Office Use Only

Project Code	
Project Type	

FINAL REPORT 2019

Applicants must read the *SAGIT Project Funding Guidelines 2019* prior to completing this form. These guidelines can be downloaded from www.sagit.com.au

Final reports must be emailed to admin@sagit.com.au as a Microsoft Word document in the format shown ***within 2 months*** after the completion of the Project Term.

PROJECT CODE	**:**	**AS317**

PROJECT TITLE	Efficiency of fertilizer N products on Calcareous and sandy soil types

PROJECT DURATION

*These dates **must** be the same as those stated in the Funding Agreement*

Project Start date	01/07/2017					
Project End date	30/06/2019					
SAGIT Funding Request	2017/18		2018/19		2020/21	

PROJECT SUPERVISOR CONTACT DETAILS

The project supervisor is the person responsible for the overall project

Title:	**First Name:**	**Surname:**
Dr	Sean	Mason

Organisation:

Agronomy Solutions Pty. Ltd.

Mailing address:

Telephone:	**Facsimile:**	**Mobile:**	**Email:**

ADMINISTRATION CONTACT DETAILS

The Administration Contact is the person responsible for all administrative matters relating to the project

Title:	**First Name:**	**Surname:**
Mrs.	Anna	Walker

Organisation:
Agronomy Solutions Pty. Ltd.

Mailing address:

Telephone:	**Facsimile:**	**Mobile:**	**Email:**

PROJECT REPORT

Provide clear description 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 communication programs

This project outlines while there might be some interactions with different N products causing lower efficiencies for crop N uptake and growth these differences are not consistent and there appears to be no benefit of choosing one N product over the other when considering NUE.

Applying relatively high amounts of N in various forms (40 kg N/ha) with the seed didn't affect early crop growth or ensuing grain yields even in susceptible soil types found at the Lameroo and Karoonda trial sites.

Unfortunately, product interactions and NUE were not tested under severe N deficiency or high crop yields demanding higher N demand from various N sources. Most sites were either non-responsive to N applications (Lameroo – 2017, Brinkworth – 2018, Karoonda - 2018) or marginally responsive (Condowie - 2017).

Despite the lack of responsiveness, we did show that there potentially might be some issues with placing DAP near the seed in a soil type like Lameroo. Further trials are required to confirm this result.

Applied N significantly ($p < 0.05$) increased grain protein levels and high NUE values were obtained at low applied N rates at sowing for Brinkworth and Karoonda (apart from UAN applied at 10 kg N/ha).

Project Objectives

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

This project aims to assess the effectiveness of different fertilizer N products in delivering plant available nitrogen forms on predominantly Calcareous and lighter textured soils in a field environment.

In order to fulfil the project objective, the aims will be:

i) Assess the pools of mineral/inorganic N (NO_3, NH_4) derived from different N forms/fertilizer products at intervals during crop growth in contrasting soil types
ii) Determine the availability and efficiency of different N fertiliser forms for plant uptake and grain yield.

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.

We believe the project outcomes were achieved as outlined in the response to the KPIs (see below) albeit with a couple of issues that are discussed below.

The key to assessing the efficiency of different N fertilizer products is to ensure that they are tested on sites where N is limited. Three of the four sites have low profile N as measured at the start of the season but with climatic seasons that ensured at these sites during 2017 and 2018, yield potentials < 2t/ha meant that a large proportion of crop N demand was supplied by the starting soil N levels and ensuring mineralization that occurred.

Responses at three sites occurred but optimal N rates were low which meant that other parameters other than yield were assessed to determine product efficiencies (e.g. protein).

All trials were sown by AgXtra and in general were maintained at a high standard. One site that was located by AgXtra with the target of it being a low N site in 2017 (Lameroo) when measured had relatively high starting soil N values. We took greater control of site selection in 2018 and targeted a site in the Mallee where we had previously seen different product efficiencies in the glasshouse (Karoonda).

Key Performance Indicators (KPI)

*Please indicate whether KPI's were achieved. The KPI's **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 (Y/N)***	***If not achieved, please state reason.***
1: Site selection and implementation of two N response trials across South Australia (Condowie, Karoonda)	Y	Two sites were located near Condowie and near Lameroo.
2: Collation and analysis of all results from the response trials (soil test results, crop N responses).	Y	Results from 2017 trials were collated and relevant statistical analysis performed.

3: Progress report submitted to SAGIT	Y	Please refer to progress report submitted in February 2018
4: Site selection and implementation of two N response trials across South Australia (Condowie, Karoonda)	Y	Two sites were located near Brinkworth and near Karoonda.
5: Collation and analysis of all results from the response trials (soil test results, crop N responses).	Y	Results from 2017 trials were collated and relevant statistical analysis performed.
6: Progress report submitted to SAGIT	Y	Please refer to progress report submitted in Jan 2019
7: Final report submitted to SAGIT	Y	

Technical Information (Not to exceed **three** pages)

Provide sufficient data and short clear statements of outcomes.

Due to the extensive data set generated for this project, all tables and figures have been included on a supplementary document for referral.

KPI 1: Two sites for the N responsive trials were selected, one at Lameroo (a suggestion of AgXtra) and the other next to the TOS P trial (AS216) at Condowie.

The trials at Lameroo and Condowie compared the response of wheat to various N products using a combination of sowing and in-season applications. The N products tested we selected based on their appropriate commercial use and were DAP, SOA, UAN and Urea. Rates up to 80 kg N/ha were used. Sowing dates were 15th of May for the Lameroo site and the 6th of June for the Condowie site.

Site characterization (see supplement report) was performed at trial establishment and in season soil N results were taken at GS30 from the control plots of each replicate bay.

In season soil N levels

Soil samples taken across both sites at GS30 revealed while levels in the 0-10cm were low to moderate there was significant amounts of nitrate-N at depth (table 1 Supplementary document - SD). It appears at both sites there is enough N to support a 3.5-4 t/ha grain yield if each tonne of grain requires 40 kg N/ha. This doesn't factor in the crop N already accumulated at the GS30 stage.

KPI 2:

NDVI data at GS30 (see supplementary report data – table 3 SD). At this growth stage crop demand for N has been generally low and therefore large responses are not expected.

Lameroo:

There was no significant difference between the NDVI results of the control and those where N was applied, however there was a significant ($p < 0.05$) difference between products. The main reason was the poor performance of DAP which appeared to generate seed bed toxicity issues even at low rates. Relative yield and optimal N rates are still presented even though there was no significant N effect.

Condowie:
As with the Lameroo site there was no significant difference between the NDVI results of the control and those where N was applied however there was a significant ($p < 0.05$) difference between products. No general trends of which product was performing better could be established. Relative yield and optimal N rates are still presented even though there was no significant N effect.

Grain yields at Maturity
Lameroo:
As expected from the in-season soil N results this site was not responsive to applied N. Overall there was a significant product effect where SOA out yielded DAP (Figure 3 SD). The poor yields at GS30 caused by DAP application appears to have translated to grain at some rates.

Protein
Grain quality analysis from each treatment revealed very high protein levels (>13 %) which further indicates luxury N was present at this site. Applied N did increase grain protein levels but there was no significant product effect (table 4).

Condowie:
A significant N response was obtained with low N rates (10, 20 kg N/ha) providing the highest yields and maximizing NUE when applied at sowing (figure 3 – SD). There was no benefit of applying N at GS30. While there was no significant product effect ($p = 0.052$) at the 10 kg N/ha sowing rate SOA and DAP appeared to outperform UAN and Urea.

Protein
Grain quality analysis from each treatment revealed high protein levels (12-13 %) which further indicates near luxury N was present at this site. Applied N did increase grain protein levels but there was no significant product effect (table 4).

KPI 4: After the unsuccessful trial location of one of our sites in 2017 we invested greater time in locating likely N responsive sites which were validated with soil test results before sowing (table 2 - SD).

In collaboration with Therese McBeath (CSIRO) we were able to locate a section on the dune soil type at the Mallee Sustainable Farming (MSF) site located near Karoonda in the mallee region. This soil type was used in the glasshouse trial for AS116 where significant differences in DM yields were obtained by using different N sources. This trial was sown to Mace wheat on the 6th of June 2018.

The other site was located at our Brinkworth focus site which also contained trials associated with AS118 and AS216. This site had low N through the profile at the start of sowing and was sown to Mace wheat on the 25th of May 2018.

Unfortunately, the 2018 season for both trial site locations was not favorable for large yields which would drive crop N demand and increase the chances of crop responses to the N applied at both sowing and at GS30 (see climatic data in supplementary file). Yields at Brinkworth reached 1.8 t/ha and an impressive 2.3 t/ha at Karoonda given the lack of GSR.

KPI 5: Collation and analysis of all results.

