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Site-specific Farming 5

Collecting sensor data.
(Courtesy of Brian Arnall, Oklahoma State University, used with permission.)

Active-optical Sensor Algorithms for Corn Yield Prediction and as a Corn Side-dress Nitrogen Rate Aid

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Sensors for use in determining corn side-dress N rates

Active-optical light sensors have been available for agricultural use for about 30 years. People are most familiar with imagery and data from passive light sensors.

A passive light sensor is a sensor that detects the reflection of visible light or other kinds of electro-magnetic radiation emitted by the sun or an artificial light source. Examples of a passive light sensor are aerial photographs/images and satellite imagery.

An active-optical light sensor emits its own light in specific wavelengths and it has the ability to measure the intensity of the light reflected into the instrument compared to the light emitted.

Collecting sensor data.
(Courtesy of Brian Arnall, Oklahoma State University, used with permission.)

The active-optical sensors that relate to this publication have the ability through modulated light pulses (similar to light-based UPC code such as in product packages at the grocery store, but through varying the length of on-off light emission). The modulation is used to filter out light that does not conform to the same modulation sequence as the emitter. Therefore, the instrument measurements are not influenced by changes in sunlight intensity, cloud cover, passing clouds or nighttime, resulting in similar readings regardless of ambient light conditions. The only condition that hinders measurement consistency is leaf wetness from rain, recent irrigation or early morning dew.

The two active-optical sensors utilized in NDSU corn N-rate trials are the GreenSeeker™ (Trimble, Sunnyvale, California) and the Holland Scientific Crop Circle™ (Holland Scientific, Lincoln, Nebraska). The GreenSeeker sensor readings were based on red and near-infrared sensors. The Crop Circle sensor included red, red edge and near infrared light sources and sensors. The red, near infrared and red edge light sources differed in wavelength, so the algorithms for GreenSeeker red cannot be used as a predictive tool by the Crop Circle red algorithm. The GreenSeeker is based on a red sensor with 660nm wavelength and near infrared with 770nm wavelength. The Crop Circle red sensor is based on red 670nm wavelength and near infrared with 760nm wavelength. The Crop Circle red edge sensor uses the same near infrared 760 nm wavelength, and the red edge band is 730nm wavelength.

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Algorithms

The algorithms were developed using N-rate corn trial data from 2011 through 2021 obtained from across North Dakota. These algorithms consider that the only reason for yield differences are N availability within the study.

The choice of algorithm will depend on the region of the state, the tillage practice and soil texture category. North Dakota is divided into West River (everything west of the Missouri River) and Eastern North Dakota (everything east of the Missouri River). Long-term no-till is defined in eastern North Dakota as a field in no-till, strip tillage using a coulter (not discs) or shallow one-pass seeding for at least six continuous years. Tillage deeper than 2 inches is considered conventional till, except for a strip-till or anhydrous ammonia shank. No-till after conventional till is considered conventional till until the field is continuous no-till for at least six years. A high clay soil is a soil with more than about 30% clay, and includes soils with a Bearden texture or higher clay amount. Fargo, Hegne, Viking, Bearden and related soils fall into this category. A medium-textured soil includes silt loams, fine sandy loams, loams, sandy loams and loamy sands.

How to Use an Active-optical Sensor

To use an active-optical sensor for the purposes of site-specific N side-dress N application, an N-rich or N-sufficient area in the field must be established. If the soil test N within the field is less than 100 pounds N per acre from the 2-foot depth, a variable rate base N rate should be applied so that the preplant N total is at least 100 pounds per acre. Adequate preplant/at-planting N availability is important because supplementing N-stressed corn early in the season does not result in as high a yield as supplementing N-healthy corn. Use of zone soil testing to prepare for this base rate is strongly recommended unless a recent history of manure application makes grid sampling more practical. At the time of the base N application preplant, a small area the width of the applicator and about 100 feet long, within soil category and intended hybrid, should receive an N rate to achieve at least 200 pounds N per acre total for the field area. This is the N non-limiting, or N-rich, area.

The rainfall patterns should be considered between preplant N application and side-dress application. If on a sandier soil, a single rainfall event should be more than 2 inches, some leaching of the preplant application may have occurred. Similarly, if rainfall results in sustained moisture saturation in high clay soils between preplant and sidedress, significant denitrification and gaseous N loss may have occurred. In either case, supplementing the additional N to the N-rich, N-sufficient area may be required.

At the time of sidedress, the growing degree days from planting date should be entered into the controlling computer unit. The growing degree days from planting can easily be found using the NDAWN corn growing degree tool and knowing the planting date (https://ndawn.ndsu.nodak.edu/corn-growing-degree-days.html).This is necessary to standardize the data through the calculation of INSEY (in-season estimated yield). The INSEY is a standardizing number that allows the application to be made plus or minus two corn leaf stages and still be able to use the same algorithm.

The INSEY value calculation is **sensor reading** divided by **growing degree days from planting**.

Algorithms are available for the V6 growth stage. The algorithms are valid from V4 to V8. When the applicator enters the field with the sensor or sensor array attached in front of the applicator unit, it first senses the N-rich, N-sufficient area. The average reading from the N-rich/N-sufficient area is entered into the spray controller. If the readings in the rest of the field are within 5% of the N-rich/N-sufficient area, then no supplemental N is required. If the reading is more than 5% less than the N-rich/N-sufficient area, the algorithm predicts the lower yield probable if no additional N is applied. The difference between yield predicted in the N non-limiting area and the yield predicted outside the N non-limiting area is used to calculate the N rate.

