Office Use Only	
Project Code	
Project Type	

FINAL REPORT 2023

Final reports must be submitted using the online application form at www.sagit.com.au with this Word document attached ***within two months*** after the completion of the Project Term.

PROJECT CODE	**ELD-03422-R**
PROJECT TITLE	
Nitrogen strategies for HRZ wheat in waterlogged soils and denitrification	

PROJECT DURATION *These dates **must** be the same as those stated in the Funding Agreement.*						
Project start date	**1/06/2022**					
Project end date	**30/06/2023**					
SAGIT Funding	2022					

PRINCIPAL INVESTIGATOR *(responsible for the overall project and reporting)*		
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ADMINISTRATION CONTACT DETAILS *(responsible for all administrative matters relating to project)*		
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PROJECT REPORT: *Please provide a clear description for each of the following:*

Executive Summary (200 words maximum)

A few paragraphs covering what was discovered, written in a manner that is easily understood and relevant to SA growers. A number of key dot points should be included which can be used in SAGIT communications.

Six nitrogen application strategies and three nitrogen inhibitor products were assessed for their ability to prevent nitrogen loss that occurs during waterlogging in a high yielding wheat scenario. Total Nitrogen Recovery percentages were calculated for selected treatments to measure nitrogen loss and assess if either strategy or inhibitors reduced that loss.

- The treatments with no inhibitor or loss mitigation strategy resulted in up to 20% of total nitrogen being unaccounted for, leaving denitrification as the likely main cause of loss.
- Comparing the six application strategies, the most common strategy surveyed, 1/3rd of budgeted nitrogen applied post waterlogging, resulted in the highest yielding bracket with significantly less nitrogen loss.
- There was no difference in yield or nitrogen loss if the '1/3rd post' strategy had nitrogen applied soon after waterlogging or 3 weeks after.
- Treatments using EnPower, a DMP nitrification inhibitor, resulted in the highest total nitrogen recovery as well as yielding in the equal highest significant bracket.
- No Polymer coated urea treatments achieved high yields or high total nitrogen recoveries.

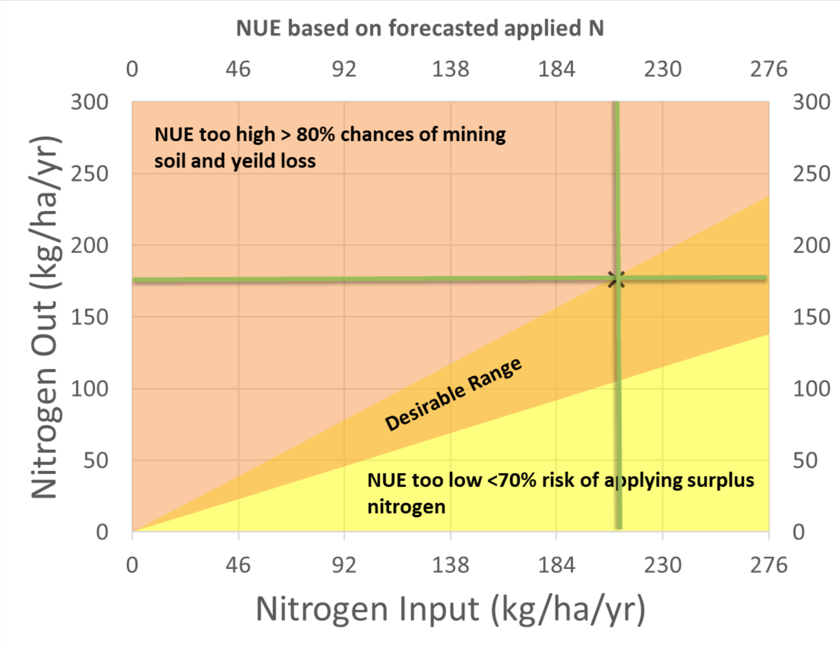
In general, results showed that the DMP inhibitor had a lasting effect of 50 - 60 days, suggesting applications need to be made no later than six to seven weeks before waterlogging.
The SA South East can experience different severities and durations of waterlogging, which is likely to result in different outcomes each year. In this trial in 2022, the additional cost of the DMP inhibitor was close to the same dollar value as the amount of the nitrogen that it retained.

Project objectives

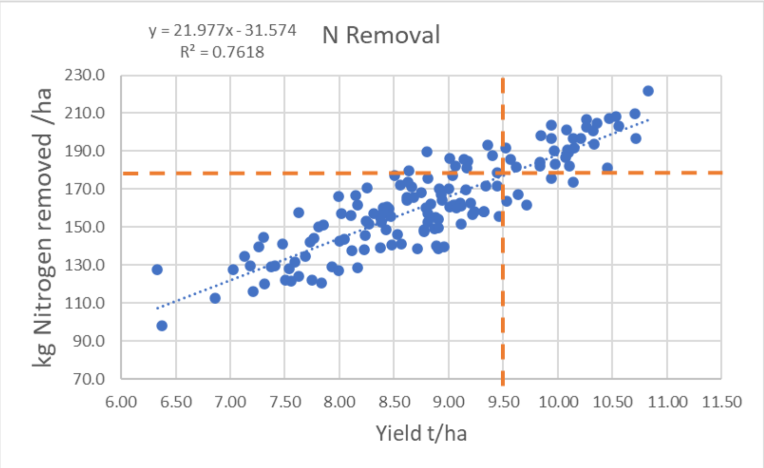
A concise statement of the aims of the project in outcome terms should be provided.

The main objective was to quantify the amount of nitrogen lost from denitrification in a high nitrogen requiring wheat crop in waterlogged conditions. The project assessed and compared the outcomes of different nitrogen application strategies and three urea inhibitors.
Attempts to measure or prevent each of the other nitrogen loss pathways other than denitrification were made so that any amount of nitrogen unaccounted for could be deemed lost from denitrification. Deep N tests were collected before seeding and after harvest on selected treatments, including one Deep N test sampled down to 2m to measure nitrogen lost from leaching. Grain yield and total grain nitrogen removal were measured as well as stubble biomass and its total nitrogen content. This information combined was used to report Total Nitrogen Recovery percentages between treatments, which highlights any treatment that increased the use and removal of nitrogen or suffered less nitrogen loss.
Two assessments were selected to measure differences in losses and compare treatments, the Total Nitrogen Recovery (TNR) is a measure of all nitrogen inputs and outputs including mineralisation and pre seeding soil nitrogen, calculated as
(Stubble nitrogen content + Post harvest Deep N + Grain nitrogen removal) ÷ (Applied nitrogen + Pre seeding Deep N test + Mineralisation – immobilisation) X 100
TNR is a percentage of how much nitrogen is used by the crop and retained in the paddock post-harvest. The higher the TNR up to 100% the better, as this measurement considers not only the nitrogen required for the crop but also soil microbial activity and soil carbon cycles. Any amount less than 100% is unrecovered and deemed lost, the project prevented volatilisation and measured no leaching, so the loss calculated is mostly denitrification, except for some smaller loss pathways which cannot be measured.

