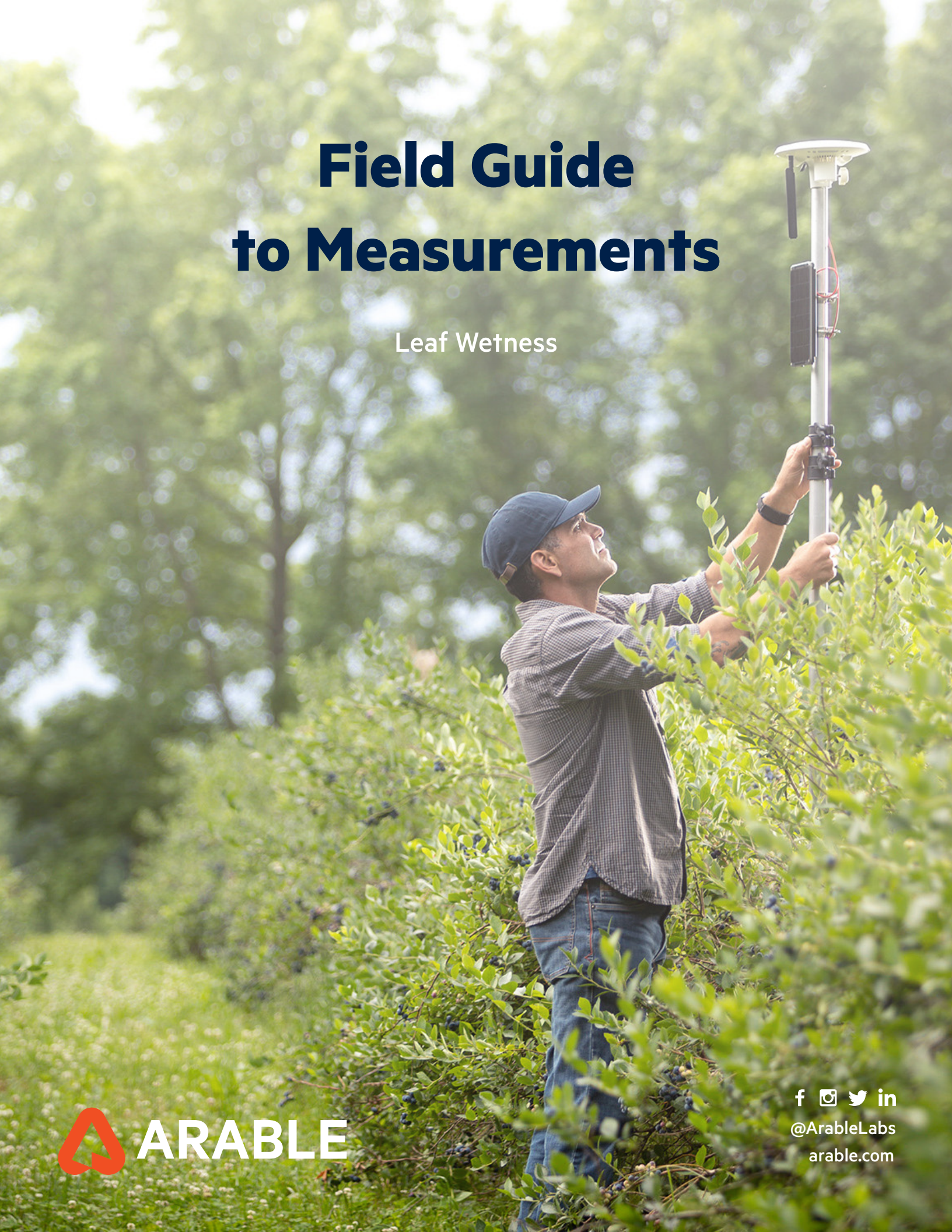
Field Guide to Measurements

Leaf Wetness



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LEAF WETNESS

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APPLICATIONS:

Crop protection, disease risk, pesticide scheduling, irrigation scheduling

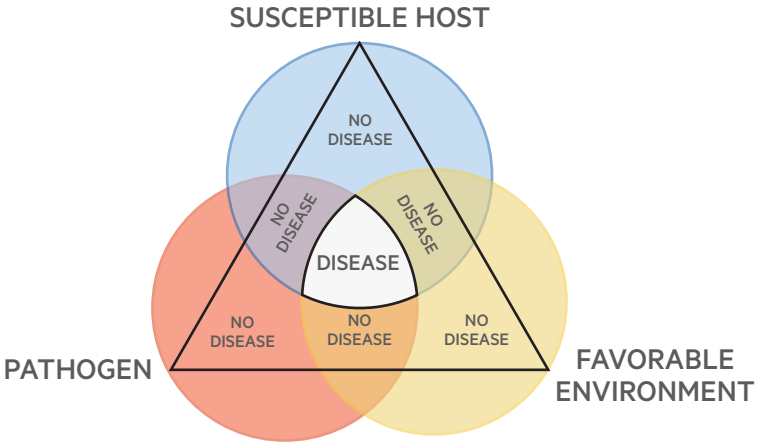
OTHER RELATED MARK MEASUREMENTS:

Relative humidity (RH)
Air temperature (T)
Growing Degree Days (GDD)
Normalized Difference Vegetation Index (NDVI)
Chlorophyll Index (CI)

What is it?

