouse air temperature, humidity, CO_2 provision and irrigation by means of simultaneous ventilation and enrichment. A computer-based control and monitoring system was designed and tested. A microcontroller receives data on greenhouse environment conditions from a number of sensors installed inside and outside and transfers the data to and from a PC via RS 232 port. Accordingly, it changes the state of greenhouse control devices, heaters, fans, etc., to reach the desired condition. Performance of the controller was evaluated by installing it in a greenhouse. For the uncontrolled experiment, it was found that the outside or ambient temperature was always less than the temperature inside the greenhouse. This is a further confirmation of true greenhouse effect. It was found that the rate of change within the greenhouse in the upper part i.e. near the plastic cover, was higher than that of the height of plant. The temperature in the greenhouse increases along the height of the greenhouse due to receiving solar incident radiation. During the temperature decrease, it was found that the heat exchanges are mostly occurring near the plastic cover. When the controller was put into operation, it was found that contrary to the previous case. This is partly due to the use of re-circulating fan with an attached perforated polyethylene tube in guiding the air toward the plant root zone. In an attempt to control both the temperature and humidity inside the greenhouse fair results were obtained. The system response for temperature control was satisfactory, about 10 minutes. However, the time constant of mist and fog system was rather long, about 30 min, in reaching to the desired humidity.

Key Words: Greenhouse; Temperature; Humidity; Data-acquisition system

INTRODUCTION

The cost of growing crop in a greenhouse is greater than growing it in the field; hence for the greenhouses to remain competitive they have to be able to reduce the cost of production and increase crop yields. Energy costs typically account for 15 to 40% of plant production costs (Takakura *et al.*, 1971). The efficiency of plant production in greenhouses depends significantly on the adjustment of optimal climate growth conditions to achieve high yield at low expense, good quality and low environmental load. To achieve these goals several parameters such as air temperature, relative humidity (R.H.) and CO_2 concentration must be controlled optimally given certain criteria through heating, ventilation and CO_2 injection (Kimball, 1986).

Greenhouse environment control considerations provide an introduction to many options available in greenhouse controls. Early greenhouse control was as simple as pulling a chain to open or close a vent, turning a valve to control heat or irrigation, or throwing a switch to activate a pump or fan. Over the years this evolved as greenhouse systems themselves became more complex and more reliable. Early automated control consisted of independent thermostats and timers. Even these simple devices allowed major advances in efficiency and product quality and made grower's lives simpler. However, many of these control devices and methods cannot deliver the level of automation and efficiency needed in today's dynamic, competitive environment. Several models have been developed to represent greenhouse environments over the years varying in complexity and detail (Chalabi *et al.*, 1996; Gates *et al.*, 1999; Ameur *et al.*, 2001; Marhaenanto *et al.*, 2002). As operating costs increased, and greenhouse systems became increasingly complex, the demand grew for increased control capability. The computer revolution of the early 80s created the opportunity to meet the needs for improved control. Consequently, there have been dramatic improvements in control technology. Today, computerized control systems are the standard for modern greenhouses, with continued improvements as the technology advances. Environment conditions can be maintained by these computerized control systems, where the system can be operated manually or automatically. Main components of any control system are measurement, controller, data processing, data acquisition and recording. In the environment control system, each parameter must be maintained continuously within a certain range. It needs a complex control system because there are many conditions that depend on the kind of plant and distribution of parameter values at certain times. A number of sensors, switches, actuators (e.g. fans, ventilator & sprayer) must be

installed in the system. Consequently, there are many devices that must be handled in the operation. The use of a computer system will be absolutely necessary to handle control system in order to maintain temperature and humidity with high accuracy.

The objective of this research was to develop a computer-based monitoring and control system for a greenhouse and test its performance inside a home made greenhouse.

MATERIALS AND METHODS

The main purpose of a greenhouse is to provide and maintain the environment that will result in optimum crop production or maximum profit. This includes an environment for work efficiency as well as for crop growth. There has been much research and design about environment control using sophisticated technology (automated or computerized), but those applications are mostly still in industrial sectors. In the agricultural sector, especially in developing countries such as Iran, the application of the environment control technology is still limited, because of its high cost.

