Proximal Sensing Provides Precision N Management

Studies indicate fluorescence sensing provides good indication of corn nitrogen deficiency.

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The Fluid Journal • Official Journal of the Fluid Fertilizer Foundation • Early Spring 2013 • Vol. 21, No. 2, Issue # 80

Summary: *Early detection of nitrogen (N) deficiency is essential to site-specific N management for practical and physiological reasons. Current proximal sensing techniques based on reflectance do not allow reliable detection of N deficiency prior to V8 growth stage of corn. Another technique based on fluorescence also offers the possibility to detect N deficiency of plants. Our results, acquired from greenhouse-grown plants, indicate that fluorescence sensing provides a good indication of corn N deficiency from V5 growth stage of corn.*

Global N use deficiency (NUE) is less than 40 percent. The growing amount of nutrients from agricultural activities that leaches in the environment, plus the higher price of N fertilizers, constitute serious concerns of the public and farmers. One way of improving NUE is by targeting N-fertilizer when and where the plant will absorb it and turn it into yield. Corn plants do not need the same quantity of N across the season. The maximum N uptake period starts around V6 to V8 growth stages and lasts up to the V16 to V18 growth stages. It is at the beginning of this period that N should be available for the plant in sufficient quantity.

Managing N

Nitrogen under the form of nitrates (best form for plant absorption) is very soluble and mobile and N fertilizer applied before the maximum N uptake period has greater chances to leach into the environment, especially in spring conditions when precipitation events are more frequent. On the other hand, if the N fertilizers are applied after the beginning of the maximum N uptake period, the plant will absorb suboptimal quantities of N and the yield will be lower. Thus, to better manage N fertilizer and increase NUE, temporal heterogeneity in N needs should be taken into account and N should be applied around the V6 to V8 growth stages of corn. Accordingly, spatial heterogeneity of N needs should also be taken into account for optimal N use.

Sensing tools

The soil fertility varies from one location of the field to the other and N fertilizer application can be spatially modulated according to soil fertility. Based on the maximum N uptake period, the appropriate N rate should be decided between V6 and V8 growth stages of corn. However, current proximal canopy sensing tools using normalized difference vegetation index (NDVI) provide a poor correlation with yield prior to the V8 growth stage of corn. Using leaf reflectance sensors, plants with N deficiency seem to be detected too late for practical implementation of site-specific N management. Another emerging approach for the detection of N deficiency in corn is the use of florescence sensors.

Fluorescence

Fluorescence is a property of certain pigments, the fluorophores, which re-emit light after being exposed to light. Chlorophyll is a fluorescent pigment that emits fluorescence in the red to far-red (690 nm to 740 nm) regions of the light spectrum after light excitation. Fluorescence emitted in the red to far-red region of the spectrum is often referred to as chlorophyll fluorescence (ChlF) and can be used to assess plant chlorophyll content. Another study observed significantly different ChlF emission between corn plants with complete nutrient supply and corn plants with N deficiency at both 690 mm and 740mm. A fluorescence-based index, called the N balance index (NBI), exploits the ratio of far-red fluorescence excited by UV light to red fluorescence, excited by either green or red light to detect N deficiency of green plants.

"Fluorescence sensing provides a good indication of corn N deficiency"

Hypothesis

The hypothesis of this study was that the sensing of fluorescence has the potential to detect N-deficiency in corn earlier than the V8 growth stage. The specific objective was to determine if fluorescence sensing can detect