NDVI data at GS21-25 (see supplementary report for graphs – figure 1-2 SD).
At this growth stage crop demand for N has been generally low and therefore large responses are not expected.

Brinkworth:
No significant differences in NDVI readings were obtained between treatments for this early crop growth stage. Starting soil N levels should have meant the crop N demand which is low early on would have been met. While not significant trends with applied N occurred and the highest applied N rate as urea appeared to decrease early biomass production (see supplementary data).

Karoonda:
No significant differences in NDVI readings were obtained with increasing N at Karoonda but there was a significant overall product difference ($p = 0.041$) where overall NDVI readings from UAN were significantly greater than N applied as urea or SOA.

NDVI data at GS39-40 (see supplementary report for graphs – figure 1-2 SD).
At this crop stage the 6 replicates of applied N at sowing were randomly split so 3 of the 6 replicates had the same amount of N applied at GS30 while the remaining 3 replicates were left alone and therefore only reflecting benefits of N applied at sowing.

Brinkworth:
Significant differences in NDVI readings were obtained between treatments for both applied N ($P = 0.001$) and overall product used (0.049) (figure 1). There was no significant product x N rate interaction.

Karoonda:
No significant differences in NDVI readings were obtained with increasing N at Karoonda potentially due to high variability (CV = 22%) between replicates which is applied when treatments are reduced to 3 replicates.

Grain yields
Brinkworth:
The poor finish to the 2018 growing season at Brinkworth meant that significant responses to applied N at early growth stages didn't translate to significant overall increases to grain yields (figure 4 SD).

Karoonda:

No significant differences in grain yields were obtained with increasing N at Karoonda (figure 4 SD) potentially due to high variability seen at GS40 translating to grain measurements (CV = 20%).

Grain quality (See supplementary report – figure 5 to 16 SD)

Full grain quality analysis of these trial results highlights the importance of a season finish in order to make full use of applied N particularly in season applications. Both sites had non-significant responses to applied N in terms of grain yield but there was significant ($p < 0.05$) increase in grain protein and overall grain N uptake which meant that applied N was getting into the wheat crop. There was no effect of which source of N was applied, however. Nitrogen management was important in terms of grain protein levels and the ensuing wheat grade, but this wasn't reflected in the gross margin analysis as the differences between prices for varying wheat grades is quite small (see appendix). As expected from the small insignificant increases in grain yield with applied N the lower rates of N generally resulted in the highest Nitrogen Use Efficiencies (NUE). The treatment which resulted in the highest gross margin at Brinkworth was 20 kg N/ha applied as Urea at sowing closely followed the split application of Urea at 20 kg N/ha both at sowing and GS30 which was driven by higher yields. At Karoonda the lowest rates of DAP generated the highest gross margins again due to high relative yields which were 10 kg N/ha applied at sowing closely followed by 10 kg N/ha applied at both sowing and GS30.

Grain nutrient uptake

The proceeding glasshouse trial work which led to the field validation step showed that there were interactions with Urea and micronutrient availability which generated significantly lower biomass. All products tested in that study were highly efficient at supplying N to an enclosed soil system. We decided to test the interaction of different N products with other nutrient uptake in the grain by measuring nutrient concentrations in the grain of each treatment. Apart from significantly increasing N content there was no other significant nutrient effects by applying N in various forms at the two 2018 trial sites.

Conclusions Reached &/or Discoveries Made (Not to exceed <u>one</u> page)
Please provide concise statement of any conclusions reached &/or discoveries made.

This project outlines while there might be some interactions with different N products causing lower efficiencies for crop N uptake and growth these differences are not consistent and there appears to be no benefit of choosing one N product over the other when considering NUE.

Applying relatively high amounts of N in various forms (40 kg N/ha) with the seed didn't affect early crop growth or ensuing grain yields even in susceptible soil types found at the Lameroo and Karoonda trial sites.

Unfortunately, product interactions and NUE were not tested under severe N deficiency or high crop yields demanding higher N demand from various N sources. Most sites were either non-responsive to N applications (Lameroo – 2017, Brinkworth – 2018, Karoonda - 2018) or marginally responsive (Condowie - 2017).

The climatic conditions at all sites in 2017 and 2018 meant that yields generally below 2t/ha didn't drive the demand for N and the starting soil N available in the soil profile was able to fulfill the majority of crop N demand.

Despite the lack of responsiveness, we did show that there potentially might be some issues with placing DAP near the seed in a soil type like Lameroo. Further trials are required to confirm this result.

In line with this observation trials being run by Therese McBeath (CSIRO) has shown benefits of placing DAP below the seed (~ 5cm) compared to with the seed at field sites in the Mallee region. It is speculated that the cause of this might be that more of the soil area where roots access nutrients are enriched with N due to the deeper placement. It also cannot be ruled out that yields are reduced due to potential hostile soil conditions generated by DAP placement near the seed

Applied N significantly ($p < 0.05$) increased grain protein levels and high NUE values were obtained at low applied N rates at sowing for Brinkworth and Karoonda (apart from UAN applied at 10 kg N/ha).

Intellectual Property

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

No extensively new IP has been generated from this project. The main message is that the choice of which N product to use shouldn't factor in different efficiencies of each product.

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.

- *Main findings of the project in a dot point form suitable for use in communications to farmers;*

Please refer to the conclusions reached section for the major findings in dot form which we think are suitable for use in communications to farmers.

- *A statement of potential industry impact*

While the findings of this project may lack industry impact a positive outcome for growers is that they shouldn't be concerned about consistent differences in the efficiencies of various N products. Growers should still be encouraged to practice best N management in terms of application rates at sowing. Knowing your starting soil N profile is a key step in making in season N decisions.

- *Publications and extension articles delivered as part of the project;*

No extension activities have occurred for this project as we were waiting for 2018 trial results before confirming the 2017 observations. We will continue to communicate these results through our channels as it highlights the importance of considering a range of factors in order to make an informed N decision.

- *Suggested path to market for the results including barriers to adoption.*

The importance of soil testing, assessing in season soil conditions, yield potentials and climatic conditions continually need to be communicated for greater NUE.

POSSIBLE FUTURE WORK

Provide possible future directions for the research arising from the project including potential for further work and partnerships.

None suggested. CSIRO continue to work with placement of various N sources to maximize root access to applied N.

AUTHORISATION
Name: Sean Mason
Position: Research Agronomist - Director
Signature:
Date: 31st August 2019

Submit report via email to admin@sagit.com.au as a Microsoft Word document in the format shown ***within 2 months*** after the completion of the Project Term.

AGRONOMY SOLUTIONS

RESEARCH • EDUCATION • ADVICE

AS317: Efficiency of fertilizer N products on Calcareous and sandy soil types

Supplementary Report associated with final report

Table of Contents

1 Trial Summary

This project aims to assess the effectiveness of different fertilizer N products in delivering plant available nitrogen forms on predominantly Calcareous and lighter textured soils in a field environment.

2 Trial Sites

Regions

Trials were performed at Condowie (Mid-North), Lameroo (Mallee) in 2017 and Brinkworth (Mid-North), Karoonda (Mallee) in 2018

Each site was fully characterised for N availability (0-50cm) and other soil characteristics.

3 Crop and Variety Information

As per the protocol all trials were sown with Mace (moderate maturing).

4 Trial design and treatments

All trials were designed by Agronomy Solutions in consultation. Trials were set out in a randomised split-split plot design. AgXtra were responsible for sowing, generally maintenance and harvesting the trials.

3 Replicates of each treatment, five N rates, four N products, two application timings (sowing and GS30)

5 Trial assessments

Plant	NDVI @ GS30
	Yield – maturity and quality
	Grain nutrient uptake
Soil	Site classification - comprehensive soil test

6 Statistical Analysis

Statistically significant differences between treatments were assessed by a one-way ANOVA using software package Genstat 18th Edition

Genstat outputs for each trial (grain yields) are not shown but can be sent on request.