The second assessment, Nitrogen Use Efficiency (NUE), calculated as *Grain nitrogen removal ÷ total applied nitrogen X 100.* NUE measures how effectively the crop has used the fertiliser applied nitrogen, the NUE percentage increases as grain nitrogen removal increases or when nitrogen application rate decreases. This is useful for comparing fertiliser strategies focusing on applied nitrogen only. Unlike TNR, NUE is ideal between 70% - 80%, below 70% it's likely the crop has been supplied a nitrogen rate surplus to demand, greater than 80% means the paddock has been mined of nitrogen and will likely lead to soil organic carbon drawdown and yield loss, high NUE however may be desirable for example if soil nitrogen status has soil tested extremely high. Caption 1 below visualises the NUE for this trial, the average yield of the significant treatments is 9.5t/ha, caption 2 shows the grain nitrogen removal for 9.5t is approximately 180kg of nitrogen, where 210kg of nitrogen supply is needed to achieve a NUE within 70-80%



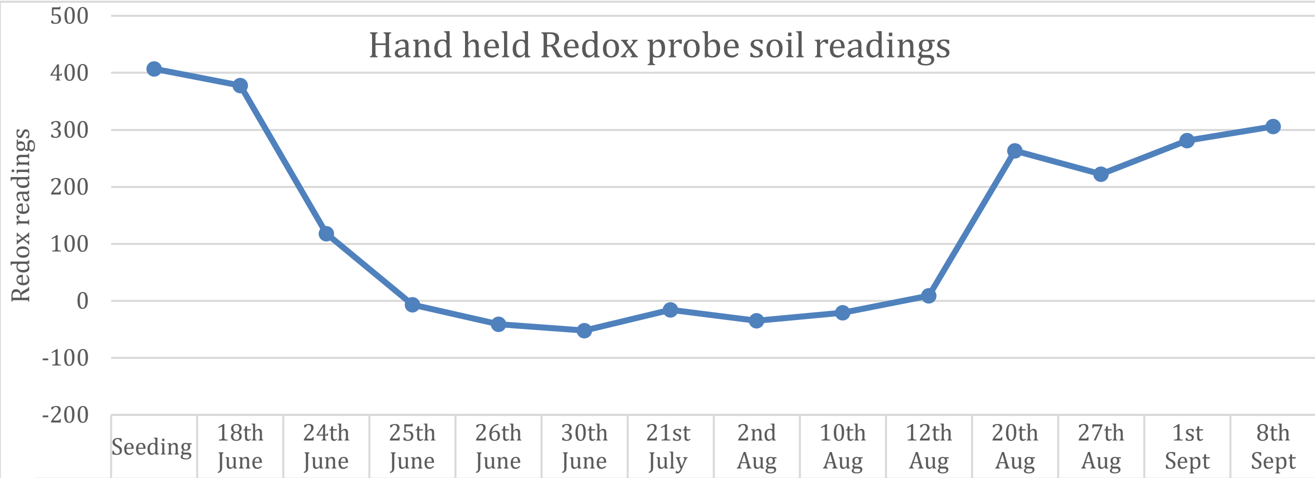
Caption 1: NUE Visualisation for this trial



Caption 2: Grain nitrogen removal against yield t/ha for each plot

In field sap nitrate testing was assessed using a Horiba nitrate sap meter. This is generally not regarded as a viable option to assist with nitrogen decision making. Having an infield sensor to determine crop nitrogen status would be a valuable tool for making application decisions before waterlogging. Sap nitrate was assessed on three treatments at each growth stage to see if there was a relationship between nitrogen applied and sap readings. The meter readings varied greater than the difference between treatments, there was also an issue of the meter not settling on a final reading. After the fifth round of sampling Instruments Choice requested the meter be sent back, after 6 weeks we received a new meter and seemed to have the same experience. The testing was not completed, the five sample stages collected showed no difference between treatments. The decision was made to order a new SPAD Chlorophyll meter in preference to assess at the next opportunity.

A Redox reduction probe, or oxidation meter, was used to investigate any relationship between redox potential and soil moisture status. This appears to be a poorly researched subject and theoretically may be a useful tool to determine the soil's potential to cause denitrification, the usefulness would be post waterlogging to determine when the soil is back to a state of oxidation. There was a trend in redox readings as the paddock become waterlogged and dried shown in Figure 1. This is a subject matter for higher level research and has been discussed with Giacomo Betti GRDC Manager of cropping systems.



	Seeding	18th June	24th June	25th June	26th June	30th June	21st July	2nd Aug	10th Aug	12th Aug	20th Aug	27th Aug	1st Sept	8th Sept
Redox	407	378	118	-7	-41	-52	-16	-35	-21	9	263	222	281	306

Figure 1: Redox probe readings by date

A total of four untreated controls were included to investigate apparent mineralisation. Currently the standard practice for estimating mineralisation contribution is to multiply the soils organic carbon (SOC) by 15% then multiply by growing season rainfall. However, experience has shown at times when both rainfall and SOC are high this equation can over predict mineralised nitrogen supply, seemingly there is a certain amount of SOC mineralisation that can potentially occur during a single growing season. Other research has shown that only 4-5% of total SOC measured at seeding can mineralise within a single growing season. By measuring pre-seeding soil nitrogen levels and subtracting grain nitrogen removal, stubble nitrogen content and post-harvest soil nitrogen, net mineralisation of untreated plots can be estimated. In this trial, presented in Table 1, it appears that the alternative method of 4.5% of total SOC mineralising was more accurate than the traditional 0.15 multiplied by rainfall.

Table 1: Apparent mineralisation calculations on the untreated controls.

	Post harvest Soil	Grain N Removal	Stubble N	Starting N	**Apparent Mineralisation**
untreated 1	31	131	31	110	**83**
untreated 2	27	136	33	110	**86**
untreated 3	33	141	27	110	**91**
untreated 4	29	138	30	110	**87**
Standard	OC 2%	X 0.15	X 407mm rain		**122**
Total SOC X 4.5%	OC 2%	* 4.5%			**90**

Overall Performance

A concise statement indicating the extent to which the project objectives were achieved, a list of personnel who participated in the Research Project including co-operators, and any difficulties encountered and the reasons for these difficulties.

