ScanSpectrum
qed.ai

Spectroscopy made portable, affordable, and adaptable

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Climate Resilient Rice Commercialization Sector Development Program, RICESDP
Asian Development Bank (ADB)

Inspiration

From working on numerous soil and crop development projects in Africa, we witnessed that analytical chemistry is desperately needed everywhere, but is still universally unaffordable and inaccessible.

Below is a picture of an ICP-MS – the inductively coupled plasma mass spectrometer. A complex machine, it is the universal gold standard for performing elemental analysis of substances like soils and plants. But it costs upwards of 250,000 USD, requires stable electricity, and many countries don't have even *one* of them!
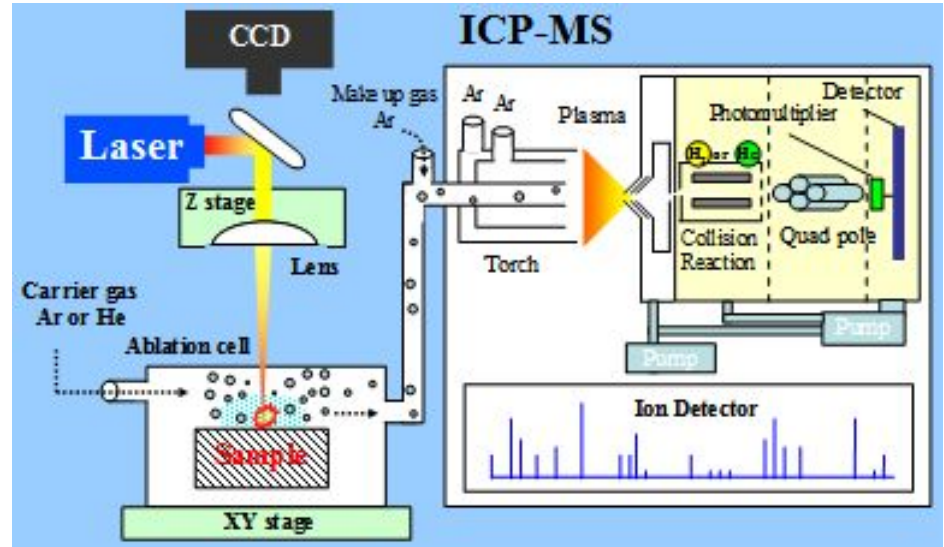
Inspiration

Rather than struggling to build labs in tough environments and manage the logistics of shipping samples there from the field, we can try to miniaturize the lab, and bring the lab to the field. This requires making lab equipment portable, affordable, rugged, and "good enough" for practical decision making.

We focused our engineering skills on spectroscopy, which analyzes the properties of soils and plants through their interactions with light. It is one of the fundamental tools in laboratory research.

Inspiration

One early inspiration was the Public Lab spectrometer, a do-it-yourself kit crafted from paper, which shines light at a target and measures the spectrum of the reflection, using a phone camera.

After running our own experiments, we aimed to substantially elevate performance and consistency. We built our own spectrometer that upgraded many components, improved resolution and signal-to-noise-ratio, built solid enclosures, and expanded beyond the RGB spectrum.
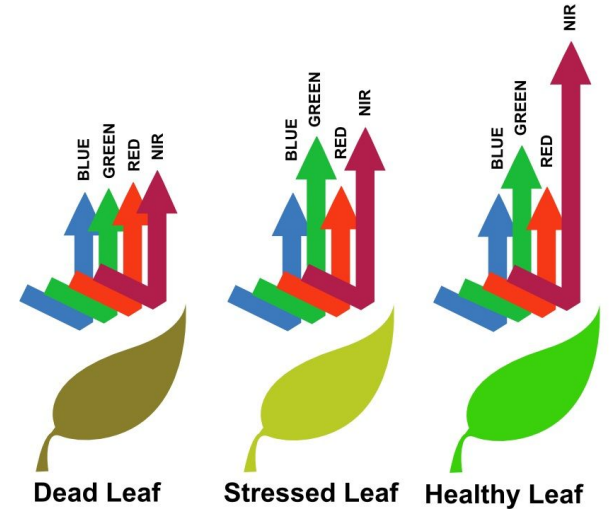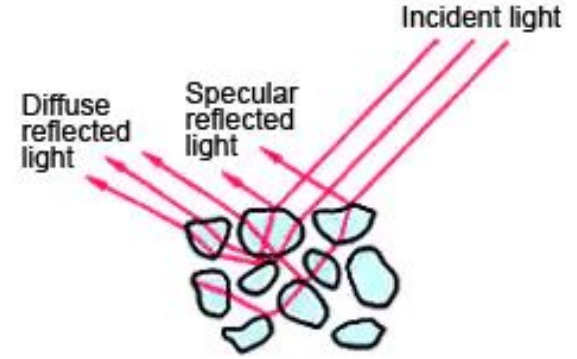
Early Days (2017)
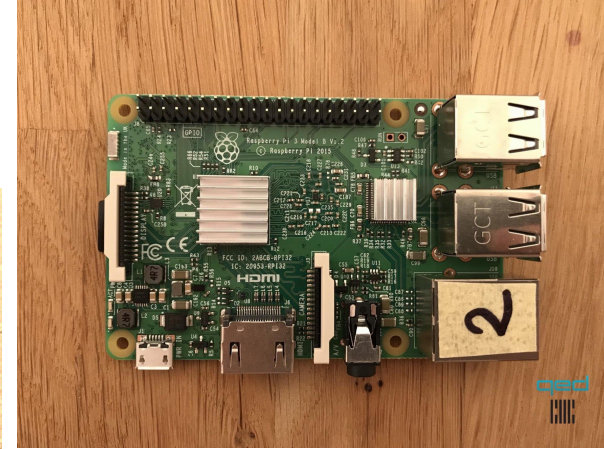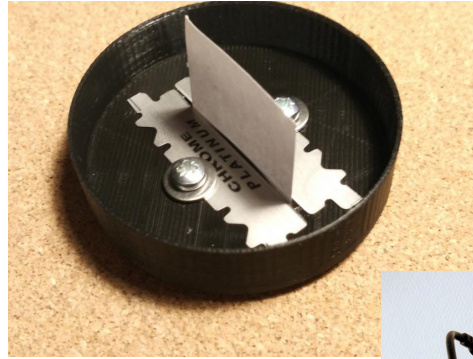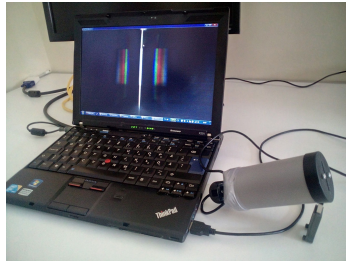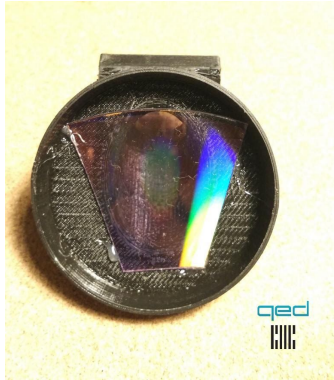
ScanSpectrum (2023)

