e-GRO Alert


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Dialing in Diagnostics: Lettuce Leaf Tissue Standards

Revised leaf tissue nutrient standards for greenhouse lettuce published.

Figure 1. When making sure your crop is on target through predictive sampling or when nutrient disorders occur, there is a need for refined standards in order to make correct diagnosis. (Photo: Brian Whipker).

The ever-increasing buzz of how "big data" can be utilized in all aspects of science, including agriculture presents novel solutions to advance growing practices going forward. Greenhouse production we are blessed with the ability to grow thousands of species. It is never boring! However, greenhouse crops lack the large datasets that are commonly available for larger commodities such as corn, soybeans, and wheat. This is also our dearth, for our primary attention focuses on the major crops.

Being technical problem solvers for growers, our toolbox for leaf tissue nutrient standards is limited. Our best resource is the Plant Analysis Handbook IV by Bryson et al. (2014). This offers a baseline set of values that focused on a survey approach of sampling "healthy" growing plants. It is the guide used by most leaf tissue nutrient analysis labs in

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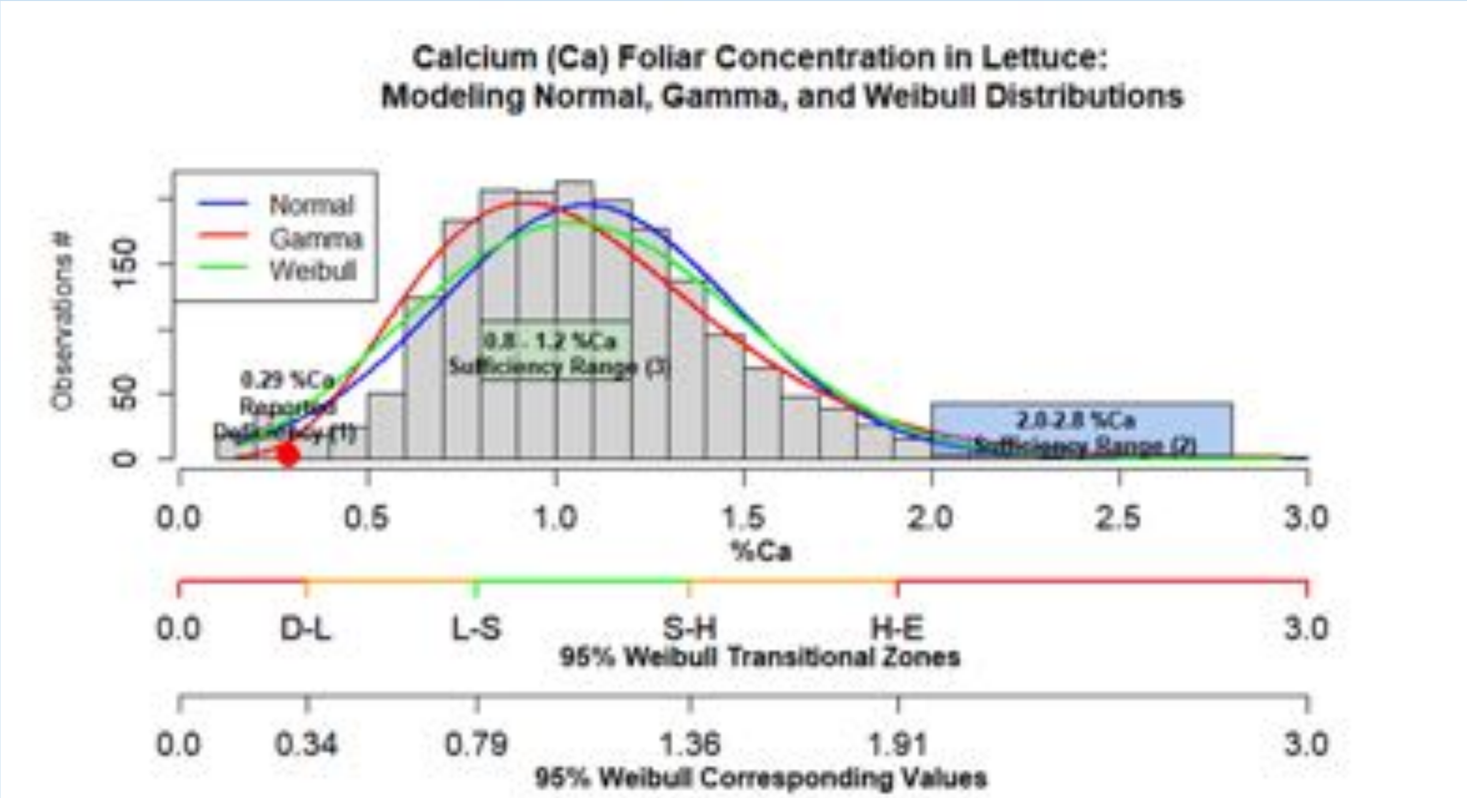