7 Trial Reporting

Site soil Characteristics

Table 1: Soil characteristics of the two sites located for the N responsive trials in 2017

		Lameroo			Snowtown	
		0-10	10-30	30-50	0-10	10-30
pH 1:5 water		7.98	8.85	9.09	8.41	8.43
pH CaCl2		7.41	8.1	8.45	7.69	7.76
Salinity EC 1:5	dS/m	0.23	0.36	0.57	0.16	0.23
Boron	mg/kg	1.6	8.9	21	2.2	2.1
Potassium (K) - AmmAc	mg/kg	281	417	397	771	427
Calcium (Ca) - AmmAc	mg/kg	2730	4530	4200	5100	5150
Magnesium (Mg) - AmmAc	mg/kg	320	972	1260	426	512
Sodium (Na) - AmmAc	mg/kg	115	611	1210	103	183
Copper (Cu)	mg/kg	0.23	0.5	0.53	0.57	0.78
Zinc (Zn)	mg/kg	0.34	0.08	0.1	0.94	0.36
Manganese (Mn)	mg/kg	3.4	1.8	1.4	7.6	4.6
Iron (Fe)	mg/kg	18	16	16	4	4.5
Nitrate - N (2M KCl)	mg/kg	14	23	24	18	41
Ammonium - N (2M KCl)	mg/kg	3.6	3.2	3.5	2.6	2.2
Colwell Potassium	mg/kg	340	440	410	670	380
MCP Sulfur (S)	mg/kg	4.7	12	21	6.5	7.1
Organic Carbon (W&B)	%	1.2	0.78	0.47	1.1	0.72
Colwell Phosphorus	mg/kg	18	7	6	17	14
PBI $_{+ Col P}$		36	144	159	100	138

Table 2: Soil profile N of the two sites chosen for N responsive trials in 2018

Brinkworth

Sample ID	Depth (cm)	Nitrate (mg/kg)	Ammonium (mg/kg)	Total N (mg/kg)	Total N (kg/ha)	Profile N (kg/ha)
Core 1	0-10cm	22	1.3	23.3	28	58
	10-20cm	13	1.5	14.5	17	
	20-30cm	4	0.6	4.6	6	
	30-40cm	2.9	0.7	3.6	4	
	40-50cm	2.1	0.5	2.6	3	
Core 2	0-10cm	16	1	17	20	44
	10-20cm	7.4	0.8	8.2	10	
	20-30cm	3.5	0.7	4.2	5	
	30-40cm	3	0.9	3.9	5	
	40-50cm	2.9	0.8	3.7	4	

Karoonda

Sample ID	Depth (cm)	Nitrate (mg/kg)	Ammonium (mg/kg)	Total N (mg/kg)	Total N (kg/ha)	Profile N (kg/ha)
Core 1	0-10cm	12.5	6.4	18.9	25	57
	10-30cm	6.3	0.3	13.2	20	
	30-60cm	2.4	0	7.2	12	
Core 2	0-10cm	13.8	7.5	21.3	29	64
	10-30cm	6.5	0.6	14.2	21	
	30-60cm	2.3	0.7	9	14	

2017 trials

NDVI assessments @ GS30

Table 3: Summary of the NDVI results from Lameroo (top) and Condowie (bottom) with related statistical analysis at the bottom of each table.

Product	N rate	NDVI - mean	Std. Error	Relative yield %	Optimal N
Control	0	0.423	0.023	106	0
DAP	5	0.395	0.029		
DAP	10	0.415	0.023		
DAP	20	0.387	0.026		
DAP	40	0.402	0.033		
Control	0	0.423	0.023	86	33
SOA	5	0.445	0.020		
SOA	10	0.438	0.032		
SOA	20	0.483	0.022		
SOA	40	0.483	0.014		
Control	0	0.423	0.023	90	5
UAN	5	0.475	0.023		
UAN	10	0.477	0.032		
UAN	20	0.465	0.022		
UAN	40	0.473	0.017		
Control	0	0.423	0.023	89	43
Urea	5	0.395	0.023		
Urea	10	0.403	0.023		
Urea	20	0.472	0.022		
Urea	40	0.440	0.024		

Source of variation	P value	LSD
N_rate	0.694	ns
Product	0.002	0.043
N_rate.Product	0.657	ns

Product	N rate	NDVI - mean	Std. Error	Relative yield %	Optimal N
Control	0	0.237	0.020	78	6
DAP	5	0.288	0.013		
DAP	10	0.303	0.019		
DAP	20	0.292	0.016		
DAP	40	0.305	0.020		
Control	0	0.237	0.020	70	22
SOA	5	0.263	0.009		
SOA	10	0.308	0.016		
SOA	20	0.317	0.022		
SOA	40	0.278	0.018		
Control	0	0.237	0.020	80	17
UAN	5	0.248	0.019		
UAN	10	0.292	0.019		
UAN	20	0.285	0.023		
UAN	40	0.288	0.011		
Control	0	0.237	0.020	78	16
Urea	5	0.262	0.022		
Urea	10	0.295	0.020		
Urea	20	0.295	0.013		
Urea	40	0.273	0.017		

Source of variation	P value	LSD
Product	0.044	0.031
N_rate	0.071	ns
Product.N_rate	0.851	ns

2018 Trials
NDVI results at GS21-25

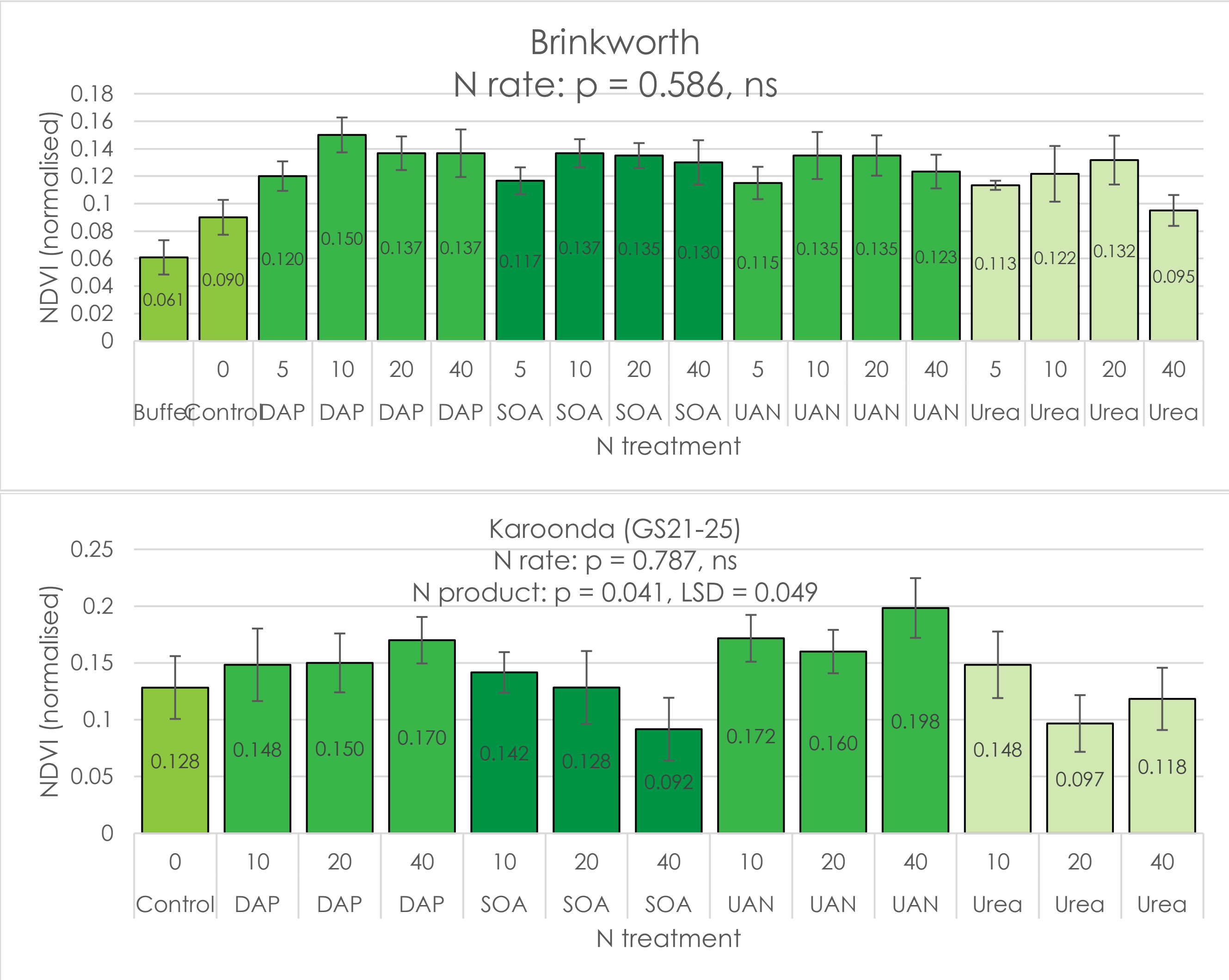


Figure 1: NDVI results for each N treatment at Brinkworth (top) and Karoonda (bottom) at GS21-25.