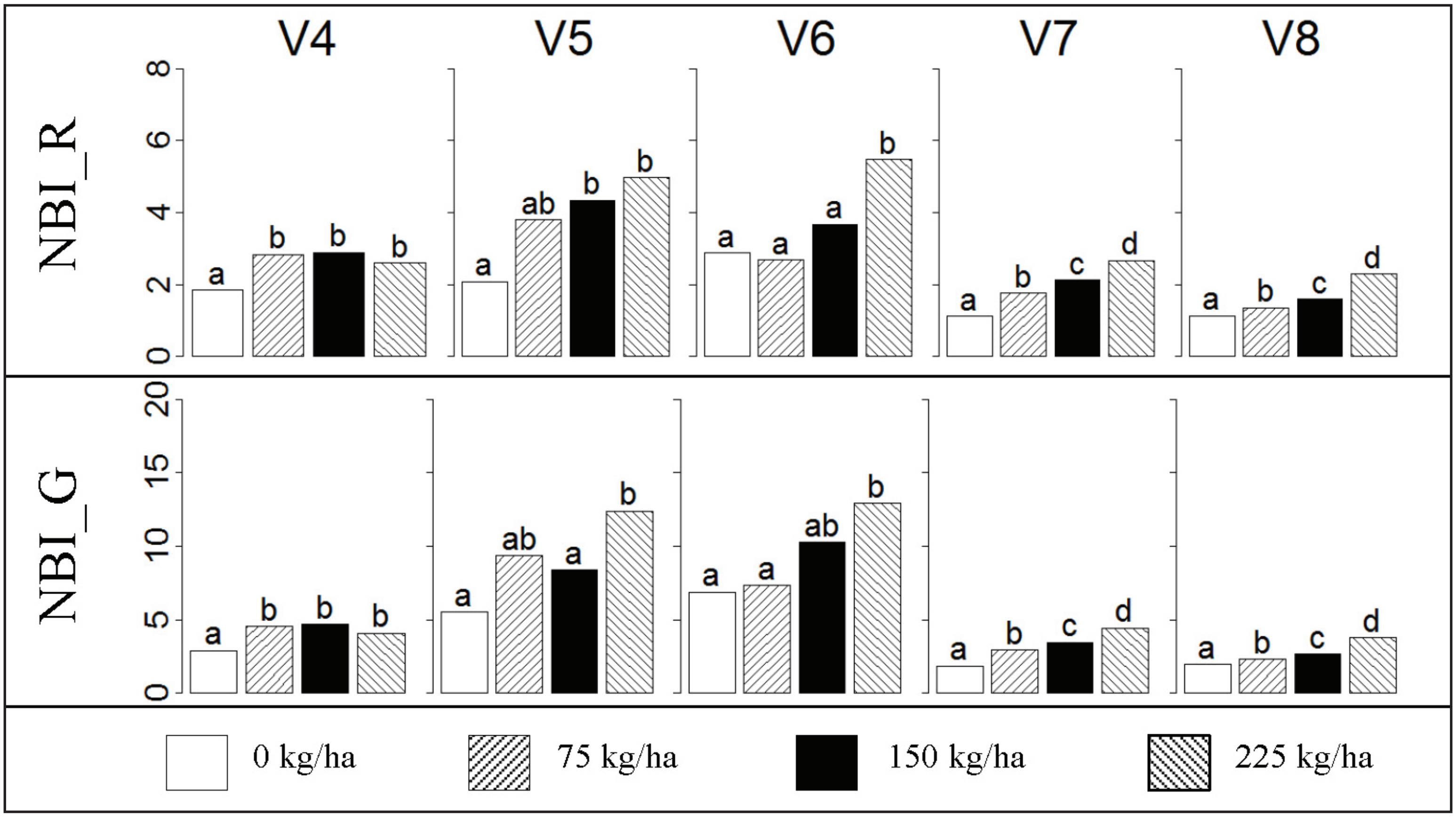

Figure 1: *Different letters indicate significant difference within same growth stage and fluorescence parameter.*

differences in corn plants treated with four different N rates before the V8 growth stage of corn.

Methodology

Location. This experiment was conducted in a greenhouse at Colorado State University.

Soils. Among five locations where soil was collected, the soil with the lowest residual N content was chosen as the soil used for the greenhouse study. Soil texture was classified as a sandy clay loam and residual NO_3-N content was 1.7 mg/kg.

Containers. Corn plants were grown in eighty 11-liter plastic pots. Each pot contained 8 kg of soil. There were three corn plants per pot. Weeds were hand-removed every other day. Water was supplied by drip irrigation every day.

Treatments. Four nitrogen rates were used:

- Control
- Low (75kg/ha)
- Intermediate (150kg/ha)
- High (150 kg/ha).

Prior to planting, N was added as NH_4NO_3 at rates of:

- 0 mg/pot for control
- 583 mg/pot for low N pots
- 1,167 mg/pot for intermediate N pots
- 1,750 mg/pot for high N pots.