The controller was designed to maintain temperature, relative humidity and water availability in a desired range. The controller consisted of three temperature sensors and a number of timers for irrigation. The relative humidity was measured using wet bulb temperature sensor. The outputs of controller operate a sprayer pump to increase humidity, a dripper for water supply, a fan with ventilation rate of 850 m^3/h to let air in and two fans, each with a ventilation rate of 280 m^3/h, to ventilate air out. Mist and fog systems produce tiny water droplets that evaporate, thereby cooling and humidifying the greenhouse air.

Electronic circuitry. The main controlling board is shown in Fig. 1. It uses an AT90S8535 CPU chip (ATMEL Corporation, 2003), a 2×12 segment Liquid Crystal Display module, a power supply (Fig. 3a), an IC 74C573 to activate actuators relays (Fig. 3b) and an IC MAX 232 interface card for sending /receiving data to microcontroller from RS 232 serial port to a personal computer (PC).

As described in the scheme of Fig. 1, the processing card is made of the AT90S8535 microcontroller associated with the usual buffering and addressing devices. IT has 8K bytes In System Programmable (ISP) flash memory, 512 bytes EEPROM, 32 I/O port pins, three Timers, ADC 8-channel, internal synchronous dynamic random access memory (SDRAM) of 512 bytes and many other peripherals. The microcontroller is driven by an 8 MHz crystal.

The LM335 is a precision, easily calibrated, integrated circuits temperature sensor. Operating as a two-terminal Zener diode, the LM335 has a breakdown voltage directly proportional to absolute temperature at+10mV/^{o}K. When calibrated at 25°C the LM335 has typically less than 1°C error over a 100°C-temperature range. The relative humidity (R.H.) was measured with a home made capacitor type sensor. The conditioning circuitry for temperature and humidity measurements are shown in Figs. 2a and b.

Interface design. The greenhouse automatic monitoring and control system can be developed easily by using electronic logic circuits (logic gates) such as integrated circuits (ICs) and microcontroller, available in the market. Nowadays the chip is sold as a computer system. Using a computer system, a flexible, whether simple or complex, automatic control system can be developed.

For the purposes of this work, a flexible, object oriented, user friendly, application graphical user interface (GUI) program incorporating control algorithms was needed for monitoring of greenhouse air temperature and humidity. Thus, a program, written in Visual Basic programming language, was developed specifically for this purpose. The greenhouse control and monitoring software run under Windows 98/ 2000/ XP operating systems. Using the software, operation of controller could be set in manual or automatic mode with changeable setting of parameter ranges (Fig. 4).

As can be seen from the main GUI of the program shown in Fig. 4, environmental conditions can be maintained by a control system, where the system can be operated manually or automatically. In the manual mode, the operator acts as a decision-maker to take an action to maintain certain conditions of the system. The operator gets the information about system condition by measuring some system parameters and thinks logically to respond and take an action on the system. In the automatic mode of operation, the operator only sets some criteria of condition (set points, offset values, types of fruit, etc.), and decision making is by the system itself to activate/deactivate actuators automatically. The implemented GUI consists of four windows; *main* menu (Fig 4), general *setting* menu (Fig. 5a), advanced *settings* menu (Fig. 5b) and *detail view* menu which uses the data obtained from the microcontroller for further analysis and plotting purposes. Each of these windows has a number of subsections based on the design criteria for the program development.

Experimentation. Performance of the system was evaluated by installing it in a constructed model greenhouse. The model greenhouse has a floor area of 8 m^2, (2 m wide×4 m long), covered with double inflated 200µm polyethylene films. The sets of experiments were carried out during the autumn season in the city of Karaj: the uncontrolled mode of operation and the controlled mode. The simulation results achieved for these cases for the air temperature and relative humidity are shown. In these figures, Tmid is the temperature at the height of plant, Tup is the temperature near the roof, Tout is the outside temperature and R.H. is the relative humidity. Hence, Tmid, Tup and R.H. indicate the inside condition and Tout indicates the outside condition. The outside condition represents ambient condition weather.

