Sensing Nitrogen Deficiencies in Winter Wheat and Bermudagrass

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The potential replacement of wet chemical methods with non-destructive spectral analyses was first seen over 20 years ago. Near infrared (NIR) diffuse reflectance spectrophotometry was initially used to measure protein, moisture, fat and oil in agricultural products. Leaf reflectance measurements at 550 nanometers (nm) (green) and 675 nm (red) have been used to estimate the nitrogen (N) status of various growing crops.

The NIR spectral region has also been used for predicting organic carbon (C) and total N in soils. Each constituent of an organic compound has unique absorption properties in the NIR wavelengths due to stretching and bending vibrations of molecular bonds between elements. One band (780 to 810 nm) is particularly sensitive to the presence of amino acids (R-NH_2) which are the building blocks of proteins. The presence and/or absence of these amino acids largely determines the N content of the plant. Because of this, many researchers believe that if the plant canopy could be characterized using spectral data, the development of an indirect soil test (or measure of soil nutrient supplying capacity) could be possible.

When white light from the sun strikes the surface of soil or plants, it is reflected in wavelengths that have a characteristic frequency and energy. The visible portion of light can be separated into red, orange, yellow, green, blue and violet. The yellow-green color that we associate with N deficiencies should be characterized as having more violet light absorbed by the plant material, or alternatively, the reflected intensity of green in plants should be characterized as the amount of red light absorbed. Phosphorus deficiencies in plants should theoretically result in increased absorbance of green light since increased purple coloring of leaf margins is expected. What is actually being measured in many sensor based systems is ‘spectral radiance’, or the radiated energy from plant and soil surfaces.

Non-destructive sensor based methods of analyses could replace many of the wet chemistry soil testing methods that are in place today. Recent work has targeted indirect measurements of the nutrient status in soils using spectral radiance data collected from growing crop canopies every 10 sq. ft. Because large differences are now known to exist betwen forage and/or soil samples collected less than 3 feet apart in some fields, the development of indirect sensing technologies will be necessary if this variability is to be treated.

Research prototypes of sensor based systems are now capable of detecting nutrient needs on-the-go and can simultaneously apply prescribed fertilizer rates based on those needs. Spectral radiance measurements for red (660 nm) and NIR (780 nm) wavelengths measured in winter wheat from December to February using photodiode based sensors have shown high correlation between the normalized difference vegetative index [NDVI, (NIR-red)/(NIR+red)] and wheat forage N uptake. This is important since several researchers have demonstrated that wheat forage total N uptake during the winter months can be a predictor of topdress N needs. Because N uptake can be predicted indirectly using spectral radiance measurements, sensors can reliably provide measurements equivalent to 'on-the-go' chemical analyses.

Work at Oklahoma State University has focused on using whole-plant total N in winter wheat at growth stage Feekes 5 as an indicator of fertilizer N need. The relationship between total forage N uptake at Feekes growth stage 5 and NDVI from five experiments is reported in **Figure 1**. Similar results have been found in bermudagrass forage N uptake and NDVI. Based on the indirect measures of total N uptake (NDVI), significant increases in wheat grain yield from topdress N applied between December and February have been found. Various researchers have found increased fertilizer N use efficiency in winter wheat when N was split applied or topdressed before mid January. Variable rate technology capitalizes on this timing-related efficiency gain, while also having the potential to increase N use efficiency due to finer resolution of rate applied.

Photodiode based sensors (4 white boxes) collect spectral radiance measurements in the red (660 nm) and NIR(780 nm) regions. Rear nozzles of applicator are capable of applying a prescribed N rate (0 to 100 lb N/A) to each 10 sq. ft., travelling at 10 miles per hour.

The variable N applicator developed at Oklahoma State University is illustrated in the above photo. In addition to improving site-specific N use efficiency, this technology will likely decrease the risk that over fertilization poses to the environment while maintaining or increasing yield.

Initial results suggest that fertilizer N use efficiency has increased from 50 to 70 percent using adjusted fertilizer N based on NDVI at Feekes growth stage 5. This is largely because the sensors are capable of

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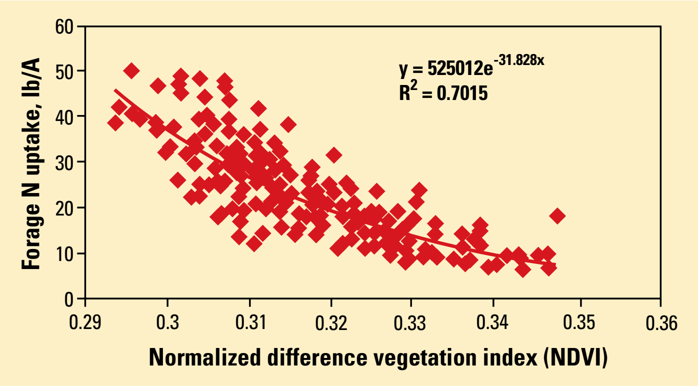

Figure 1. Relationship between NDVI and forage N uptake in winter wheat (Feekes growth stage 5) from five field experiments.

non-foliar and $Ca(NO_3)_2$ treatments. Different results were obtained for the NT cotton. Foliar K reduced Alternaria leaf spot and premature defoliation when compared with foliar $Ca(NO_3)_2$, but the non-foliar check was intermediate. Foliar K increased both CT and NT yields relative to the other foliar treatments.

Broadcasting K for the Loring silt loam did not affect Alternaria leaf spot or premature plant defoliation for either tillage system. Conventional tillage yields were not affected by soil applied K, but NT yields were increased by the 60 lb/A rate. Foliar-applying K reduced Alternaria leaf spot and premature plant defoliation in both tillage systems when compared with the other two foliar treatments. Conventional tillage yields were unaffected by the foliar treatments, but NT yields were greater for the foliar K relative to the $Ca(NO_3)_2$ foliar treatment.

Conclusions

Reduction of Alternaria leaf spot severity and premature leaf drop of cotton produced on soils low in extractable K can be accomplished by applying K to the soil or to the leaves. Yields were also increased by both soil- and foliar-applied K. Early identification of Alternaria leaf spot within a cotton field may indicate a low level of extractable soil K. On soils testing high in extractable K, Alternaria leaf spot severity and premature leaf drop were not factors affecting cotton yields. BC

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detecting large differences within extremely small areas (10 sq. ft.) in an entire field. Instead of applying a fixed rate to a 100 acre field, this technology allows us to apply the prescribed amount to 435,600 individual 10 sq. ft. areas within the 100-acre field at N rates that range from 0 to 100 lb/A.

It is important to note that there will be many interfering factors affecting fertilizer recommendations when using sensor based systems. While formal field experiments can remove all other factors excluding those being evaluated, the real world poses many additional problems. If a weed is present, and the sensor responds to it, one agronomic decision could be to not fertilize that area (decreased potential for weed seed). Not fertilizing this area will ultimately lead to increased field variability for that fertilizer nutrient. Alternatively, fertilizer could be applied as normal, and a point injector could be used to 'spot' treat for weeds as they are detected in the field. Added problems include the presence of clouds, time of day, plant variety, stage of growth, percent coverage, weed interference, nutrient interactions, and many others. BC

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