Fluid JOURNAL
Official Journal of the Fluid Fertilizer Foundation
Winter 2009
Vol. 17 No. 1, Issue #63

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Complexities Involved In Better Estimating Corn Grain Yields

Studies build on attempts to achieve more accurate methods, using normalized difference vegetation indices (NDVI) and crop/soil variables.

Summary: *With our goal of determining better corn grain yield estimates, multiple stepwise regression was conducted to determine what measurements best correlated with grain yield at four corn growth stages. Results show that at the V8, V10, and V12 growth stages, leaf nitrogen (N) content had the highest correlation with grain yield. At the V14 growth stage, normalized difference vegetation indices (NDVI) had the highest correlation with corn grain yield. However, different sensors, and/or using multiple variables, did not increase the correlation with grain yield at any of the growth stages tested.*

Enhancing the efficiency of farm inputs, without negatively impacting profitability or the environment, has been a primary focus of precision agricultural research for quite some time. Quantifying the N requirements of corn plants is an important component of this research. Being able to accurately estimate corn grain yield would allow us to better determine the amounts of N needed for plant growth. Currently, research is being conducted using NDVI to quantify the N requirements of corn plants. NDVI has proven to be very effective in determining in-field corn leaf N variability. However, estimating corn grain yield based on NDVI measurement has been challenging.

Accurate grain yield estimation would greatly assist agronomists and farmers in making in-season variable-rate N applications.

With the premise that NDVI readings alone are not an accurate estimator of grain yield, we decided to conduct a study to determine if additional measurements such as SPAD chlorophyll content, corn leaf N content, soil N content, and corn plant height would, in themselves or in conjunction with one another and NDVI, better correlate with corn grain yield than NDVI alone. This was done over four fluid fertilizer application rates of 0, 50, 100, and 175 lbs/A and over four different corn growth stages of V8, V10, V12, and V14 in an effort to determine if the N rate applied to the corn and the timing of these measurements affected the yield correlation.

The objective of this study was to determine what variable or combination of variables--including NDVI, SPAD, corn leaf N content, and soil N content--best correlate with corn grain yield and therefore may be used to increase the accuracy of corn grain yield estimation and expected grain yield based on in-season N recommendations.

Sensors used

Results show that the commercially available active handheld sensors used were able to distinguish in-

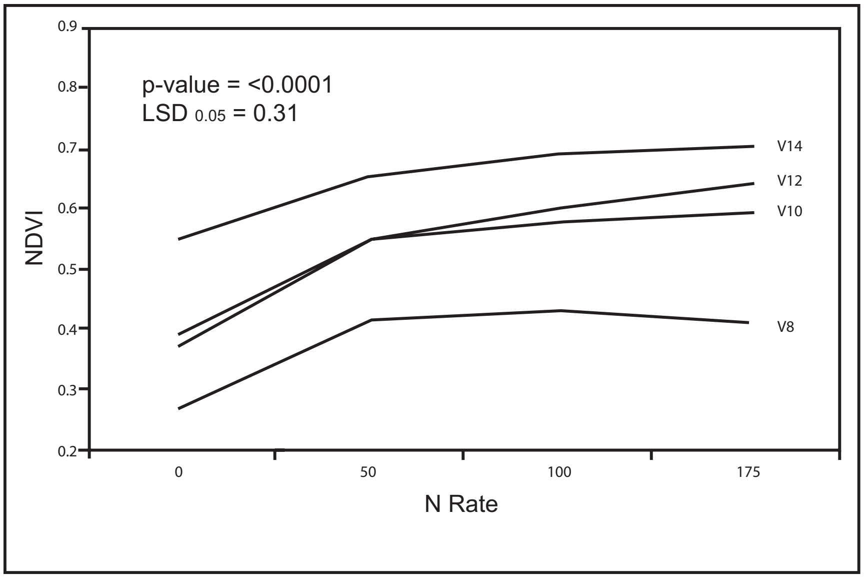

Figure 1. Crop Circle™ NDVI readings by corn growth stage over N rate.

