Use of Active Optical Sensors for Crops in Brazil

By J.P. Molin

Active optical sensors have been evaluated as a new approach for precision agriculture and have been successfully used on grain crops and cotton for real-time, site-specific N management. The Precision Agriculture Research Group of the University of São Paulo has been involved with several activities related to the major optical sensors currently on the market (GreenSeeker, CropCircle, and N-Sensor).

During the last 3 years, the behavior of the normalized difference vegetation index (NDVI) in wheat, triticale, barley, corn, cotton, and sugarcane was evaluated using similar procedures in a series of field plots. Experiments have shown increasing NDVI readings in response to increasing N rates, foliar N content, and grain yield. In one of the investigations with wheat, a preliminary model for an in-season estimated yield index (INSEY) versus yield was obtained based on several locations and seven local varieties **(Figure 1)**, using the GreenSeeker sensor (Povh et al., 2008b).

In one of the field tests (Povh et al., 2008a), the objective was to establish an application rate for N using variable rate technology (VRT) in wheat based on the readings of the GreenSeeker sensor and the model from **Figure 1**. The experiment was conducted in a small field of 5.4 ha in the region of Campos Gerais of Paraná. The data were collected **(Figure 2a)** and post processed for the generation of NDVI **(Figure 3a)**, an N recommendation map **(Figure 3c)**, and in-season application with liquid N fertilizer **(Figures 2b and 2c)**. Nitrogen rates were simplified to 20, 40, and 60 kg/ha because of equipment limitations.

The experiment also consisted of strips receiving 120 kg N/ha, which served as a reference for the sensor, and strips that received 18.4 and 52.4 kg N/ha that were complemented with additional N based on the active optical sensor readings. Altitude was used as criteria for field stratification **(Figure 3b)**. At maturity, the field was harvested and yield mapped **(Figure 3c)**. In addition, a series of 96 plots (5 m by 9 rows)…eight for each treatment (variable and constant rate and each altitude class)…were manually harvested and the data were statistically analyzed by comparing yield averages with the Snedecor F test at 5% level of significance.

The results **(Table 1)** allow that spatial variability of NDVI exists, even in areas where constant rates of N were applied, showing that the crop responds in a non-uniform manner inside the same field. The methodology used for the variable-rate N application, using the crop as indicator, proved to be effective at determining N rates, with higher economy of fertilizer in areas with lower yield potential. Although reaching a high economy, the yield of the treatments receiving variable N rates were not statistically different from the treatments receiving fixed N rates.

In sugarcane in Brazil, there are a series of activities being conducted. The one in the most advanced stage is using the N-Sensor to indicate N application demands in commercial sugarcane fields. Eight fields of commercial sugarcane were evaluated under varying soil textural conditions ranging from sandy to heavy soils, ratoon stages, varieties, and harvesting time along the 8 months of the harvesting season. The sugarcane fields were scanned using the N-Sensor three times during the 2009 season, at 20, 40, and 60 cm of average stem height **(Figure 4)**. The measured reflectance maps were processed and divided into five classes. For each class, two samples were collected to measure aboveground biomass; total N content was analyzed and N uptake was calculated.

The project is generating a large amount of data and providing the proper measurements of parameters for modeling biomass and N uptake in sugarcane. According to the data already collected, the N-Sensor is able to detect the variability of biomass and N supply by the soil. The results indicate the presence of variability of biomass production and N-uptake in sugarcane resulting from distinct varieties, soil, and season period, but the differences are not affecting the detection of actual biomass and N-uptake by the N-Sensor. Based on the early results from this study, an initial algorithm is being proposed to conduct real-time, variable-rate N application based

Table 1. Wheat yield data from plots in each altitude class.

	Wheat grain yield, Mg/ha					
	Elevation 1		Elevation 2		Elevation 3	
	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
Flat rate	3.3	3.5	3.0	3.0	2.6	2.9
Variable rate	3.3	3.6	3.2	2.9	2.7	3.0