The most challenging aspect of the project was selecting a site to provide both a significant nitrogen response and a reasonable level of waterlogging, as waterlogging is the driver of denitrification. Finding sites within a paddock that offer a uniform area of waterlogging severity and duration is challenging and requires good support from the grower cooperator. Wetter areas of the paddock often host higher levels of ryegrass which needed to be managed. The site location and rainfall received was able to provide the negative effects from waterlogging enough to see results. Each year the South East can succumb to different severities and duration of waterlogging at different times of the year, 2022 resulted in 2-3 weeks of mild waterlogging late in the season during September/October.

Seasonal rainfall conditions at Kybybolite resulted in 80mm above yearly average rainfall, mostly occurring during spring, the site become waterlogged twice for 10-14 days during September and October which is generally a month later than average.

Table 2: Average rainfall for Kybybolite and the 2022 rainfall totals

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	25	17	38	15	60	63	30	89	60	99	74	28
Avg	**25**	**17**	**26**	**29**	**49**	**63**	**71**	**71**	**57**	**45**	**33**	**32**

No frosts or hail events were recorded on the site.

All treatments were successfully applied on time. The double inhibitor urea to prevent volatilisation and denitrification mixed well. Unfortunately, damage was done to the high nitrogen rate treatments at seeding where 115kg of nitrogen was applied down the shoot causing fertiliser toxicity to some plots. The risk of potential toxicity was taken based off experience from the previous year's trials receiving 138kg of nitrogen at seeding with no toxicity, this site was perceived to have stronger soil and conditions were ideal leading us to believe the risk was low. This has had some impact on the trial results but not to the determent of the objectives, the trial site yield response plateaued at 130kg of applied nitrogen and hence the 230N treatments did not increase yield. In future when applying high up front nitrogen treatments a different strategy will need to be taken.


Picture 1: A 230N treatment in the foreground showing toxicity compared to a 92N treatment in the back ground.

Tiller counts were collected twice across six treatments before and after waterlogging to observe if there was a treatment effect in reducing the number of tillers lost during waterlogging.

To produce evidence of denitrification and to assess if a strategy or inhibitor reduced the nitrogen loss, 39 deep soil nitrogen and stubble nitrogen tests were collected post-harvest across three reps from 13 treatments.

The SARDI Struan agronomy team were contracted to manage and assist with all aspects of the trial site and some of the assessments including plant counts, tissue testing, biomass cuts and soil testing. Vickery Fertiliser was contracted to provide their soil testing trailer and assistance with the Deep N soil testing post-harvest, this provided access to a deeper soil probe and extra labor making it possible to collect all samples in one day.

It was the intention and agreement made with SAGI that they provide statistical support and analyses of the results, as well as support with any challenges that might occur. After the application was submitted it was realised that SAGI do not have the capacity to provide the support and they fell through on the agreement, the budget was redirected to SARDI to complete the statistics using GenStat. In future the biometricians that have been nominated by SAGIT will be approached. No technical statistical challenges were encountered.

KEY PERFORMANCE INDICATORS (KPI) *Please indicate whether KPIs were achieved. The KPIs **must** be the same as those stated in the Application for Funding and a brief explanation provided as to how they were achieved or why they were not achieved.*		
KPI	**Achieved**	**If not achieved, please state reason.**
Site selection ready to sow early May – completed pre seeding tests	Yes ☒ No ☐	A suitable site was selected on time, this required a very good grower cooperator who knew where the wetter areas of paddocks are. All pre seeding tests were collected, SARDI collected a deep nitrogen test down to 2.1m.
Split application of nitrogen applied, tiller counts, in crop tests	Yes ☒ No ☐	Applications of nitrogen, tiller counts and all in crop tests were successfully completed. Some deep soil in crop tests to measure the nitrogen form were completed twice as the results from the first test showed that the samples may have been collected too late post treatment. SARDI completed tiller counts twice at GS30 and again post waterlogging for comparison.
Harvest, stubble testing, post harvests soil tests	Yes ☒ No ☐	The site was harvested successfully without issues. Stubble testing for nitrogen content was completed on time before any post-harvest rain. Working with Vickery Fertiliser to collect a large number of post-harvest soil tests worked well, the extra staff and equipment meant the samples could be collected in one day. A protocol was designed to create consistency with sampling including taking the sample from the crop row, 3 samples per plot and to a depth of 110cm.

TECHNICAL INFORMATION (Not to exceed **three** pages)

Provide sufficient data and short clear statements of outcomes.

Three enhanced nitrogen products and six urea application strategies were assessed, the DMP nitrification inhibitor EnPower from Incitec was studied more extensively as it's more readily available to growers and most commonly used in other research projects. Note EnPower was formally named ENTEC, the product changed names after this project was completed.

Urea was compared to DMP urea at five acceding rates, 100kg/ha to 500kg/ha, this was replicated again with split timings.

Six strategies were assessed using straight urea:

1. applying 1/3rd of the budgeted nitrogen requirement 2 weeks post water logging
2. applying 1/3rd of the budgeted nitrogen requirement 4 weeks post water logging
3. applying 1/3rd of the budgeted nitrogen requirement 2 weeks post water logging at a higher rate.
4. applying 1/3rd of the budgeted nitrogen requirement during waterlogging with foliar UAN.
5. Applying the budgeted nitrogen split 4 times termed "Little bits more often."
6. Increasing wheat seeding rate by 50% on a standard treatment

Table 3 treatment list in order of yield result, green highlights the treatments that are significantly different from the untreated by LSD 1.195t