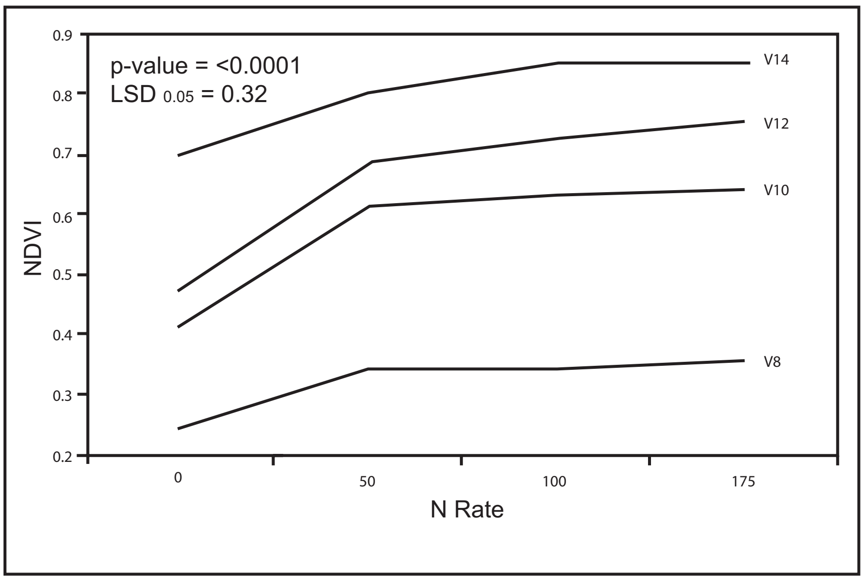

Figure 2. GreenSeeker™ NDVI readings by corn growth stage over N rate.

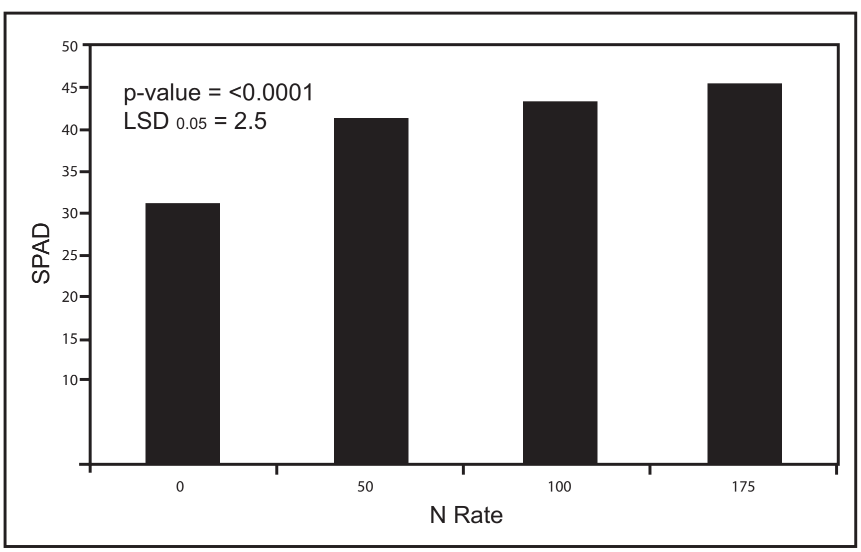

Figure 3. SPAD readings by N rate.

season N variability in corn (Figures 1 and 2). While each sensor yielded different levels of NDVI, the overall trend of the NDVI readings for each sensor generally increased with increasing corn growth stage.

Table 1 shows that both sensors were able to account for similar levels of variability when NDVI was regressed on yield. The r-square for each sensor generally increased with each successive crop growth stage. The highest r-square from NDVI readings was collected at the V14 crop growth stage. The Crop Circle™ sensor achieved an r-square of 0.71 and the GreenSeeker™ achieved an r-square of 0.75 at the V14 crop growth stage. These results suggest that both sensors used in this study correlated relatively well with corn grain yield at later (V14) corn growth stages without the aid of any other ancillary crop or soil variables that often are destructive to the plant. However, these correlations still leave a significant hole in determining accurate N requirements.