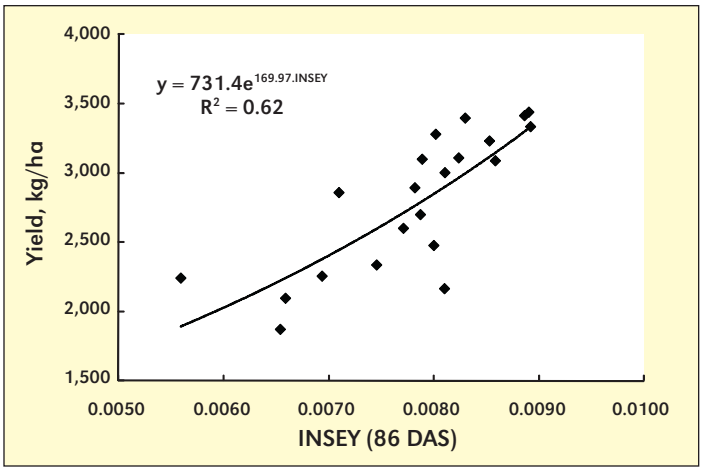

Figure 1. Exponential model relating INSEY calculated at 86 days after sowing (DAS) using a GreenSeeker sensor and wheat yield, based on experimental plots containing varying N rates and varieties.

Abbreviations and notes: N = nitrogen.

Figure 2. Scanning the field with the sensor (A); N VRT application based on the post-processed map (B) and (C).

on sensor readings.

The use of field plots to evaluate the behavior of NDVI in sugarcane is labor intensive because of the amount of material needing to be manually harvested. Despite this difficulty, experiments were conducted to measure the effect on NDVI of increasing N rates, plant N content, and yield. In these studies, the sensor used was the CropCircle. Measurements were collected for varying soil textures ranging from sandy to heavy clay soils, different ratoon stages, and harvesting times. The fertilizer treatments were N rates ranging from 0 to 200 kg/ha. The initial results indicated that the sensor was able to distinguish among N rates, allowing for an algorithm capable of real-time application of N to be developed. **Figure 6** shows examples of readings collected at 50 and 75-cm height, on four experiments varying in crop age and soil types. The results indicate that the vegetation index behavior follows a similar pattern as the crop grows, but is still sensitive to field conditions, thus requiring specific models for different situations.

In another study on sugarcane, active optical sensors were tested to evaluate the correlation between