Spectral range	400-1000 nm
Resolution (FWHM)	3 nm
Measurement time	4s
Spectral image size	1920 px
Working modes	transmittance using standard cuvettes; reflectance
Weight (full kit)	860 g
Dimensions (case)	27.5 x 24 x 7.5 cm
Operating temperature	0-70°C
Power requirements	5V, 2A USB source

Reflectance Mode

Press borosilicate glass aperture against any surface of interest, and pull the trigger. Within seconds, ScanSpectrum measures its **diffuse reflectance**, from which many properties can be determined.

Example: Leaf health can be characterized by measuring ratios of different reflected bands. For instance, **NDVI := (NIR - Red) / (NIR + Red)**

Incident light

Diffuse reflected light

Specular reflected light

BLUE GREEN RED NIR

Dead Leaf

BLUE GREEN RED NIR

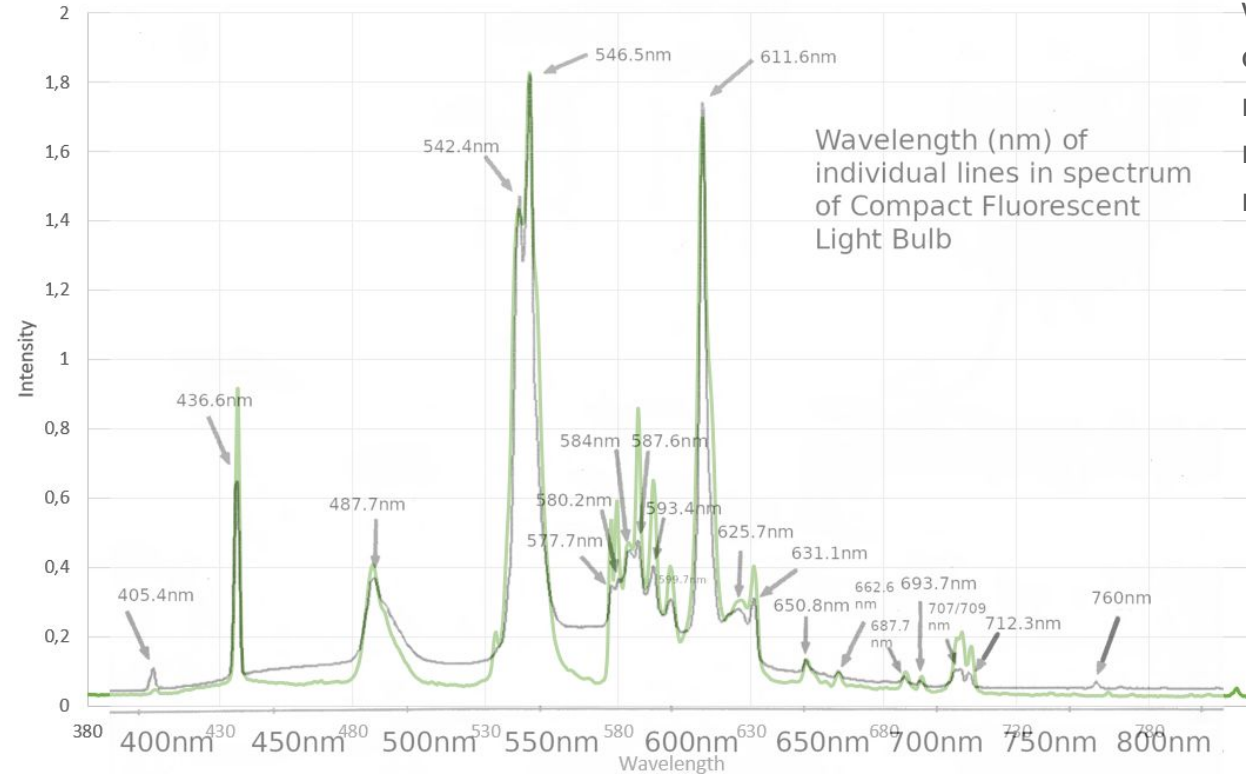**Stressed Leaf**

BLUE GREEN RED NIR

Healthy Leaf
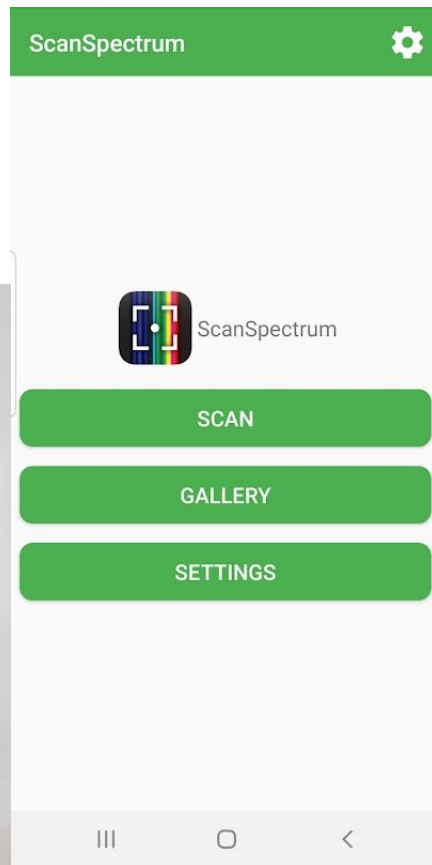
Accuracy of Measurement

ScanSpectrum's performance is similar to that of benchtop lab spectrometers.

Here, we see the ideal spectrum of a compact fluorescent light (CFL) bulb, which is universally standardized, compared against ScanSpectrum's measurement of a CFL bulb. They match nearly identically! We achieve a resolution of 3 nm.

CFL light scan by Scan Spectrum