NDVI results at GS39-40

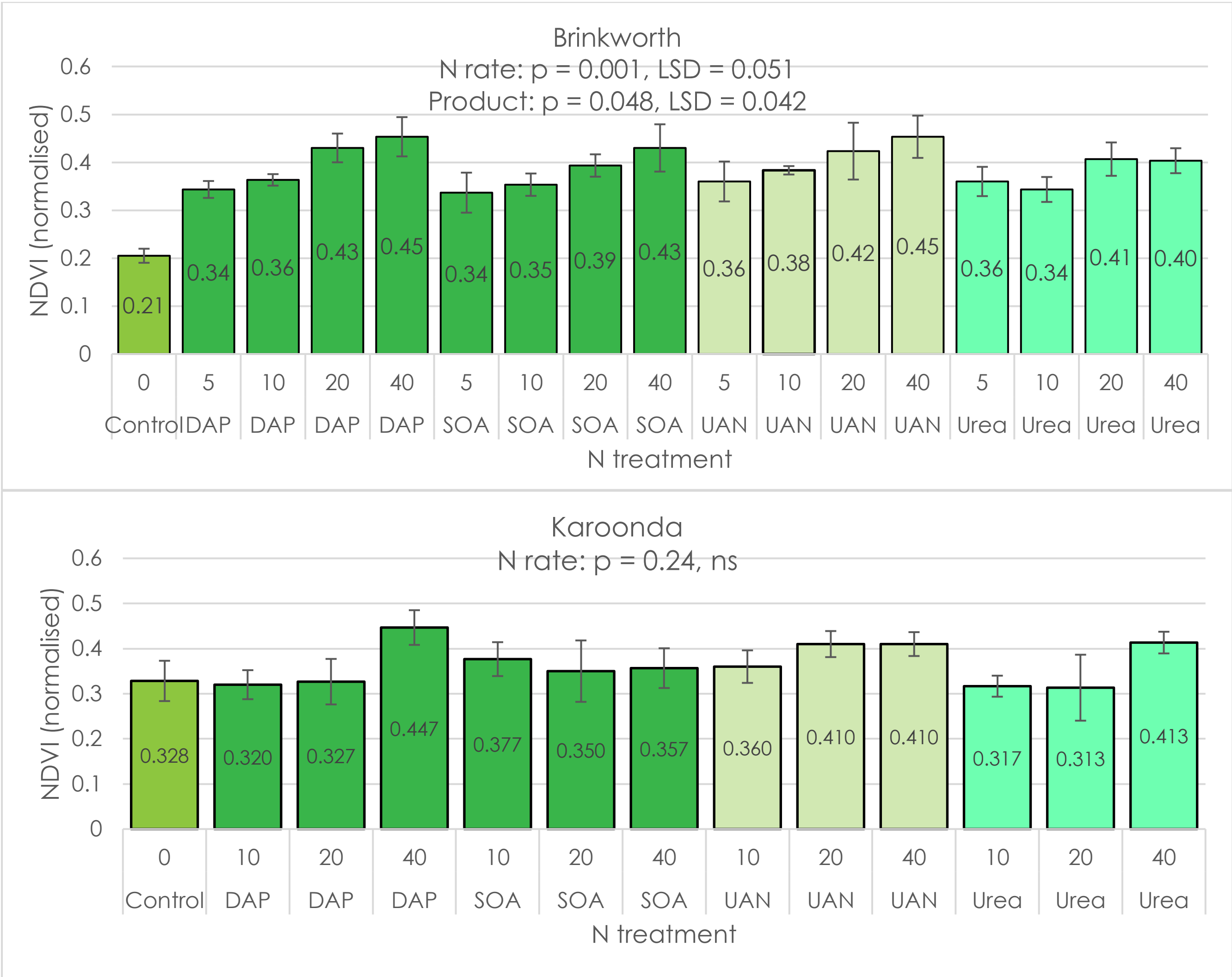
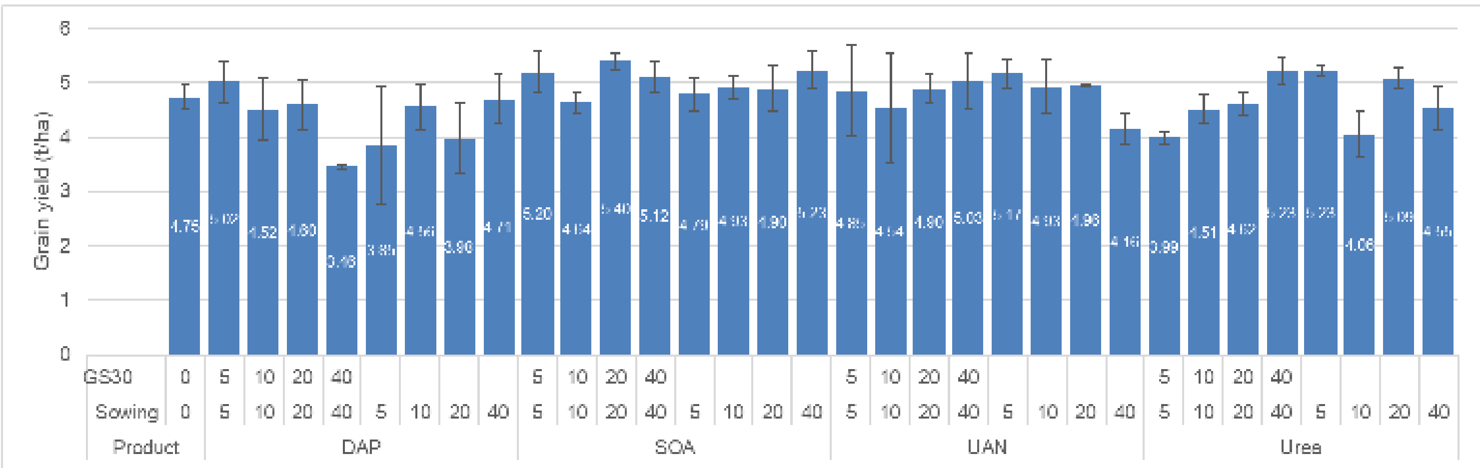
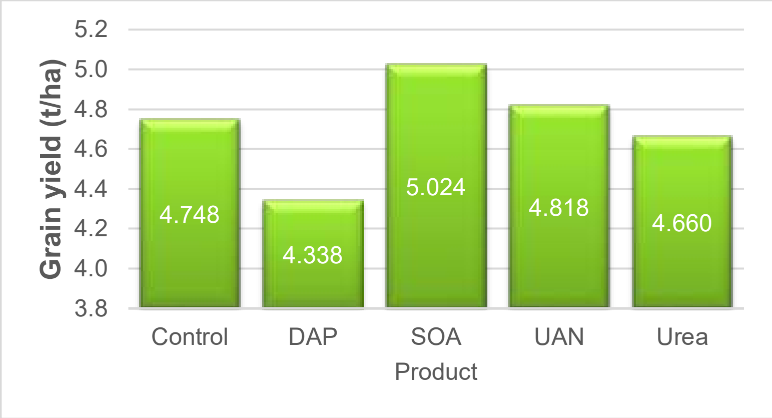


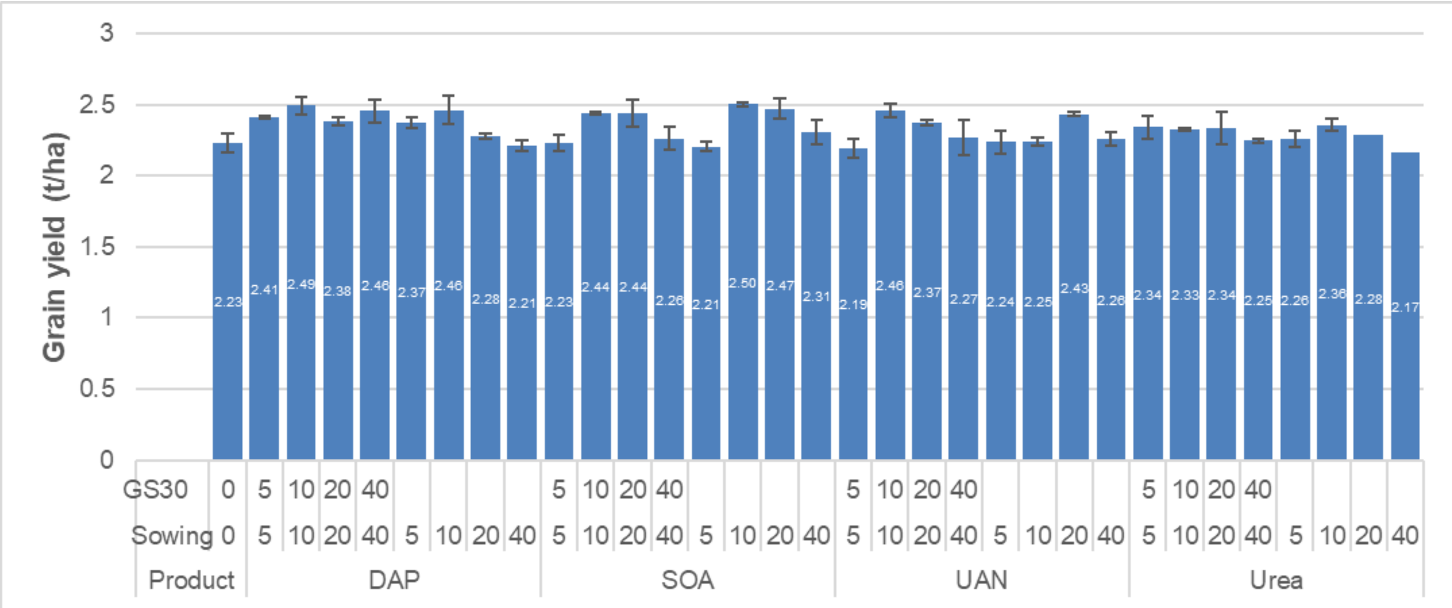
Figure 2: NDVI results for each N treatment at Brinkworth (top) and Karoonda (bottom) at GS39-40.