Leaf wetness (LFW) is simply the presence of water on the surface of the crop. Although this sounds innocuous, it is exactly what some microorganisms or small arthropods need to go from harmless bugs to crop-destroying pests.

Why do we measure it?



The disease triangle illustrates the phenomenon of plant disease. Based on *21st Century Guidebook to Fungi, SECOND EDITION, by David Moore, Geoffrey D. Robson and Anthony P. J. Trinci*, updated July, 2019.

When is a bug a pest?

The virulence of a pathogen is an interplay between factors: the environment, the plant (the pathogen's host), and the time that these factors are present. Bacteria, viruses, fungi, oomycetes, and invertebrates only become pests when their population surpasses a certain threshold and begins to cause damage. For pest populations to grow past that threshold, the required plant and environmental conditions must be met for the organism to do the two most important things in life: eat and reproduce. Leaf wetness is one of the most commonly used indicators that a field is an appetizing breeding and feeding ground for pests. This is because dew provides a favorable environment for spores germination and the temperature during the wet period determines the rate of infection—especially bacterial, fungal, and oomycete species.

How do we measure it?

At Arable, we meticulously monitor those factors through the following conditions:

ENVIRONMENTAL CONDITIONS

- Air and leaf temperature (T)
- Dew point temperature (T_{dew})
- Relative humidity (RH)
- Precipitation (Precip)
- Soil water content (SWC)
- Saturated vapor pressure (e_{sat})
- Actual vapor pressure (e_a)
- Vapor pressure deficit (VPD, or $e_{sat} - e_a$)

PLANT CONDITIONS

- Normalized Difference Vegetation Index (NDVI)
- Growing Degree Days (GDD)
- Chlorophyll Index (CI)
- Leaf Wetness (LFW)

Arable reports daily LFW as the hours after midnight when the environmental conditions are suitable for moisture to settle on the leaf surface. We know a leaf is wet when the leaf temperature is equal to or below the dew point temperature (the temperature at which air cools to reach saturation). To figure this out, we first do calculations based on four variables: surface temperature (T), relative humidity (RH), vapor pressure (e_a), and dew point temperature (T_{dew}).

First, we calculate the actual vapor pressure in the air. What is the pressure differential between how saturated the air is with water and how saturated it could be?

$$e_a = e_{sat}RH$$

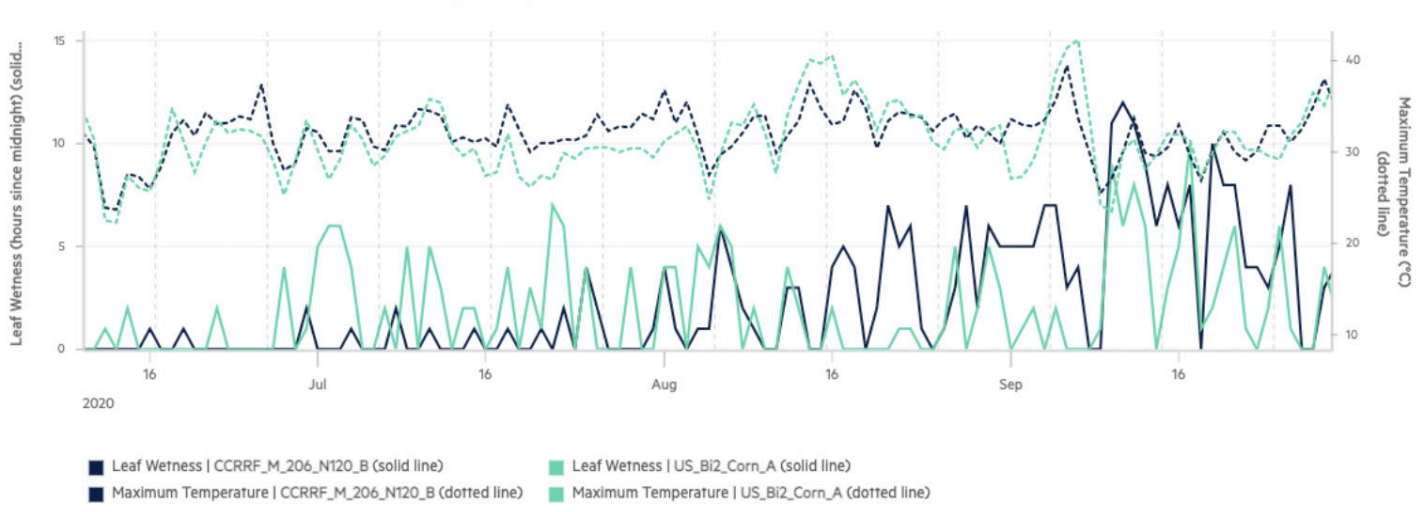
Second, we calculate the dew point temperature. What temperature does it need to be for the air to become so saturated with water vapor that it condenses into liquid?

$$T_{dew} = \frac{116.91 + 237.3 \log(e_a)}{16.78 - \log(e_a)}$$

Finally, the output is the result of Arable's unique model which incorporates measurements of relative humidity, precipitation, dew temperature, and surface temperature to find out how long the leaf temperature is below or equal to the dew point temperature, which translates to a metric of leaf wetness duration over a 24-hour window.