Ancillary Data

Analysis for the ancillary crop and soil data is presented in Figures 3, 4, 5, 6 and 7. The corn grain yield data by applied N are also presented there. SPAD leaf chlorophyll content, soil N content, and corn grain yield are a function of applied N rate. Leaf N content and plant height are the function of an applied N rate and corn growth stage interaction.

SPAD leaf chlorophyll content increased with increasing N application rate. The 175 lbs N/A rate had the highest SPAD reading, the 50 lbs/A rate had the lowest (except for the check), and the 100 lbs/A rate was intermediate.

Corn leaf N content increased across applied N rates at all growth stages except V8, which increased up to 100 lbs/A and then decreased at 175 lbs/A. Leaf N content also decreased with each successive growth stage, the V8 growth stage having the highest leaf N content at all N rates, with V10, V12, and V14 each decreasing in leaf N.

Soil N content at each N application rate did not follow any trend as results appeared to be random. The soil N variable has many other factors contributing to it rather than just applied N. Residual soil N, organic matter mineralization, and other factors likely contribute to soil N, meaning applied N rate alone may not necessarily be a good indictor of this variable.

Plant height also increased with corn growth stage but not necessarily with applied N rate. At all growth stages there was an increase above 0 lbs/A rate, but at the V8 and V10 growth stages

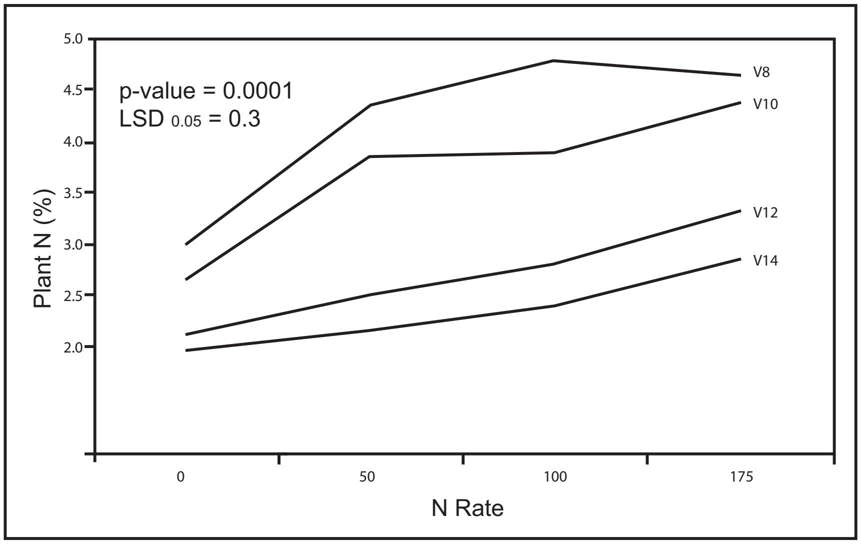

Figure 4. Corn leaf N content by N rate.

