Using soil sensors, plant tests and multispectral images to monitor nitrogen placement strategies for wheat subject to waterlogging

James Brinkhoff[1], Leigh Vial[1,2], Laura Kaylock[3], John Hornbuckle[2]

[1] Deakin University, Geelong, Australia. *@cerrf_griffith*
[2] Irrigation farmer, Moulamein.
[3] Western Murray Land Improvement Group. *@WesternMurray*

Contact: *james.brinkhoff@deakin.edu.au*

Trial plan

A winter wheat trial was established to assess the whole-season nitrogen (N) availability against different nitrogen placement strategies when subject to waterlogging. A number of monitoring strategies to track the soil status and nitrogen uptake over the season are compared.

There were two irrigation treatments, (i) non-waterlogged and (ii) waterlogged. The waterlogged treatment was imposed 74 days after sowing (DAS) by holding water on selected plots for 12 days. All plots received MAP+1.0%Zn at 150kg/ha in the seed row. There were five Urea N fertilizer treatments: (i) none (C), (ii) 290 kg/ha topdressed early before waterlogging (TDE), (iii) 290 kg/ha topdressed late after waterlogging (TDL), (iv) 190 kg/ha banded in the mid-row (MRB1) and (v) 290 kg/ha banded in the mid-row (MRB2). The plots were approximately 4m x 20m, and there were at least 4 replicates of each of the 20 irrigation x N treatments. The N placement and timing is illustrated in Figure 1. The hypothesis was that the MRB Urea would have a slower release and would be better preserved during the waterlogging event so that more N would be available to the wheat throughout the season.

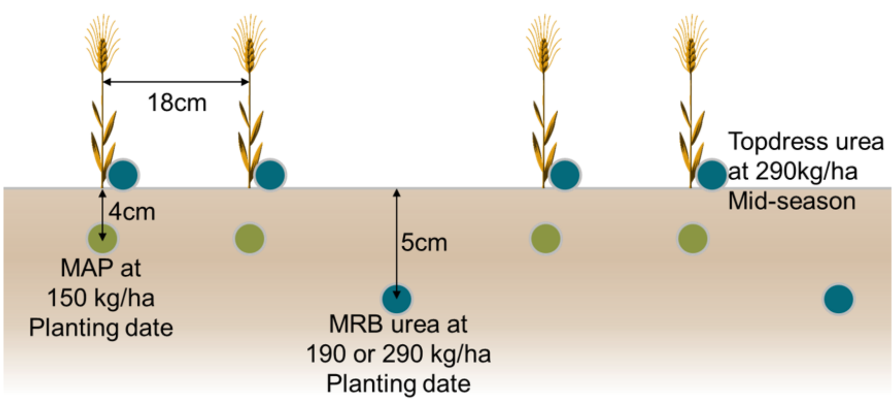


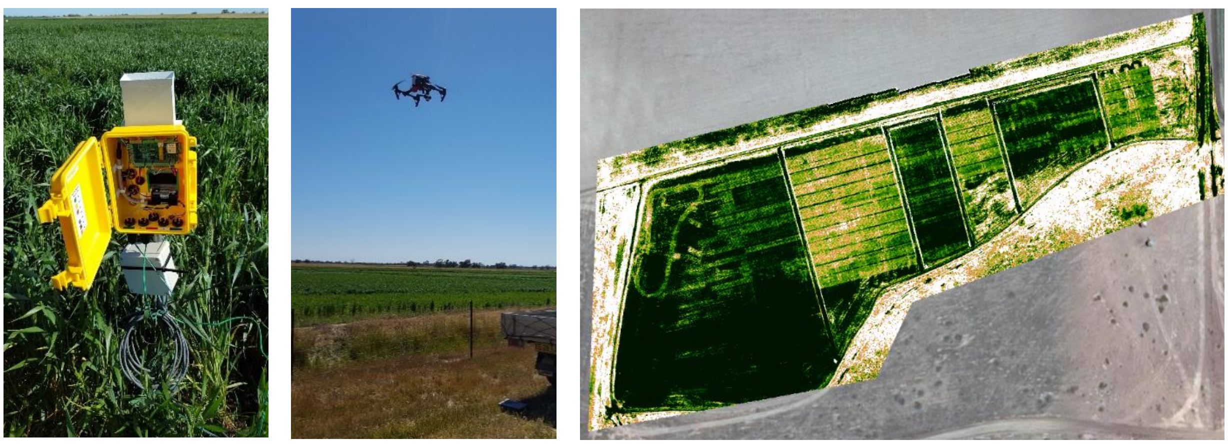
Figure 1. Nitrogen placement and timing.

Monitoring

Waterlogging status was monitored using 12 WiField WiFi-based loggers. The WiField unit was developed by Deakin University and is available from Goanna Telemetry.

These were connected to soil tension sensors, multi-sensor capacitance probes, redox probes and rain gauges. A single solar-powered WiFi access point with a 3G modem provided data coverage across the site so all data was available online in real time. Waterlogged status was associated with redox potentials indicating plant limiting soil redox levels (< 350 mV) and matric potential indicating saturation (> -5 kPA).