Treatment	Treatment X Var X Rate	Treatment #	t/ha		% Untreated
ENTEC	Big Red 138N EnPower	10	7.65	a	95
1/3 N Post water logging extra N	Big Red 230N	28	7.86	ab	97
ENTEC	Big Red 46N EnPower (46%)	8	8.00	abc	99
Untreated	Big Red 0N	1	8.06	abcd	100
1/3 N During water logging UAN	Big Red 184N	26	8.14	abcde	101
UAN nil entrench (Injection)	Big Red 230N straight UAN	32	8.21	abcdef	102
Standard Practice x1.5 seed rate	Big Red 184N	29	8.30	abcdefg	103
Urea	Big Red 92N	3	8.30	abcdefg	103
Urea	Big Red 46N	2	8.31	abcdefg	103
ENTEC	Big Red 230N Split EnPower	22	8.57	abcdefghi	106
Urea	Big Red 138N Split	15	8.63	abcdefghi	107
Urea	Big Red 230N	6	8.66	abcdefghi	107
Urea	Big Red 138N	4	8.75	abcdefghi	109
ENTEC	Big Red 184N EnPower	11	8.75	abcdefghi	109
Urea	Big Red 46N Split	13	8.78	abcdefghi	109
N90 Seeding - Agricoat (46%)	Big Red 184N N90	35	8.87	bcdefghi	110
Little bits more often	Big Red 184N	30	8.87	bcdefghi	110
UAN Entrench (1.7 L/ha) top dress (Injection)	Entrench Streaming Nozzles Top Dress	33	8.94	bcdefghij	111
Urea	Big Red 92N Split	14	8.95	bcdefghij	111
ENTEC	Big Red 46N Split EnPower	18	9.02	bcdefghij	112
All N Post water logging	Big Red 184N	27	9.05	bcdefghij	112
N90 Seeding - Agricoat (46%)	Big Red 230N N90	34	9.14	cdefghij	113
Urea	Big Red 184N Split	16	9.25	defghij	115
ENTEC	Big Red 230N EnPower	12	9.26	efghij	115
ENTEC	Big Red 138N Split EnPower	20	9.34	efghij	116
Urea	Big Red 230N Split	17	9.35	fghij	116
ENTEC	Big Red 184N Split EnPower	21	9.37	fghij	116
1/3 N Post water logging early	Big Red 184N	24	9.39	fghij	117
Urea	Big Red 184N	5	9.44	ghij	117
ENTEC	Big Red 92N EnPower	9	9.55	hij	119
ENTEC	Big Red 92N Split EnPower	19	9.59	ij	119
Entrench 1.7 L/ha + UAN (Injection)	Big Red 230N Entrench UAN	31	9.67	ij	120
1/3 N Post water logging later	Big Red 184N	25	10.08	j	125
	Mean		8.85		
	Untreated (Treatment 1)		8.06		
	LSD		1.195		
	cv%		4		

Table 3 shows a group of treatments which are significantly different from the untreated, highlighted green, no treatment within this group is significantly different from each other. These treatments have become the focus for further assessment.

Most inconsistencies can be explained as some treatment results are not consistent with the expected outcomes. For example in treatments 10 and 4 where similar treatments of equivalent urea rates were applied, due to ryegrass treatment 10 was the lowest yielding where it was expected to be at least equal to treatment 4. Treatment 11 (184N EnPower) is the only unexplainable poor performing treatment which did not yield significantly more than the untreated, the scale and complexity of the trial with challenges such as waterlogging which are usually avoided is the likely the cause of the noise observed in the results.

Treatments 10 and 28 which yielded less than the untreated both had plots in rep 2 which had significant levels of ryegrass in a small patch, these plots yielded 3t/ha less. Treatment 15's (Urea at 138kg of N) unexpected low yield is caused by one poor yielding plot in rep 4 due to very extreme waterlogging in a small patch the width of that plot. No straight urea 230kg nitrogen treatments were significant due to the fertiliser toxicity, some inhibiter urea 230n treatments are significant as there was no visual fertiliser toxicity in the inhibited urea treatments.

Two of the six strategies resulted in a significant difference.

Strategies 1 and 2 – (applying 1/3rd of required nitrogen 2 or 4 weeks post waterlogging) was the only strategy to significantly improve yield, with no significant difference between the two timings of the post waterlogging application, both applications were applied immediately before rainfall. Strategy 3 (1/3 post at a higher rate) suffered from ryegrass in rep 2 and hence did not yield side by side with strategy 1 and 2.

Strategy 4, applying foliar UAN during waterlogging, performed poorly, it's likely the nitrogen was not taken up by the crop canopy while the plants were suffering from dormant growth and potentially the applied nitrogen was lost before the crop recovered.

Strategy 5 "Little bits more often", performed poorly which observations suggested there wasn't enough nitrogen applied prior to waterlogging. Past research shows that early nitrogen applications to increase tiller count and canopy growth before waterlogging results in a better crop post waterlogging. This was the only treatment to receive the 184kg of nitrogen over four timings and it is also possible that when this treatment received straight urea shortly before a waterlogging event, that some of the applied nitrogen was lost.

Strategy 6, increasing seeding rate by 50%, was sown with 337 plants per square meter, compared to 225 plants, interestingly there was no significant difference in tiller count from the increased seeding rate, however at emergence this treatment had the highest plant count at 178 plants. There was no assessment that showed increasing the seeding rate reduced nitrogen loss or improved nitrogen use efficiency. It is likely this conclusion is due to all other treatments having an appropriate seeding rate, if this trial had several treatments with incrementally reduced seeding rates, then potentially a trend would show that higher seeding rates would improve nitrogen use efficiency.

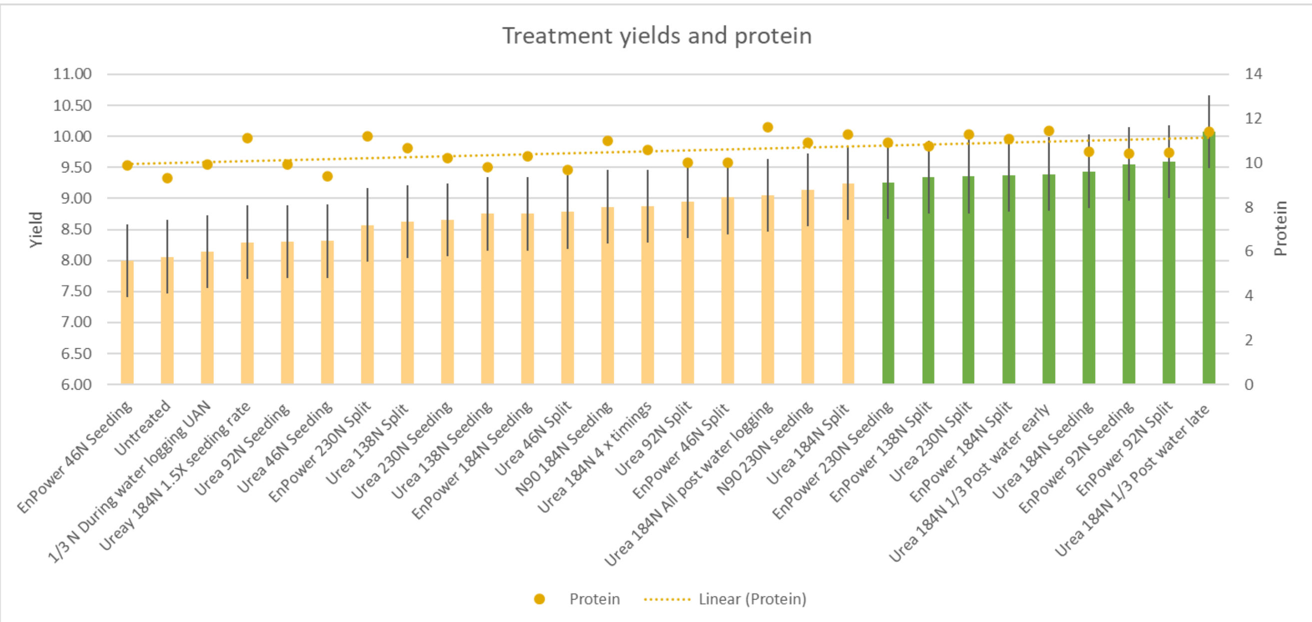


Figure 2 Treatment yields and grain protein, green bars denote significantly different treatments.