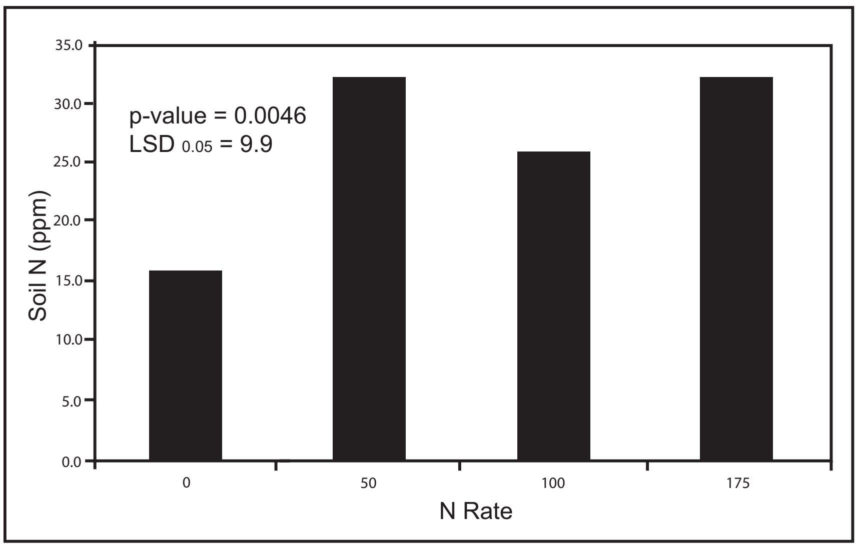

Figure 5. Soil N content by N rate.

there was no significant difference in height across N rates. At the V12 growth stage there was a significant difference in plant height at the 175-lb/A rate when compared to 50 lbs/A. The 100-lb/A rate was intermediate. At the V14 growth stage there was a significant difference in plant height across all applied N rates.

Corn grain yields of 166, 135, 110 and 59 bu/A at N rates of 175, 100, 50, and 0 lbs/A, respectively, were found and used against crop, soil, and NDVI variables to test correlation. The results of the crop and soil variables suggest that all variables tested, except soil N content, may be a good indicator of crop yield.

R-square coefficients

Table 1 shows the r-square coefficients of each variable and how it correlates to crop yield. R-square is a good indicator of how much of the variability in yield each tested variable explains. An r-square was calculated for each variable at each corn growth stage.

V8. At this growth stage leaf N content was the best variable for yield correlation with an r-square of 0.64. No other variable had as high an r-square (including any insignificant multiple regressions) and there were no significant multiple regressions. No combination of variables used in the stepwise multiple regression increased the r-square found with just the leaf N content alone. Compared to NDVI r-square, leaf content was better correlated to grain yield with the Crop Circle™ having an r-square of 0.51 and the GreenSeeker™ having an r-square of 0.49. All other variables had r-squares less than 0.50, suggesting they are not highly correlated or good estimates of yield variability.

V10. At this growth stage, corn leaf N content

Corn Growth Stage	V8	V10	V12	V14
	---------------------------------R-Square---------------------------------			
Predict Yield By:				
Crop Circle NDVI	0.51	0.59	0.69	0.71
GreenSeeker (Red) NDVI	0.49	0.66	0.66	0.75
SPAD	0.39	0.59	0.57	0.43
Soil N	0.31	0.05	0.10	0.27
Leaf N	0.64	0.74	0.74	0.50
Plant Height	0.45	0.62	0.49	0.61
Multiple Regression	--------	--------	0.84 (Soil N + Leaf N)	--------

Table 1. R-Square values for various corn growth stages, corresponding to the sensor and measured soil and crop variables as determined by multiple regressions.

was again the best estimate of yield variability with an r-square of 0.74. At this corn growth stage the NDVI sensor r-squares increased for both sensors with the Crop Circle™ having an r-square of 0.59 and the GreenSeeker™ having an r-square of 0.66. The increase in r-square at this growth stage correlates to the increase in plant biomass for higher NDVI readings and the more linear leaf N content compared to the V8 growth stage. At the V10 growth stage, SPAD reading and plant height variables had similar r-squares with 0.59 and 0.62, respectively. Again, there were no significant multiple regression values and even with the insignificant results there were no r-squares higher than 0.74. These results suggest that at the V10 corn growth stage plant leaf N content is the best indicator of grain yield.

V12. The primary difference between the V12 and V10 growth stages is in plant height where the r-square drops to 0.49 and the V12 growth stage has a significant multiple regression with a combination of soil N and leaf N yielding an r-square of 0.84. However, this value is curious considering soil N content did not correlate to N application rate of corn grain yield and the individual soil N r-square is only 0.10. This multiple regression most likely is an artifact of the data and we have to assume that leaf N content again best explains the corn grain yield variability.

