ELECTRONIC LEAF WETNESS DURATION SENSOR: WHY IT MUST BE PAINTED

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INTRODUCTION

Leaf wetness duration (LWD), promoted by dew, rainfall, fog, or irrigation, is one of the most important factors influencing plant disease outbreaks and severity. It is used as an input parameter in many disease warning systems (HUBER & GILLESPIE, 1992; KIM et al., 2002).

Measurement of leaf wetness is often problematic. According to MAGERY (1999) and MADEIRA et al. (2002), LWD is a difficult variable to measure and can not be considered a true atmospheric variable, as it is related to structural and optical surface properties and microclimate.

The sensors used to measure LWD may be classified in three groups (GILLESPIE & KIDD, 1978; GETZ, 1991): static leaf wetness instruments, which give only an indication of wet or dry conditions; mechanical leaf wetness instruments, which record the change in sensor length, size or weight caused by dew deposition; and electronic leaf wetness instruments that promote a change in sensor resistance or capacitance.

With the expansion of the automatic weather stations network in Brazil, the use of electronic sensors, normally flat, printed-circuit wetness sensors, has increased. However their use requires attention to some details, such as the angle of deployment, orientation, calibration, number of sensors, and painting to produce accurate data (GILLESPIE & KIDD, 1978; LAU et al., 2000; MADEIRA ET AL., 2002; MONTEIRO et al., 2002).

According to LAU et al. (2000), the angle of deployment and orientation have less influence on LWD records than the paint coating. These authors found that unpainted sensors failed to respond to dew onset in 15.4% and 30.8% of the cases for sensors deployed at 30^o and 45^o respectively. On the other hand, painted sensors responded during each dew event for all the angle deployments used. GILLESPIE & KIDD (1978) used different colors to paint the mock leaf sensors and verified that those painted with off-white and very light gray gave the best approximation to the drying rate of real leaves.

The purpose of this study was to compare and evaluate the performance of electronic leaf wetness duration sensors to measure LWD under two sensor conditions: unpainted and painted, in a cotton crop canopy.

MATERIAL AND METHODS

The field experiment was carried out during the summer of 2001/02, from December to March, in an area cultivated with two cultivars of cotton crop (IAC23 and Coodetec) in Piracicaba, State of São Paulo, Brazil (Lat.: 22^{o}42'S, Long.: 47^{o}30'W, Alt.: 546masl).

Inside the crop area six automatic micro-stations were installed, measuring air temperature, relative humidity, and LWD (Model 237 – Campbell Sci., angled at 20^o) (Figure 1) at the top of the cotton canopy. Rainfall also was measured inside the crop area by a Texas Electronics Tipping Bucket Gauge, Model TE525M.

Figure 1. Micro-station inside the cotton crop with the air temperature, relative humidity, and LWD sensors.

The micro-stations were programmed to measure the variables each second and average them each 15 min using a data acquisition system (Campbell Scientific, Model CR23X).

The data were divided in two periods: a) from 18/Dec to 10/Jan when the sensors were unpainted, and b) from 20/Jan to 13/Feb when the sensors were painted with white latex paint (two coats of paint). The data analysis included evaluating the Coefficient of Variation (CV% = (Standard Error / Mean) * 100) among the six sensors for each day, and the relationship between the measured LWD (mean for the six sensors) and the number of hours with relative humidity above 90% (NHRH>90%), used as an indicator of dew presence (RAO et al., 1998; SENTELHAS et al., 2003).

RESULTS AND DISCUSSION

The coefficients of variation (CV%) for the LWD daily measures among the six sensors are presented in Figure 2, where it is possible to see the huge difference between the unpainted and painted sensors. For the period when the sensors were unpainted (Figure 2a), the daily values of CV% ranged from 2.3 to 139.3%, with an average of 67.4%. In this sensor condition, CV% values smaller than 20% occurred only on days with rainfall, indicated by the arrows. As found by LAU et al. (2000), the unpainted sensors in this study also failed to respond at all during some high relative humidity events.

For the period when the sensors were painted (Figure 2b), the CV% values decreased markedly, especially during days with wetness promoted by dew, ranging from 0 to 31.2%, with an average of 9.3%. In this case the painting increased the sensitivity of the sensors to detect small water droplets (GILLESPIE & KIDD, 1978), reducing the underestimation of LWD.