In crop deep nitrogen soil tests were collected to assess if the DMP nitrate inhibitors held the applied nitrogen in the ammonium form. Nitrogen in this form is immune to losses such as leaching and denitrification. When urea is applied to the soil it is hydrolysed into ammonium nitrogen then quickly nitrifies into nitrate nitrogen, then nitrate taken up by the crop. The perceived understanding is that DMP inhibitors hold the nitrogen in the ammonium form and that crops can take up nitrogen in this form. In crop Deep N tests were collected 56 days after application on the 14th of August and again on the 5th of September, 14 days after the second application. However, evidence collected at this site as well as other research shows that the wheat continued to take up nitrate and the ammonium pool created by the DMP inhibitor slowly released into the nitrate pool at a rate faster than crop demand. Figure 3 below presents the results from late season tissue testing from four treatments showing a strong relationship between calcium uptake and nitrogen rate applied which can provide indirect evidence of nitrate uptake. When plants take up nitrate NO3- they require a cation such as Ca^{2+} to balance the charge. Observations from other research reports ammonium having a phytotoxic effect on roots, ammonium also has minimal movement in the soil away from placement towards root systems. In contrast nitrate moves freely in soil towards the root system down a concentration gradient, as plants remove soil nitrate surrounding nitrate moves into that area of reduced concentration.

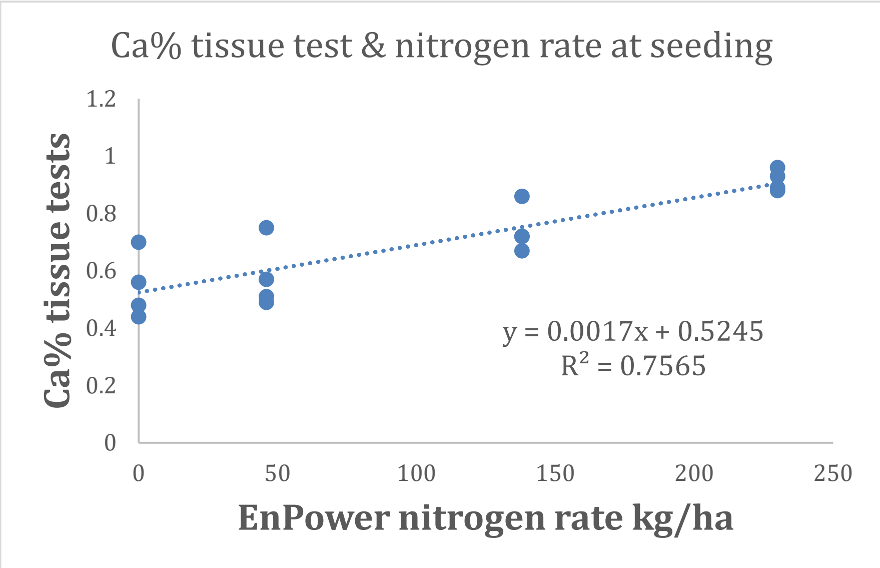
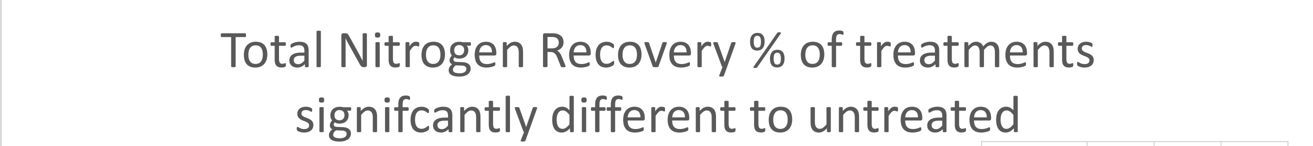


Figure 3: Tissue test results comparing the relationship between nitrogen applied and Ca concentration in tissue tests.



	Grain	Stubble	Soil
CV	4.9	15.9	10.07
LSD	4.34	2.82	2.28
P Value	0.09	0.73	0.04

Figure 4: Total nitrogen recovery in the soil, stubble residue and grain removal from significant different treatments

Figure 4 shows the Total Nitrogen Recovery for treatments in the significant yielding bracket. TNR considers the total amount of nitrogen measured after harvest in the soil, stubble and grain removal, against the total amount of available and applied nitrogen to plots through pre seeding deep nitrogen tests and mineralisation modeling. Any amount less than 100% is the percentage of nitrogen that cannot be accounted for and is likely due to denitrification, as there was no evidence of leaching and volatilisation was prevented. When considering the difference ranging from 2% - 13% found between straight urea and inhibitor urea this is further evidence of denitrification occurring at this site. Not all possibilities of nitrogen loss pathways could be measured, for example other fractions of carbon immobilisation, microbial activity and foliar ammonia gas loss during senescence, it is important to consider that not all of the unaccounted nitrogen in this trial is lost to the environment.

Looking at the three highest TNR results in figure 4 it was observed that as the EnPower rate increased the recovery reduced, especially when the 184N rate was applied which was excess nitrogen to crop demand. We can see when straight urea is used if all the nitrogen is to be applied prior to waterlogging there is no difference in TNR between splitting the application or applying all at seeding.

