Greenhouse Environment: Air and Water Monitoring

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AbstractTogether with light and soil, air and water quality control are fundamental to theproductivity and quality of greenhouse grown products. But control implies monitoring, i.e. measuring the physical, chemical and biology parameters used to access quality.
The chapter presents solutions for air and water quality monitoring that can be used in greenhouses.

Keywords:greenhouse, greenhouse environment, air quality control, water quality control

1 Introduction

One of the most basic and thus critical and priority problems of humankind is food. Water and food shortage affect a huge percentage of the 7 billion people that inhabit Earth in 2011. According to FAO [1], over 1 billion people are undernourished (2/3 living in Asia) and about 30 000 die daily of hunger, while also about 1 billion people does not have access to drinking water. The undernourished people has been increasing at an average rate of 10 million per year, which means that the target of 420 million undernourished people by 2015 established in the 1996 World Food Summit is probably unreachable. The desertification of Earth, increasing at a rate of about 1200 hectares/hour, does not help in the reduction of food problems. In what concerns water, things look a bit better and the target set by the Millennium Development Goal (MDG) relatively to drinking-water and sanitation (MDG 7, Target 7c) of reducing in 50% by 2015 the proportion of people without sustainable access to safe drinking-water and basic sanitation seems viable.

While some look for non-traditional forms of nourishing people (e.g. through pills), the mainstream of research is still about increasing food production using fewer resources and at a faster pace. But food and water quantity are not the only problem to overcome. The stress to increase productivity may lead to food quality problems and to a negative environmental impact of agricultural activity. Fertilizers and pesticides are fundamental in nowadays agriculture, but they contain products that are potentially dangerous to humans, animals and the environment. Tests conducted in soils used for horticulture near Lisbon, Portugal, show high concentration of chromium, nickel, lead and cadmium. Chemical tests conducted by researchers from the Instituto Superior de Engenharia de Lisboa (ISEL) on samples of Galician cabbages reveal levels of lead concentration of up to 2.1 mg/kg of dry material, i.e. 1025% over the authorized value while the same grown organically still reaches values around 0.3 mg/kg of dry material, i.e. 150% over the authorized value. This shows that organic production assures the absence of pesticides but not of atmosphere-transported pollutants or the uptake by the plants of the pollutants in the soil (e.g. heavy metals). The chemicals and heavy metals in the soil also may contaminate water resources that are used for irrigation or human consumption.

One possible way to increase the production of fruits and vegetables is by protected cultivation using greenhouses.

Greenhouses are structures covered with transparent glass or plastic films specially designed to grow plants inside. Greenhouses can modify crop micro climate according to plant needs and therefore contribute to increase crop productivity and produce quality.

The degree of environmental control provided by a greenhouse varies with its characteristics and the technological sophistication of the equipment. The basic type is the cheap mild-winter greenhouse [2] with a simple structure covered with plastic film and with no heating. These greenhouses are well fitted to regions with favorable climate where it is possible to grow out-of-season products providing incipient environmental control.

In the case of less favorable climates greenhouses have to be more weather proof and to be able to change the micro-climate according to crop requirements. A high-tech greenhouse can have full control of air temperature and humidity combining heating with cooling systems; atmospheric CO_2; and light intensity combining shading and artificial illumination. The choice of the most adequate level of greenhouse technology to be used in a certain situation is usually the result of a cost-benefit analysis. For instance the commercial production of top-quality tomatoes during the winter season in The Netherlands is the paradigm of high investments on cutting-edge greenhouse technology and fine-tuned environmental control.

Greenhouses can be used for many and diverse purposes such as: growing crops in regions with an inadequate climate; extending crop growing season or producing completely out-of-season; increasing crop yield; protecting crops from weather accidents such as rain or frost; and improving product quality relatively to open-field cultivation. Each of those situations may require specific type of equipment for environmental control but they all have in common the need of an accurate monitoring of the various parameters of greenhouse micro-climate.

In developed countries most greenhouse crops are grown in soilless cultivation using organic or inert substrates with no contact with the soil. This system allows a much better control of crop water and nutrient supply relatively to traditional soil cultivation, it is independent of soil characteristics and it can use irrigation water of much lower quality in comparison with soil cultivation. When soilless cultivation uses a closed system it is possible to recirculate drainage water with fertilizers, which are not released outside the system [3].Water use efficiency of these systems reaches a maximum among agricultural activities.