V14. Results at this growth stage show that the NDVI sensors best explain corn grain yield variability, with the Crop Circle™ having an r-square of 0.71 and the GreenSeeker™ having an r-square of 0.75. As the corn continues to get bigger more light is reflected to the sensor, resulting in more accurate NDVI calculations and higher r-square values when explaining yield variability. At this growth stage the leaf N content r-square drops to 0.50, suggesting that the levels of N in the leaf are now too low to accurately equate to yield as N is most likely being distributed to other parts of the plant to prepare for tasseling and subsequent pollination. Again, no multiple regressions were significant and all other measured variables had low r-squares.

Overall

Flag leaf N content best correlated to grain yield at the V8, V10, and V12 crop growth stages. At V14, NDVI had the highest correlation to grain yield and was similar for both sensors tested. No combination led to a higher correlation with grain yield than both leaf N content and NDVI did at the aforementioned growth stages. While we did not increase yield correlation in this study, the variables tested did help to increase our understanding of how these variables correlate with grain yield and provide valuable information for subsequent attempts to increase yield estimation accuracy.

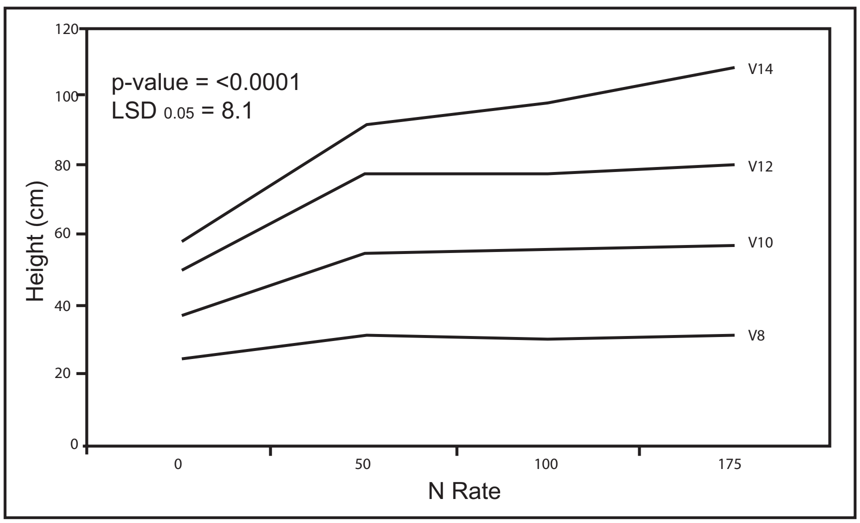

Figure 6. Corn plant height by N rate.

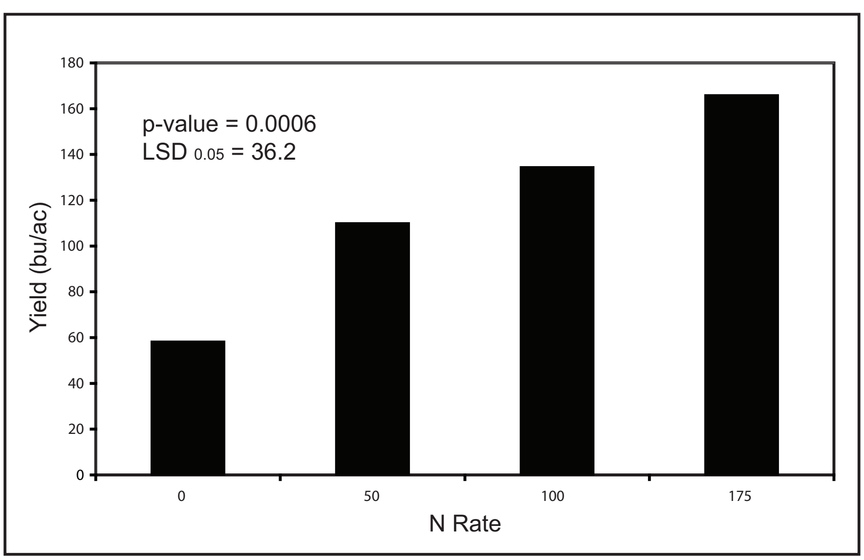

Figure 7. Corn grain yield by N rate.

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