Fröschle, Heike; Ströbel, Markus; Geiss, Joschko and Köller, Karlheinz

The Hohenheim module and calculation model for dew simulation

Leaf surface wetness along with dewfall, which frequently occurs during spring and summer in Central Europe, are critical factors regarding the formation and control of plant diseases. A simulation module and a corresponding calculation model were created in order to reproduce dewfall and the formation of dew, as well as its impact on arable crops on a laboratory scale.

Keywords
Dew simulation, modelling

Abstract
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An important aspect of plant disease control and protection is leaf surface wetness duration, because spores of many pathogens need a film of water over the leaf tissue in order to germinate and infect the host [1–5]. In this context, dew is particularly important with regards to the infection of plant foliage by a number of pathogenic fungi [6]. In order to be able to reproduce coherences e.g. the dew formation process and the behaviour of dewdrops on different surfaces or cultivations, as well as the exclusion of site-related factors influencing the formation of dew on a laboratory scale, a simulation module and a corresponding calculation model were created.

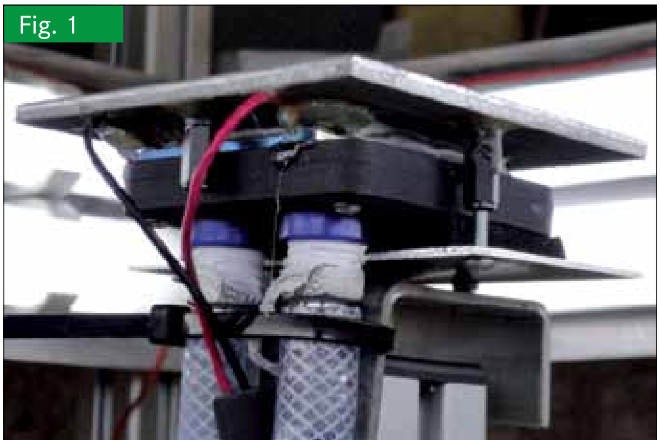
Test setup

The test setup is composed of two parts: a sensor part including an infrared thermometer (Optris CS LT 15K, Optris GmbH, Germany) to measure the surface temperature, as well as a temperature and humidity sensor (HYT 271, Hygrosens, Germany), and the temperature control using a controllable Peltier element (TEC1 12708, HB Electronic Components, USA) for leaf cooling. In the measuring system, the Peltier element acts as a heat pump, hence one side is cooled down and thus can be used for dew simulation, whereas the other side is heated. The rear side of the Peltier element is protected against overheating by a water cooling device (**Figure 1**). The entire system is controlled by the specially designed DewAlyzer Software (ILFtec, Germany). During the measuring operation, the aluminium plate attached to the Peltier element and hence the leaf connected to it via a contact medium, are cooled to a designated surface temperature, using a PID controller. Thus, a temperature curve following pre-selected temperature steps is delineated by the control software. The temperature curve appoints the required time period until the designated surface temperature is reached. For the entire measuring operation, the surface temperature is monitored by the infrared thermometer and passed on to the software, which calculates the percentage of dew formation on the leaf surface in due consideration of dew point temperature as well as ambient temperature and humidity (**Figure 2**).

Calculation methodology used for the model

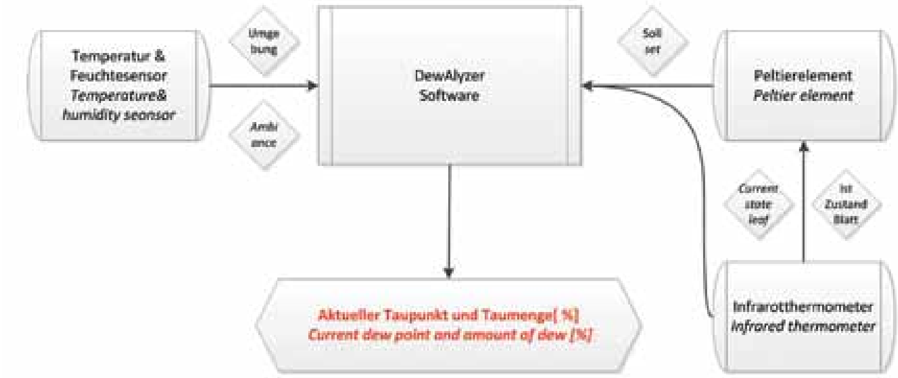
The dew point is a humidity measure determined by a temperature, the dew point temperature. In analogy to the dew point there is a frost and an ice point [7]. Different liquid or solid accumulations (dew & hoarfrost) characterized as coating or glaze, will develop when reaching these points. Accumulations can arise via condensation or sublimation in the air and usually occur during nights with clear skies and feeble winds, when the surface of the earth can be cooled effectively [8]. As at dew-point level *td* [°C] the vapour pressure is similar to the