Figure 2. Calcium leaf tissue standards evaluated by distribution curves which defined more robust nutrient ranges. (Figure: Patrick Veazie)

the United States. While these values provide a target range for "healthy" plants it does not allow you to determine what would be considered deficient, low, high, or excessive values in order to properly diagnose a problem (Fig. 1). This provides a challenge when diagnosing nutritional problems when values fall outside of what is considered "healthy". This creates a need to develop a better method, but the number of species, cost, and time makes this a challenge.

The North Carolina Department of Agriculture and Consumer Services (NCDA&CS) began examining their methods for providing recommended ranges for horticulture crops and wanted to improve them. Together, the large historical grower sample dataset of NCDA&CS, coupled with plant nutrition studies conducted at NCSU focusing on lettuce, we aimed to expand our dataset to include both grower and research samples to capture diagnostic and predictive samples nationwide. To enhance the dataset, we reached out to our colleagues for additional samples. Working with Dr. Cari Peters of J.R. Peters, Dr. Jennifer Boldt of USDA, Dr. Neil Mattson of Cornell University, Dr. Jake Holley of Colorado State University, Dr. Nathan Eylands of University of Minnesota, and Dr. Roberto Lopez and Devin Brewer of Michigan State University, we were able to amass a dataset of 1950 observations. Additionally, with the assistance of Dr. Hsuan Chen at NCSU we developed and evaluated a method of creating distribution curves that would best represent the non-normalized distributions associated with the foliar nutrient concentrations of greenhouse grown lettuce.

