Evaluating leaf wetness duration models and their influence on a disease-warning system for strawberry

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Introduction

- **Disease-warning systems** help to optimize fungicide sprays, alerting when there are favorable environmental conditions for disease development.
- **Strawberry Advisory System (SAS)** is an example of a strawberry warning-system for **Anthracnose** and **Botrytis**, the main diseases in the crop production. SAS advices when growers should spray their fields, reducing applications up to 50% in comparison with the weekly calendar-based sprays;
- SAS and other disease-warning systems commonly monitor **LWD** and **temperature** to provide disease risk alerts.

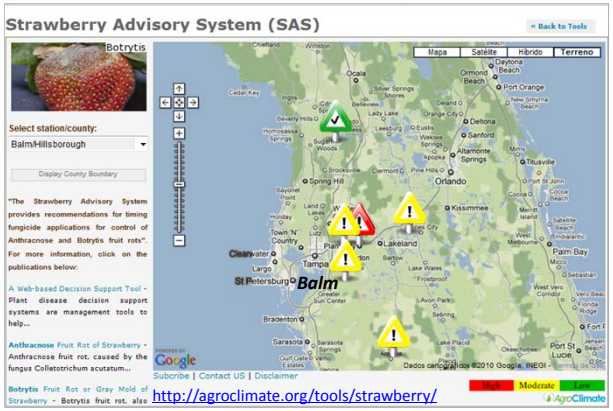

Figure 1. Florida Automated Weather Network (FAWN) stations used in SAS.

- **Leaf Wetness Duration (LWD)** is the period that the leaves of a crop are moist.
- Dew deposition and rainfall are the main **triggers** of moisture;
- LWD data are not usually available and might not be reliable, since there are different types of sensors and their coating, calibration, deployment angle and orientation, and height of installation are not standardized;
- **Modeling** LWD is an alternative to obtain reliable data for using as input in disease-warning systems. LWD models are classified into two categories: **physical** and **empirical**. The advantage of this last one is less complexity, but it might require local calibration for better performance.

Objectives

1. To evaluate the performance of four models to estimate LWD;
2. To evaluate how different LWD models influence SAS spray recommendations.

Material and Methods

- **Study Area and Data Source**

- A weather station with the top sensors available in the market of net radiation, relative humidity, temperature, and wind speed was installed in Balm (Figure 1).
- LWD measurements were obtained from a Florida Automated Weather Network station (FAWN) located in Balm. The period analyzed corresponds to the 2011/2012 and 2012/2013 strawberry seasons.

- **LWD Models**

- Classification and regression tree, CART, estimates LWD based on dew point depression, wind speed, and relative humidity through a binary classification tree;
- Dew point depression, DPD, based on the difference between air temperature and dew point temperature, 2°C onset and 3.8°C;
- Number of hours with relative humidity equal or greater than 90%, NHRH≥90%;
- Penman-Monteith, P-M, aerodynamic resistance model based on energy balance approach.

- **Disease risk occurrence**

- Anthracnose and Botrytis infection indexes were calculated based on LWD and temperature.

Figure 2. Strawberry diseases.

- **Data Analysis**

LWD models evaluation

- Daily measured and estimated LWD were compared based on coefficient of determination (R^2), Willmott agreement index (D), mean error (ME), mean absolute error (MAE), and efficiency (EF).
- 15-minute intervals measured and estimated were compared based on the fraction of correct estimates (F_C), the correct success index (C_{SI}), the false alarm ratio (F_{AR}), and the bias (B_S).

Influence of LWD models on disease risk occurrence

- Disease infection indexes were calculated using measured and estimated LWD and the results were compared based on R^2, D, ME, MAE, and EF.
- Disease risk occurrence calculated using measured and estimated LWD were compared based on F_C, C_{SI}, F_{AR}, and B_S, according to the contingency table above.

		Event	
		Model – spray	Model – no spray
Event	Sensor – spray	Hits (X)	Misses (Y)
	Sensor – no spray	False alarms (W)	Correct negatives (Z)

Results

- **LWD Models Evaluation**

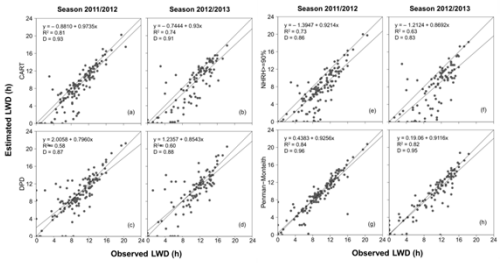

Figure 3. Relationships between observed and estimated LWD.

