HHXRF, TXRF, MICRO-XRF

FROM SEED TO HARVEST

XRF Solutions for Mineral Nutrient and Heavy Metal Analysis

Innovation with Integrity

XRF Solutions for Agriculture Applications

Bruker's portfolio of XRF analyzers includes various handheld, portable and benchtop spectrometers. They provide elemental analysis solutions to measure mineral nutrients and screen for dangerous levels of heavy metals and other toxic elements. Our XRF spectrometers are used around the world for applications from seeds to harvest, enabling profitable and high-quality yields at large, small-holder, urban and boutique farms.

X-ray fluorescence analysis of plants

Key environmental factors, such as temperature, humidity, light, soil pH and mineral nutrients, affect the quality of a plant system.

Potential success is best assessed when information on all these environmental factors is available in real-time, throughout the life cycle of the plant system.

XRF is a non-destructive elemental analysis method with minimal to no sample preparation which provides real-time value-driven data from the root to the shoot of any plant system.

Several Bruker XRF instruments can be used to easily measure mineral nutrients and to screen for dangerous levels of heavy metals and other toxic elements:

- Portable XRF spectrometers (S1 TITAN, TRACER 5, CTX) quickly monitor mineral nutrients, heavy metals, and other elements in-situ to determine ultra-low elemental concentrations in liquids and biological tissues.
- Micro-XRF spectrometers (M4 TORNADO, ELIO) provide elemental density distribution maps of plant biosystems.
- TXRF spectrometers (S2 PICOFOX, S4 T-STAR®) easily determine ultra-low elemental concentrations in liquids and biological tissues.

Handheld, mobile, and portable benchtop XRF analyzers (HHXRF and PXRF)

S1 TITAN, TRACER 5 and CTX are the most agile XRF analyzers to simultaneously measure elements from sodium (Na) to uranium (U) at concentrations as low as parts-per-million (ppm) to high percentage levels. These analyzers can be used on samples of any form (liquid, solid, powder, film) and the analysis can be performed in any location – in a greenhouse, in the field, or even at sea. Factory ready calibrations for soils, plants and fertilizers are available. EasyCal PC software is also available for customers to develop their own calibrations.

Figure 1
Handheld, mobile, and portable benchtop XRF analyzers (HHXRF and PXRF)
Left top: S1 TITAN
Left bottom: TRACER 5
Right: CTX

Portable and laboratory benchtop micro-XRF analyzers (micro-XRF)

M4 TORNADO and ELIO are micro-XRF spectrometers providing composition and element distribution maps (2D area scans). The high-performance laboratory spectrometer M4 TORNADO provides a small spot size (down to < 20 µm) and allows multilayer analysis (12 selectable layers). The non-contact portable ELIO has a spatial resolution of 1 mm.

Figure 2
Portable and laboratory benchtop micro-XRF analyzers (micro-XRF)
Left: ELIO
Right: M4 TORNADO

Portable and laboratory benchtop total reflection X-ray fluorescence analyzers (TXRF)

S2 PICOFOX and S4 T-STAR® are mobile and laboratory TXRF spectrometers for ultra-trace (sub-ppb) to high percentage elemental analysis. These instruments only require very small sample amounts in the ng or µg range and have low operating costs. Moreover, these "green" analyzers do not require the use of time-consuming sample digestion with hazardous chemicals.

Figure 3
Portable and laboratory benchtop analyzers (TXRF)
Left: S2 PICOFOX
Right: S4 T-STAR®

Plant-based Agriculture

Plant-based agriculture involves the science, art, and skill of cultivating profitable commodity crops which provide health benefits and enjoyment.

Scientists help develop practices for sustainable and regenerative agriculture to enhance soil and crop quality, boost crop resilience, reduce unnecessary inputs, regain nutrient density of foods and restore the fertility of soils. In addition to increasing healthy crop yields, these practices can help mitigate the impact of changing climate on soil and crop health, including the ability to retain and sequester CO_2 and to increase the capacity of soils to hold more water.

Physical components of a plant system

Plant systems start with quality seeds placed in planting media such as soil, peat moss, coconut coir, rockwool, perlite, vermiculite or an aqueous solution. Needs for inputs, such as fertilizers, vary depending on the plant, the condition of the media for that plant and the overall environment the plant has grown in. Plants also need quality water for their physical ability to absorb nutrients. A robust root system helps deliver water and minerals up to the shoot system.

