NIR to enhance precision crop management

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in a rice hull

- This project investigated combining the precision of the NIR tissue test with the sampling ease of remote sensing
- NDVI images are useful in providing guidance for where to take samples from rice crops for analysis using the NIR tissue test but should not be used to predict nitrogen uptake and fertiliser application rates
- The data from two seasons use of the Hyperion satellite sensor are encouraging, however many more samples over several years are needed to obtain robust calibrations

Nitrogen management of a rice crop is a complex task. Panicle initiation is a critical time when crop nitrogen can be assessed and deficiencies rectified. Growers, agronomists and researchers have strived for many years to improve the reliability of determining the nitrogen fertiliser requirements of the rice crop at this time.

Over 40% of rice growers use the SunRice NIR Tissue Test analysis and fertiliser recommendation service in any one year. This is an extremely high adoption rate for a soil or plant analysis service, but there are weaknesses of the current system, including:

- time required to collect and preserve the samples
- large number of growers who do not use the service
- minimal sampling intensity relative to the variation across a crop
- the expectation that the fertiliser needs of rice vary widely across a field.

A project was established to investigate the potential of combining the precision of the NIR Tissue Test with the sampling ease of remote sensing. The aims of this project were to provide:

- an evaluation of the potential of available airborne scanning NIR sensors to determine variations in dry matter and shoot composition (eg nitrogen and starch) across rice crops
- an understanding of the limitations of fresh tissue analysis by airborne NIR sensors
- calibrations for nutrients in fresh rice tissue for use in interpreting data obtained from airborne NIR sensors
- a basis on which to keep the NIR Tissue Testing Service in line with the latest technology.

Scanning fresh rice tissue

A typical NIR (near infrared) spectrum of rice tissue is a series of crests and troughs extending across the 400–2500 nanometre (nm) range of the electromagnetic spectrum. In Figure 1, where the spectra of both fresh and dry, ground tissue are plotted, the effect of water content on spectra can be seen. Also contained in the spectrum is a large amount of information about the chemical composition of the tissue. Much of the nitrogen information is in the spectral regions 1450–1600 nm and 2000–2300 nm regions, water peaks are seen at 1420 and 1900 nm and chlorophyll peaks are in the 400–700 nm range.

Normalised Difference Vegetative Index (NDVI)

Many rice growers are currently using NDVI images to determine where to take samples from their rice crop for analysis by NIR tissue test. NDVI images provide a good visual representation of differences in crop growth and are very useful in aiding site selection for tissue test sampling.

However some farmers are using the NDVI image to directly determine where to apply their panicle initiation nitrogen and the rate. ***This is a very risky practice and is not recommended.*** NDVI is a poor estimator of dry matter and a very poor estimator of the nitrogen content of the canopy. The reason for this is the wavelength spectra used for NDVI.

NDVI is calculated from the 660–680 nm and 780–840 nm wavelength bands. As can be seen from Figure 1, the parts of the spectrum used to calculate NDVI are not related to nitrogen. The poor correlations between NDVI and fresh weight, tissue nitrogen and nitrogen uptake are shown in Table 1. A correlation of 0.90 or higher would be needed to give confidence that the sampling technique would provide reliable predictions.

Hyperspectral imagery

In 2002 hyperspectral (many wavelength) reflectance data were acquired from the Hyperion sensor which is mounted in NASA's EO-1 satellite that orbits 705 km above the earth's surface. It records light reflected from the earth across the wavelength range 400–2500 nm. The minimum recorded area (pixel) is a 30 m x 30 m square.

The atmospherically corrected spectral reflectance data were imported into the software from the NIR instrument used for the tissue nitrogen test. The satellite data were calibrated with the fresh weight, nitrogen content (%N) and nitrogen uptake values from 38 rice crop sample sites in Coleambally. Preliminary calibrations for fresh weight, % nitrogen and nitrogen uptake were produced with the nitrogen uptake relationship presented in Figure 2.

On 3 January 2006 hyperspectral reflectance data was again acquired from the Hyperion sensor. In the Murrami area 10 farms were sampled with rice plant samples obtained from 42 sites. The fresh samples were weighed, scanned with a scanning radiometer and then microwave-dried, ground and scanned on the NIR used for the tissue nitrogen test. There was a delay of six weeks before the satellite reflectance data was available and then more time was taken to geo-reference and atmospherically correct the reflectance data.