Fig. 1



Test setup along with Peltier element and water cooling system (Foto. H. Fröschle)

Fig. 2



Schematical calculation method

saturated vapour pressure, in the calculation model, the dew point calculation is performed via transposition of the MAGNUS formula (1).

$$td = 237{,}2\,°C\; lg\left(\frac{e}{6{,}1\,hPa}\right) \Big/ \left[7{,}5 - \lg\left(\frac{e}{6{,}1\,hPa}\right)\right] \qquad \text{(Eq. 1)}$$

$$e = 6{,}1\,hPa \bullet 10^{\,(7{,}5\,td)/(td + 237.2\,°C)}$$

Furthermore, again following [7] spread *(ΔTd)* is defined as a measure of humidity (2). Whilst in the presented case, *T* corresponds to the leaf temperature and *td* represents the dew point.

$$\Delta Td = T - td \qquad \text{(Eq. 2)}$$

Based on the prior, regarding the climatic model, the amount of dewfall on the leaf surface (*Qd*) is calculated, representing the integral of the temperature deviation between dew-point temperature and leaf surface temperature Δ*Td*, referred to time *(*t) (3).

$$Qd = \int_{t1}^{tn} \Delta Td(t)\,|\Delta Td(t)|\,dt \qquad \text{(Eq. 3)}$$

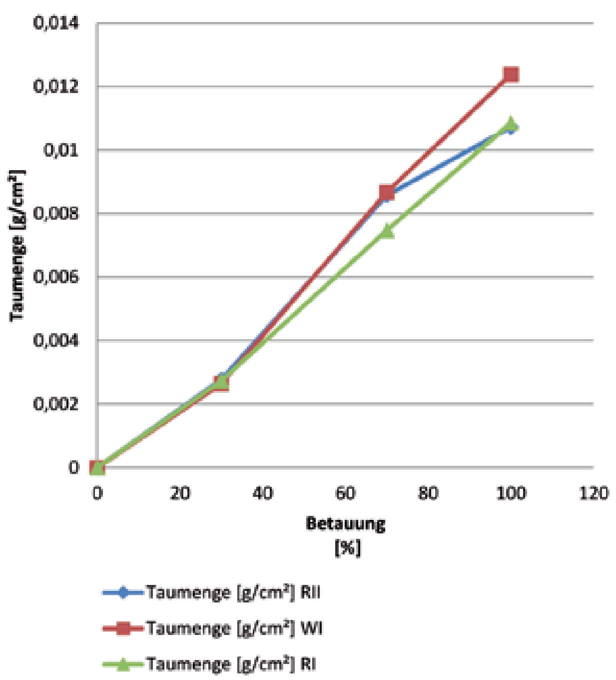
Results

Using a standardized card web (Procter&Gamble GmbH & Co Operations oHG, Deutschland) dew formation characteristics can be analyzed with regards to linearity or non-linearity, and the amount of dewfall [g/cm^2] can be determined for different cultivations. Following the exemplary dew formation graph, as depicted in **Figure 3**, representing the cultivations of rapeseed (RI: BBCH 15-18 und RII: BBCH 62-65) and wheat (WI: BBCH 12–21), linear characteristics were established regarding the augmentation of dew for the different cultivations.

Conclusion

To date, the description of dew formation processes as well as its retention period, at a given ambient temperature and varying humidity, represents the key field of application for the presented system. The calculation and simulation model has been improved and verified in analysing the characteristics of different dew formation processes regarding various cultivations. Thus, regarding the entire cultivation period, dew formation can be assessed precisely; hence the moment in time for pesticide applications can be optimised.

Fig. 3



Dew formation [g/cm^2] regarding the cultivations of rapeseed and wheat

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Authors

M.Sc. Heike Fröschle is research associate, **Markus Ströbel** is a member of the technical staff and **B.Sc. Joschko Geiss** is a student at the Department of Process Engineering in Plant Production (Head: **Prof. Dr. Karlheinz Köller**) at the Institute of Agricultural Engineering at the University of Hohenheim. Garbenstrasse 9, 70599 Stuttgart, E-mail: h.froeschle@uni-hohenheim.de