Another way to judge the importance of painting these electronic sensors is by comparing

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their response to another estimator of LWD. Figure 3 presents the relationship between LWD measured and estimated by the NHRH>90%. For the unpainted sensors (Figure 3a) this relationship resulted in a slope of 0.87, representing an underestimation of 13%, and in a poor precision (R^2 = 0.54). On the other hand, when the painted sensors were used (Figure 3b) the underestimation fell to 7% and the determination coefficient (R^2), which represents the estimate precision, increased to 0.89.

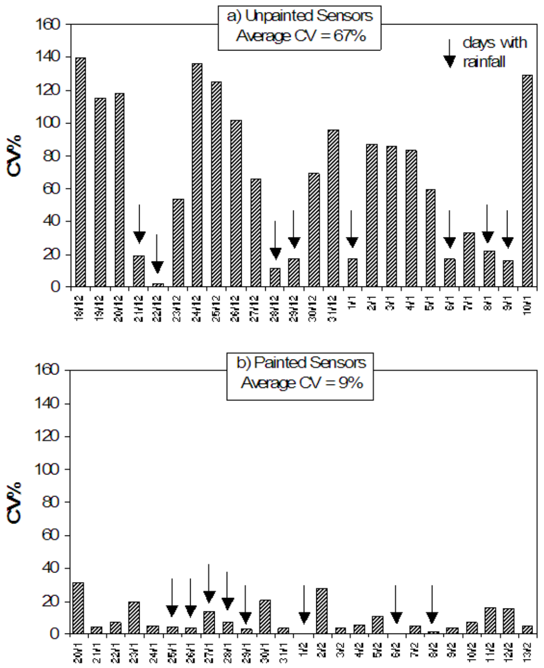

Figure 2. Coefficient of variation (CV%) for the LWD measurements using electronic leaf wetness sensors unpainted (a) and painted (b). The arrows indicate the days with rainfall.

CONCLUSIONS

The results presented in this study show that electronic leaf wetness duration sensors must be painted to reduce the underestimation and increase the precision of the measurements. Painting increases the ability of the sensor to detect and measure the wetness promoted by small water droplets and reduces the variability among sensors.

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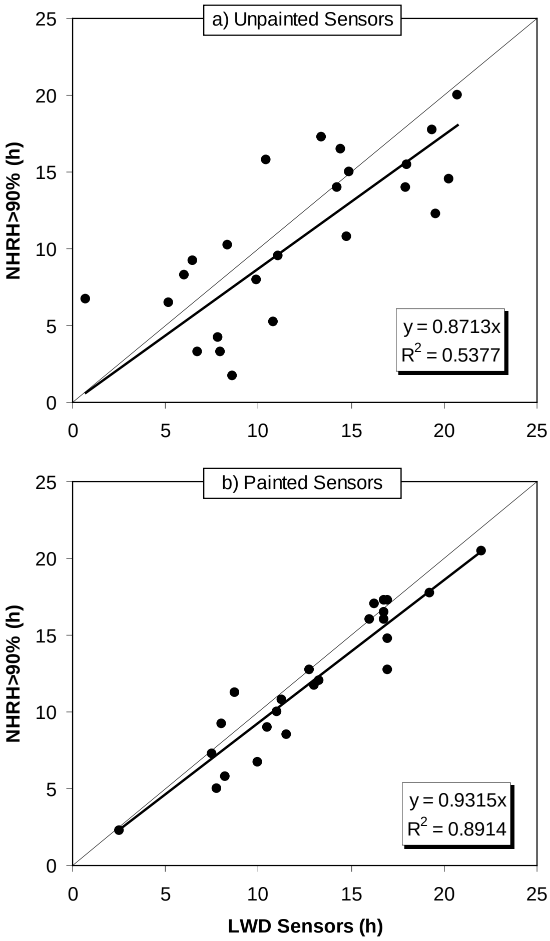

Figure 3. Relationship between the measured LWD (mean for the six sensors) and NHRH>90% with the sensors unpainted (a) and painted(b).