- Soil: holds roots and contains or stores minerals, metals and water; other grow media include peat moss, coconut coir, rockwool, perlite, vermiculite and aqueous solutions.
- Seeds: contain protein, starch, and oil to help in the early stage of growth and development.
- Fertilizers, amendments, insecticides, fungicides and herbicides: supplement nutrients, improve soil characteristics and protect from insects, molds, and weeds.
- Water: quality water helps a plant to stand enabling transport of minerals and metals.
- Root system: tap and lateral roots provide stems and leaves with water and minerals.
- Shoot system: stems, nodes, buds, leaves, flowers and fruit accumulate minerals and metals.

Figure 4
Schematic representation of the physical components of a plant system.

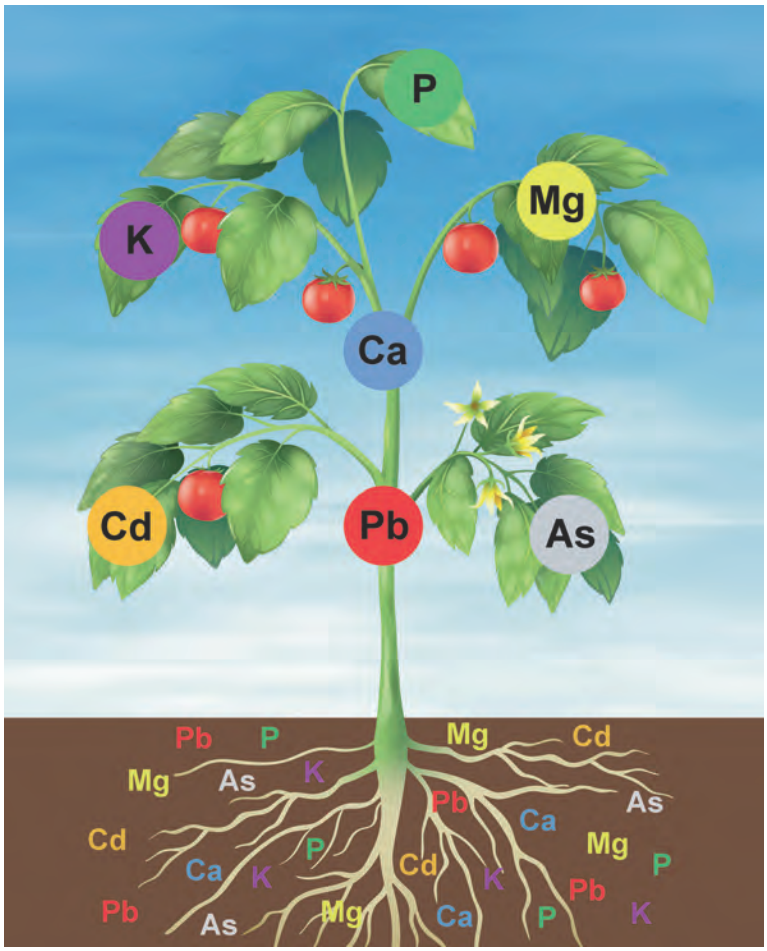


Figure 5
Handheld XRF spectrometers like the S1 TITAN are used to quickly screen soil for minerals and toxic metals.

Figure 6
The CTX is a portable benchtop spectrometer and pre-calibrated to measure elements for a given application.

Soil

Healthy soil and other grow media secure roots and store minerals, metals and water for plants. Planting media is ideally rich with mineral nutrients and devoid of toxic elements, especially heavy metals. PXRF is a standard method to characterize soil content. It can be directly measured with handheld XRF spectrometers to quickly screen for elements of interest, minerals and dangerous levels of toxic metals.

The most accurate and precise XRF results for soil samples are achieved with lab-like sample preparation. Methods like the US EPA Test Method 6200 and norms like EN 15309:2007 and ISO 13196:2013 provide guidance for direct soil, bagged soil and lab-like prepared soil measurements. These norms describe how to correlate XRF results with ICP/AA measurements of certified reference materials.

Soil-plant spectral diagnostics labs around the world use X-ray fluorescence analyses to develop soil nutrient maps which characterize native composition for science-based agriculture best practices. They support farmers with limited resources in challenging climates to ensure they are supplementing native growing conditions with correct and cost-effective additives.

Seeds

Biofortified seeds are used to increase mineral nutrients, especially zinc and iron, in place of soil fertilizers. PXRF/TXRF/micro-XRF elemental analyzers are used in research and development to help track seeds which yield nutrient dense grains faster and more accurately. Portable benchtop XRF analyzers are used to confirm seeds labeled as biofortified at supply stores are in fact fortified with the mineral nutrients specified and not just priced as such.

