LEAF WETNESS MEASUREMENT: COMPARISON OF CYLINDRICAL AND FLAT PLATE SENSORS UNDER DIFFERENT FIELD CONDITONS

Paulo C. Sentelhas[1], Terry J. Gillespie[2], Eduardo A. Santos[3]

ABSTRACT – Leaf wetness duration (LWD) measurements obtained with painted cylindrical and flat plate sensors were compared under different field conditions in Elora, ON, Canada. The sensors were installed in four different crops: mowed turfgrass, maize, soybean, and tomatoes during the Summer of 2003 and 2004. Flat plate sensors were deployed facing north and at 45^o to horizontal and cylindrical sensors were deployed in the horizontal. At the turfgrass both sensors were installed at 30 cm above the ground, while at the crop fields the sensors were installed at the top and inside the canopy (except for maize, with a sensor only at the top). Considering flat plate sensor as reference (Sentelhas et al., 2004), the results showed that cylindrical sensor overestimated LWD by 1.1 to 4.5 hours, depending on the crop and position. The main cause of the overestimation was the deposition of big drops at the bottom of the cylindrical sensors, which required much more energy and time to evaporate. The difference between sensors when evaporating wetness formed during the night was around 1.7 hours. Cylindrical sensors also detected wetness earlier than flat plates, around 0.7 hours. These results allow us to conclude that cylindrical sensors should be used with caution for operational LWD measurements.

INTRODUCTION

Leaf wetness duration (LWD) is a difficult variable to measure or to estimate because it is driven by both atmospheric conditions and their interactions with the structure and composition of the vegetative community (Magarey, 1999). However, many efforts have been made during the past 35 years to develop electronic sensors to measure LWD (Huber & Gillespie, 1992, Sentelhas et al., 2004).

Recent studies showed that flat plate sensors, installed at 30 cm above the turfgrass, deployed at 30^o to 45^o to horizontal, and facing north, can provide accurate measurements of LWD when compared to visual observations (Sentelhas et al., 2004), and that this sensor protocol is a good option to estimate crop LWD (Sentelhas et al., 2004, Sentelhas et al., 2005). On the other hand, cylindrical sensors, developed by Gillespie and Duan (1987) for use in onions, are a cheaper option to measure LWD, since they are very simple to make. The cylindrical sensor has the same principle of measurement as the flat plate sensor, but its sensing surface is facing all 2π directions, while flat plate only faces the sky. This kind of sensor have been made by the Ontario Weather Network (OWN) and used in its weather station network to run disease warning-systems.

Gillespie and Duan (1987) tested cylindrical sensors and compared its performance whith flat plate and site-specific sensors, both at controlled and field conditions. In this study they concluded that dew tipically fell 1 to 2 hours earlier and lasted 2 to 3 hours longer on flat plates than on cylinders. However, authors did not give enough information about how sensors were deployed and if the measurements were compared to visual observation.

The objective of this study was to evaluate the performance of cylindrical sensors at different field conditions when compared to flat plate sensors, which can be considered as a reference (Sentelhas et al., 2004).

MATERIAL AND METHODS

The experiments were carried out at Elora Research Station - University of Guelph, in Elora, ON, Canada ($43^o49'$ N, $80^o35'$ W), during the summer of 2003 and 2004.

Painted LWD sensors were installed in four different crops: mowed turfgrass, maize, soybean, and tomatoes. Two kinds of sensors were used: flat plate (Model 237, Campbell Scientific, Logan, UT) and cylinders (diameter = 14 mm and length = 20 cm, OWN, Ridgetown, ON) (Figure 1). Flat plate sensors were deployed facing north and at 45^o to horizontal and cylindrical sensors were deployed in the horizontal. At the turfgrass field both sensors were installed at 30 cm above the canopy, while at the crop fields the sensors were installed at the top and inside the canopy, except for maize where only one sensor at the top was installed.