This data is being used to test the predictive capability of the calibration developed from the 2002 data. The results from the two seasons Hyperion sensor data is encouraging. The number of samples in each year was small but when both years' data were combined the predictive values improved. More data is needed and the plan is to increase the number of sites to test the correlation of satellite hyperspectral data with crop nitrogen content and nitrogen uptake.

It should be noted that the calibrations initially obtained for the current NIR Rice Tissue Test improved steadily from 1987 and that the calibrations obtained from the satellite data preliminary study are not much worse than those we began with in 1987. This work needs to continue for several years to develop robust calibrations and work out the best way to utilise this technology in rice crop management.

Future availability, cost, cloud cover and turn-around time encountered in the use of satellite imagery are major concerns to be resolved before this technology can be used with confidence.

Implications

This project has proved that rice crops can be assessed for variability of dry matter and nitrogen uptake, which are required for better fertiliser management, using reflectance spectra recorded from satellites.

The findings require expansion in future seasons to:

- achieve calibrations which provide accurate analyses across all varieties, rice areas and years, for all tissue constituents currently available to farmers using the NIR Tissue Test
- determine the limitations of satellite vs air-borne sensors in routine use by the Australian rice industry.

There is also an expectation that the assessment of the variability of crops will allow rice growers to apply the appropriate (variable) rates of fertiliser. The findings of the current study indicate that the determination of the most appropriate and economical rate of fertiliser can be based on actual values for crop nitrogen uptake in areas as small as 30 m x 30 m. The guidelines for such calculations are needed.

RIRDC Project DAN-222A

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Table 1: Correlations of NDVI with the fresh weight, % nitrogen and nitrogen uptake data for fresh rice in 2002

Source of reflectance data	No. of samples	Correlation (r^2) for fresh weight	Correlation (r^2) for %N	Correlation (r^2) for N uptake
Radiometer (hand held)	34	0.29	0.22	0.33
Hyperion (satellite)	38	0.54	0.03	0.42

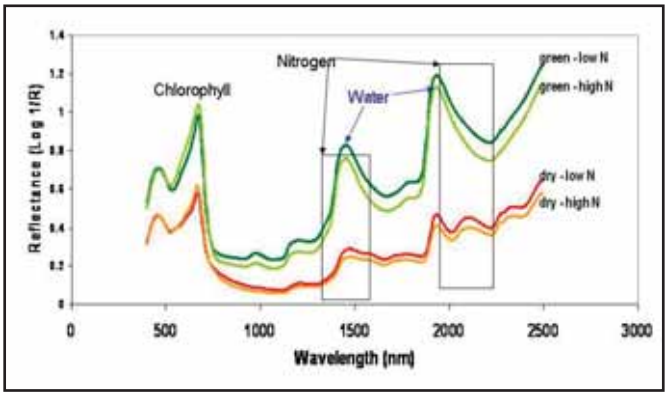

Figure 1: Typical spectra of fresh (green) and dry ground (orange) rice tissue showing the location of typical nitrogen, water and chlorophyll absorption bands. Samples of tissues were collected from high and low nitrogen status crops.

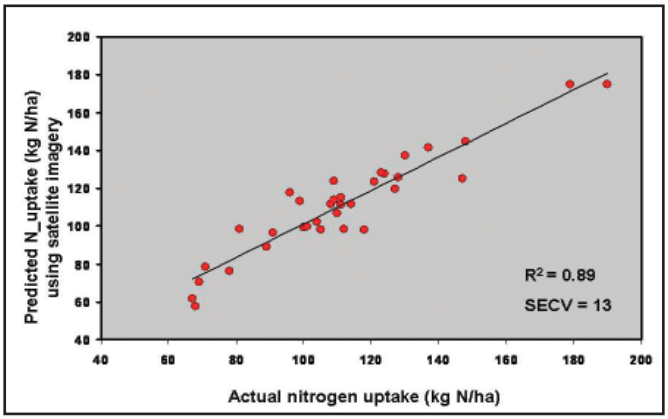

Figure 2: Preliminary prediction of nitrogen uptake (kg N/ha) in standing rice crops using Hyperion satellite imagery (400–2500 nm), compared with calculated uptake.