Greenhouse climate control using wireless sensors

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Abstract
The aim of this paper was to study the main ambient parameters inside a greenhouse with a modern wireless sensor network in order to reach the optimization of the production process.
The research was carried out in a greenhouse sited in Balestrate (in the province of Palermo, Sicily); the crop was courgette; the plants showed a high density distribution so that their vegetation took up a large part of the greenhouse area.
Inside the greenhouse a wireless sensor network made up of three node sensors was located. The sensors were located vertically in the middle cross section of the greenhouse both inside and outside the vegetation. This allows to obtain the microclimate inside the greenhouse and to verify the possible differences of the measured quantities among the three sensors in order to rationalize the main cultivation techniques. The measurements were carried out every 6 minutes in the space of 24 hours; the tests were repeated during the period April-May 2008. Also outside temperature and relative humidity were recorded by means of a data logger equipped with a thermo hygrometer probe.
The results showed that the mean values of temperature and relative humidity in the part of the greenhouse concerned with the vegetation, differ from the highest part of the structure not involved in the plants. Continuously monitoring these areas, it's possible to appropriately and rationally plan the most important cultivation techniques carrying into effect natural and forced ventilation in order to maintain the optimal microclimatic conditions in the areas directly in contact with the plants.

Keywords: greenhouse, temperature and relative humidity, wireless sensors.

Introduction

Crop production in greenhouses in Sicily has highly increased in the last years from the economical point of view both for the higher profit guaranteed by the advanced or deferred crops and for the growing demand of the market.

The control of the main ambient parameters inside the greenhouse (temperature, relative humidity) plays a very important role in order to optimize the production process [Monarca et al., 2003; Abreu et al., 2004; Carrara et al., 2004; Ottosen et al., 2004].

The systems mostly used in Sicily to record the climate parameters inside the greenhouses are made up of fixed measuring stations realized by cabled sensors applied to some pre-fixed points. On the contrary, the modern wireless systems give the possibility of accurately control the ambient parameters inside the greenhouse with great flexibility due to the facility in positioning the sensors and the possibility of moving them. However, these systems till today are not present in the greenhouse management in Sicily where their introduction should represent a remarkable innovation (Carrara et al., 2007).

The aim of this paper is the optimization of the production process inside the greenhouse through the control of the main ambient parameters with a modern wireless sensor network.

Materials and Methods

The research was carried out in a greenhouse sited in Balestrate (in the province of Palermo, Western Sicily); the crop was courgette (*Lagenaria siceraria, fam. Cucurbitaceae*). The greenhouse had a steel frame and an elliptic roof; the walls and the roof where realized with plastic films (PE). The greenhouse has three spans each 8 m wide and 30 m long, north-south oriented. The height of the structure at the centre is 3.90 m; the plants were planted in the soil in rows parallel to the gutters, with a distance of about 1 m between adjacent rows and 1.50 m in the same row. The plants were irrigated around their roots by a drip system.

The plants showed a high density distribution (fig.1) so that their vegetation took up a large part of the greenhouse area, in this way outlining an environment with a specific micro-climate that is very important for plant protection and growth. The precise control of this environment could allow to carry out aimed interventions with remarkable advantages both on the reduced use of the raw materials and on the environment.

Figure 1. Crop inside the greenhouse

Inside the greenhouse a wireless sensor network made up of three node sensors was located. The node sensors, put inside a box, fed by batteries, measured temperature and relative humidity (Sensirion SHT 11, fig.2, measurement range: 0-100% RH, -40-123.8°C temperature); the collected data were downloaded employing the wireless communication in the band ISM with frequency 433 MHz.

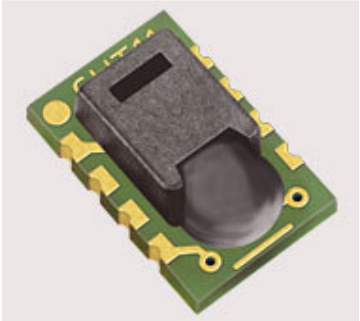

Figure 2. Wireless sensor Sensirion SHT 11.

The sensors (fig.3), called S1, S2, S3, were located vertically in the middle cross section of the greenhouse (fig.4) as follows:

- S1 inside the crop, 1.40 m high from the ground in the middle of the productive area;
- S2 at the top of the crop, 2.10 m from the ground;
- S3 outside the crop, 3.00 m from the ground, in the middle of the area not taken by the vegetation.