Easy to use

Live Demonstration

Plant Stresses

Easily calculate all indices in range 400-1000 nm

- Normalized Difference Vegetation Index (**NDVI**)
- Photochemical Reflectance Index (**PRI**)
- Water Band Index (**WBI**)
- Red Edge stress
- ...

All changes in color and infrared (IR) are connected with water stress, nutritional stress, or diseases.

Plant nutrition

The spectral range used by ScanSpectrum can determine content of chlorophyll A and B, carotenoids, anthocyanin or total nitrogen in the leaves.

Foliar Chlorophyll Content
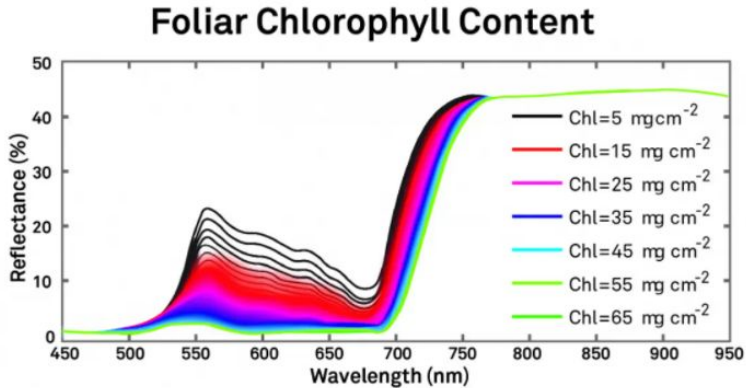
Figure 5. How foliar chlorophyll content affects reflectance

Guide to Nutrient Deficiency Symptoms

Image credit: Pinterest/pin/446982331751909158/
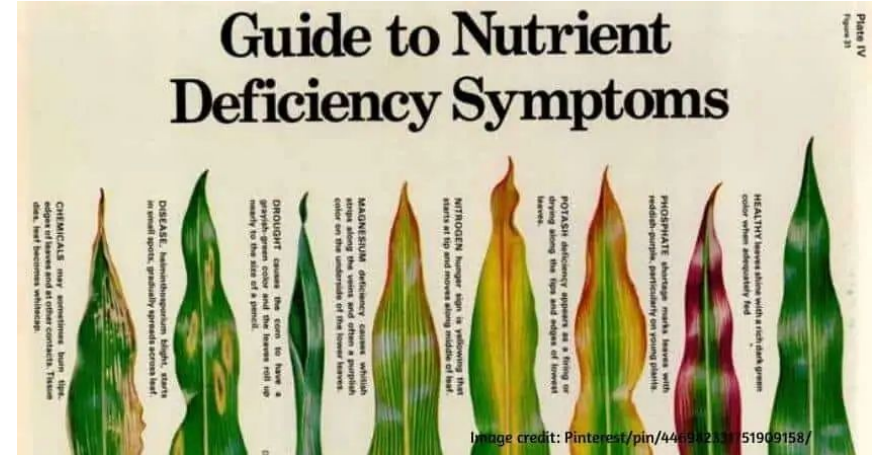
Hypothesis: ScanSpectrum combined with spectral modeling may enable it to perform early detection of nutritional deficiencies in leaves, instead of relying on human visual examination by the time of maturity when it is too late

Breeding

NDVI and other indices help plant breeders identify varieties with high performance potential

ScanSpectrum

Used to look at reflectance as leaflets expand

Prototype

Day 1

Day 2

Day 3
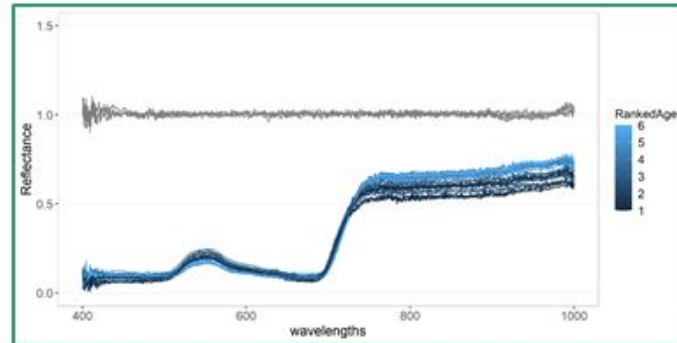
Traces from ScanSpectrum of cowpea leaves

