Towards a 3D wetness Sensor

Wetness (the presence of free water on a surface) plays a very important role in the epidemiology of plant pests. It is involved in most of the events of plant contamination by airborne fungal pathogens, and it also influences egg-laying by insect pests as well as the development of mites. It also intervenes in other areas, which do not concern agriculture.

The epidemiological models used to analyze the risk of disease development on the aerial parts of plants mostly use wetness values that are measured by sensors either placed in the crop canopy or estimated based on air humidity. The wetness sensors currently used in agriculture work by measuring the dielectric constant of a surface that is in contact with the sensor (THIEBEAU and ALAVOINE, 2018)2. These sensors must be calibrated to function correctly, and the methods for calibrating them are well-documented (Baudais et al. 2021)3. Regular maintenance allows for some repeatability of the measurement. However, this maintenance is expensive and the sensors are widely considered as unreliable for agricultural uses (Fatthy, 2016)1, so much so that many modelers "secure" the wetness values, using a model based on psychrometric charts or on artificial intelligence (AI). Commercially available wetness sensors are flat and small, but the specific size does not matter as long as it represents an area of a few square centimeters. From an agronomist's point of view, they all have the disadvantage that they do not reflect the complex superposition of leaves that may occur in the canopy of a plant. In the field, the extent of leaf superposition depends on the plant species, its phenological stage, and on the crop management practices of the farmer. Another drawback of current commercial sensors is that they do not adequately reflect all leaf orientation conditions and their exposure to light or wind. It is now essential to have sensors that can reflect all orientations, all overlaps and all slopes. It may be possible to equip a plant with multiple sensors, but this practice is difficult to standardize. A "wetness range" is provided to the user by some sensors, based on the output level of the transmitted signal. However, this remains a management by extrapolation of the measurement, based on a hypothesis of the behavior of the plant cover. Currently, it is quite possible, thanks to 3D printers (or any other device), to design a panel of small surfaces (flat or curved) that can be equipped with sensors. These sensors could even be printed directly, to obtain a greater diversity of surfaces representative of the vegetation, while keeping a modest sensor size. The 3D sensor should be able to describe the humidification by taking into account at least three criteria absent from "2D single-sensors": the diversity of coverings, orientations and slopes present in a plant cover. It is likely that this type of sensor will be more expensive than the simple plates currently available. However, even if they are not used on all farms, they could at least serve as a reference in research and development stations. The ideal sensor does not exist because it is not possible to represent all cultivated species or all their stages of development. 3D sensors will also provide a variable output signal, with a level of uncertainty. However, it must be recognized that the plates currently used are simplistic. The fact that the ideal sensor does not exist cannot justify sticking to this type of device. Many shapes can be imagined: chevrons installed on a vertical helix, surface elements inscribed in concentric spheres, etc. The 3D printer opens up the possibility of complex nested surfaces and why not the shape of a bunch of grapes, to take into account mildew contamination in the highly protected areas of the “belt”. What is surprising is that this system does not exist to date. This paper is a call for the realization and democratization of wetness sensors that are both more representative and more versatile.