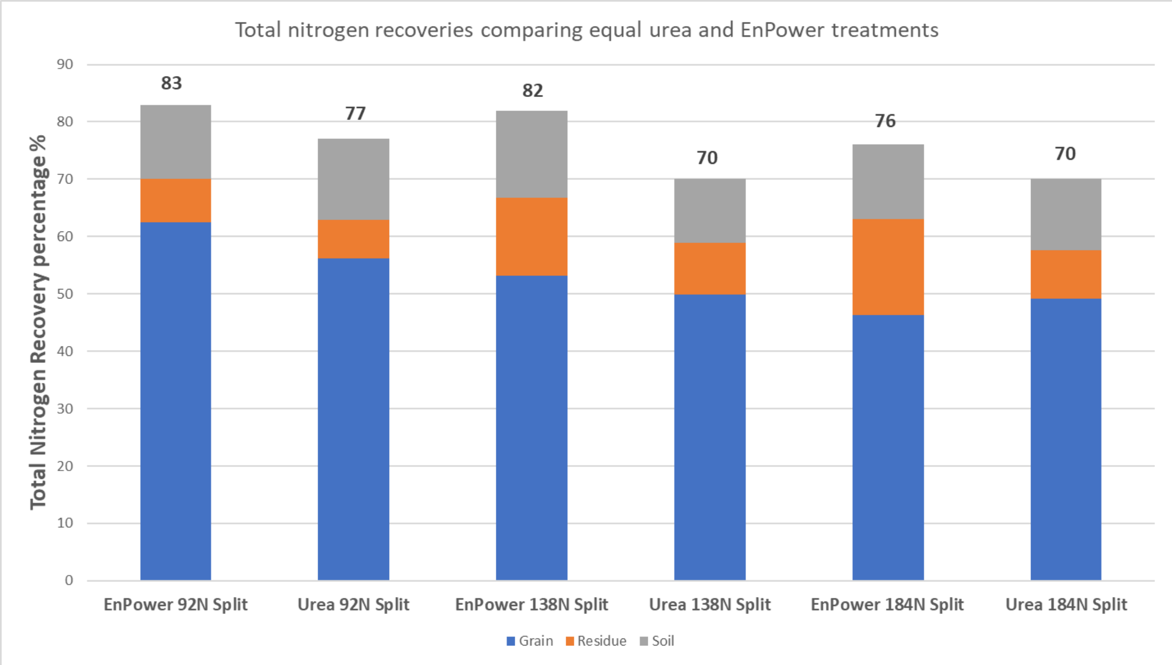


Figure 5: Comparing nitrogen recovery percentages between straight urea and EnPower of equal nitrogen rates.

Figure 5 compares nitrogen recoveries focusing on the equal rate treatments between EnPower and straight urea, results are showing a trend of improved nitrogen recovery where the inhibiter is applied. The 138N treatments are the most appropriate rate for this trial and hence show the greatest difference between recoveries.

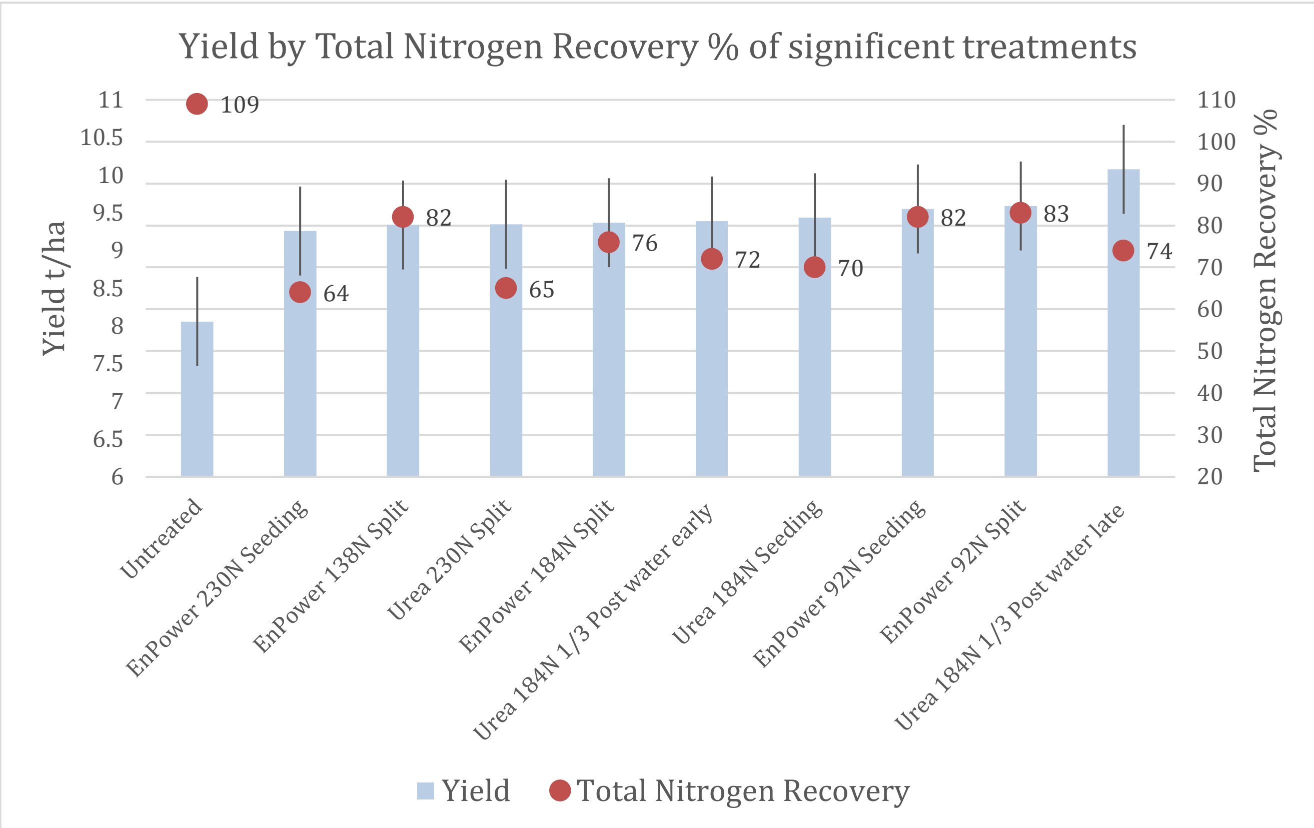


Figure 6: Nitrogen recovery percentage and yield of treatments with significant differences.

Figure 6 visualises the treatments with a significant yield over the untreated alongside the nitrogen recovery. Fertiliser trials are generally seeking the highest yielding treatment, however in this trial improving nitrogen recovery is an equal priority.