NDVI or other vegetation indices

Food integrity

Blue tortillas are sold for premium prices (33% more) due to higher nutritional content. Consequently, they are being faked with dyes.
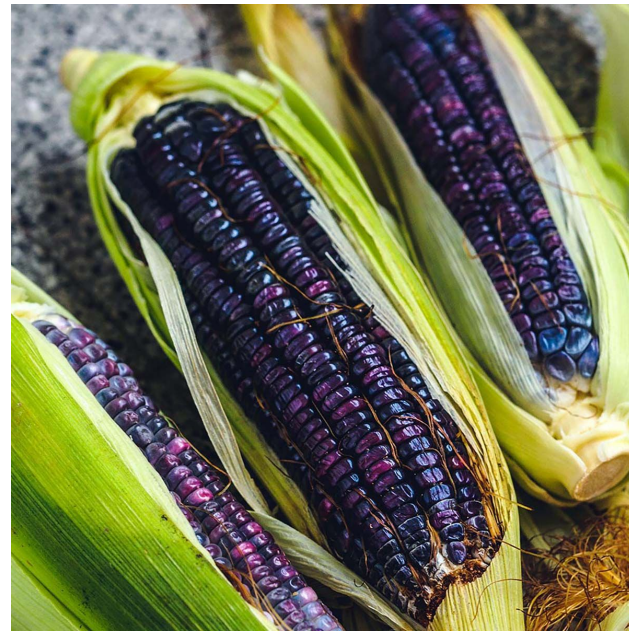
Food integrity

Blue tortillas are sold for premium prices (33% more) due to higher nutritional content. Consequently, they are being faked with dyes.

Nixtamalized blue flour (Local market)
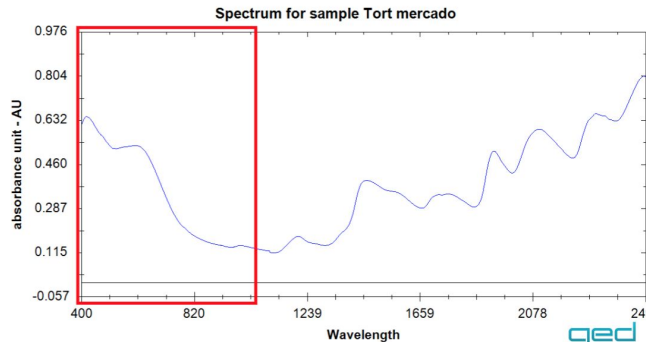
Nixtamalized "fake"blue flour
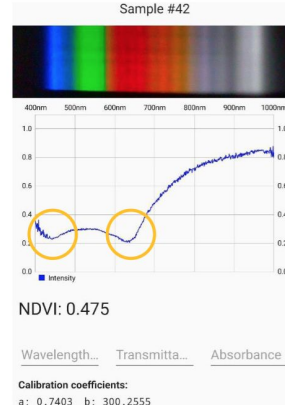
QED ScanSpectrum, portable, cheap, identifies same signature (reflectance)

80,000 USD NIR spectrometer at right (absorbance) stuck in a lab

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80,000 USD NIR spectrometer at right (absorbance) stuck in a lab