Yield difference (bushels per acre)
X 56 pounds per bushel
X 1.25% N in the grain
= (required to make up the additional yield)
(N required to make up yield difference)
divided by an efficiency factor
= (N rate, pounds N per acre)

The efficiency factor usually used for an in-soil application, such as anhydrous ammonia or coulter-applied UAN, is 0.6

The efficiency factor recognizes that supplemental N is never 100% effective. A post-emergence application is the most efficient application, with 60% efficiency estimated, assuming rainfall within a few days of application if surface applied, or if the N was subsurface-applied with a coulter or shank.

If the surface application was followed by a considerable stretch of dry weather, an efficiency value of 0.2 would be a better estimate of its efficiency.

Other Considerations

Poor sensor values unrelated to N nutrition and not fixable with supplement N

It is possible for some field areas to have low plant stand, bare areas and areas with poor growth due to high salts or other nutrient problems. In each algorithm table, there is a column titled "minimum INSEY for N rate." The controller should be programmed so that if the INSEY is below the suggested minimum value, no N is applied.

Sulfur deficiency interference

If the INSEY value is lower in the N-rich/N-sufficient area than in other field areas, the reason is due to sulfur deficiency. If a grower experiences this, the reason is usually that the field is sulfur deficient. Application of a soluble sulfate or thiosulfate fertilizer should be applied as soon as this condition is evident. Once the sulfur is taken up by the corn, the N-rich/N-sufficient area will exhibit similar greenness or be greener than the rest of the field, depending on field N availability status.

Programming a minimum N rate

Some growers may choose to program a minimum rate of side-dress N into the algorithm even if there is less than 5% difference between the field reading and the N non-limiting area. A value of 30 to 50 pounds N per acre would be a reasonable value for a minimum N rate.

A minimum N rate between 30 and 50 pounds N per acre would be reasonable rates to consider.

Algorithm inputs for the use of GreenSeeker and Holland Scientific Crop Circle sensors in North Dakota corn yield prediction and for use in directing N rates for side-dress N application

Long-term no-till, state-wide, using relative yield and relative INSEY, scanning at V6

Sensor	Wavelength for NDVI	Relative Yield Prediction Formula	Minimum INSEY
GreenSeeker	Red	Relative Yield = (0.427 X Relative INSEY) + 0.494	0.0001
Crop Circle	Red	Relative Yield = (0.452 X Relative INSEY) + 0.491	0.0001
Crop Circle	Red Edge	Relative Yield = (0.157 X Relative INSEY) + 0.749	0.00003

High Clay Soils Eastern North Dakota, scanning at V6

Sensor	Wavelength for NDVI	Yield Prediction Formula	Minimum INSEY
GreenSeeker	Red	Yield = (94,334 X INSEY) + 102	0.0002
Crop Circle	Red	Yield = (99,434 X INSEY) + 114	0.0002
Crop Circle	Red Edge	Yield = (162,602 X INSEY) + 119	0.00015

Medium Texture Soils Eastern North Dakota, scanning at V6

Sensor	Wavelength for NDVI	Yield Prediction Formula	Minimum INSEY
GreenSeeker	Red	Yield = (59,291 X INSEY) + 126	0.0002
Crop Circle	Red	Yield = (69,211 X INSEY) + 124	0.0002
Crop Circle	Red Edge	Yield = (108,089 X INSEY) + 132	0.00006

Example of how sensor algorithm works and calculates the N requirement in the field for high clay and medium textured conventional till fields.

Example of algorithm calculation, conventional till fields:

Yield predicted in N non-limiting strip – **120 bushels per acre**
In-field yield estimated – **60 bushels per acre**

Difference between N non-limiting yield prediction and in-field yield prediction

60 bushels per acre X 56 pounds per acre = 3,360 pounds corn per acre difference if no N is applied
3,360 pounds corn per acre X 0.0125 pounds N per pound of corn = 42 pounds N per acre
42 pounds of N deficiency divided by 0.6 efficiency factor = 70 of N per acre required at that location

Example of algorithm calculation, long-term no-till fields:

The long-term no-till algorithm formulas relate relative sensor INSEY to relative yield, not the actual values. Calculate INSEY using the value from the N-rich/N-sufficient area as the denominator and the field INSEY values at any point as the numerator, multiplying times 100 to get percent. The resulting values will range from zero to 100%. The relative yield is the percent yield. This value is up to the user depending on their yield history and any other factor that they think might influence the yield that current season.

Relative yield of N-sufficient area – 100%
Relative yield of example field area – 80%
Relative yield difference – 20%

Estimate of yield based on the season and past field history – **180 bushels per acre**

Yield difference is 180 X 0.2 = 36 bushels per acre
36 bushels per acre X 56 pounds per bushel = 2,016 pounds grain yet to achieve
2,016 pounds grain X 0.0125 N in grain = 25 pounds N in achievable yield
25 pounds N / 0.6 efficiency factor = 42 pounds supplemental N needed for the area

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