The tendency is for growers to use greenhouses with increasing capacity for environmental control with the objective of achieving higher yields of better quality products delivered at the right time of the year and according to market demand. The development of crop growing models provides information about set-points for a high number of variables related to air, substrate, water and plants that have to be accurately measured. This requires the measurement of diversified physical and chemical parameters and the processing of gathered data. If one aims at a fully automated operation, software for data processing, for data fusion and to control the hardware that based on the fused data acts to keep the relevant parameters within the desired values is required. In the paragraphs that follow, the authors will discuss in more or less detail all the problems and solutions to achieve that goal. We will start by detailing the parameters that should be measured and controlled and their range of values. Next, we will look into measuring solutions, namely into those that are compatible with on-site, real time operation. The chapter ends with a conclusion.

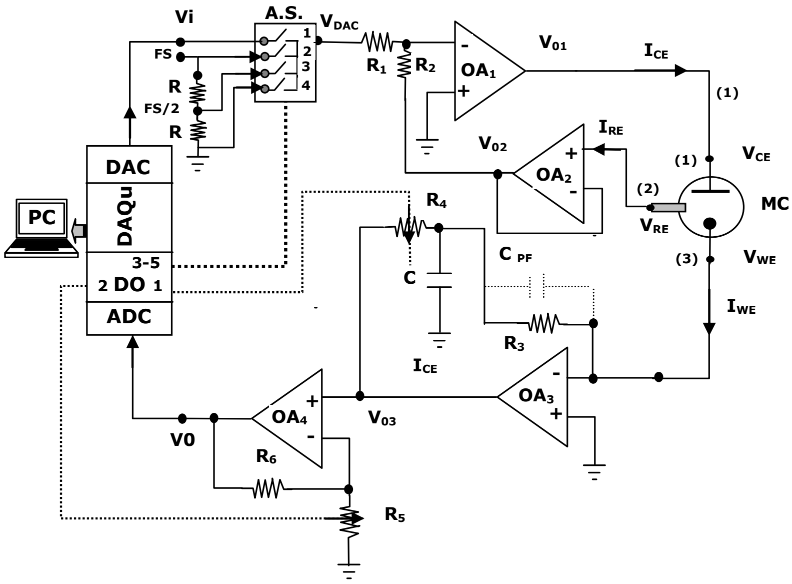

Fig. 15. Schematic diagram of the electrical circuit (MC-measuring cell, DAQu-data acquisition unit, ADC- analog to digital converter, DAC- digital to analog converter, OA- operational amplifier, AS- analog switch)

Basically, after a pre-concentration phase, a positive potential, with linear variation, is applied to the counter electrode of the MC and the current peaks, associated with the redox potential of each metal dissolved in the solution, are generated and detected by the current to voltage converter that is connected to the working electrode of the MC. It is important to underline that before measurement the oxygen must be removed from the solution in order to avoid large measurement errors.

4 Conclusion

Food demand increases as the world population continuously grows. Such raising demand requires higher productivity levels of quality products.

One way by which agriculture is answering the challenge is by increasing the production of products for human consumption in controlled environments, i.e., in greenhouses. Nowadays, and in developed countries, most greenhouse crops are grown in soilless cultivation using organic or inert substrates with no contact with the soil. The tendency is for growers to use greenhouses with increasing capacity for environmental control. The development of crop growing models provides information about set-points for a high number of variables related to air, substrate, water and plants that have to be accurately measured.In this chapter the authors paid particular attention to the critical variables of air and water.

Two issues deserve a comment here: (1) plant growing depends not on the air temperature but on leaf temperature. Usually the difference is not large, but 1ºC is already meaningful. Thermocouples can be coupled to leaves to measure their temperature [17] but other solutions are available [18]; (2) It must be underlined that no considerations were made about sensors calibration; to maintain adequate accuracy of the measured quantities and particularly because some of the sensors and electronics are operating in field conditions, it is of paramount importance to periodically verify and calibrate the transducers, i.e., the sensors and associated electronics. If one wants to calibrate them automatically on-site without uninstalling them, careful designed hardware and software is required. The authors have been developing solutions for in-situ calibration of water quality monitoring systems and the reader may have a perception of its complexity by consulting [19][20].

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