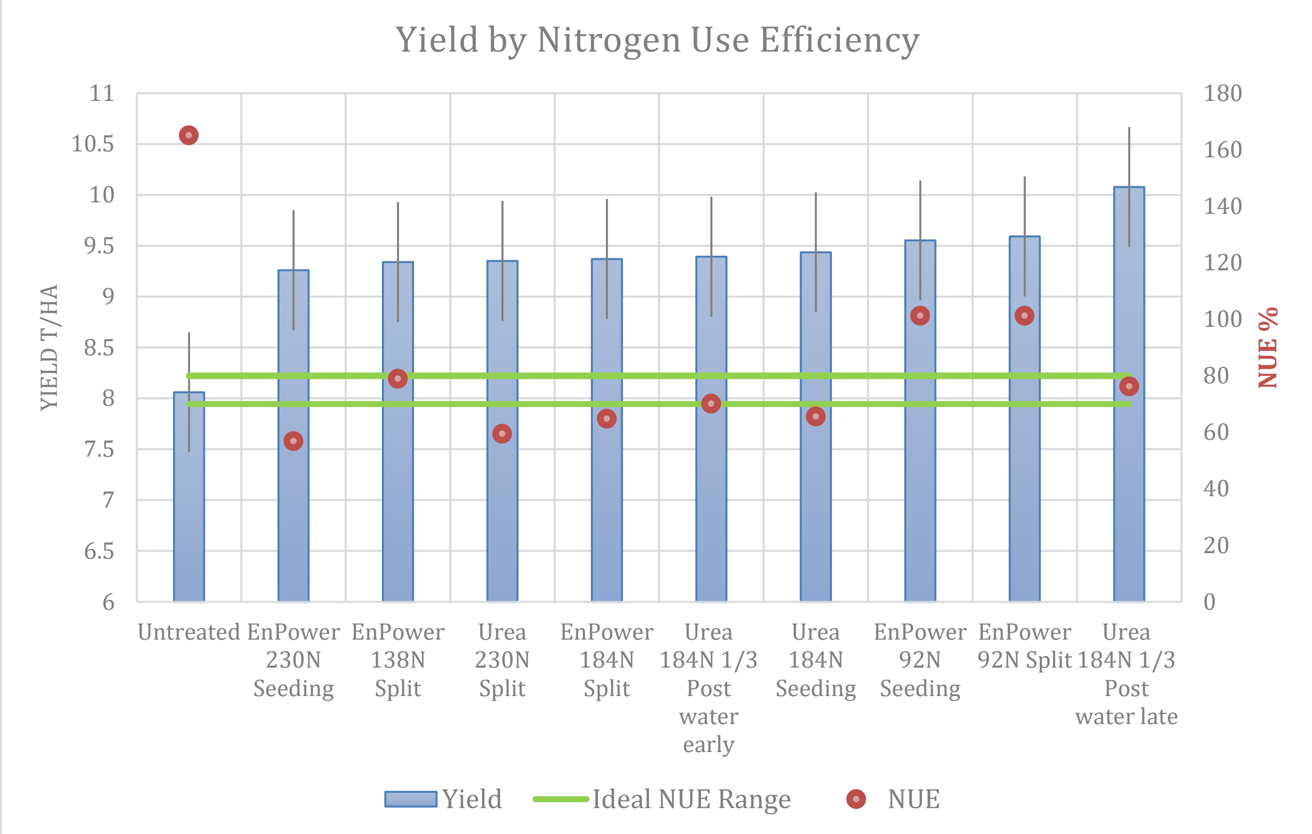


Figure 7: Nitrogen use efficiency and yield of treatments with a significant difference.

Figure 7 visualises the nitrogen use efficiency results against yield. The green lines highlight NUE between 70% - 80% which is the desired range, higher than 80% occurs when insufficient nitrogen has been applied to the crop which causes yield loss and mines the soil, below 70% indicates that a surplus amount of nitrogen has been applied to the crop, this reduces profitability and creates environmental risks. The results indicate the ideal nitrogen rate for this trial was between 138-184kg of nitrogen, the EnPower at 138kg of nitrogen achieved the same NUE as the 184kg of nitrogen as straight urea with a post waterlogging application.

When considering all three priorities being highest yield, highest TNR and a NUE between 70% - 80%, EnPower applied at 138kg of nitrogen split application is the preferred treatment.

CONCLUSIONS REACHED &/OR DISCOVERIES MADE (Not to exceed **one** page)

Please provide concise statement of any conclusions reached &/or discoveries made.

If maximising yield was the only desired outcome, then strategies 1 and 2 of applying 1/3rd of the budgeted nitrogen post water logging has been the theoretical highest yielding treatment. However, when a combination of desired outcomes includes achieving the highest nitrogen recovery as well as a nitrogen use efficiency of 70-80% then EnPower at 138kg of nitrogen split has been the most successful treatment.

Comparing net profit per treatment is challenging with this trial design, a theoretical net profit has been graphed in figure 8 below. This assumes wheat at $300, urea at $640 and EnPower at $760, taking into account the extra spreading costs with split treatments, but there is no consideration for the extra nitrogen retained from inhibitors. The 92N rate treatments have been the most profitable because that rate of nitrogen was less than crop demand without much yield penalty.

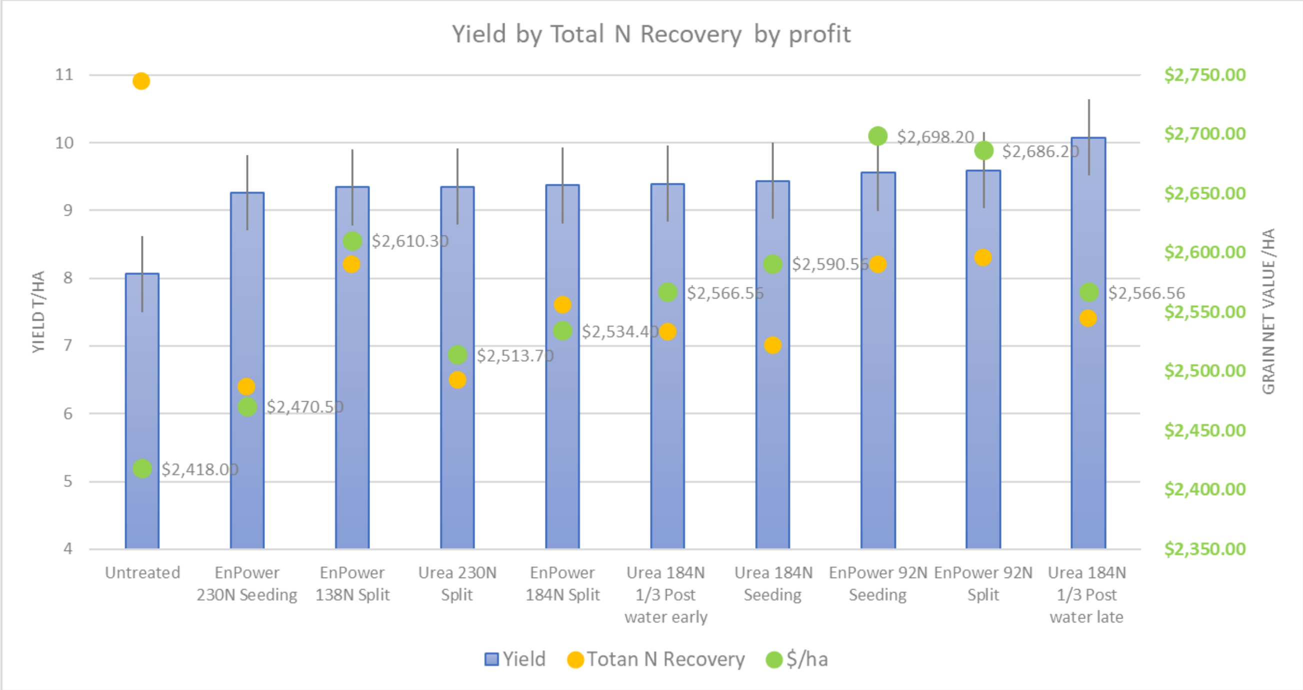


Figure 8: Yield and Total N Recovery of significent treatments by net profit/ha

The profitability of the EnPower treatments are also lower in this trial as the treatments receiving EnPower had the product at each application, whereas the extra cost of EnPower is only needed at the GS30 topdressing.