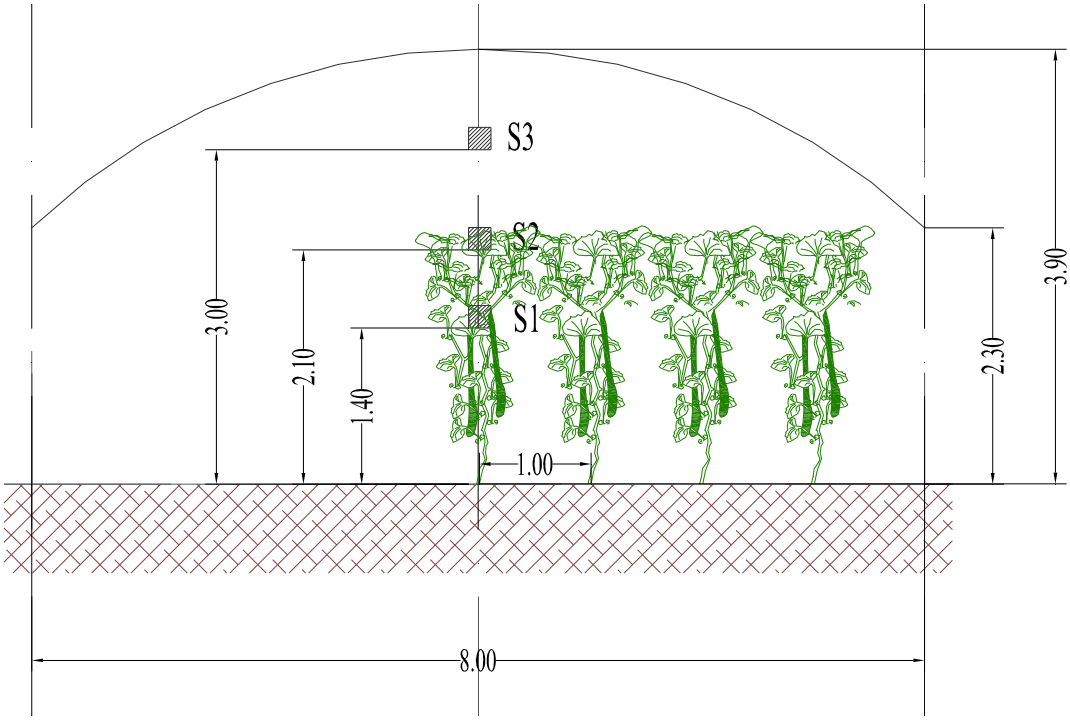

Figure 3. Section of the greenhouse with the sensors

Figure 4. Sensors' position inside the greenhouse

As a consequence, three areas were individuated and monitored one by one inside the greenhouse.

Sensor 1 represents the part interested in the productive area where monitoring the microclimate allows to evaluate the optimum time to perform chemical distribution against the adversities of the fruits.

Sensors 2 represents the area at the end of the vegetation, at the boundary with the high and free part of the structure, where monitoring the microclimate allows to evaluate the vegetative conditions of the plants in order to control the adversities that mainly affect the vegetative part of the plants themselves.

Sensor 3 represents the area located in the highest part of the greenhouse free from the vegetation, where monitoring the microclimate allows to point out the possible critical states involving the two previous areas.

This allows to obtain the microclimate inside the greenhouse and to verify the possible differences of the measured quantities among the three sensors in order to rationalize some of the main operations such as crop protection and irrigation from a sustainable agricultural point of view; the system also allows to rationalize the ventilation inside the greenhouse [Kittas et al., 2002; Romero et al., 2002].

The measurements were carried out every 6 minutes in the space of 24 hours; the tests were repeated during the period April-May 2008.

Also outside temperature and relative humidity were recorded by means of a data logger (Babuc M) equipped with a thermo hygrometer probe (BSU401) and providing real-time measurements every 6 minutes for 24 hours.

Results

Figure 5 shows the values of the temperature measured by the sensors inside and outside the greenhouse during three days representative of the whole monitored period.

It comes out that temperature inside the greenhouse shows a variability among the three areas. In particular, the highest temperature value recorded during the day by the wireless sensors decreases going from sensor 3 to sensor 1: 25°C outside the greenhouse, 29.4 °C in area 1, 33°C in area 2 and 40°C in area 3. The peaks are similar in the three days represented in figure 5.