Fig. 1. Block diagram of the proposed data-acquisition system

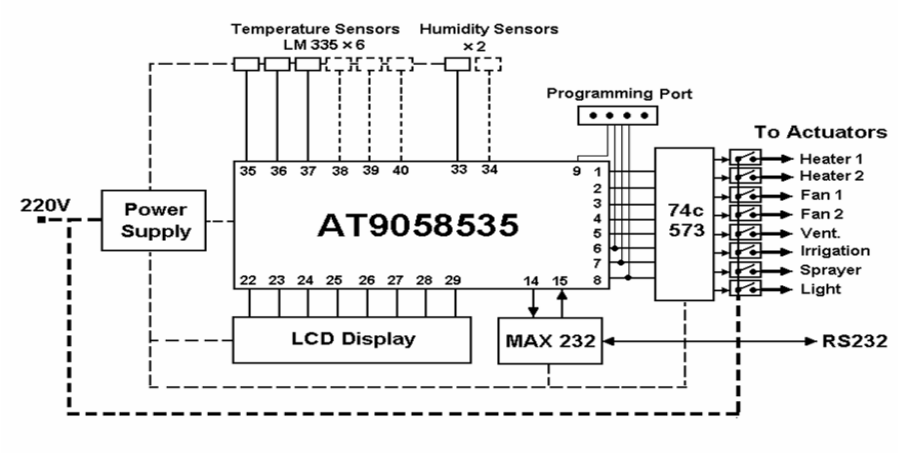


Fig. 2. Conditioning circuits for (a) temperature and (b) humidity measurements

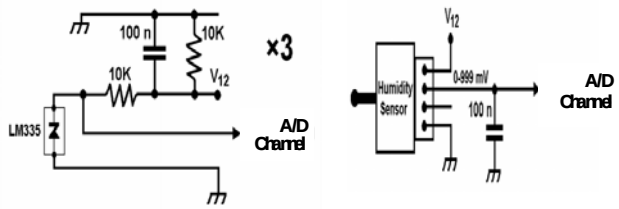


Fig. 3. Electronic circuitry for (a) power supply and (b) relay activation

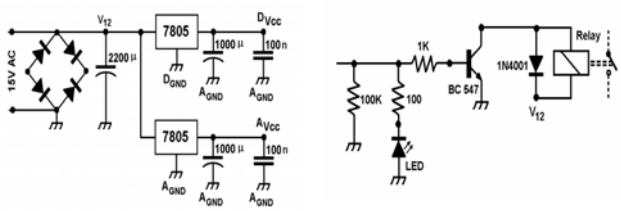


Fig. 4. Main graphical user interface of the Greenhouse Control & Monitoring Software