Table 1. Statistical indexes comparing measured and estimated LWD.

Models / Season	R^2	D	ME (h)	MAE (h)	EF (%)	F_C	C_{SI}	F_{AR}	B_S	p-value
CART										
2011/2012	0.81	0.93	-1.13	1.54	70.4	0.92	0.82	0.04	0.88	0.0371*
2012/2013	0.74	0.91	-1.46	2.05	59.7	0.90	0.78	0.05	0.86	0.0324*
DPD										
2011/2012	0.58	0.87	0.11	1.76	50.0	0.91	0.81	0.11	1.01	0.8390
2012/2013	0.60	0.88	-0.25	2.12	48.5	0.89	0.77	0.12	0.98	0.7207
NHRH≥90%										
2011/2012	0.73	0.86	-2.13	2.38	42.8	0.89	0.74	0.03	0.77	0.0000*
2012/2013	0.63	0.83	-2.54	3.02	23.3	0.86	0.69	0.05	0.75	0.0002*
P-M										
2011/2012	0.84	0.96	-0.25	0.98	83.3	0.95	0.87	0.05	0.97	0.6250
2012/2013	0.82	0.95	-0.71	1.34	79.0	0.93	0.85	0.05	0.93	0.2781

- **Influence of LWD models on SAS recommendations**

Table 2. Statistical indexes comparing the Anthracnose infection index calculated with measured and estimated LWD.

Models / Season	R^2	D	ME (h)	MAE (h)	EF (%)	F_C	C_{SI}	F_{AR}	B_S	p-value
CART										
2011/2012	0.80	0.94	-0.01	0.02	0.78	0.95	0.72	0.09	0.85	0.3204
2012/2013	0.80	0.93	-0.02	0.03	0.77	0.90	0.62	0.18	0.88	0.1968
DPD										
2011/2012	0.54	0.79	0.03	0.05	-0.38	0.92	0.67	0.27	1.22	0.0974
2012/2013	0.64	0.85	0.02	0.05	0.12	0.90	0.67	0.27	1.20	0.3158
NHRH≥90%										
2011/2012	0.82	0.91	-0.02	0.03	0.77	0.95	0.70	0.00	0.70	0.0538
2012/2013	0.85	0.94	-0.03	0.04	0.78	0.90	0.59	0.11	0.72	0.0496*
P-M										
2011/2012	0.78	0.93	-0.01	0.02	0.76	0.95	0.76	0.08	0.89	0.3158
2012/2013	0.80	0.94	-0.02	0.03	0.76	0.90	0.58	0.06	0.64	0.3350

Table 3. Statistical indexes comparing the Botrytis infection index calculated with measured and estimated LWD.

Models / Season	R^2	D	ME (h)	MAE (h)	EF (%)	F_C	C_{SI}	F_{AR}	B_S	p-value
CART										
2011/2012	0.87	0.96	-0.04	0.05	0.83	0.98	0.73	0.11	0.90	0.0996
2012/2013	0.77	0.92	-0.05	0.07	0.72	0.94	0.63	0.00	0.63	0.0808
DPD										
2011/2012	0.56	0.85	0.02	0.08	0.24	0.96	0.63	0.38	1.60	0.4090
2012/2013	0.59	0.87	0.01	0.10	0.41	0.91	0.55	0.33	1.13	0.6914
NHRH≥90%										
2011/2012	0.82	0.92	-0.07	0.08	0.70	0.98	0.73	0.11	0.90	0.0018*
2012/2013	0.74	0.89	-0.08	0.10	0.59	0.92	0.44	0.00	0.44	0.0028*
P-M										
2011/2012	0.83	0.95	-0.02	0.04	0.81	0.99	0.80	0.00	0.80	0.2875
2012/2013	0.77	0.92	-0.05	0.07	0.72	0.92	0.47	0.11	0.56	0.1109

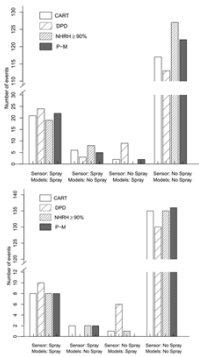

Figure 4. Anthracnose (top) and Botrytis (bottom) spray recommendations based on measured and estimated LWD.

Conclusions

DPD model overestimated LWD when values were < 12 h, overestimating the number of sprays recommended, whereas NHRH90% underestimated LWD and sprays. CART and P-M underestimated LWD, but still had reasonable performance to be used in disease spray recommendations.