Applications of Nitrification inhibited urea at seeding showed no sign of success in this trial and should instead be top dressed within 50 days of waterlogging. Results will of course vary where waterlogging occurs shortly after seeding.
Increasing seeding rate higher than the standard 225 plant per meter did not improve yield or nitrogen recovery.

It is likely that a combination of inhibitor and strategy is needed to achieve the best outcome for waterlogged paddocks. In this trial the treatments using inhibitors had the inhibitor treated urea for every application, however results are showing that inhibitors at seeding and post waterlogging are not required. Potentially the ideal inhibitor plus strategy combination would be to split the required nitrogen into three applications, straight urea at seeding, DMP inhibitor urea at GS30 and straight urea post waterlogging, this recommendation needs validating.

Polymer coated urea performed poorly in this trial. The polymer coating slows the release of urea from the granule, once released it is quickly converted into nitrate nitrogen just as straight urea. Because nitrogen loss from waterlogging is only prevented if it is held in the ammonium form it is likely the polymer urea was converted into nitrate before waterlogging. Polymer coated urea needs to be applied early due to the slow release to keep up with crop nitrogen demand, which means investing in the product early with a high rate of nitrogen before seasonal conditions are known. The polymer coated urea is a similar theory to the strategy of applying urea ‘little bits more often’, feeding the crop the nitrogen it needs for a shorter period so that when waterlogging occurs there is not a large pool of freely available nitrogen.

Entrench works similar to EnPower applied as a liquid injection with UAN which performed equally with DMP treated urea.

INTELLECTUAL PROPERTY

Please provide concise statement of any intellectual property generated and potential for commercialisation.

Nil

APPLICATION / COMMUNICATION OF RESULTS

A concise statement describing activities undertaken to communicate the results of the project to the grains industry. This should include:

- *Main findings of the project in a dot point form suitable for use in communications to farmers;*
- *A statement of potential industry impact*
- *Publications and extension articles delivered as part of the project; and,*
- *Suggested path to market for the results including barriers to adoption.*

Note that SAGIT may directly extend information from Final reports to growers. If applicable, attach a list of published material.

- DMP Nitrification inhibitor treated urea top dressed within 50 days of waterlogging reduced nitrogen losses from denitrification by 5% - 15%.
- Using inhibitors at seeding time was not an effective strategy in this trial in 2022.
- Where straight urea is used, the best strategy to achieve yield potential and reduce the impacts from pre GS60 waterlogging is to apply 1/3rd of the budgeted nitrogen post waterlogging.
- On average, the most appropriate time to invest in DMP inhibitor treated urea such as EnPower is at GS30 top dress if waterlogging is likely within 7-8 weeks.
- Enhanced nitrogen products should only be used in combination with a reasonable nitrogen budget.
- 11% protein was the ideal target for maximising yield in feed wheat.

The aim of this project was to find evidence of denitrification in the South East, determine if strategies or inhibitors reduce the nitrogen loss from denitrification and narrow the list of products and strategies. Further work is needed on combined strategy plus inhibitor and to validate the results with different waterlogging severities and soil types.

There are two main impacts these findings may have on the industry, one from an environmental perspective, in the future the industry will potentially be called to reduce emissions and our environmental footprint, so any effort to reduce nitrogen loss to the environment without disruption to the farm business logistics and profit could be important. Additionally, if the inhibitors trialed consistently reduce loss of applied nitrogen by 10% then the amount of nitrogen applied may be reduced by as much, leading to a positive impact on the net profit.

At the time of writing, no publications had been prepared. A results evening with the Millicent AgBureau was held on the 24th May. A presentation of these results will be held at the Naracoorte Regional GRDC grower meeting on the 27th of June, further presentations will be offered to other groups.

Barriers to adoption of these inhibitors has been the lack of evidence of their effectiveness, further work is needed, however this project's success has been a major driver forward. During the last ten years the cost of EnPower has reduced from $350p/t to $110p/t, which has now become a viable option. Following this trial two growers with two different soil types have volunteered to apply two 5ha strips of EnPower to continue to work.

POSSIBLE FUTURE WORK *Provide possible future directions for the research arising from the project including potential for further work and partnerships.*
The list of potential strategies and types of inhibitors that mitigate the negative impacts of waterlogging has been reduced. Further work is needed to produce in field evidence that inhibitors are not required when applying urea 2-4 weeks post water logging. Further work is needed to confirm that the combined strategy and inhibitor is the best practice. Ideally a similar but smaller trial should run over multiple seasons to capture the variance of waterlogging timing and duration that can occur in different seasons. It would also be appropriate to run a similar trial on the high organic carbon alkaline soils of the South East, results may vary compared to the loam soils of this site. The high SOC country also receives a different kind of waterlogging, this site was exposed to too much rain in a short amount of time, the black plains country often suffers from the water table rising above the soil level, so results may vary significantly. This year, two growers have nominated to apply supplied DMP treated urea over a 5ha strip, the nitrogen recovery assessments will be run again at a paddock scale, one of the sites will be located on the black plain's country. Future work should consider investigating if a grower could successfully run three to four years of nitrogen budgeting off a deep soil test. Urea inhibitors and nitrogen strategies only provide benefits when used with an appropriate nitrogen budget. Feedback from growers and advisers suggests the industry is lacking capacity to keep up with soil testing demand, from a service provider's perspective Deep N testing is also not a profitable service, time consuming with significant capital. If by combining some other assessments and tests with a Deep N test such as measuring immobilisation and grain nitrogen content, potentially we could extend the number of years a nitrogen budget remains accurate. The soil and tissue tests collected during this project also indicated the potential of the inhibitors to exacerbate any existing potassium deficiency, by increasing the ammonium soil content. Potassium deficiency is also a bigger issue for crops that suffer from transient waterlogging. A meeting with Malcolm McCaskill and Nigel Wilhelm on the potassium results highlighted the opportunity in future inhibitor trials to have a closer look.