Portable Light Element Analysis for Nutritious Crop Management

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Introduction

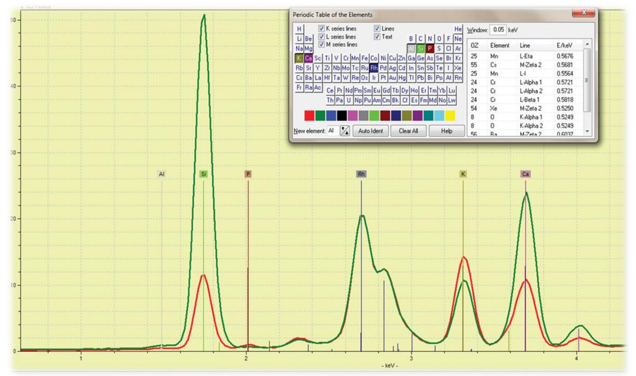
Portable XRF is generally used for on-site soil investigations of heavy metals caused by anthropogenic pollution and their migration due to climate change or catastrophic geological and extreme weather events. This presentation describes portable X-ray Fluorescence (XRF) analyzers that are also capable of light element measurements and sophisticated spectral analysis.

These features expand the use of portable and handheld XRF to on-site efficacy studies of light-element fertilizers, pesticides, fungicides and other treatments. They enable scientists to investigate plant uptake and the mobility of nutrients, such as magnesium, phosphorus, sulfur, potassium and calcium. Handheld XRF analyzers can even be used to monitor light element (P) fertilizer run-off.

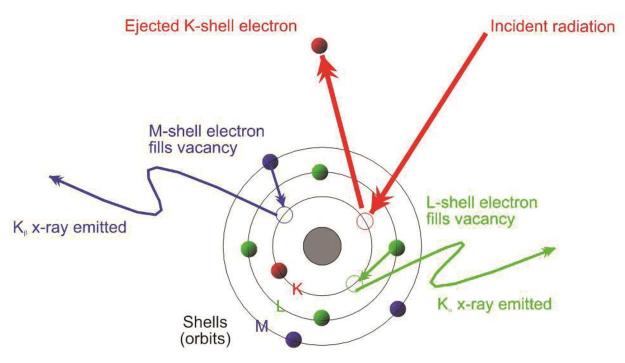
XRF Technology

As humans, we characterize an object by “capturing” what we see at a molecular level when light shines on it. For instance, we see color differences in the leaves of two brands of corn seed, light and dark green. XRF characterizes what it sees at an elemental level in the form of photon energies and intensities. For instance, it sees more phosphorus and potassium in the light green leaves.

Molecular View of Corn Leaves



Elemental View of Corn Leaves



XRF Photon and Electron Interactions

Portable XRF Equipment

Portable XRF analyzers used for this review enable adjustable tube power, changeable standard or user-fabricated filters and can be equipped with a vacuum or helium photon path to provide useable detection limits for portable light element analysis. Combined with highly sophisticated spectral analysis capability, these XRF systems provide a critical tool which helps scientists understand plant uptake and mobility of nutrients.

Tracer Handheld XRF Analyzer

ELIO Portable XRF Analyzer

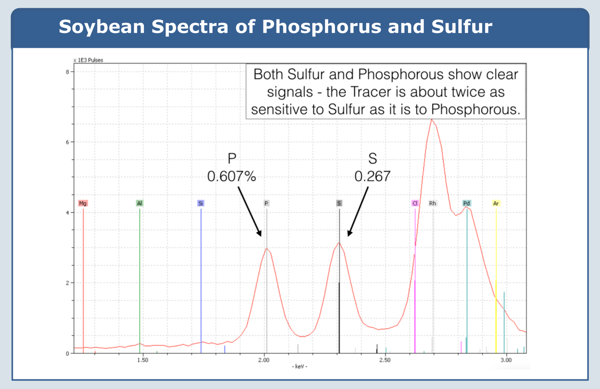
Results

Light Elements in Soybeans

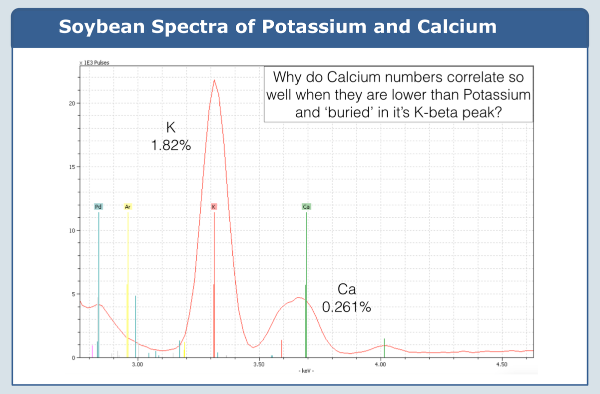
The sulfur containing amino acid in soybeans, methionine, is a critical source of nutritional protein. Monitoring the sulfur substrate, as well as calcium and potassium, helps scientists support commercial and poor rural community farmers to achieve higher soybean yields.