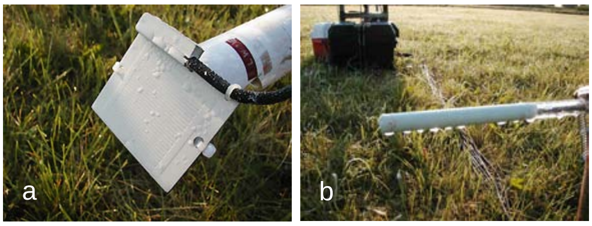

Figure 1. Flat plate (a) and cylindrical (b) LWD sensors installed over turfgrass, in Elora, ON, Canada.

Differences in time of wetness detection and evaporation between flat plate and cylinders were determined, considering each crop and all crops together. Daily LWD data obtained with both sensors were also compared using linear regression analysis.

RESULTS AND DISCUSSION

Considering the flat plate sensor as the reference (Sentelhas et al., 2004), the results showed that cylindrical sensors overestimated LWD on average by 1.1 to 4.5 hours (Table 1). The main cause of the overestimation was the deposition of big drops at the bottom of the sensor (Figure 1b), which require much more energy and time to evaporate.

The longer differences between the two sensors inside the crops (4.4 hours) than at top

[1] Professor, Departament of Exact Sciences, ESALQ, University of São Paulo, Piracicaba, SP, Brazil. Fellow of CNPq. E-mail: pcsentel@esalq.usp.br
[2] Professor, Department of Land Resource Science, Ontario Agricultural College, University of Guelph, Guelph, ON, Canada. E-mail: tgillesp@lrs.uoguelph.ca
[3] M.Sc. candidate, Departament of Exact Sciences, ESALQ, University of São Paulo, Piracicaba, SP, Brazil.

positions (1.8 hours) is also related to the deposition of drops at the bottom of the cylinders, which require much more time to evaporate inside the canopy, where sunshine and wind are very low. More details about the differences of LWD between sensors can be seen in Figure 1, for grass, Figure 2, for crop tops, and Figure 3, for inside the canopies.

Table 1. Average (Avg) LWD measured by flat plate (FP) and cylindrical (CYL) sensors in different crop canopies and positions, in Elora, ON, Canada.

Crop/Position	Year	LWD (h)		Diff.
		FP	CYL	(CYL-FP)
Turfgrass	2003	14.1	15.7	+1.6
Turfgrass	2004	13.9	16.6	+2.7
Maize-Top	2003	14.5	15.6	+1.1
Soybean-Top	2004	14.8	17.4	+2.6
Soybean-Inside	2004	12.7	16.9	+4.2
Tomato-Top	2004	14.7	16.4	+1.7
Tomato-Inside	2004	15.4	18.9	+4.5
Avg Turfgrass				+2.2
Avg Top				+1.8
Avg Inside				+4.4
Overall Avg				+2.6

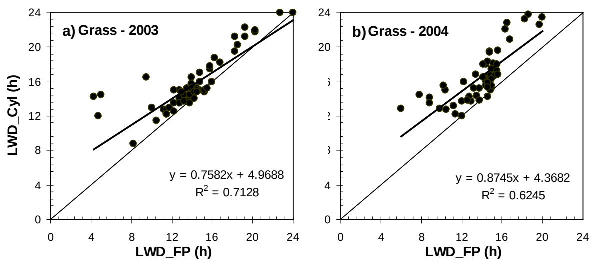

Figure 1. Relationship between LWD measured by flat plate and cylindrical sensors over turfgrass, in 2003 (a) and 2004 (b).

The analysis of the time that each sensor required to detect and to evaporate wetness (Table 2) provides us with more details about the performance of cylinders in relation to flat plates. The differences between flat and cylindrical sensors when evaporating the wetness formed during the night was on average 1.7 hours (Table 2), considering all conditions (nights with dew and dew+rain). Cylindrical sensors also detected wetness earlier than flat plates, around 0.7 hours (Table 2). These results allow us to conclude that cylindrical sensors should be used with caution for operational measurements, mainly when deployed in the horizontal, when big drops can form at the bottom of the sensor. New studies must be done to determine the best deployment of this sensor for operational LWD measurements for disease warning-system purposes.