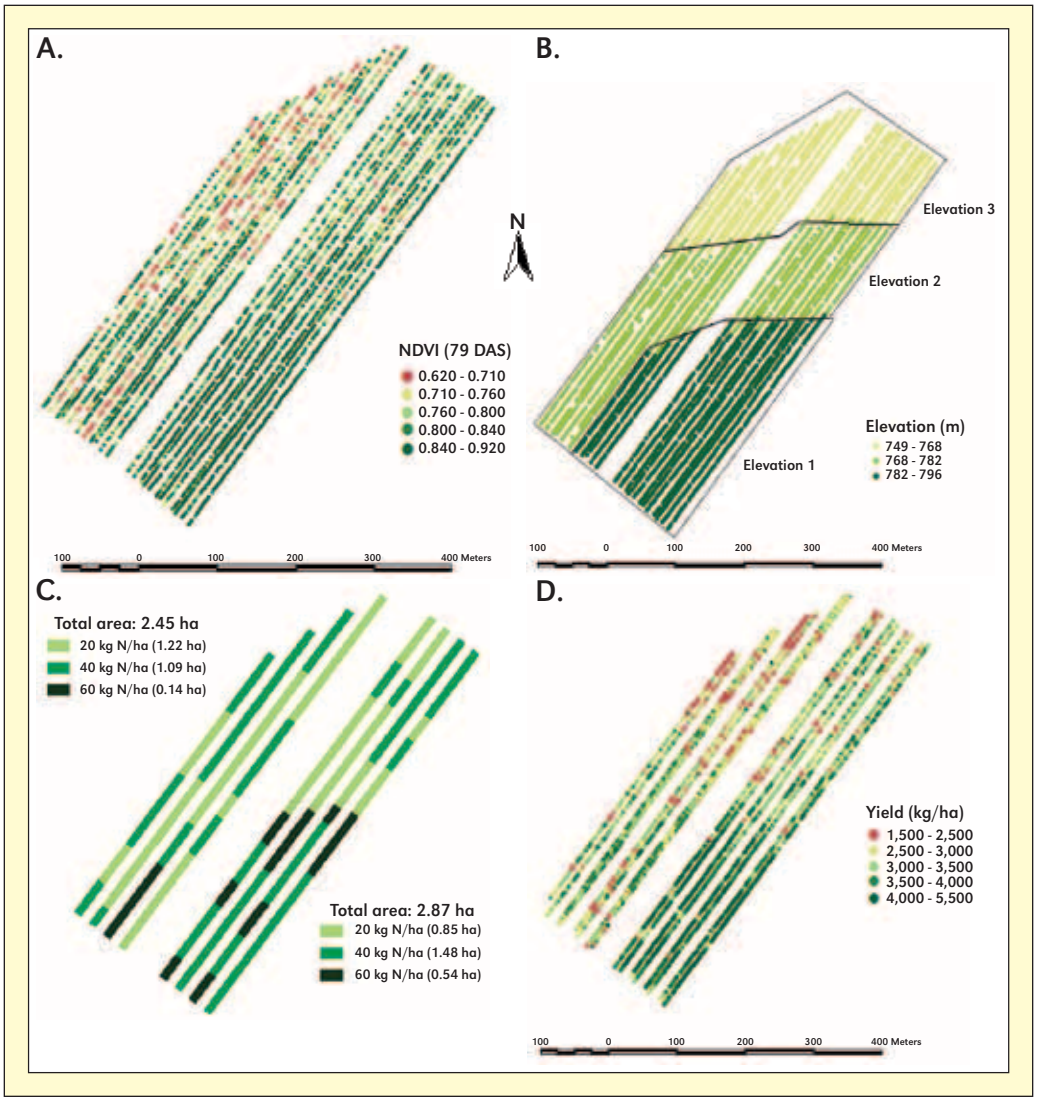

Figure 3. Map of NDVI at 79 DAS (A), three altitudes (B), N rated applied (C), wheat yield (D).

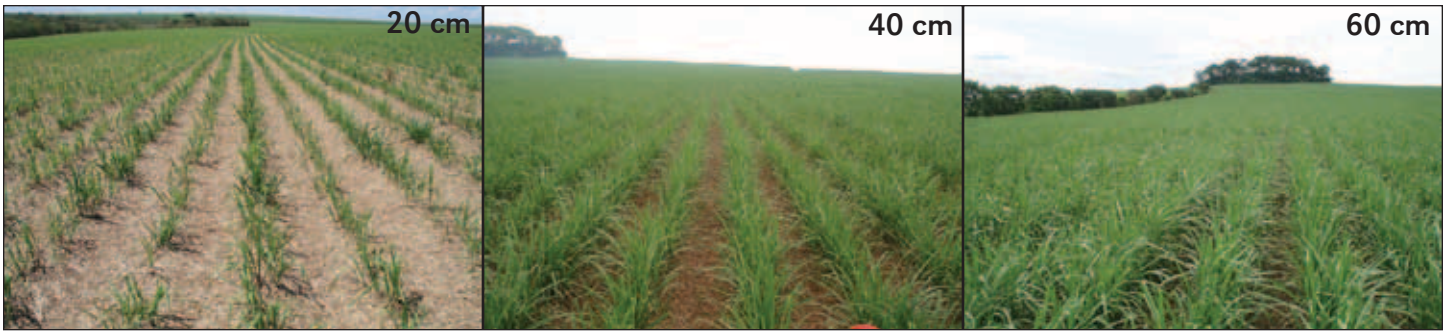

Figure 4. Sugarcane field status at the scanned stages.

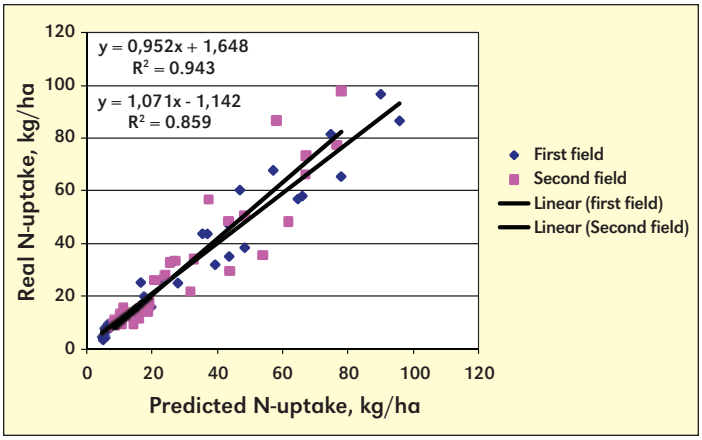

Figure 5. Sensor-predicted N uptake plotted against actual N-uptake for two fields, one on sandy soil and the second on clay soil.