Grain yields
2017 trials



Source of variation	P value	LSD
Product	0.044	0.54
Rate	0.993	ns
Product.Rate	0.326	ns

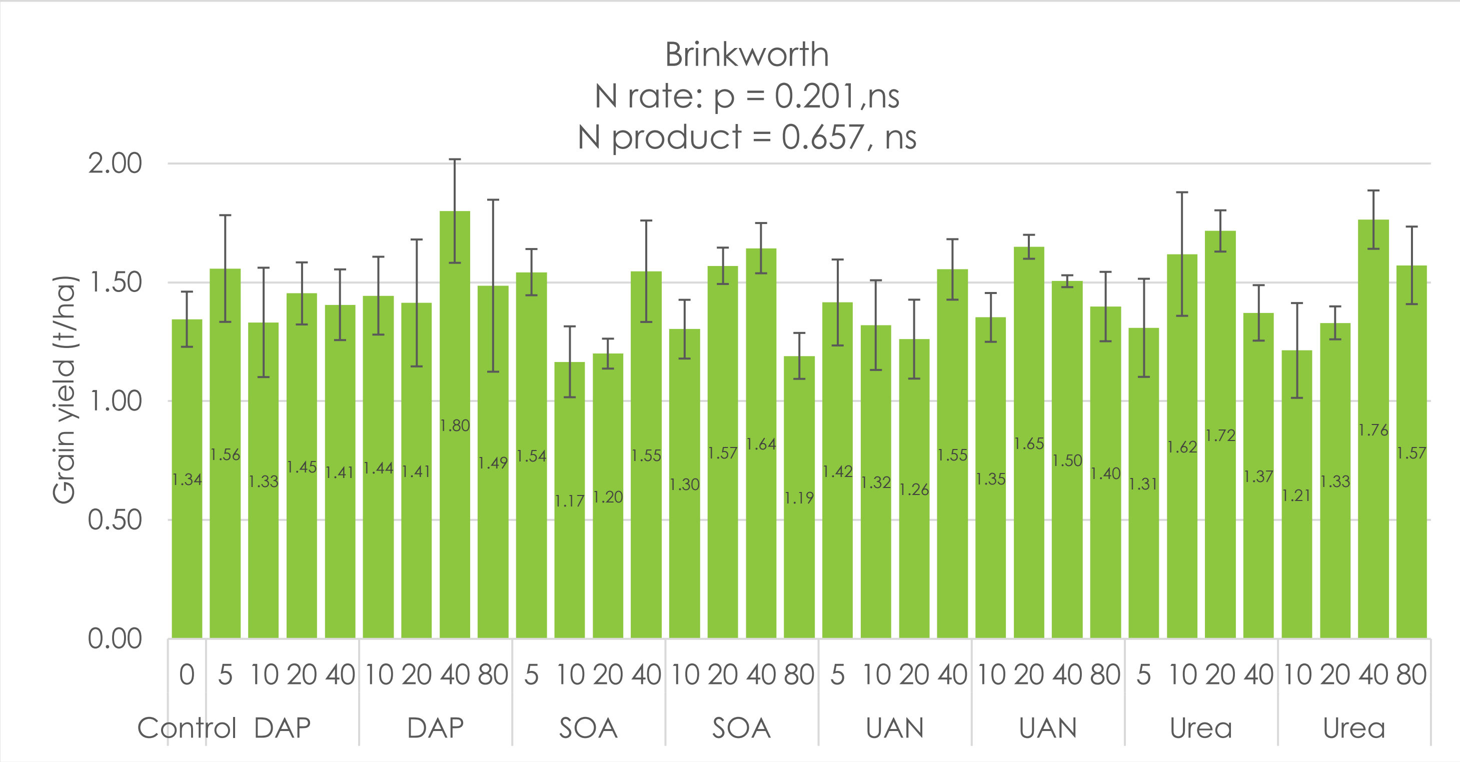




Source of variation	P value	LSD
Product	0.052	ns
N_rate	0.023	0.09
Product.N_rate	0.471	ns

Figure 3: Grain yield results for each N treatment either applied all at sowing or split at sowing and at GS30 for Lameroo (top) and Condowie (bottom) with related statistical analysis below each figure. The figure in the middle is significant product effect obtained at the Lameroo site.

2018 Trials



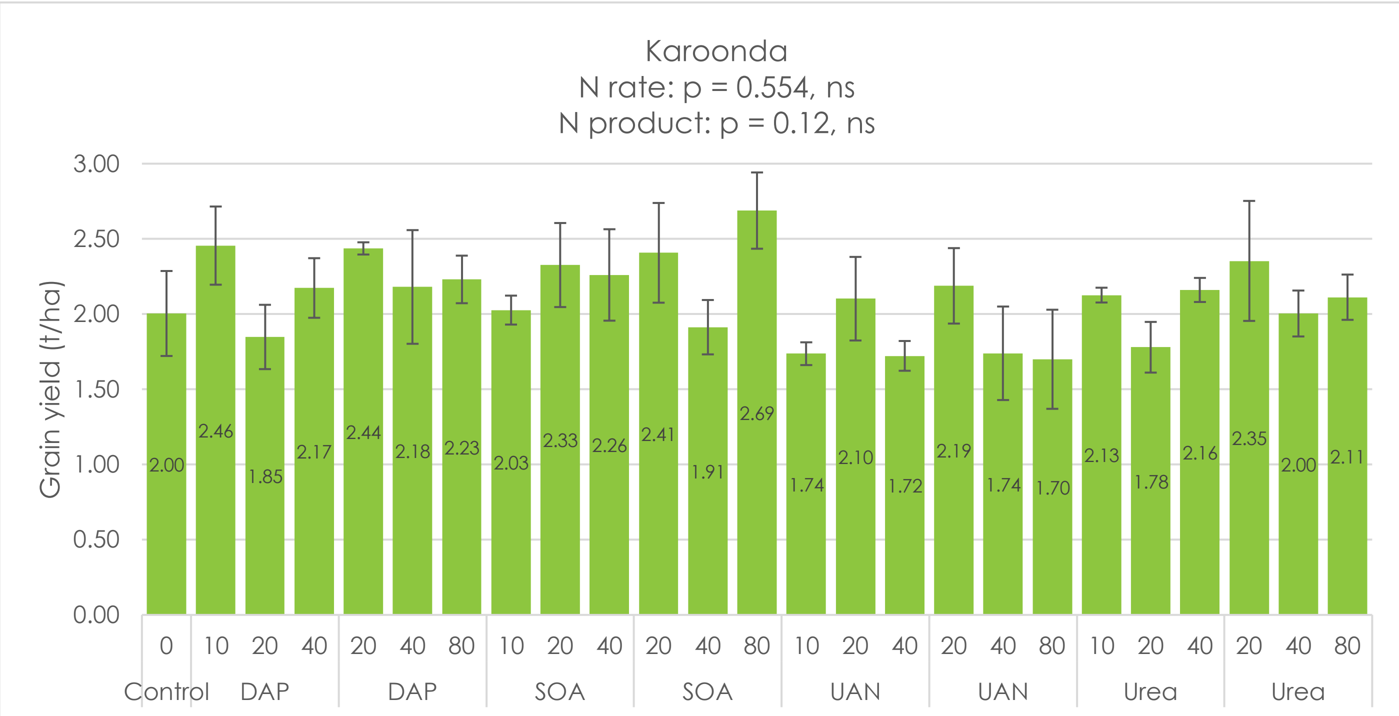


Figure 4: Grain yield results for each N treatment either applied all at sowing or split at sowing and at GS30 for Brinkworth (top) and Karoonda (bottom) with related statistical analysis

Grain Protein:

2017 trials

Table 4: Statistical analysis of grain protein results obtained for the two trial sites. Significant differences were obtained by increasing N rates but there was not product effect.