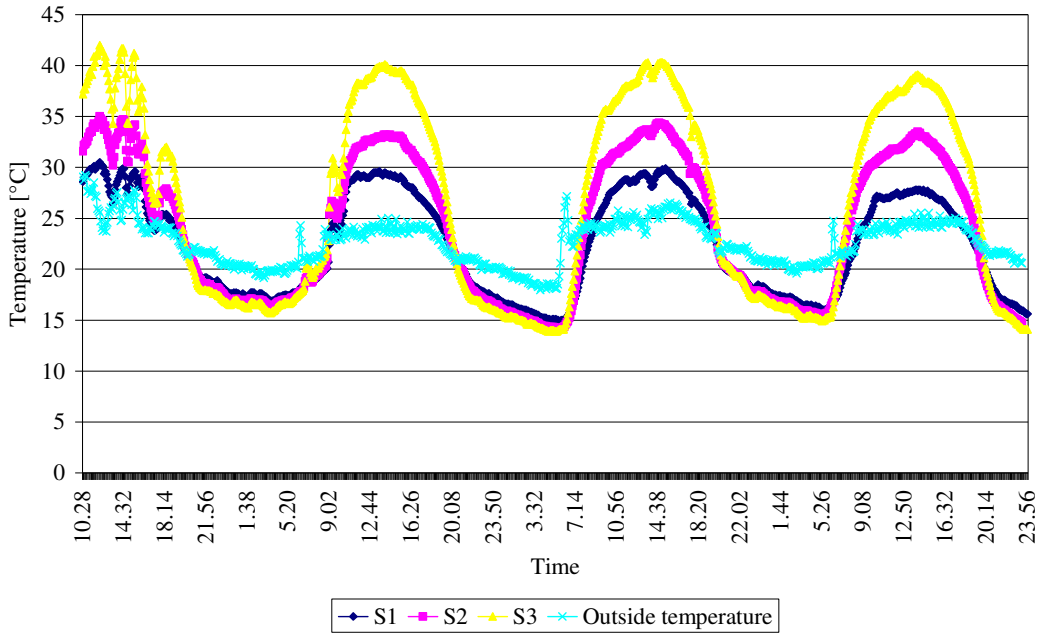

Figure 5. Temperature measured by the sensors

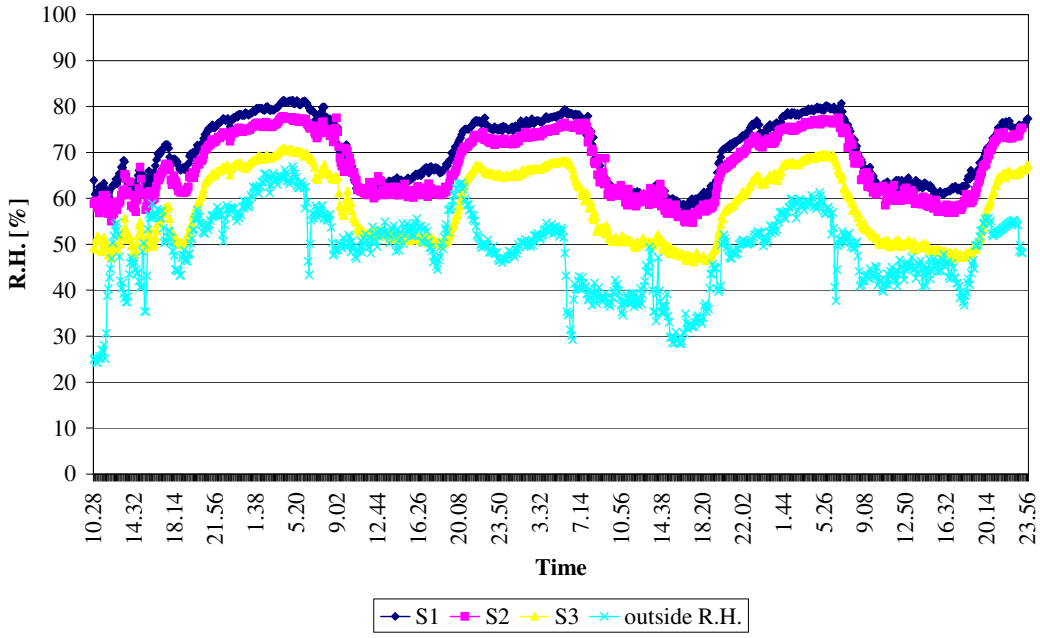

Figure 6. Relative humidity measured by the sensors

From here it comes out that during the day, temperature inside the greenhouse respect to the external one shows a 15% mean increase in area 1, a 24% mean increase in area 2 and a 38% mean increase in area 3. During the night, the mean values of temperature recorded by the three sensors area similar and show a mean 20% decrease respect to the external values.

Figure 6 shows the values of relative humidity measured by the sensors inside and outside the greenhouse during the three days. It emerges that the values recorded by sensors 1 and 2 are very similar; this can be attributed to the intense vegetative activity conditioning the microclimate of the area taken by the plants.

The highest value of relative humidity recorded during the day by the wireless sensors decreases going from sensors 1-2 to sensor 3. The peaks are on average 62% in the area 1-2 and 50% in the area 3, in spite of the mean outside values of relative humidity show a certain variability.

Conclusions

The aim of this study was to monitor the main ambient parameters inside the greenhouse cultivated with courgette, it allowed to obtain interesting information about the distribution of temperature and relative humidity values in different areas directly and indirectly involved in the plants.

The mean values of temperature and relative humidity in the part of the greenhouse concerned both with the productive area and the whole vegetation, show differences with the highest part of the structure not involved in the plants. Continuously monitoring these areas, it's possible to appropriately and rationally plan the most important cultivation techniques carrying into effect natural and forced ventilation in order to maintain the optimal microclimatic conditions in the areas directly in contact with the plants.

In this way it would be possible to reach a rational management of the resources respecting the environment.

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