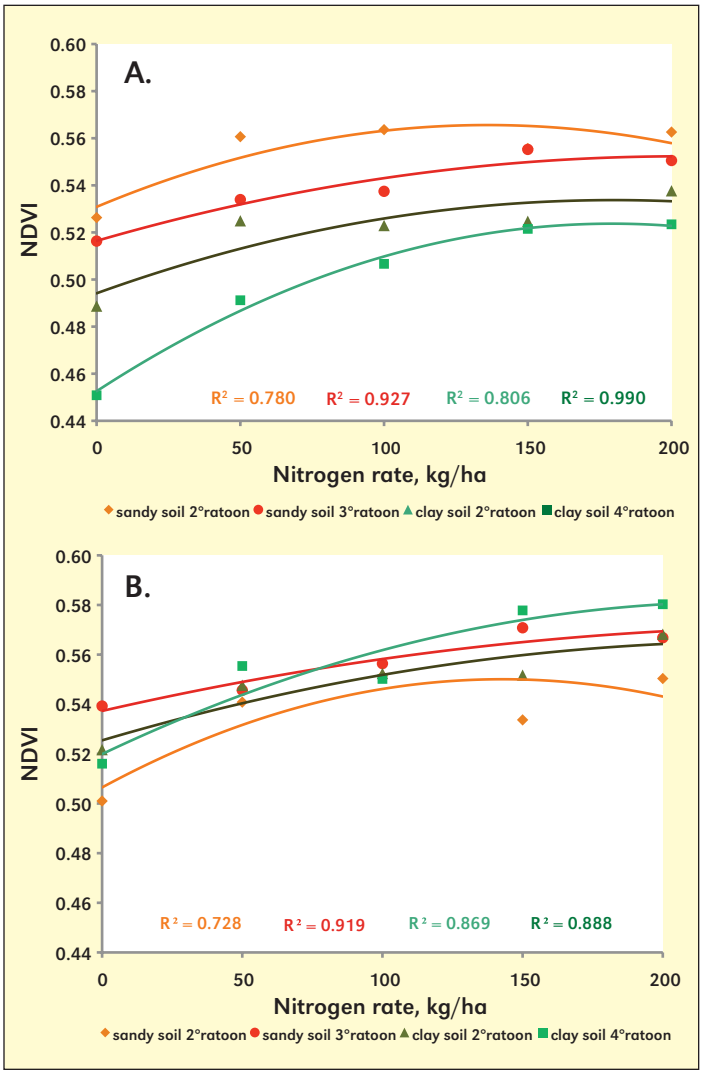

Figure 6. NDVI curves for N rates applied to four sugarcane experiments. Readings were collected at 50-cm (A) and 75-cm height (B) (after Amaral et al., 2010).

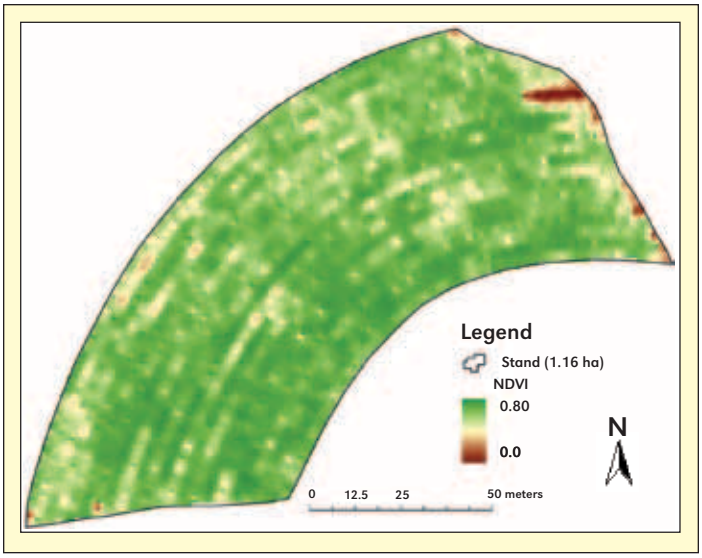

Figure 7. Map of NDVI levels obtained from sugarcane rows. Low index levels were associated with cane failures 100 days after planting (after Alvares et al., 2008).

NDVI and crop failures. Manual measurements are regularly conducted by a quality control crew between 2 and 3 months after planting and require significant labor. High levels of failures indicate the necessity of site-specific replanting or in some cases total replanting of a field. The same process may be used as criteria to decide on a ratoon field, when it has to be eliminated for replanting, based on crop failures. Initially, plots were located inside several fields and scanned. Results show high correlations between NDVI and the percentage of crop failure measured by the conventional method, indicating that it may be a promising alternative for failure measurement on sugarcane areas. As an example, one small field (1.16 ha) was scanned every two rows and the map **(Figure 7)** shows the vegetation index levels dropping in some spots, indicating the presence of failures that may be properly managed. BC

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