Parameter	Description	Formula*
NBI_R	Nitrogen balance index (red)	$\frac{1}{500}\sum_{i=1}^{500}\frac{FRF_{UV_i}}{RF_{R_i}}$
NBI_G	Nitrogen balance index (green)	$\frac{1}{500}\sum_{i=1}^{500}\frac{FRF_{UV_i}}{RF_{G_i}}$

**Fluorescence waveband is indicated as FRF for far-red fluorescence and RF for red fluorescence and induction waveband is in subscript. UV=Ultra-violet; G=Green; R=Red.*

Table 1: *Parameters used for this study along with their description and formula.*

Potassium phosphate and zinc were added at rates of:

- 2,899 mg of KH_2PO_4
- 53 mg of $ZnSO_4$

Sensor used for the study was a Multiplex®3 hand-held multi-parameter optical sensor. It automatically computes two N balance indices: the green (NBI_G) and red (NABI_R) shown in Table 1.

Results promising

Fluorescence. Two parameters were investigated to detect corn N deficiency. The first parameter was the N balance index measured with red excitation (NBI_R) and it presented good potential for N-deficiency detection from V5 growth stage of corn (Figure 1). From V7, all four N-rate treatments were significantly different. The second parameter was the N balance index measured with green excitation (NBI_G) and it presented good potential for N-deficiency detection from V6 growth stage of corn (Figure 1). From V7, all four N treatments were significantly different.

N effect. The different N treatments had a significant effect on dry weight (Figure 2). Dry weights resulting from 150 kg/ha N and 225 kg/ha N were not significantly different from each other. All other treatments resulted in significantly different dry weights.

The main outcome of these results is the fact that induced fluorescence, as measured by Multiplex®3, enabled the detection of N deficiency prior to V8 growth stage of corn (Figure 2). Both NBI_R and NBI_G enabled the distinction between the lowest N rate (0 kg/ha) and the highest N rate (225 kg/ha) from the V4 growth stage of corn. Previous studies have observed the potential of induced fluorescence to detect N deficiency. However, no paper in published literature has mentioned the potential for induced fluorescence to detect N deficiency at such early growth stages.

Our results indicate that induced fluorescence is a promising approach to detect N deficiency in corn at early growth stages, opening new possibilities for the practical implementation of site-specific N management. These results were obtained in a greenhouse environment. Field experiments should be implemented to evaluate the potential of this technology in a corn field environment.

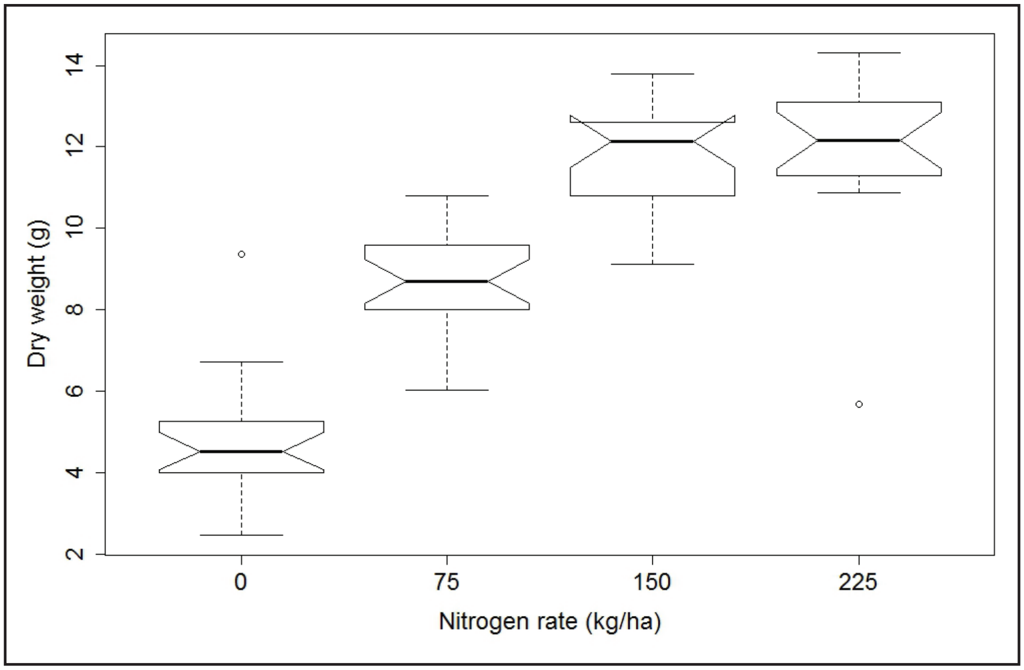

Figure 2: *Boxplots of the difference in dry weights for 4 N rate treatments.*

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