Lameroo

Source of variation	P value	LSD
Product	0.688	ns
Rate	0.009	0.3015
Product.Rate	0.873	ns

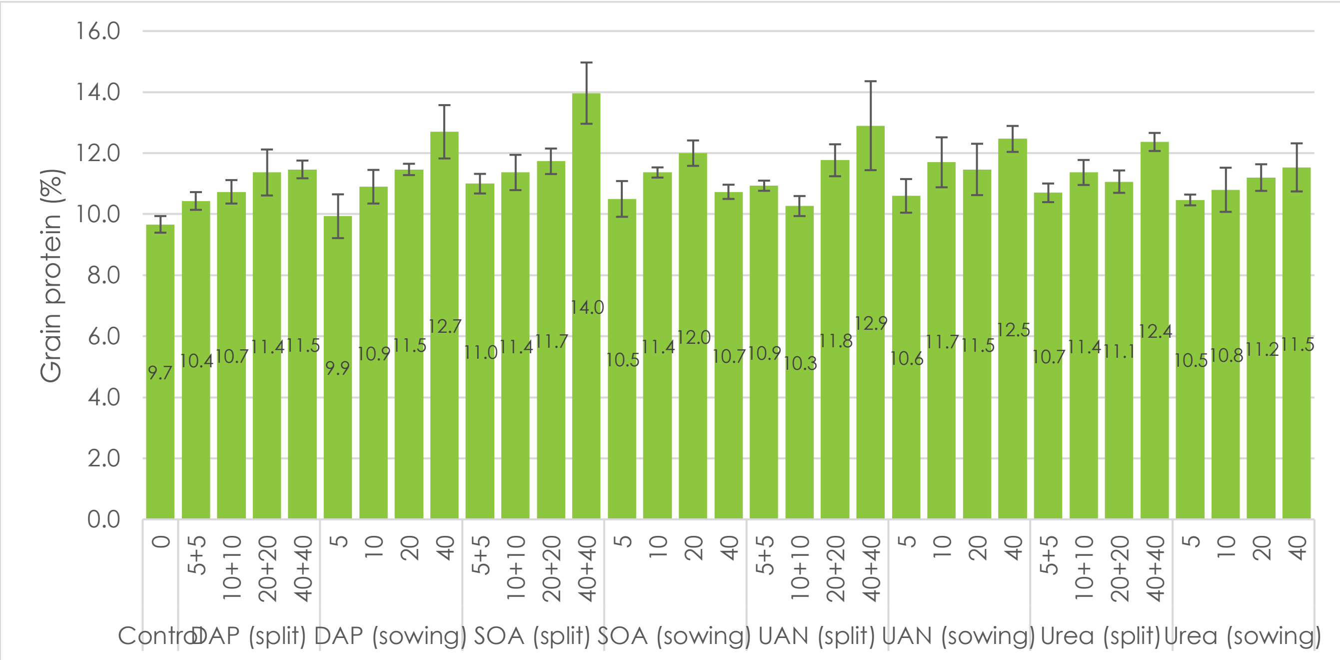
Condowie

Source of variation	P value	LSD
Product	0.712	ns
N_rate	0.02	0.5662
Product.N_rate	0.783	ns

2018 Trials

Brinkworth

Grain protein results



Statistical output

Category	P value	LSD
N Product	0.001	0.849
N rate	<0.001	0.705
N Product x Rate	0.407	ns

Figure 5: Grain protein results for each treatment applied at the Brinkworth trial site with associated statistical analysis. Error bars represent standard error of three replicates.

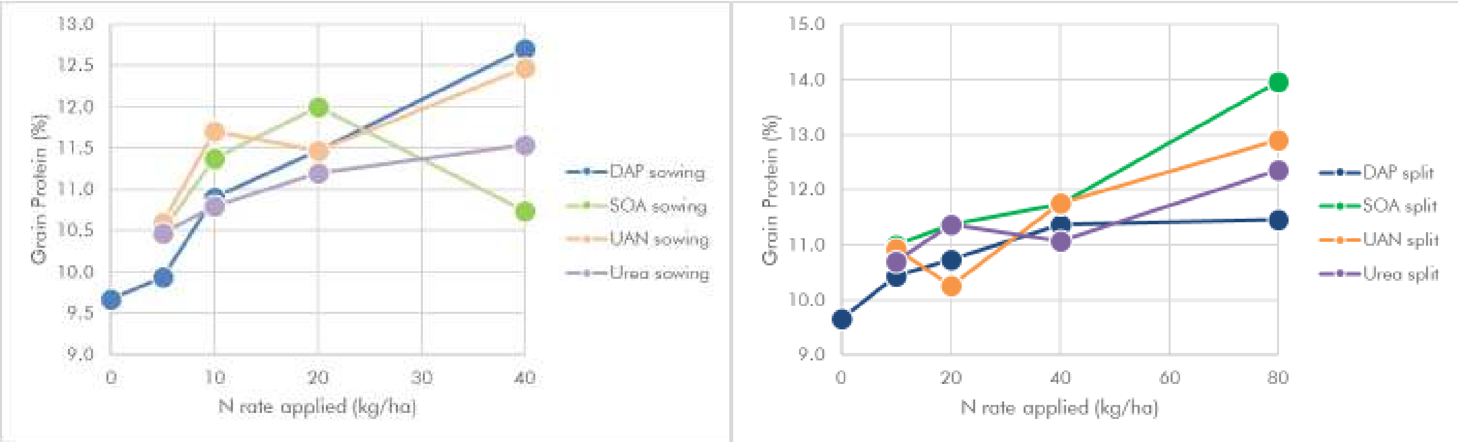
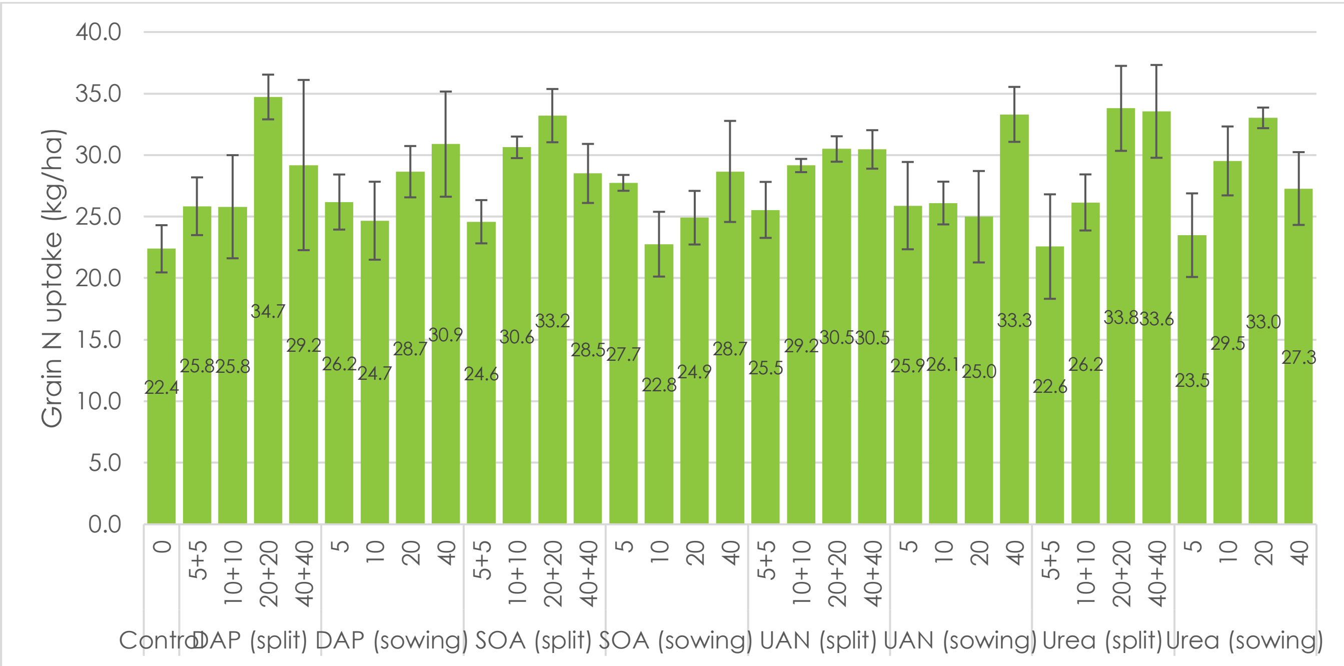


Figure 6: Grain protein results with increasing N rates applied at sowing only (left) and split between sowing and GS30 (right) for the Brinkworth site.