58 59 60 61

68 69 70 71

Experimental samples from CIMMYT-MX
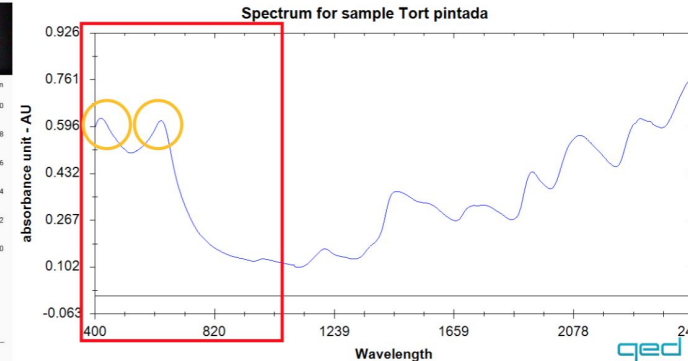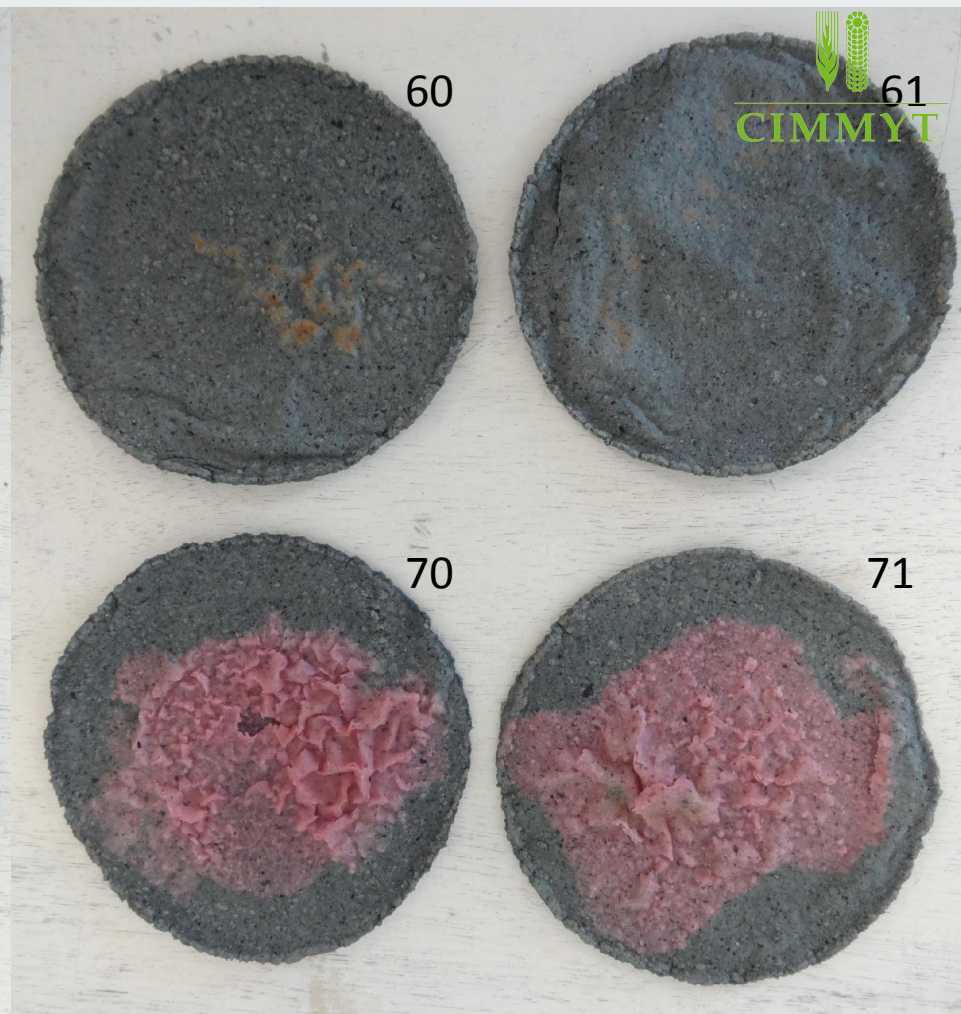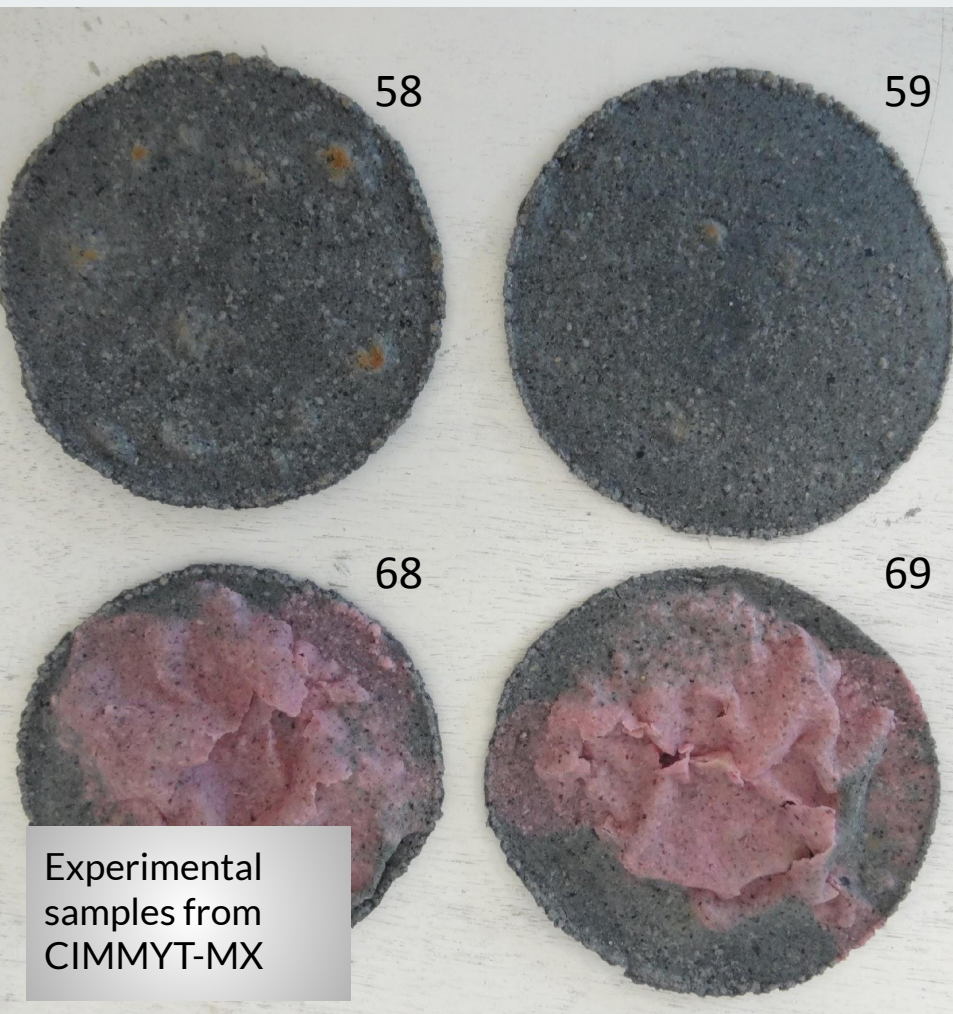
Food safety

Defining calcium hydroxide content by direct scans of tortillas. **Different calcium levels are *distinguishable* from the spectra!**

1.5% calcium hydroxide used in production processes = **less chances for acrylamide neurotoxin presence**