REFERENCES

Huber, L., Gillespie, T.J. Modeling leaf wetness in relation to plant disease epidemiology. Annu Rev Phytopathol, 30:553-577, 1992.

Gillespie, T.J., Duan, R.-X. A comparison of cylindrical and flat plate sensors for surface wetness duration. Agric For Meteorol, 40:61-70, 1987.

Magarey, R.D. A theoretical standard for estimation of surface wetness duration in grape. PhD dissertation. 1999. Cornell University, Ithaca, NY, USA.

Sentelhas, P.C., Gillespie, T.J., Gleason, M.L., Monteiro, J.E., Helland, S.T. Operational exposure of leaf wetness sensors. Agric For Meteorol, 126:59-72, 2004.

Sentelhas, P.C., Gillespie, T.J., Batzer, J.C., Gleason, M.L., Monteiro, J.E., Pezzopane, J.R., Pedro Jr, M.J. Spatial variability of leaf wetness duration in different crop canopies. Int J Biometeorol, 2005 (in press).

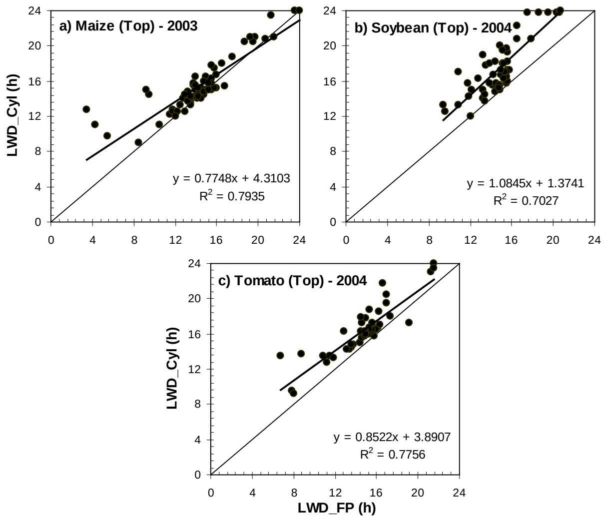

Figure 2. Relationship between LWD measured by flat plate and cylindrical sensors at the top of maize (a), soybean (b), and tomato (c) crops.

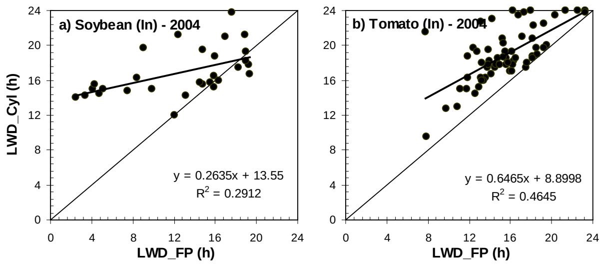

Figure 3. Relationship between LWD measured by flat plate and cylindrical sensors inside of soybean (a), and tomato (b) canopies.

Table 2. Wetness onset and dry-off differences between measurements obtained by cylinders and flat plate LWD sensors (CYL – FP).

Crop/Position	Year	Onset		Dry-off	
		n*	Diff.# (min)	n*	Diff.# (min)
Turfgrass	2003	68	-27	67	+47
Turfgrass	2004	91	-10	94	+115
Maize-Top	2003	71	-18	71	+31
Soybean-Top	2004	42	-25	40	+117
Soybean-Inside	2004	21	-165	22	+218
Tomato-Top	2004	44	-16	44	+73
Tomato-Inside	2004	42	-39	42	+104
Avg Turfgrass			-19		+81
Avg Top			-20		+74
Avg Inside			-102		+161
Overall Avg			-44		+101

* n = number of days considered, # Diff. = difference in time between cylinders and flat plate to onset and dry-off.