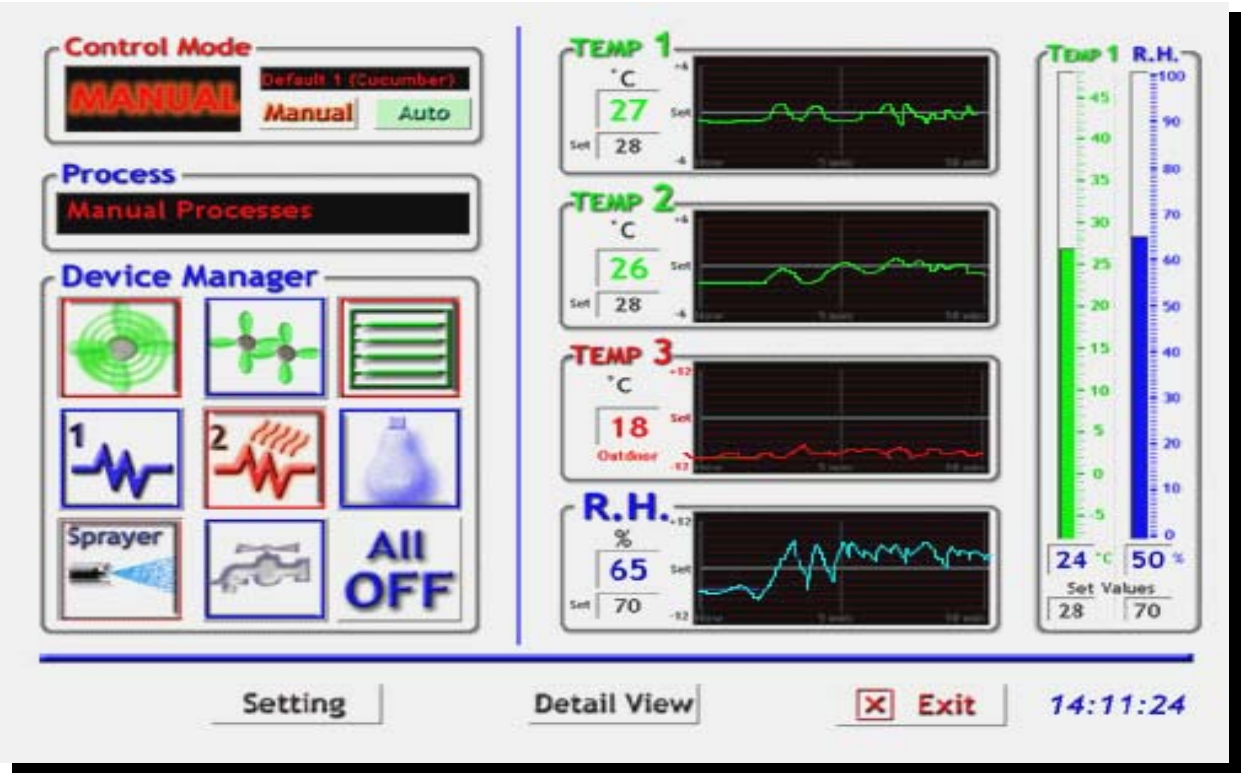


Fig. 5. Control setting menus: (a) General Settings of temperature, relative humidity, irrigation and light (b) Advanced Settings of Temperature and Humidity offset values, etc.

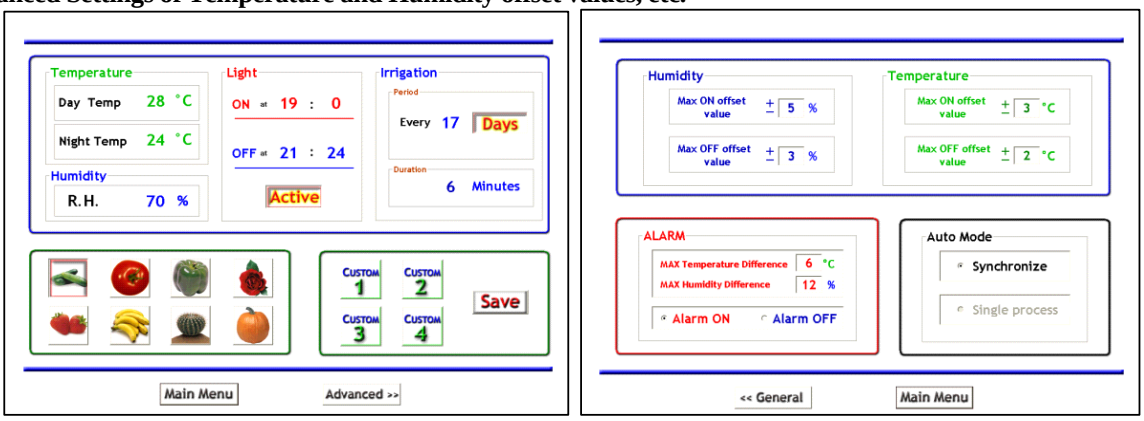


Fig. 6 shows the results for the uncontrolled experiment. The data were recorded with no operation of fans and sprayer. These show comparison between the inside and the outside condition. The results indicate that the outside temperature is always, about 15°C, less than the temperature inside the greenhouse, because the solar radiation entered the greenhouse through transparent plastic. This is a further confirmation of greenhouse effect. Also, it was found that the rate of change of temperature in the upper part, i.e. near the plastic cover, is higher than that of the height of plants. This rise of vertical temperature is due to receiving solar incident radiation. During a temperature decrease, it was found that the heat exchange near the plastic cover is occurring more rapidly. The fluctuations of temperature and to a lesser extend of R.H. in the model greenhouse during observation time were affected by natural conditions such as surface evaporation within the greenhouse, solar radiation and ambient temperature.

For the controlled mode of operation, two separate experiments are carried out: (a) temperature control only (Fig. 7a), and (b) both temperature and humidity control (Fig. 7b). The parameter settings in each of these experiments are summarized in Table I. When the controller was put into operation, it was found that Tout<Tmid<Tup. This could be partly due to the use of re-circulating fan with an attached perforated polyethylene tube in guiding the air toward the plant root zone.