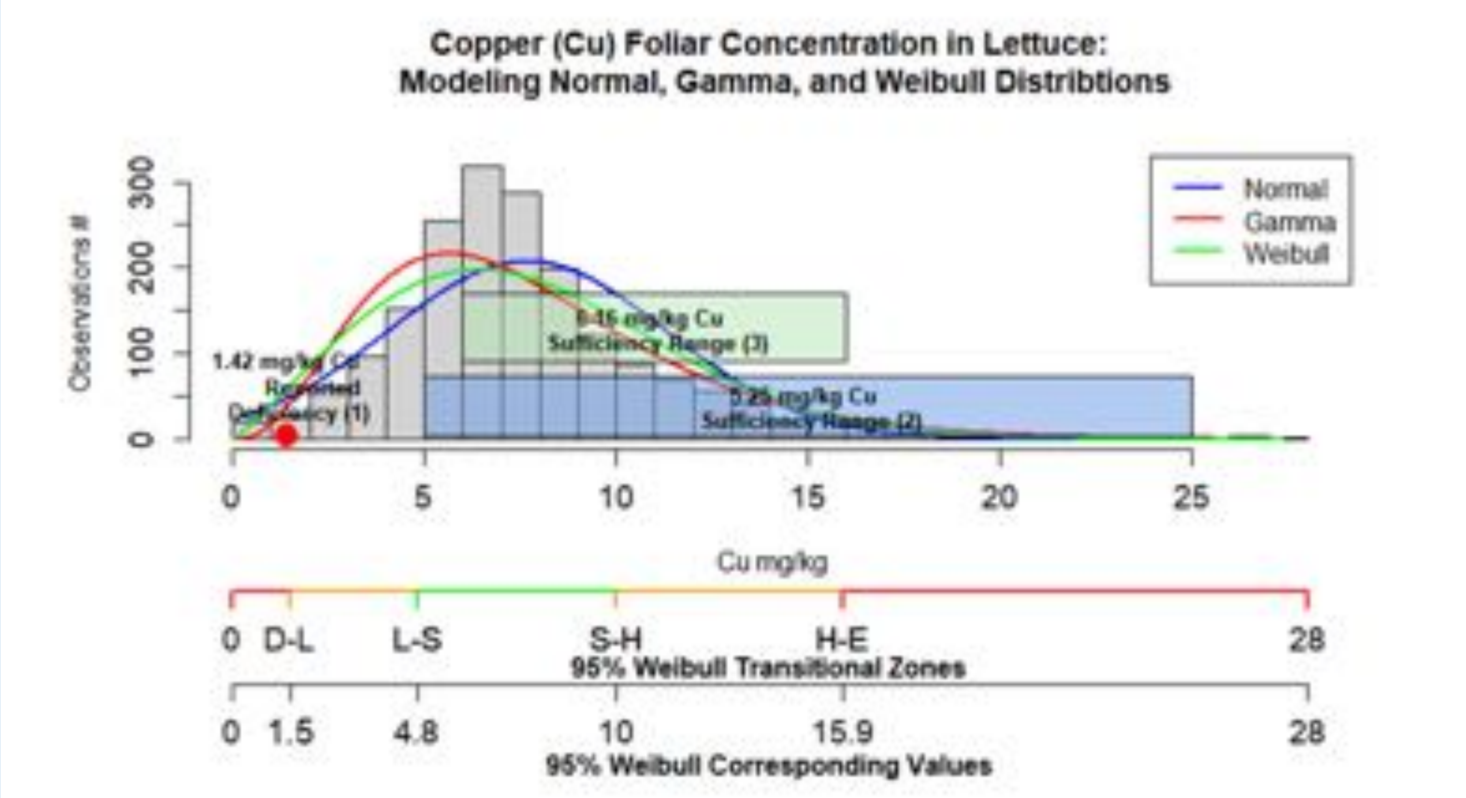

Figure 3. Copper leaf tissue standards evaluated by distribution curves which defined more robust nutrient ranges. (Figure: Patrick Veazie)

The Goal. In order to improve the diagnostic categorization of leaf tissue nutrient concentrations, our goal was to evaluate suitable data distribution curves that created more refined ranges of deficient (lowest 2.5%), low (2.5-25%), sufficient (25-75%), high (75-97.5%), and excessive (highest 2.5%) interpretation zones for each element, based on a modified Sufficiency Range Approach.

The Solution. With the large dataset available, we were impressed about how well the statistical analysis created a more refined sets of leaf nutrient standards for greenhouse grown lettuce. Table 1 contains a complete set of recommended deficient, low, sufficient, high, or excessive ranges for the primary macro- and microelements. For additional details of how the study was conducted, view a complete set of distribution curves, and recommended ranges, please download (free) the scientific paper (Veazie et al., 2024). These refined values offer an improvement in diagnosis plant nutritional problems.

To illustrate this point, with the macronutrient calcium (Ca) (Fig. 2), the results followed all three distribution curves (normal, gamma and Weibull) fairly well [based on similar Bayesian Information Criterion (BIC) scores that only varied by 28 units]. Based on these curves, a recommended sufficiency range of 0.79-1.36% Ca would be recommended. In comparing these new ranges with prior reported values, we extended the upper end of the current Ca sufficiency range of 0.8-1.2% Ca reported by Bryson et al. (2014), but lowered the upper range of 0.88-2.0% Ca reported by Van Eysinga and Smilde (1981) and 2.0-2.8% Ca reported by