Plant nitrogen status was monitored during the season using two methods. The first used a Yara N-Tester, with 30 readings taken per plot. The second method used remotely-sensed vegetation indicies calculated from images taken by a Micasense RedEdge camera mounted on a UAV. The images were reflectance calibrated and orthomosaiced in Pix4D. Vegetation indicies were derived from the orthomosaics, including normalized difference vegetation index (NDVI), normalized difference red edge (NDRE) and canopy chlorophyll content index (CCCI). Measurements were taken 47 DAS, 90 DAS and 133 DAS. In addition to these in-season N measurements, grain nitrogen content at harvest was calculated from grain protein, and yield data was also collected.

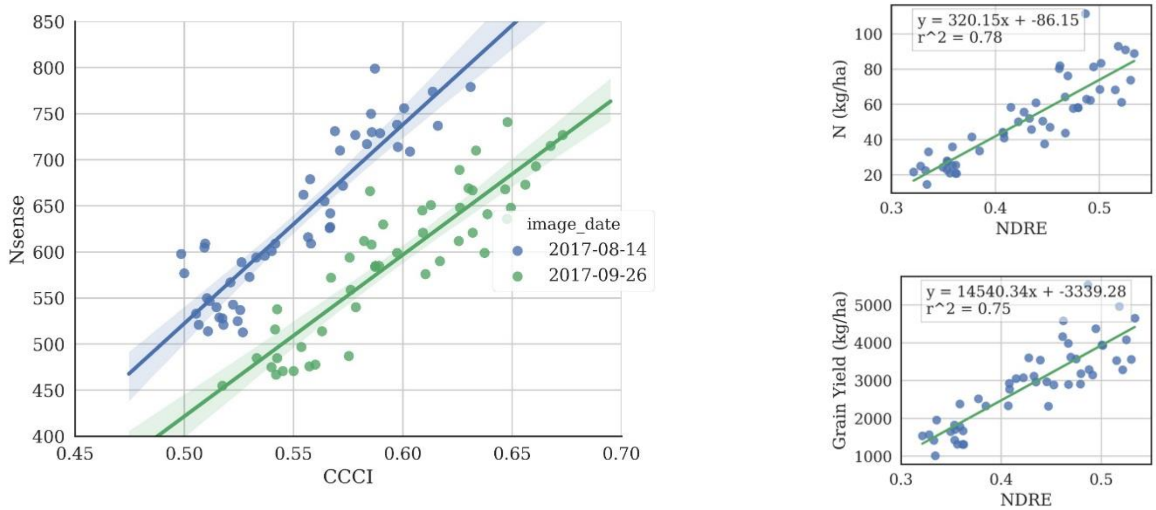


(a) (b) (c)

Figure 2. (a) WiField data loggers in the trial, taking soil moisture, rain and redox data. (b) UAV with multi-spectral camera. (c) CCCI from UAV images taken 90 DAS. The lighter areas (lower CCCI) are the waterlogged plots.

Results

The correlation between the N-tester measurements and normalized difference vegetation index (NDVI) and red edge (NDRE) was poor earlier in the season when biomass was small, but improved as the season progressed. The correlation with the canopy chlorophyll content index (CCCI) was good throughout (R^2>0.8), except for the earliest image. This demonstrates the ability of CCCI to normalize the chlorophyll estimation for biomass, as it divides NDRE (chlorophyll) by NDVI (biomass). However, the linear relationship between the N-tester readings and CCCI changed over time, as shown in Figure 3(a). This is most probably due to the N-dilution effect. As biomass increases, the N concentration (%) per leaf is diluted, which is evidenced by lower N-tester readings later in the season. As other authors have noted, remotely-sensed vegetation indicies such as CCCI are more suitable for monitoring N content in g/ha.



(a) **(b)**

Figure 3. (a) Relationship between the N-tester readings and remotely sensed CCCI. (b) Relationships between harvested grain N and yield, and NDRE.

Final harvest results were also compared with the vegetation indicies. Grain nitrogen was calculated from grain protein using the well-established relationship: Grain N (kg/ha) = Protein (%) / 5.7 x yield (kg/ha). Both Grain N and yield were well correlated with NDRE from the 133 DAS image ($R^2 > 0.75$) as shown in Figure 3(b).

All N monitoring techniques showed significant differences between waterlogged and non-waterlogged treatments at 90 DAS, with the difference reduced by 133 DAS. A summary of the differences between the N treatments is shown in Figure 4. Contrary to expectations, higher apparent N recovery efficiency was recorded in the topdressed treatments than the mid-row banded treatments, particularly the one topdressed early before waterlogging (TDE). There was no real difference in the N recovery between the MRB rates (190 and 290 kg/ha).

CCCI (133DAS)	C	MRB1	MRB2	TDE	TDL
Non-WL	0.56a	0.62b	0.63b	0.65b	0.62b
WL	0.54a	0.59b	0.59b	**0.64c**	0.61b

GN (kg/ha)	C	MRB1	MRB2	TDE	TDL
Non-WL	28a	54b	60b	**84c**	68bc
WL	26a	52b	49b	**83c**	65bc

GY (T/ha)	C	MRB1	MRB2	TDE	TDL
Non-WL	1.7a	2.9b	3.4b	4.1b	3.4b
WL	1.8a	3.3b	3.2b	4.3b	3.7b

Figure 4. Summary of differences between treatments. The top table shows CCCI from the 133 DAS image, the middle shows grain nitrogen at harvest, and the bottom show grain yield.

In the current season, the trial is being extended to multiple sites, and in-season destructive testing of plant N is being conducted to provide assessment of remote sensing to predict actual plant N uptake.

Acknowledgements

The authors thank GRDC, Murray LLS and Murray Irrigation for supporting the trial.