Calcium’s measurement is not as straightforward as sulfur because its Kα peak overlaps with the potassium Kβ peak. However, instrument parameters were optimized and data was normalized to the net Rhodium L-shell photons yielding quantitative results that correlate well with ICP data.

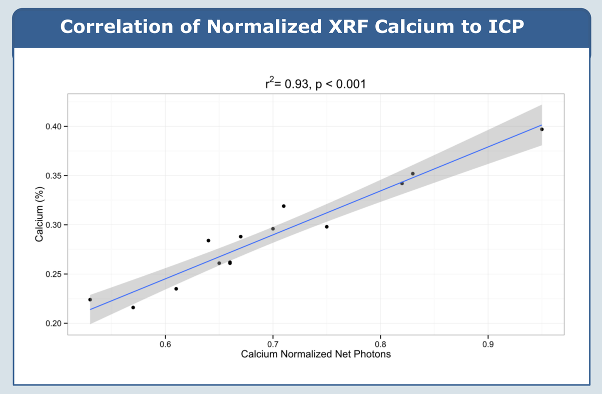
Soybean Spectra of Phosphorus and Sulfur



Soybean Spectra of Potassium and Calcium



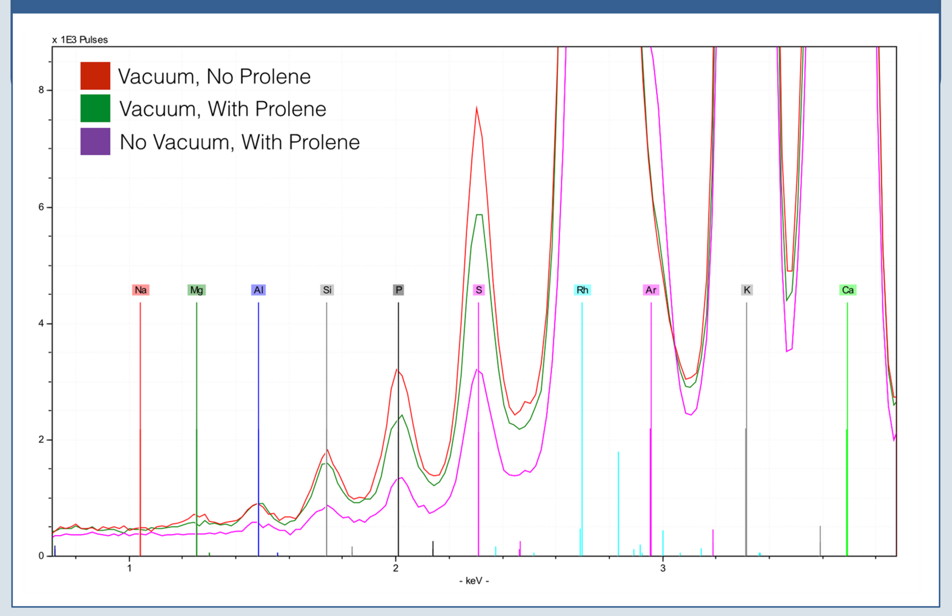
Correlation of Normalized XRF Calcium to ICP



Optimal Sample Presentation for Quantitative Plants Analysis

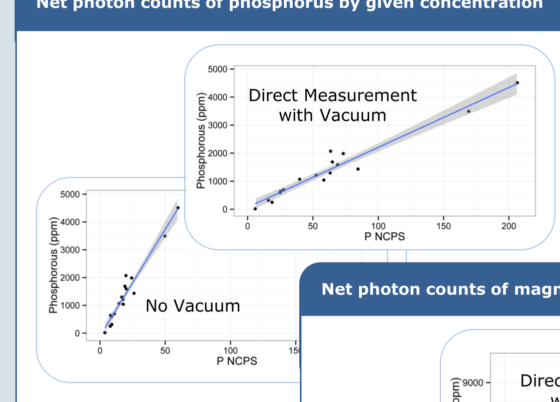
Three different sample presentation forms for NIST 1547 Peach Leaves were analyzed for 180 seconds each. These included direct measurement of plant samples on the nose of the instrument with a vacuum <5 torr, placement of sample cups using 4μm prolene on the nose of the instrument with <5 torr, and placement of sample cups using 4 μm prolene with no vacuum (e.g. dry air conditions.).