Jones (2005). The Ca deficiency foliar concentration of 0.34% Ca was slightly greater than the 0.29% Ca reported by Henry et al. (2018), which confirms that this suggested deficiency range encompasses previously reported deficient values. Currently, there are no published Ca excessive or toxicity values for lettuce. However, luxury consumption of Ca can occur when abundant Ca is supplied and this may be reflected in the higher recommended range of 2.0-2.8% Ca reported by Jones (2005). The upper 2.5% of samples set the excessive range threshold at 1.91% Ca. The proposed excessive range establishes an upper threshold to prevent the occurrence of decreased K and Mg uptake as a result of excessively high Ca foliar concentrations.

We also had similar results with the microelements. Those distributions are typically more skewed towards zero because the "normal" range is so small. An example would be copper (Cu), where most values tend to be under 10 ppm.

From Figure 3 illustrating Cu, a recommended sufficiency range of 4.8-10 ppm Cu narrows the current recommendations of 5.1-17.2 ppm (Van Eysinga and Smilde, 1981), 5-25 ppm (Jones, 2005), and 6-16 ppm Cu (Bryson et al., 2014). A deficiency range of <1.5 ppm Cu encompasses the deficiency value of 1.42 ppm reported by Henry et al. (2018), but is higher than the <2.54 ppm Cu reported by Van Eysinga and Smilde (1981). Currently, reported toxic Cu foliar

Table 1. Revised lettuce leaf tissue nutrient interpretation values based on 1950 samples analyzed by the Sufficiency Range Approach.

Element	Unit	Deficient	Low	Sufficient	High	Excessive
Nitrogen (N)	%	<2.84	2.84-4.38	4.38- 5.79	5.79-6.89	>6.89
Phosphorus (P)	%	<0.27	0.27-0.58	0.58-0.96	0.96-1.31	>1.31
Potassium (K)	%	<2.93	2.93-5.72	5.72-8.82	8.82-11.55	>11.55
Calcium (Ca)	%	<0.34	0.34-0.79	0.79-1.36	1.36-1.91	>1.91
Magnesium (Mg)	%	<0.15	0.15-0.31	0.31-0.56	0.56-0.90	>0.90
Sulfur (S)	%	<0.11	0.11-0.19	0.19-0.30	0.30-0.45	>0.45
Iron (Fe)	ppm	<35.8	35.8-77.6	77.6-148.9	148.9-247.9	>247.9
Boron (B)	ppm	<15.3	15.3-25.4	25.4-40.3	40.3-58.9	>58.9
Manganese (Mn)	ppm	<18.7	18.7-70.7	70.7-167	167-285.1	>285.1
Zinc (Zn)	ppm	<12.1	12.1-33.9	33.9-65.9	65.9-99.7	>99.7
Copper (Cu)	ppm	<1.5	1.5-4.8	4.8-10.0	10.0-15.9	>15.9

concentrations of lettuce are concentrations >21 ppm Cu (Van Eysinga and Smilde, 1981) and 20-100 ppm (Jones, 2005). This current research lowers the transition between high and excessive zones to >15.9 ppm Cu.

Conclusions. The refinement of leaf tissue nutrient standards is an ongoing process. Prior reported values helped develop initial deficient, sufficient, and in some cases excess ranges. The data utilized in creating those ranges were limited, thus in many cases, such as deficiency values, they identified a number along a wider continuum, but not the entire zone where deficient values occurred. For diagnosing nutritional problems in lettuce, a more refined system was needed. This study's approach was to utilize a larger dataset and fit appropriate distribution models to provide more defined ranges beyond the sufficiency zone to also enable the identification of samples that were deficient, low, sufficient, high, or excessive. The establishment of five ranges helps delineate previously reported lower and upper values included in the sufficiency range into more refined zones. These five zones will aid technical specialists and analytical labs in more accurately classifying and diagnosing nutritional disorders. This research demonstrates the usefulness of utilizing large datasets to make recommendations for greenhouse grown crops nationwide allowing for more precise grower resources.

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