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Thermal Photography for Detecting the Variability of Stomatal Conductance on Mango Trees

Dry stress stomatal closure and leaf temperature increases occur parallel on most plants. Therefore, thermography offers a good possibility for getting an overview of spatial distribution and temporal transpiration development. This could be shown on mango trees in a glasshouse. Outdoors, numerous climatic influences affect leaf temperature; the variability within the treetop is more pronounced. For this reason models must be developed to be able to define the relationship between dry stress and leaf temperature under various conditions.

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Keywords

Thermal images, drought stress, leave temperature

Knowledge on plants' reactions to drought stress is an important base for investigation of plant water requirement. Presently, it is investigated, how the measurement of plant stress reactions can be included in an effective irrigation control [1]. Among others, leave temperature is a reliable and easy to determine parameter, which enables conclusions on drought stress. A plant that suffers drought stress and closes the stomata of the leaves in order to minimize water consumption. Along with transpiration the cooling effect of the evaporating water decreases and leave temperature increases measurably, depending on climatic influences (air temperature, solar radiation, wind speed and air humidity). Reference surfaces are used to consider these influences on the measurement. Several studies have been published, where leave temperature has been found to be a reference for drought stress of different crops. The correlation with stomatal closure has been proven. If this technique is applied to trees and shrubs, the variability within the canopy has to be considered. Methods to determine the temperature of single leaves are subject to the same limitations as the direct determination of transpiration as a measure of stomatal conductance. If measuring a selection of leaves one by one, then a low sample size makes the statistical explanatory power questionable. The measurement of many leaves is time consuming to such an extent, that changes in the weather during the course of the day may influence the measurement. Therefore, the use of thermography offers a good possibility to gain an overview on spatial variability and temporal development of stomatal conductance. So far, this technique has been applied in grape wine production [2], where a higher uniformity as compared to fruit trees is to be expected. In the present study thermography was used with mango trees. Pictures were taken under controlled conditions in a green-house and in the field, where the high heterogeneity of the canopies was expected to produce higher

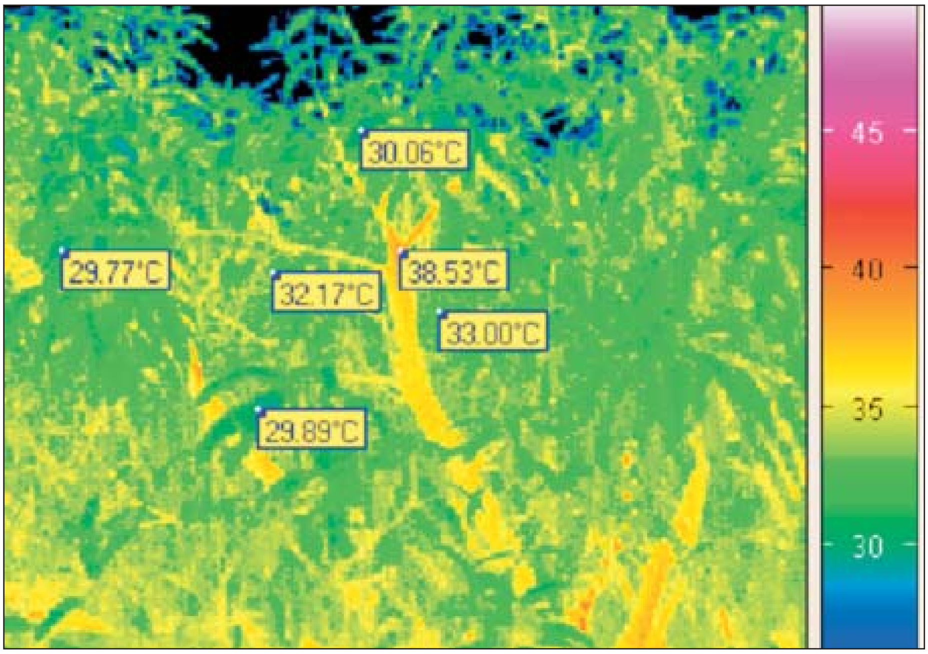

Fig. 1: Variability in the canopy of a mango tree: strongest cooling on the leaves in the periphery

temperature differences in the course of the day. All studies have been carried out in Chiang Mai, Thailand, during the dry season (March 2006). A thermo-camera type Infratec VarioCAM has been used.