Averaged spectra of tortillas by calcium content

— Lab tortillas, 1% Calcium Hydroxide, fresh tortilla
— Lab tortillas, 1% Calcium Hydroxide, tortilla + citric acid
— Lab tortillas, 2% Calcium Hydroxide, fresh tortilla
— Lab tortillas, 2% Calcium Hydroxide, tortilla + citric acid
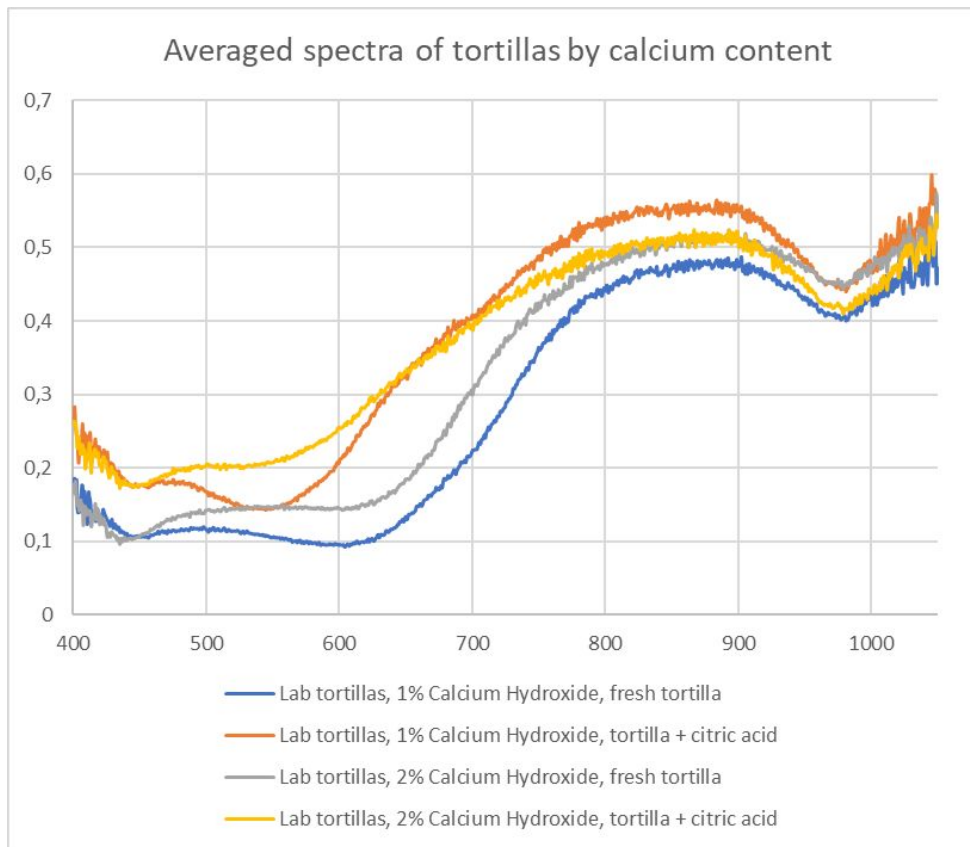
Characterizing fertilizer performance

Wheat fertilization experiment

- Mineral fertilization, early stage
- Mineral fertilization, fully developed plant
- Experimental fertilization, early stage
- Experimental fertilization, fully developed plant

Selected indices

NDVI (400-700) i (700-1000), NDVI 800 680, reNDVI 710 750, Leaf chlorophyll index, WBI (970/900), NDWI (559 864)
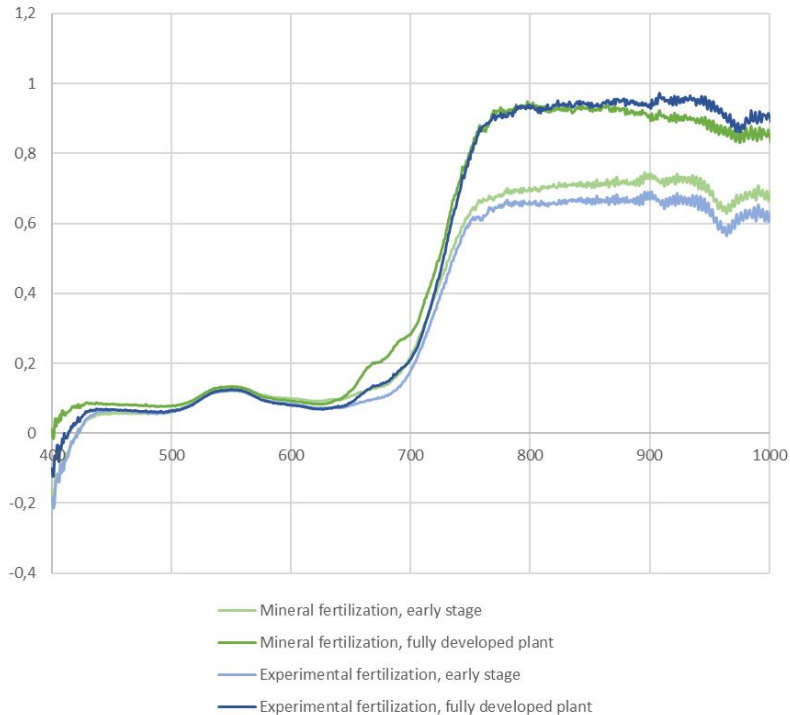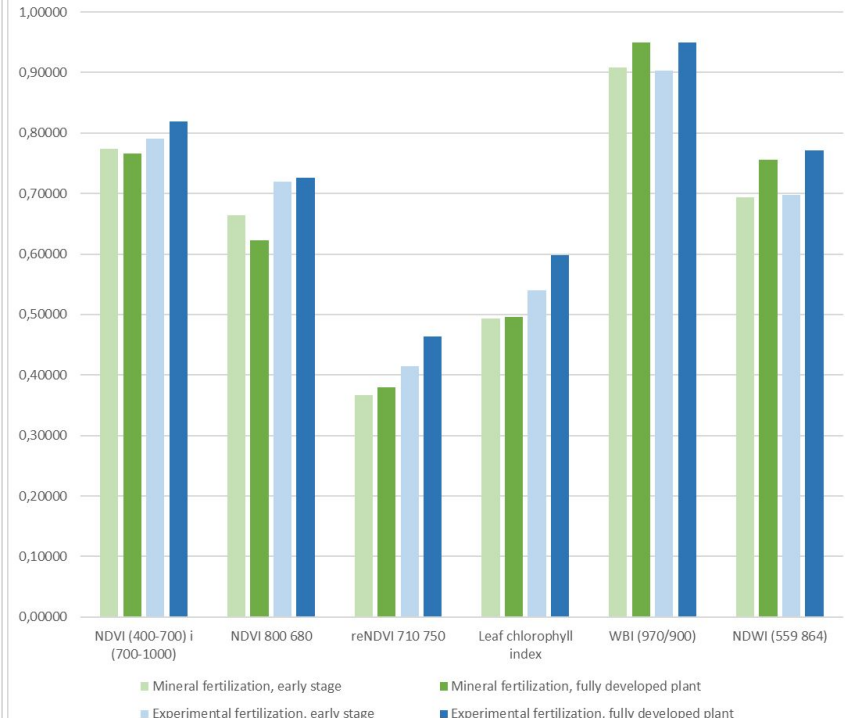
Estimating time for harvesting

Measurement of moisture content for harvesting silage. Spectra are distinguishable.

