PROGRESS IN REMOTE SENSING OF PI NITROGEN UPTAKE

The ability to measure real-time crop characteristics is allowing improved nitrogen management during the season, giving potential to increase productivity and profitability in the rice industry.

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ADVANCES in and availability of new remote sensing sensors has provided greater opportunities for agriculture.

Our team has spent five years investigating the potential of remote sensing in rice by comparing the available research, investigating commercial drone, aircraft and satellite sensors and platforms, with the aim of better predicting nitrogen uptake in rice at panicle initiation (PI).

We have identified a number of remote sensing options for rice growers. This research is part of an ongoing Rural Industries Research & Development Corporation (RIRDC) research project.

NDVI is of limited value in detecting differences in nitrogen uptake in rice crops at panicle initiation (PI) due to its saturation at nitrogen uptake levels above 80 kg N/ha.

NDRE uses wavelengths in the red edge band and it provides a stronger relationship with nitrogen uptake in rice at PI than NDVI.

A preliminary calibration has been developed for the MicaSense RedEdge sensor to directly predict PI nitrogen topdressing rates for Koshihikari, Doongara and YRK5 rice varieties using NDRE values, without the need to physically sample the crop.

Rice varieties requiring nitrogen topdressing at higher levels of PI nitrogen uptake, will still require physical sampling of the crop at PI to determine PI nitrogen uptake.

QUICK TAKE

Drone technology has assisted the rice industry in investigating a range of sensors to better predict nitrogen uptake at PI.
Remote sensing in rice historically involved the use of normalised difference vegetation index (NDVI) maps of rice fields generated from satellite, aircraft or drone sources. Although these maps can appear to show significant differences within fields, once the rice crop develops a full canopy, which often occurs before PI, NDVI becomes saturated and cannot detect difference in crop biomass or nitrogen uptake. Our research and other research across the world have shown that above a nitrogen uptake of approximately 80 kg N/ha, NDVI cannot detect difference in crop growth at PI (Figure 1a).

Many new sensors have become available in the last few years that measure an additional wavelength band called the red edge, which is a narrow band (710 to 740 nm) located between the visible red and near infrared (NIR) regions of the light spectra. This region of the spectra is very sensitive to changes in foliar chlorophyll content, which is strongly related to plant nitrogen concentration. Vegetation indices that include the red edge region, such as the normalised difference red edge (NDRE), have been found to saturate at a much higher nitrogen concentration than the commonly used NDVI. Our research shows that a better relationship exists between NDRE and PI nitrogen uptake (Figure 1b) than NDVI and PI nitrogen uptake (Figure 1a).

Once the rice crop gets past mid-tillering and particularly once it has reached PI, NDVI images of rice fields are of little value, however NDRE images are able to show differences in nitrogen uptake of the crop (Figure 3) at this later stage. Although NDRE is much better than NDVI, its value decreases for PI nitrogen uptake values above approximately 100 kg N/ha, and cannot be used as a direct nitrogen uptake prediction tool for rice varieties that require high levels of nitrogen, e.g. Reiziq®, Sherpa® and Opus®.

Available sources of NDRE imagery
In our research we compared NDRE (red edge) imagery from a number of sensors to nitrogen uptake in rice at PI. These sensors included Worldview 3 satellite and a range of drone mounted sensors (the Parrot Sequoia, MicaSense RedEdge and SlantRange). From Figure 2 it can be seen that a strong relationship between NDRE and PI nitrogen uptake exists for each sensor, but they all flatten out and become of limited value above a nitrogen uptake level of around 100 kg N/ha.

The other important factor that is evident in Figure 2 is that the relationship between NDRE and PI nitrogen uptake is different for each sensor so an individual calibration needs to be developed for each sensor. The reason for these differences is thought to be due the different location of the red edge waveband in each sensor and how the red edge shifts left or right with varying levels of plant chlorophyll.
From the NDRE and PI N uptake relationship data shown in Figure 2 it can be seen that both the MicaSense RedEdge and Worldview 3 relationships are relatively steep at lower PI nitrogen uptake values, while the SlantRange and Sequoia relationships are much flatter at the same levels. The slope of these relationships and spread of the data highlights the possibility that the MicaSense RedEdge and Worldview 3 sensors show potential for PI nitrogen uptake predictions below a nitrogen uptake value of approximately 100 kg N/ha (Figure 2).

**Using MicaSense RedEdge NDRE values**

Our research showed that below an NDRE of 0.6, the MicaSense RedEdge camera has what we consider an acceptable level of accuracy for predicting PI nitrogen uptake (Figure 4). Above an NDRE of 0.6, the curve flattens significantly and the prediction accuracy is poor and not suitable for the prediction of PI nitrogen uptake, as shown by the red box in Figure 4.

The NIR tissue test has nitrogen top dressing recommendations in the program that are based on many years of research and provide recommendations based on crop PI nitrogen uptake for each variety and water depth at microspore. The top dressing recommendations have been converted into a direct relationship with NDRE (Figure 5) based on the relationship between NDRE and PI nitrogen uptake shown in Figure 4. When the area of the graph with NDRE above 0.6 is shaded out (the red box) due to its poor prediction accuracy of PI nitrogen uptake, there is still potential for Koshihikari, Doongara and YRK5 PI top dressing requirements to be predicted using MicaSense RedEdge NDRE values directly (Figure 5).

**Drone and satellite red edge options**

From these results, drones and red edge sensors clearly have a role for rice growers looking at spatial variability of nitrogen in individual rice fields. However, as an industry-wide option the use of drones is limited by short flying time (battery life), line of sight regulations, wind and cloud conditions, often 70% image overlap requirements and the short daily data collection period (only 3 hours either side of solar noon).

Satellite imagery is really the only practical option for covering all of the rice crops in the industry in the short PI timing window. The Worldview 3 satellite based sensor has shown considerable potential with good correlations with PI nitrogen uptake, daily revisit time and 1.25 m resolution. However images are very expensive, i.e. approximately $55 per km² with a minimum capture of 100 km². The Sentinel 2 sensor offers free imagery, a 10-day revisit time and a red edge waveband (705 nm), but the resolution of the red edge band is 20 m, which is too coarse for measuring zonal variability in rice fields that contain contour banks.

Another option, which is yet to be investigated, is the RapidEye satellites that have a red edge waveband, daily revisit time and 5 m resolution. Data from RapidEye is much more cost effective than Worldview 3 but future research needs to determine its accuracy at predicting PI nitrogen uptake and if the 5 m pixel size is suitable. Remotely sensed images of rice crops can highlight within field variability of crop nitrogen uptake. Through targeted agronomy this information can greatly improve crop management decisions leading to improved grain yield and quality and ensure sustainability of rice growing in Australia.

**Where to now?**

In the 2017–18 rice season a calibration will be developed between NDRE and PI nitrogen uptake for the RapidEye satellites testing its accuracy and potential for commercial use. Options will be investigated into making satellite based red edge images available to growers in a timely manner at an acceptable price. Calibrations for the MicaSense RedEdge sensor will continue to be updated across more rice varieties.