What does the data look like?

Arable reports LFW in hours per day from 12:00am to 11:59pm.



Leaf wetness and maximum temperature at two locations in California, as viewed in Arable Web.

How can you use it?

Arable can help you predict the threat level for pest infestation by monitoring the field conditions that determine a pest's ability to eat and reproduce. In combination with the expected growth stage based on the number of growing degree days and the health status of the plant (NDVI, CI), leaf wetness hours can serve as a warning system for when to monitor your fields closely or when to plan for pest-prevention interventions. To use it effectively, you may need to know the basics about the pest under consideration such as:

- The season or plant growth stage during which the infection occurs in your region
- The temperature range at which infection generally occurs
- The leaf wetness duration typically required for infection

This information can easily be found or inferred through various research and educational institutions such as the University of California Agriculture and Natural Resources (UCANR) Integrated Pest Management (IPM) group: http://ipm.ucanr.edu/index.html

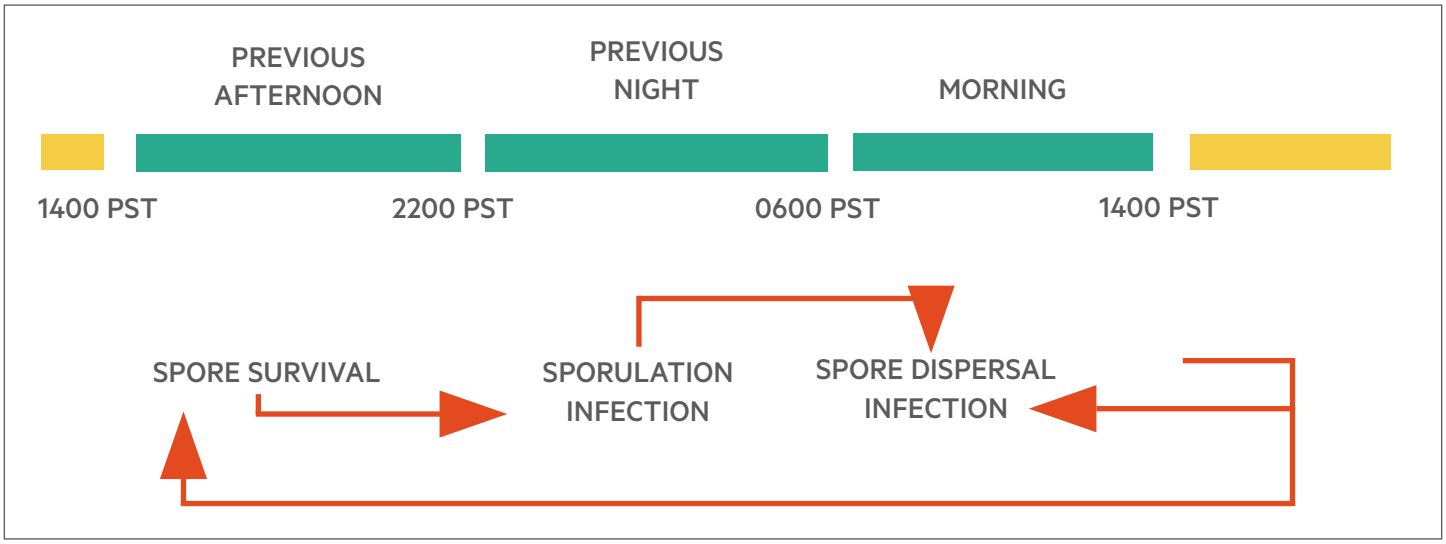
The virulence of many diseases are affected by leaf wetness, such as:

- apple scab
- cedar apple rust
- potato blight
- tomato early blight
- strawberry fruit rot
- botrytis fruit rot (strawberry & grape)
- citrus brown spot
- pear brown spot
- scotty blotch and flyspeck (apple)
- grape powdery mildew

Downy mildew on a grape leaf.

Example use case

Lettuce downy mildew (Bremia lactuae), for example, occurs during damp, cool conditions when the leaves of the lettuce are wet. Management choices such as choosing drip irrigation over spray irrigation can help reduce the likelihood that leaves are wet long enough for infection, but nothing beats the certainty of knowing how long your leaves are wet during uncontrollable weather conditions that are perfect for B. lactuae sporulation and infection. As shown below, a combined knowledge of your pest infection cycle and field condition monitoring with the Arable Mark can serve as a warning system for inoculation and symptom occurrences.



"Schematic representation of the infection cycle of lettuce downy mildew. Weather variables were summarized separately for the periods afternoon, night, and morning to match the biology of the pathogen. PST = Pacific standard time." Modified from *Scherm H., and van Bruggen, A.H.C. 1994. Weather Variables associated with infection of lettuce by downy mildew* (Bremia lactucae) *in coastal California. Phytopathology 84:860-865.*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