From the Root to the Shoot

Fertilizers, amendments, insecticides, fungicides and herbicides

Fertilizers are critical to healthy, high-yield crops. However, excess can cause runoff of phosphorus and other minerals which cause serious harm to the environment. This can affect soil, ground or surface water, and the life forms which inhabit them.

There is a renewed effort for custom blends utilizing a mix of different minerals to fine-tune fertility programs towards more efficient and profitable crop production. Specialty fertilizers with mixes of calcium, magnesium, iron, cobalt, chromium, copper, manganese, selenium, zinc and molybdenum provide even more selectivity.

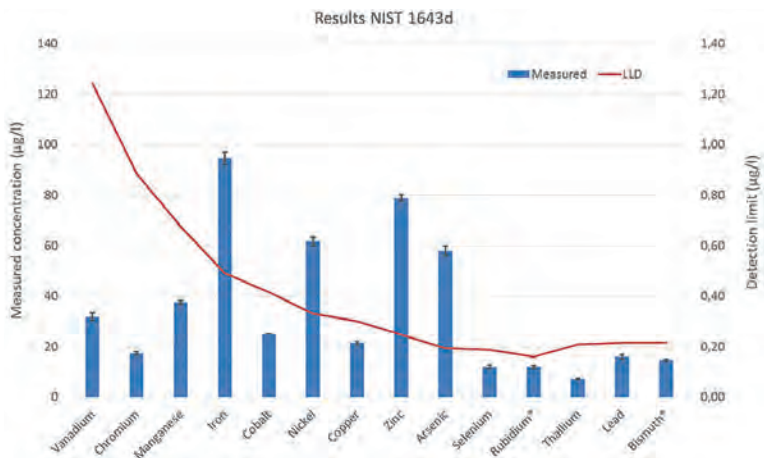
PXRF/TXRF/micro-XRF spectrometry help confirm the mineral content of fertilizer raw materials and end products, prove efficacy and value of custom blends, screen for unwanted heavy metals and pre-screen samples for difficult elements in lab analysis. The instruments also help monitoring any excess runoff in soil and water.

Figure 7
Field measurement with the S2 PICOFOX TXRF spectrometer without any need of lab equipment.

Water

Quality water helps a plant to stand which enables the transport of minerals and metals. Large farms are especially in need of managing water quality, particularly if it originates from industrial, livestock or municipal sources. In addition to identifying water use limitations, it is important to determine the amount of salts and nutrients an irrigation system supplies.

Iron and manganese are important to monitor along with the right balance of calcium, magnesium, sodium, potassium, chlorine and sulfur. Of course, quality water also needs to be screened for heavy metals and other toxic elements. TXRF is ideal for fast analysis of water and other aqueous samples.



The S2 PICOFOX and the S4 T-STAR® TXRF spectrometers provide straightforward, quick and accurate measurements of elements even at ultra-trace (sub-ppb) levels with little to no sample preparation. There is no need for gases, hazardous chemicals or labs with hoods and exhausts.

Figure 8
Analysis of the NIST 1643d water standard with the S4 T-STAR® TXRF spectrometer and calculated lower limits of detection.

Plants

Plants rich in nutrients and free from heavy metals provide multiple health benefits. Organizations around the world use PXRF/TXRF/micro-XRF techniques to help farmers increase their crop productivity, research ways to breed crops with a higher nutrient-use efficiency and teach the various aspects of botany.

The characterization of rootstocks is critical to successful commodity crop production, from bulk grains, like corn, to horticulture specialties, like apples. It is particularly key in developing productive rootstocks which effectively transport water, maximum minerals, nutrients and other metals to the shoot system.

Nutrients and dietary minerals, like phosphorus, potassium and calcium are essential for human biochemical processes. Mapping the relative abundance of nutrients in food helps quickly identify nutrient-rich locations and understand the distribution of fortificants in processed foods.

The different PXRF/TXRF/micro-XRF spectrometry techniques help monitor the plant mineral accumulation and predict disorders, such as bitter pit, which are believed to be induced by deficiencies in certain minerals.

Portable XRF spectrometers provide the compositional analysis of plants out in the field, while TXRF spectrometers enable ultra-low elemental detection limits of plant tissues. PXRF also supports the research for the optimization of surface treatments for preservation of agricultural products during storage and transport.

