

Optical Crop Sensors

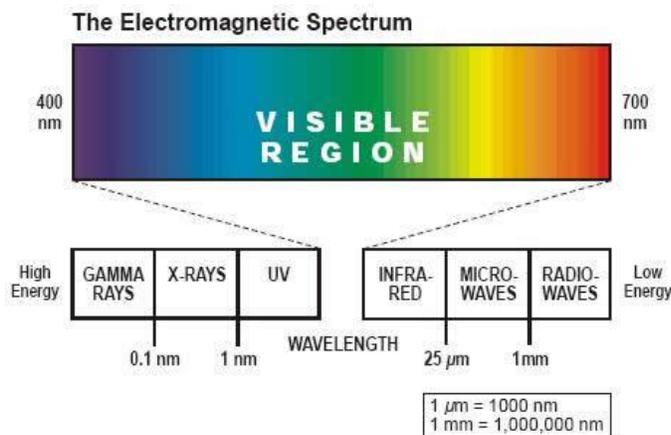
Field Crop Sensors Determine In-season Fertilization Requirements

How Do Optical Crop Sensors Function?

Optical crop sensors evaluate crop conditions by shining light of specific wavelengths at crop leaves, and measuring the type and intensity of the light wavelengths reflected back to the sensors. Not all optical sensors use the same light wavelengths. Different color light waves can be used to measure different plant properties. Commercially available crop sensors use two or more of red, green, blue or near infrared (NIR) color light waves.

The Electromagnetic Spectrum

The basic principles of optical sensing are similar to visual observations. Energy in the form of light waves travels from the sensor to the plant leaves. Light waves travel similarly to waves traveling across a lake. The distance from the peak of one wave to the peak of the next wave is the wavelength. Energy from sunlight is called the electromagnetic spectrum.



The wavelengths used in most agricultural optical sensing applications cover only a small region of the electromagnetic spectrum. Wavelengths are measured in micrometers (μm) or nanometers (nm). One μm is about .00003937 inch and 1 μm equals 1,000 nm. The visible region of the electromagnetic spectrum is from about 400 nm to about 700 nm. The green color associated with plant vigor has a wavelength that centers near 500 nm (Figure 1).

Figure 1. The visible region of the spectrum ranges from about 0.4 μm to 0.7 μm (Kyllo, 2004).

Figure 1 Electromagnetic Spectrum

Wavelengths longer than those in the visible region and up to about 25 μm are in the infrared region. The infrared region nearest to that of the visible region is the NIR region. Both the visible and infrared regions are used in agricultural optical sensing.

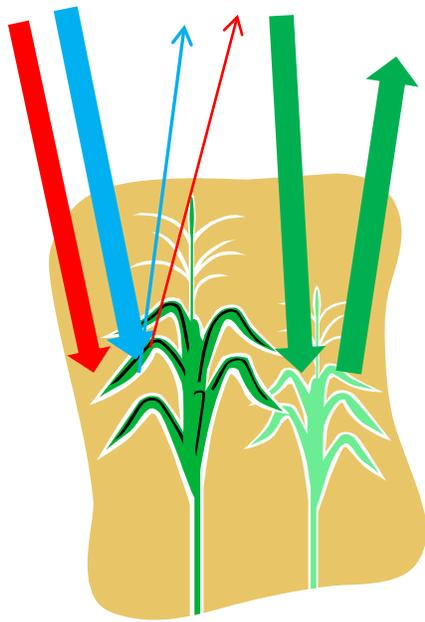


Figure 2 Plants Absorb and Reflect Light

Green plants absorb much of the visible light wavelengths, particularly the blue and red light waves, and reflect much of the green light waves. This is why plant leaves appear green to us. Sensing the reflectance of green light wavelengths from plants can provide a relative measure of chlorophyll in the leaves. Green reflectance can be used to evaluate crop nitrogen status, the degree of iron deficiency chlorosis, sulfur deficiency, or any other condition causing reduction in green color.

Plants absorb much less NIR light than red light. Darker green leaves reflect more NIR light and absorb more red light than lighter green leaves. These reflectance characteristics for visible and NIR light of plants are used to develop vegetative indices to compare the relative health of crops. The Normalized Difference Vegetation Index (NDVI) is calculated using the reflectance of red and NIR wavelengths. The NDVI formula for NDVI gives values from -1.0 to +1.0. Typical plant sensing operations give values from 0.1 to 0.9, with values ranging from 0.1 to 0.2 for soil surfaces and 0.2 to 1.0 for crop canopies. NDVI values increase as both the amount of crop cover increases, and to a lesser degree, the crop greenness increases.