Green-house studies with mango trees

The first experiments with mango trees have been carried out in the green-house. Direct solar radiation was avoided and the room was uniformly ventilated. Thus, influences by the environment could be considered uniform. Twenty-one one-year-old mango trees (*Magifera Indica*, L., cv. Chok Anan) were planted in split-root technique in two pots each, using sand as a substrate. They were grouped in three groups. The control was irrigated with 2 litres of water every two days. Two deficit irrigated treatments were established. Both of them received half of the irrigation water amount used for the control, equally distributed and on half of the root system, respectively. Air temperature, wind speed and relative humidity were documented. Thermal photographs were taken during the course of the day. In parallel, the stomatal resistance was measured at five randomly selected leaves by use of a porometer AP4 (Delta T Devices). Thermal images show a sharp increase in leave temperature in the deficit irrigation treatments. Despite largely homogeneous ambient conditions this increase is not uniform. The stomatal conductance of young leaves decreases quickly, making the leave temperature rise. A similar behaviour was observed with leaves in the periphery, whereas the cooling of leaves in the centre of the shoot is still comparatively strong. During the afternoon hours with the highest air temperature, there was an increase in leave temperature recorded for the control trees, too. However, this increase was less pronounced as that of stressed plants and the temperature development was uniform in the course of the day. Maximum differences between the treatments arose up to 8°C. Drought stress was mainly visible through high temperature differences within the tree canopy.

Field measurements

In a mango orchard the measurements have been performed on 10-year-old mango trees of the same variety planted in a 4 m • 4 m pattern. Full irrigated trees (calculated based on the climatic water balance according to Penman-Monteith) were compared to non irrigated trees. Air temperature, relative air humidity, light intensity and wind speed were determined prior to each thermal photography. The analysis of the leaves' spatial distribution was supported by digital photos. As the leave temperature in the field during the day is subject to strongly changing ambient conditions, reference surfaces have been used in order to enable quantification of the influence of transpiration. A wet tissue served as reference for the maximum cooling by evaporation. To reproduce the maximum heating of a leave, one leave on the north and the south side, respectively, have been coated with a natural resin, whereby a complete stomatal closure was artificially produced. An increase in leave temperature due to stress was observed. The variability within the canopy was very high (*Fig. 1*). In general, outer leaves showed lower temperatures. Even in non-irrigated trees much lower temperatures have been measured as compared to the coated reference leaves (*Fig. 2*).

Fig. 2: Heating of a coated leave. Transpiration is prevented by artificial stomata closure

Evaluation of the potential of thermal photography

The increase in leave temperature is clearly visible under controlled ambient conditions in the green-house and can be directly correlated to stress. Further research is needed in order to determine gradients of stress, as an early detection of stress is important, if leave temperature measurement should be used for irrigation control. Image analysis of thermal photographs offers the possibility of a sectored break-down of single plants and the determination of variability. This is important, because when stress occurs, leave temperature does not increase uniformly. With an improved data base strategic points for point measurements with a more simple instrumentation can possibly be determined.

In den field the applicability of this technique is mainly limited through the influence of environmental conditions. As a base for field application "thermal indices" as elaborated by Leinnonen und Jones based on experiments with beans and grapes [3]. The more complex shape of fruit tree canopies make the development of a radiation model necessary, by which the influence of transition areas are considered within the canopy during the course of the day. As a result – by analogy to wine – reference values can be calculated, which enable drought stress detection.

Literature

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