Spectra of NIST 1547 with three sample presentation methods

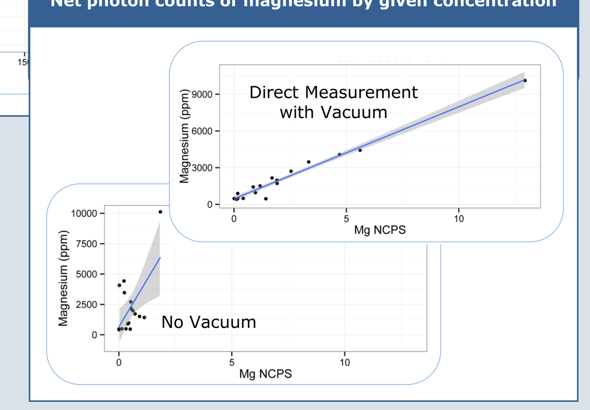


Mg at 4,000 ppm, P at 1,296 ppm, S at 1,779 ppm

Net photon counts of phosphorus by given concentration

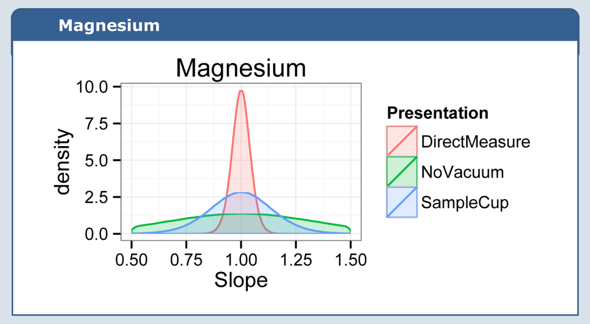


Net photon counts of magnesium by given concentration

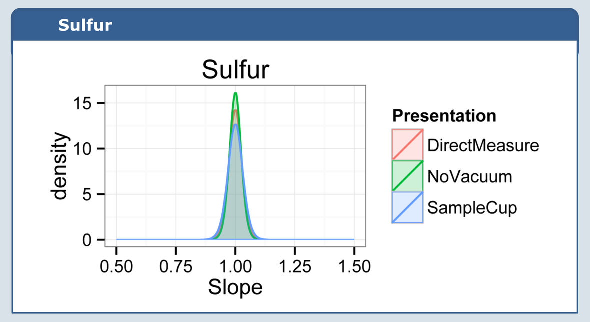


Net photon count rates by concentration data for magnesium and phosphorus with three presentation methods were compared. Markov Chain Monte Carlo regressions were run to observe variance in the slopes of the relationship for calibration performance evaluation. Sensitivity for light elements was clearly best using vacuum with direct contact. For elements heavier than sulfur, there was a less significant change in sensitivity. A slope of 1 indicates a 1:1 correspondence of measured:given.

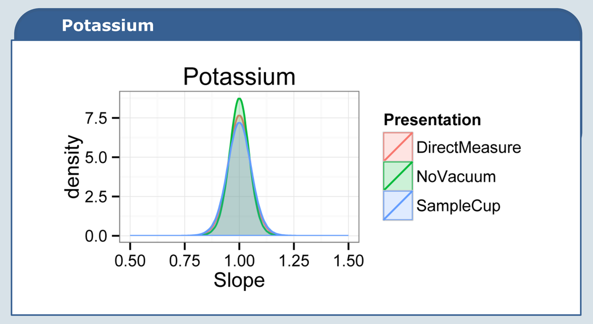
Magnesium



Sulfur



Potassium

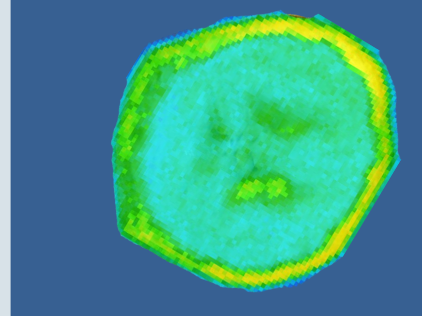


Mapping Elemental Nutrients

Elemental mapping of food with portable XRF identifies nutrient rich locations. Multiple spectral data points and digital images can be collected simultaneously and stitched together providing XRF data in definitive images of elemental nutrient distribution.

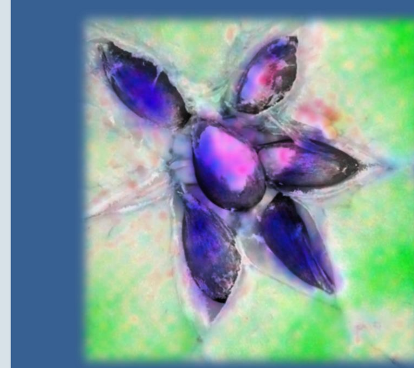
The Portable ELIO XRF Mapping System can Produce Maps of Elemental Nutrient Rich Sections of Produce

Banana Slice



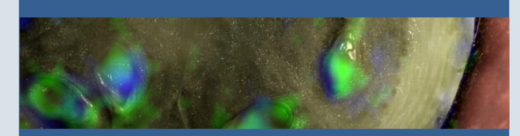
ELIO Portable XRF Map
Potassium (yellow)

Apple Core Slice



ELIO Portable XRF Map
Calcium (blue)
Potassium (green)
Sulfur (red)

Zucchini Slice



ELIO Portable XRF Map
Phosphorus (green) Potassium (blue)

Summary

Portable XRF is clearly an effective light element analysis tool for nutritious crop management. It is used to help determine ways to increase yield for adequate food supplies in poor rural communities, to help ensure food is free from heavy metal contamination, to help determine how nutrients are dispersed within produce and to help commercial producers increase profitable yields both in the field and via treatments prior to shipment.

Acknowledgements

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X-Ray Fluorescence