Crop sensors are called active sensors because they emit their own source of light onto the crop canopy and then measure the percent of light reflected from the canopy back to the sensor. The commercial GreenSeeker™, OptRx™ and the Holland Scientific Crop Circle™ sensors use light emitting diodes, and the CropSpec™ uses laser diodes for emitting light. The light reflectance is recorded by all sensors using photodiodes, which convert light waves into electrical charges, which are then digitally quantified. Since sensors use a modified light source, the reflectance can be distinguished from natural sunlight, allowing the sensors to function in any daylight or darkness, with minimal disturbance by passing cloud cover.

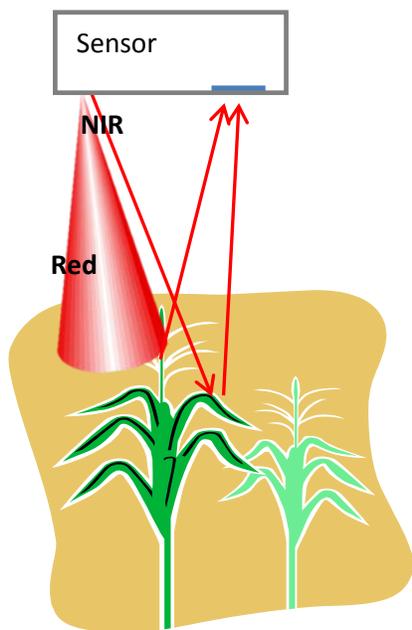


Figure 3 Red Absorbed, NIR Reflected

How Crop Sensors Determine In-season Nitrogen Fertilizer Rates

Crop sensors can be mounted on nitrogen fertilizer applicators equipped with computer processing and variable rate controllers to apply fertilizer during the growing season. Each commercial sensor manufacturer recommends specific operating procedures to calculate a fertilizer rate based on a vegetative index. The sensor software uses a step-by-step mathematical procedure, called an algorithm, to estimate a fertilizer rate.

Typical Procedures for Using Optical Crop Sensors

Step 1: Nitrogen-rich Strips

Plant a nitrogen-rich strip in each field within each variety with an abundance of nitrogen fertilizer applied prior to planting the crop. This strip must have enough nitrogen to make sure the crop plants will not show any nitrogen deficiency symptoms. The sensor is operated over the nitrogen-rich strip to establish a nitrogen-sufficient reference area in the field. The remaining areas of the field are compared to the nitrogen-rich strip to make nitrogen rate recommendations.

Step 2: Scan N reference Strip with Sensors.

The user takes sensor readings from the nitrogen-rich reference strip. The OptRx sensor uses a “virtual reference strip”, which is the healthiest area of the field. Reference values are stored in the computer for on-the-go calculations.

Step 3: Select the Appropriate Crop Algorithm.

The sensor manufacturer incorporates algorithms for each crop. The algorithms are generally based on in-season estimated yield (INSEY). INSEY is determined by dividing the sensor NDVI readings by the growing degree days. Generally, the sensors operator must enter the growing degree days for the field area into the sensor computer.

Step 4: Sensing the Field.

The operator then drives over the rest of the field, automatically sensing, calculating, and applying a variable rate of nitrogen fertilizer to the crop. Sensor values may be different if the crop leaves are wet or dry. Temperature changes throughout the day may also cause changes in sensor values. The nitrogen-rich or virtual strip should be re-sensed if the field conditions change during fertilizer application.

Potential Uses for Crop Sensors

- In-season nitrogen fertilizer
- Increase nitrogen use efficiency
- In-season crop yield estimate

Commercial Sensors

- **GreenSeeker**. NTech Industries of Ukiah, CA. Distributed by Trimble Ag, Sunnyvale, CA 94085. <http://www.trimble.com/agriculture/greenseeker.aspx> .
- **Crop Circle™**. Holland Scientific, Inc., 6001 S. 58th Street, Suite D, Lincoln, NE 68516. <http://hollandscientific.com/crop-circle-ac-470-multi-spectral-crop-canopy-sensor/>
- **OptRx**. Developed by Holland Scientific of Lincoln, NE. Marketed by Ag Leader Technology, Ames, IA 50010. <http://www.agleader.com/products/directcommand/optrx/>.
- **CropSpec**. Topcon Positioning Systems, Incorporated, Olathe, KS 66060. <http://ag.topconpositioning.com/en/ag-products/cropspec-crop-canopy-sensor>.

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