Table I. Settings for controlled mode of operation. The set points are defined in the *Settings Menu* (Fig. 5a) and the offset values in the Advanced *Settings Menu* (Fig. 5b)

Set Points	T control only	T and R.H. control
T	Day Temp = 27˚C	Day Temp = 31˚C
R.H.	---	R.H.= 70%
Offset Values	Max ON	Max OFF
T	3 ˚C	1 ˚C
R.H.	5 %	2 %

From the results shown in Figs. 6 and 7 it can be concluded that the overall performance of the system to maintain the temperature and R.H. within a given range, around the set points, is satisfactory. However, the time constant of mist and fog system is rather long, about 30 min., in reaching to the desired humidity. A RH sensor with quicker response time as well as using a better sprayer system could improve response time of the system.

CONCLUSIONS

A computer-based control and monitoring system was designed and tested. The inside air temperature and humidity simulation models were identified using the described approaches for a constructed model greenhouse. The greenhouse has a floor area of 8m^2, covered with 200µm polyethylene film. Several actuators and sensors are installed and connected to an acquisition and control system based on a personal computer and a data acquisition and control card using a sampling interval of ten seconds.

For the controlled mode of operation, the desired relative humidity was set to 70% and the inside temperature was set to 31°C. Results of the tests indicated that a long time is required for RH to attain the set point. Temperature control is, however, satisfactory. These set parameters were probably due to long time constants of controller system including sensors. The time constant of mist and fog system was rather large, about 30 minutes, in reaching the desired humidity level. Based on these observations on RH and temperature, their set values were adjusted. The lower limits were set slightly higher and upper limits were set slightly lower. The overall tests indicated that the controller worked satisfactorily but at the expanse of actuators frequent activity. For long time operation this could harm the controlling devices. A better solution would probably be the use RH sensor with quicker response time as well as using a better sprayer system could improve response time of the system. Adapting other control strategies such as PID or FLC is another possibility. Further experiments with a

Fig. 6. Measured temperatures and relative humidity in no-control operation

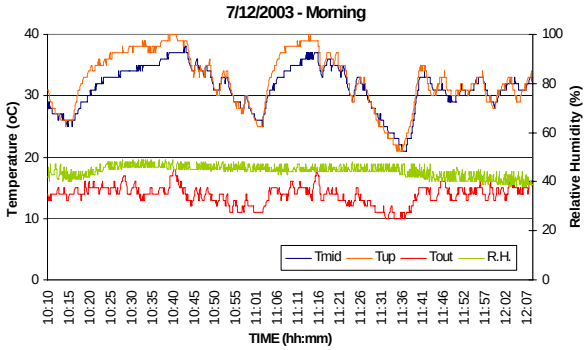
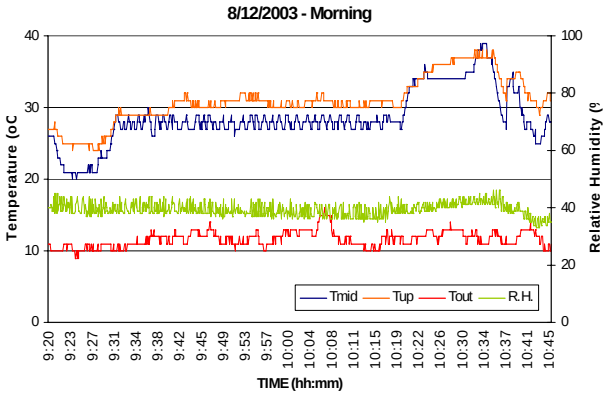
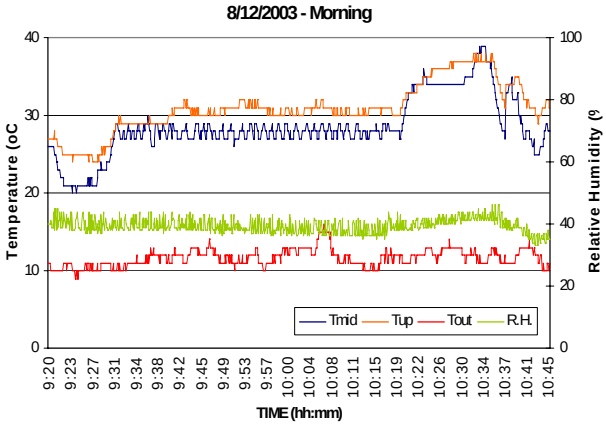


Fig 7.Measured temperatures and relative humidity under the action of controller: (a) Temperature control and (b) Temperature and RH control





modified setup will be useful to validate these preliminary conclusions.

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