Selected indices

Wheat leaf during drying in room temperature
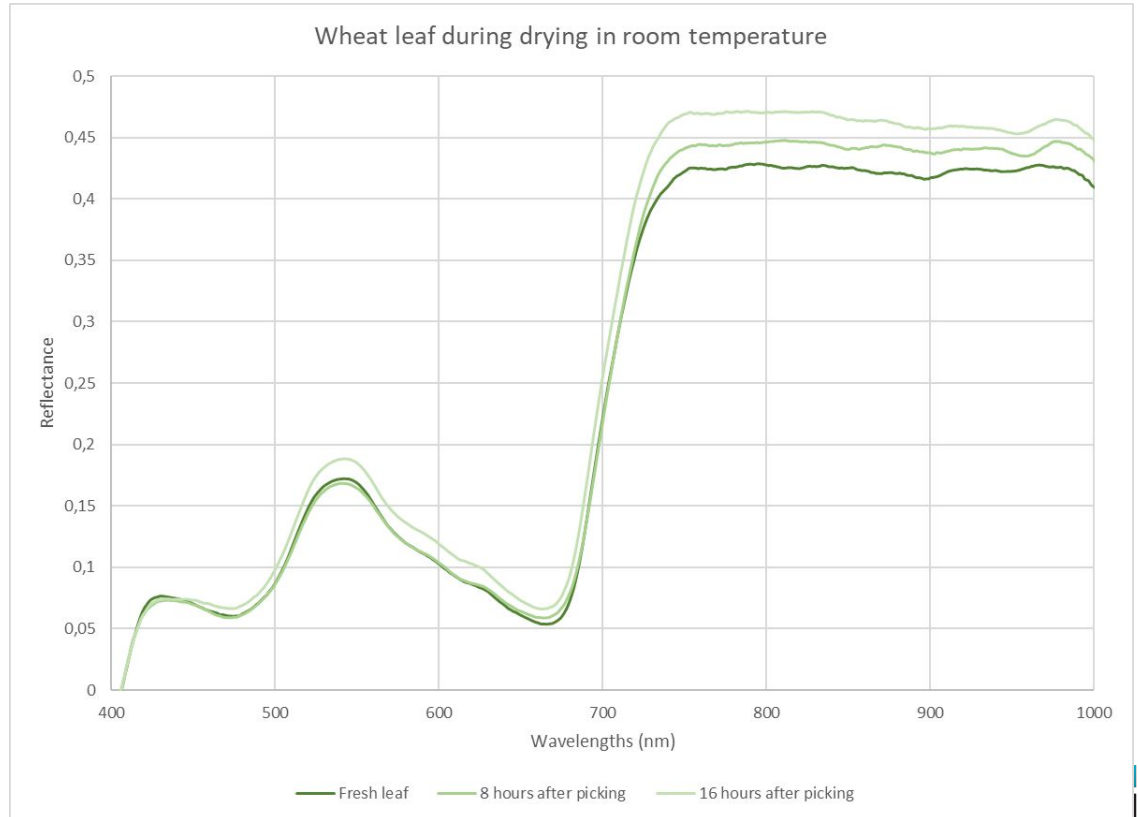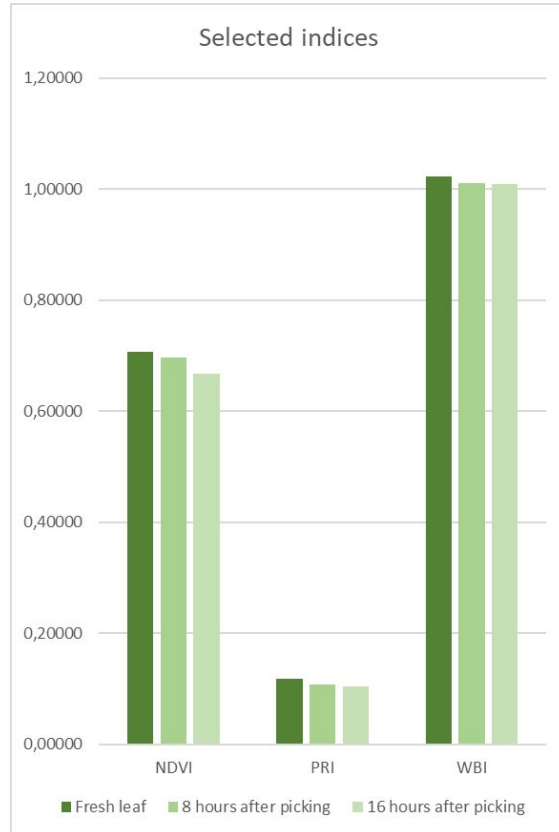
Soil carbon

Modeling suggests 0.88 r^2 for measuring Total Carbon over the 400-1000 nm range of ScanSpectrum. Seeking partners for further collaboration.

analyte	R2 with full range VIS+NIR	R2 with truncated 400-1000 nm spectrum
pH	0.80	0.67
carbon	0.95	**0.88**
nitrogen	0.89	0.80
phosphorus	0.43	0.22
potassium	0.52	0.29

Transmittance mode

Low-cost substitute for laboratory-grade UV-VIS spectrophotometers.
High linearity for any color, up to an absorbance of 1.6.

