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Practice-Oriented Leaf Temperature Measurement in Heated Greenhouses

For climate control in greenhouses, the measurement and utilization of leaf temperature is desirable. The application of different techniques of leaf temperature measurement (contact thermocouples, injection sensors, infrared sensors and image-based thermography) was studied in a practice-oriented way in ornamental plant cultures. It was possible to show the great importance of leaf temperature distribution in the greenhouse as well as the suitability of injection sensors and contact thermocouples for climate control. The use of infrared thermometers was difficult. Leaf temperature measurement through image-based thermography did not provide satisfactory results.

Plant production in greenhouses requires optimal heat-, water-, and nutrient supply. Conventional production systems control heating and ventilation according to the air temperature. In practice, leaf temperature is not employed as a controlled climate variable because its determination meets with production-technological difficulties and set values for cultures as well as information about spatial leaf temperature distribution are lacking, even though its advantageousness has been known for a long time [1]. Due to the renaissance of radiation-oriented heating systems in the greenhouse area [2], the question of optimal controlled variables poses itself again. Alternatives to the use of air temperature are being sought.

Measurements

At the Teaching- and Experimental Institute for Horticulture in Hannover-Ahlem, different pot plants (elatior begonias and New-Guinea impatiens) were cultivated in two differently heated, though otherwise identically equipped greenhouses (12.2 m • 9.2 m). In one house, heating energy was supplied by two dark radiator pipes installed underneath the energy screens at right angles to the ridge. In the other house, a conventional under-table pipe heating system coupled with stay-wall pipe heating was installed.

During the entire duration of the trials, different measurements of leaf- and air temperatures were carried out in both houses. For the measurement of the spatial distribution of leaf surface temperatures, contact thermocouples were used which were installed on the underside of the foliage leaves (*fig. 1, left*). On average, the thermocouples needed to be checked and adjusted twice a week due to plant growth. The radiation heating systems were controlled based on leaf blade temperature, which was measured using injection sensors positioned at the centre of the houses on two different plants. The sensors were inserted ~3 cm into holes previously cut into the leaf blade (*fig. 1, right*). After approximately one month, new leaves were used as measurement locations.

In addition, the plant population was analyzed on three dates using the aid of thermographic techniques. For this purpose, an infrared radiation thermometer was employed. The plant population was also measured using an infrared camera installed above the culture at a slanted angle. The measurements were carried out while the heating system was operating and the energy screen was either open or closed.

Results

The trials showed that especially in greenhouse systems where heating energy is mainly supplied in the form of radiation, leaf temperatures and their spatial distribution in the greenhouse constitute a decisive climate

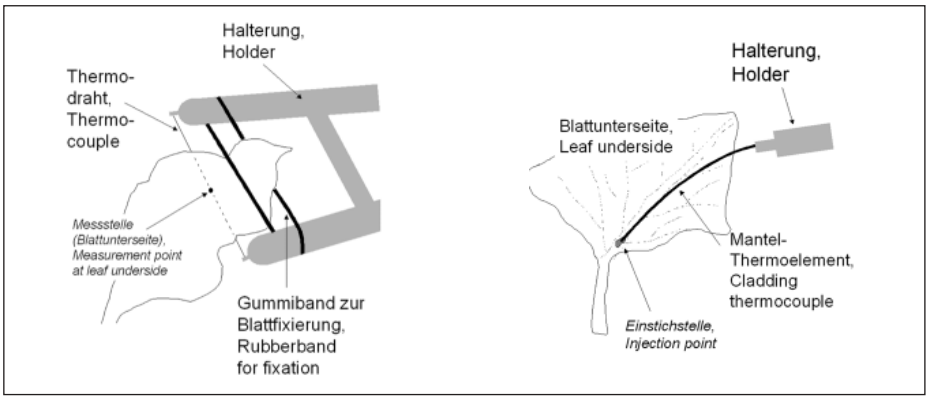

Fig. 1: Outline of the leaf temperature measurement with contact thermocouples at the leaf underside (left) and injection sensors at the leaf basis (right)

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Keywords

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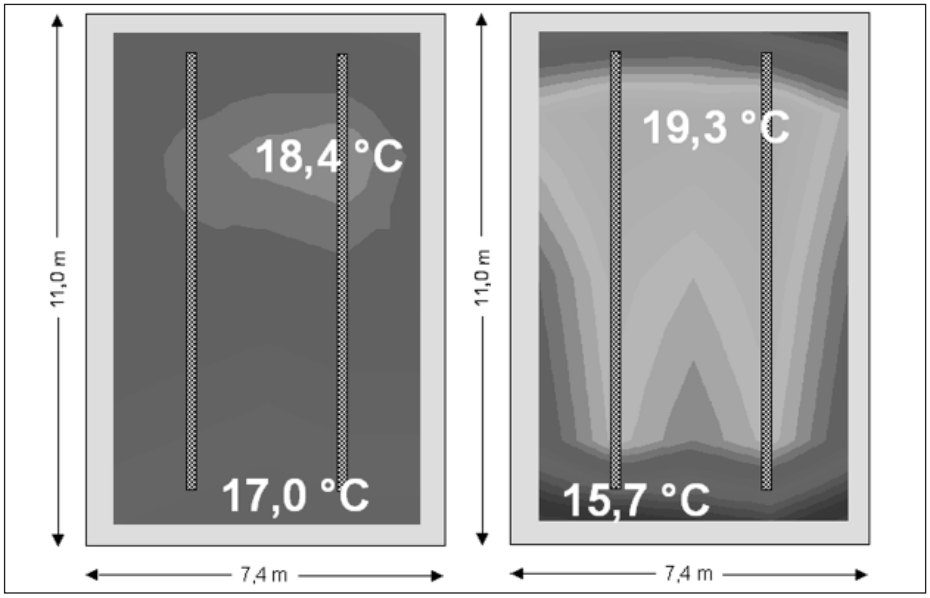

Fig. 2: Mean air temperatures (left) and mean leaf temperatures (right) during the growing period in a radiation-heated greenhouse (hatchings: positions of the radiation pipes)

reference variable (*fig. 2*). As shown in figure 2, the use of air temperature as the sole reference variable is insufficient in these situations.

Contact thermocouples and injections sensors can also be used for the measurement of leaf temperature under practical conditions. A working two-point control system was able to be realized with injection sensors. Therefore, the „fearfulness" with regard to direct measurements at the plant, which has prevailed in practice so far, is unfounded or should at least be reconsidered. However, the maintenance requirements of contact thermocouples or injection sensors must be taken into account.

For the measurement of leaf temperatures, infrared sensors (infrared thermometers) can only be used to a limited extent. Very differentiated calibration and very precise measurements are necessary in order to obtain meaningful results. The use of infrared-based imaging techniques (infrared camera) for temperature estimation is problematical because in addition of the plant populations objects which reflect or directly radiate heat (heating pipes) are included in the measurement, which leads to false interpretations.

For this reason, further studies should give the aspect of leaf temperature measurement more consideration in practical approaches. Set-value tables must be compiled which allow the gardener to realize culture programmes on a leaf temperature basis without separate experimental studies. The reference data determined in these trials may serve as a basis. Future developments will show to what extent leaf cells or miniature contact thermocouples can be used as measuring sensors in practice.

Literature

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