Micro-XRF spectrometers provide compositional analysis and the ability to map the elemental distribution in a plant. The ability to see nutrient rich locations and monitor their mobility provides data-based evidence of plant biosystem optimization.

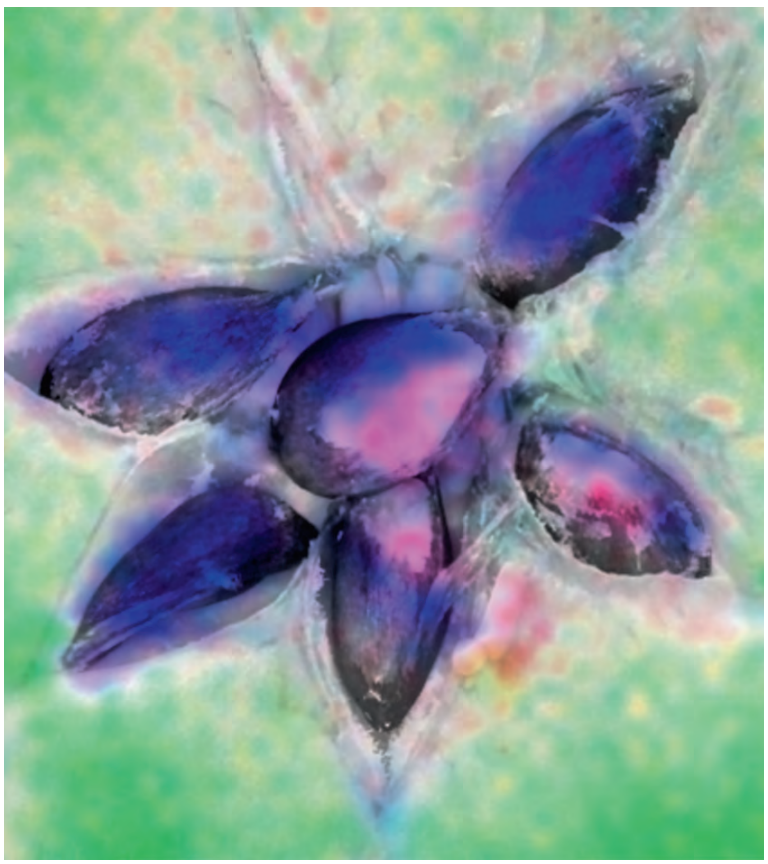


Figure 9
Analysis of an apple core with the ELIO micro-XRF spectrometer: elemental distribution map with calcium (blue), potassium (green) and sulfur (red).

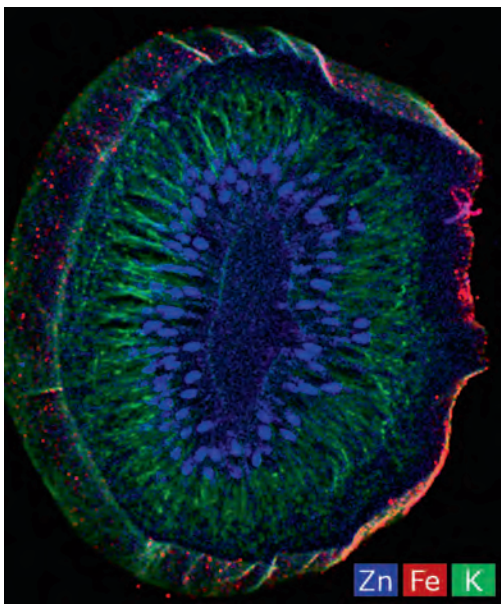


Figure 10
Analysis of a kiwi slice with the M4 TORNADO micro-XRF spectrometer: color-coded map of zinc (blue), iron (red) and potassium (green).

Further Information

Handheld/mobile/portable X-ray fluorescence (HHXRF and PXRF) spectrometers have the capability to non-destructively qualify or quantify nearly any element from fluorine to uranium, depending on specific instrument configurations.

- S1 TITAN
- TRACER 5
- CTX

www.bruker.com/hhxrf

Micro-X-ray fluorescence (micro-XRF) spectrometers are the instruments of choice for the elemental analysis of non-homogeneous or irregularly shaped samples as well as small objects or even inclusions.

- M4 TORNADO
- ELIO

www.bruker.com/micro-xrf

Total reflection X-ray fluorescence (TXRF) spectrometers are well-established for the ultra-trace element analysis on a variety of samples and very small sample amounts in the µg, ng or pg range. The transportable instruments can be used in field and laboratory.

- S2 PICOFOX
- S4 T-STAR®

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