Wavelength: 845

PLOT

a = 0,0224, b = 0.0, R^2 = 0,9998

"Standard curves"

| s1 @0 | s1 @16 | s1 @6 | s1 @11 | s1 @3 | s1 @5 | s1 @7 | s1 @20 | s1 @13 |

@0 @80 @20 @5 @40 @10
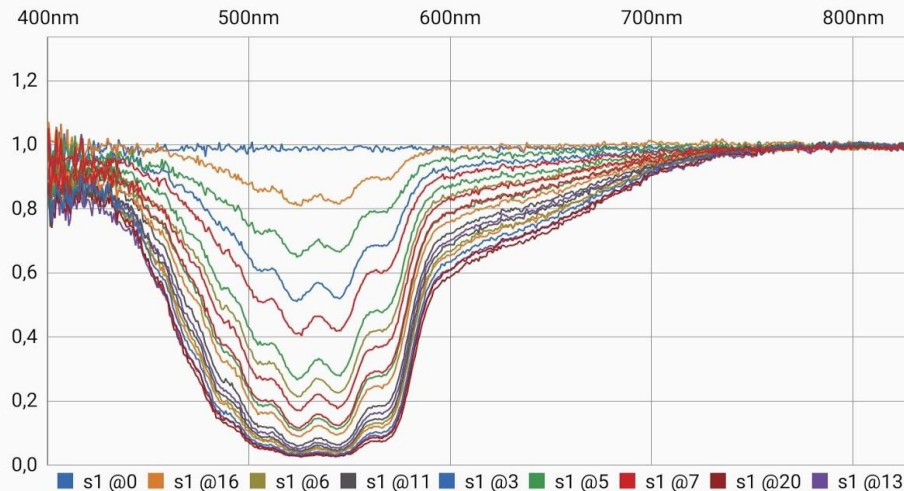
Transmittance Mode

ScanSpectrum's tip can be converted into transmittance mode, to support colorimetric analysis of samples.

1. Mix the target (e.g. soil) together with water and a color-changing reagent that reacts in proportion to a particular analyte of interest (e.g. carbon).

2. Pour solution into a cuvette.

3. Infer the concentration of analyte by analyzing ratio of transmitted light to incident light.
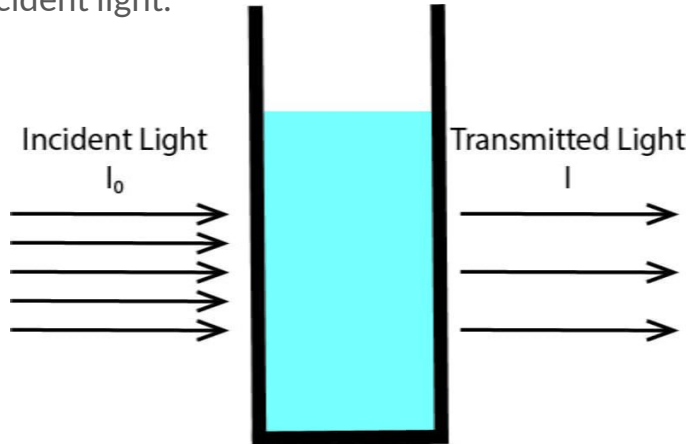
Water pollution

Turbidity of liquid (cloudiness) can be directly measured in transmittance mode.
Has applications for environmental protection, water quality, industrial engineering.
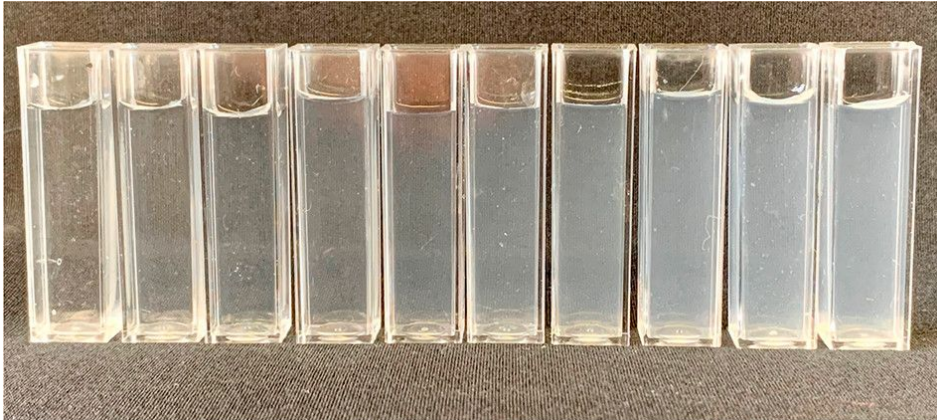
Selected current and scheduled research

- **Poland**
  - Model for estimating leaf nitrogen in maize, wheat and oilseed rape
  - Model for estimating moisture content for maize silage
  - Usability for marketing for fertilizer sellers
- **Mexico**
  - Detection of fake tortillas, testing tortilla quality
- **United Kingdom**
  - Comparison of 30 genotypes for cowpea under different lighting conditions
- **China**
  - Exploring predictability of stomatal conductance
- **Tanzania**
  - Developing methods to assist plant breeders in selecting germplasm resistant to a variety of diseases

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Summary

Advantages:

- Portability
- Use of common power banks (eco-friendly)
- Transmittance and reflectance in one device
- Good resolution (2 nm) and Signal-to-Noise Ratio (SNR) (>200)
- Easy export of data in open formats (CSV)
- Lightbulb + two LEDs
- Low cost

Cost of whole device in comparison to similar products

Quality of measurement in comparison to similar products
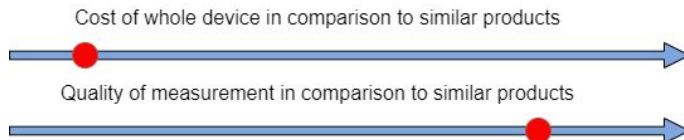
Known capabilities:

- Spectral vegetation indices (e.g., NDVI, PRI)
- Food quality inspection
- Liquid colorimetry
- Any scientific research using VIS-NIR spectroscopy …

Open question: What else is possible?

We aim to make high quality technology more affordable and accessible, to accelerate scientific inquiry and practical results in support of smallholder farmers.

For More Information

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