Nitrogen uptake (Grain):



Statistical output

Category	P value	LSD
N Product	0.106	ns
N rate	0.003	4.331
N Product x Rate	0.668	ns

Figure 7: Nitrogen uptake into the grain for each treatment applied at the Brinkworth trial site. Uptake was calculated by multiplying the grain yield obtained for each treatment with the grain N concentration obtained.

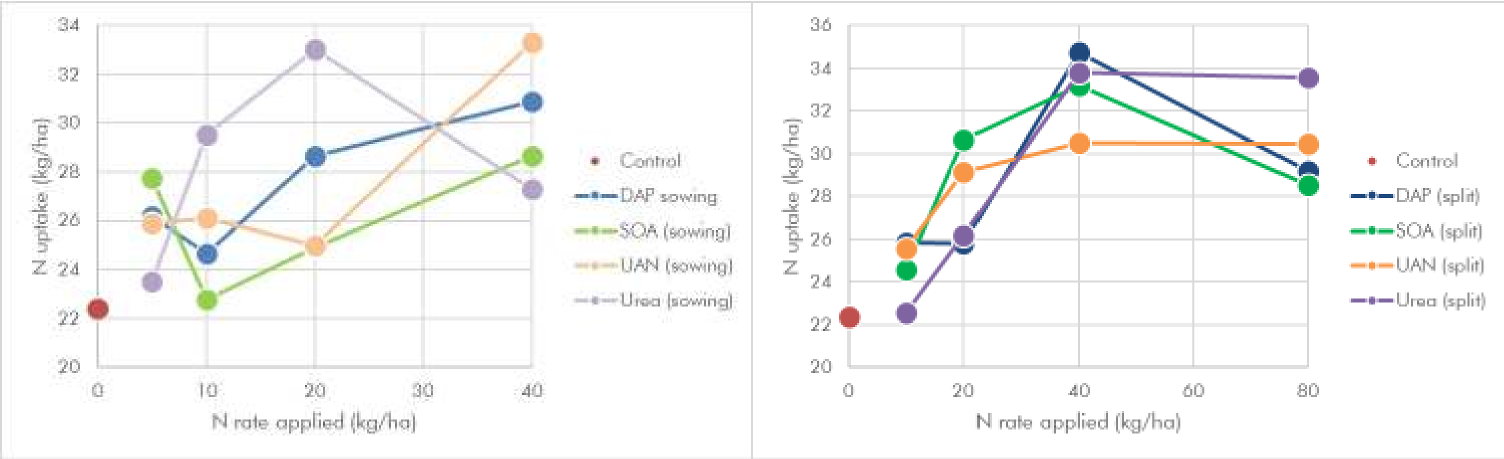


Figure 8: Overall N uptake into the grain with increasing N rates applied at sowing only (left) and split between sowing and GS30 (right) at the Brinkworth site.

Nitrogen Use Efficiency of applied N:

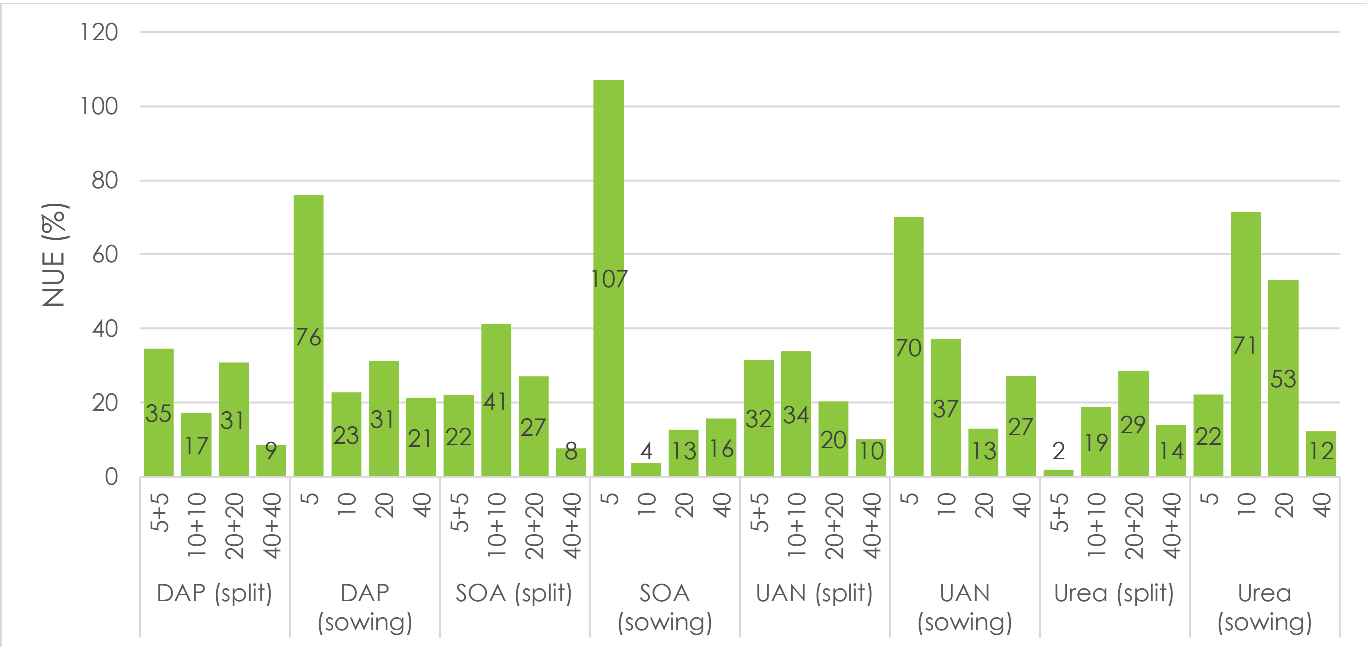


Figure 9: Nitrogen use efficiency (NUE) results for each applied N treatment at the Brinkworth trial site. NUE was calculated by subtracting the soil N supply to the grain as measured by the control off the grain N uptake for each N treatment.

Gross Margins:

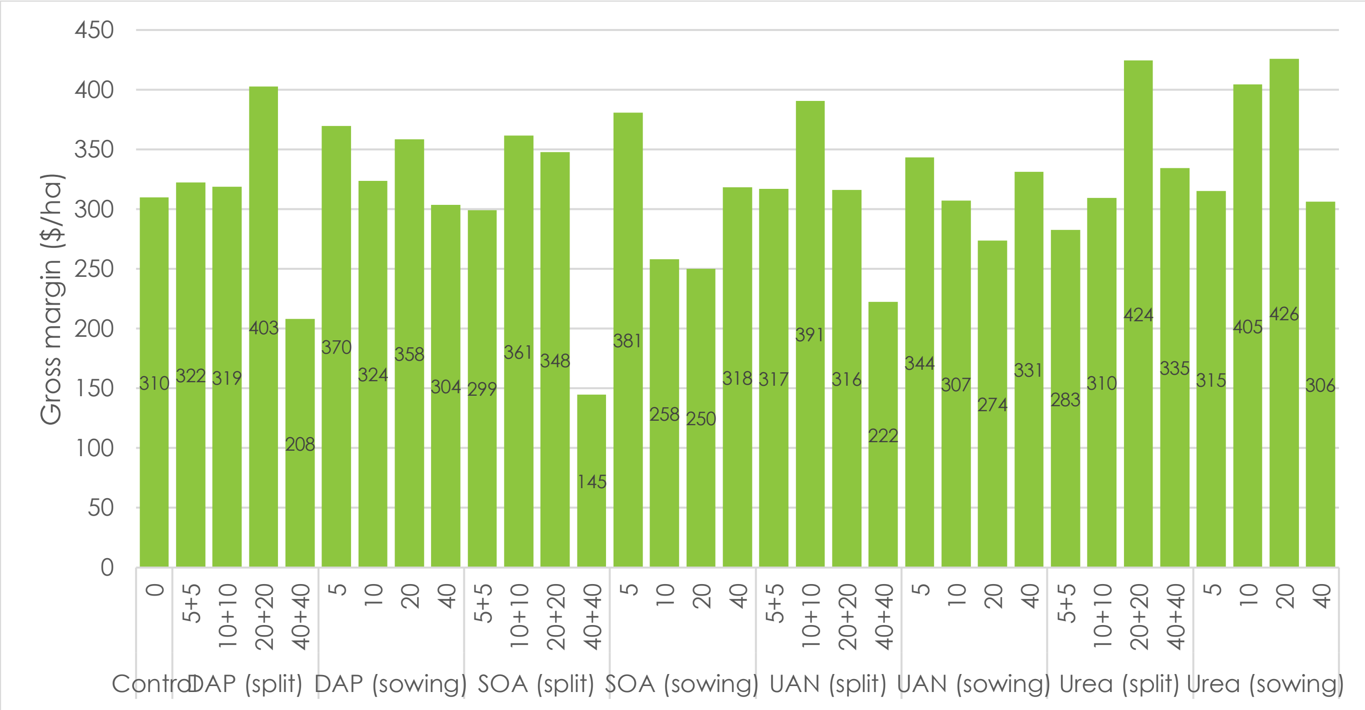
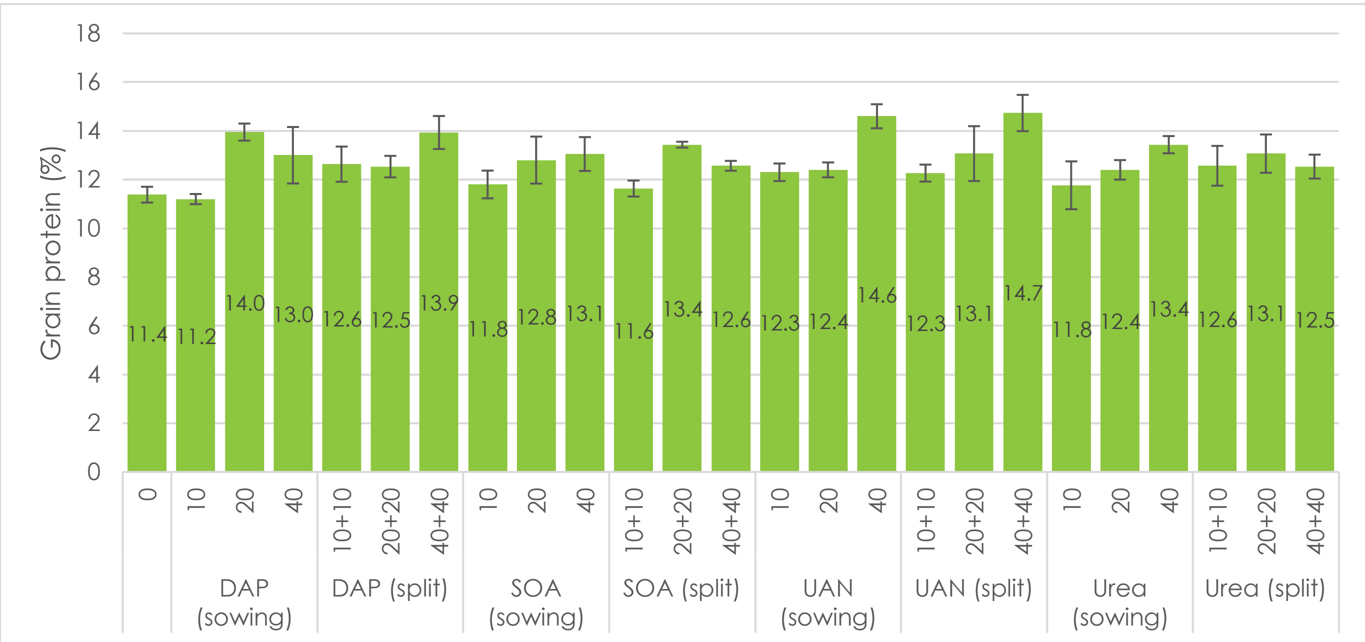


Figure 10: Gross margin analysis factoring in returns from grain yield (price determined by grade) minus the cost of the fertiliser treatments applied. See appendix for values used.

Karoonda
Grain protein results



Statistical output

Category	P value	LSD
N Product	0.013	0.846
N rate	0.003	0.946
N Product x Rate	0.286	ns

Figure 11: Grain protein results for each treatment applied at the Karoonda trial site with associated statistical analysis. Error bars represent standard error of three replicates

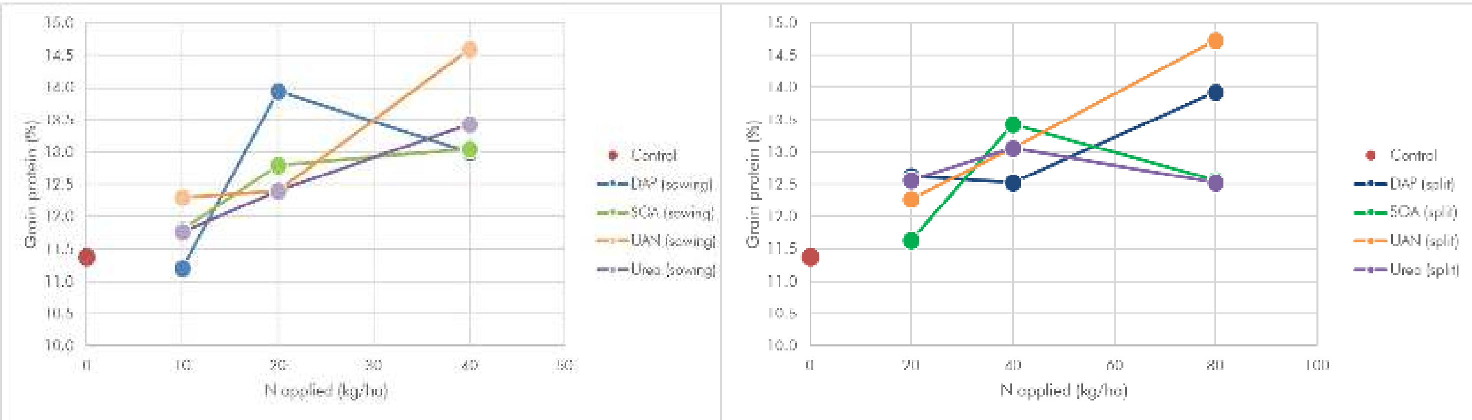
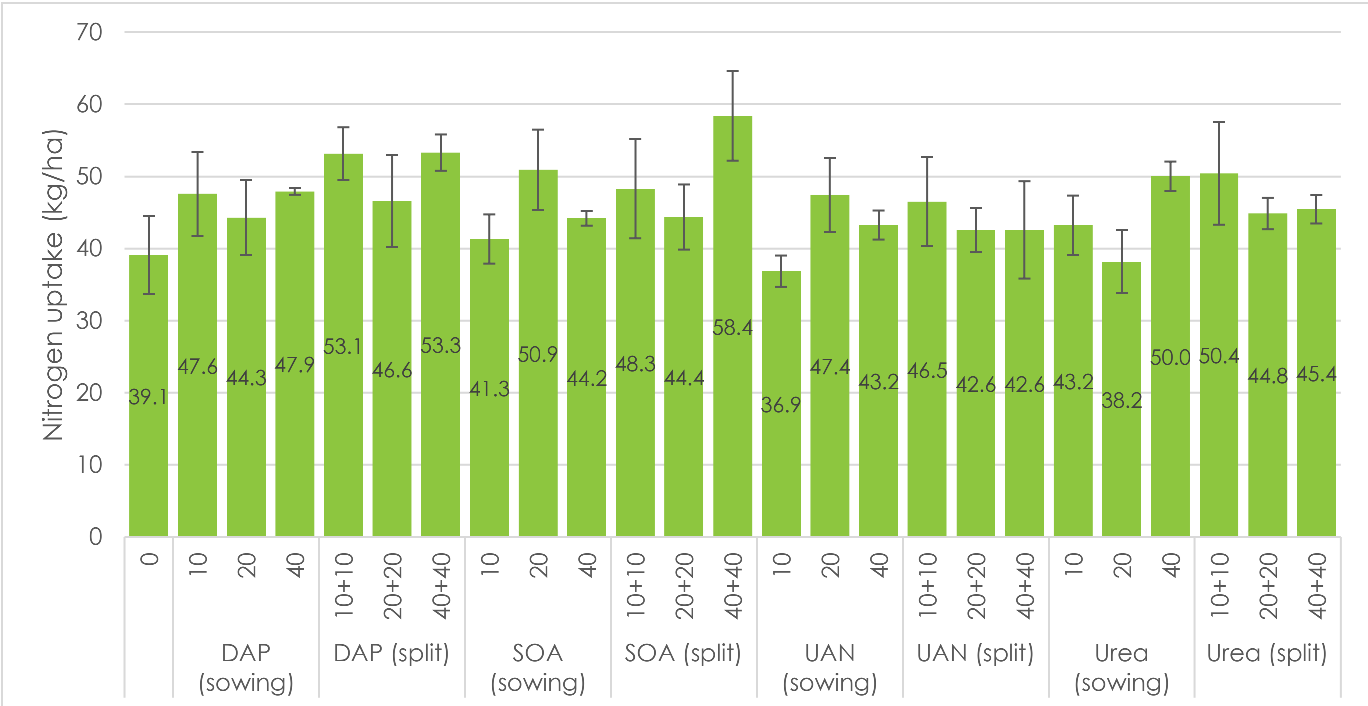


Figure 12: Grain protein results with increasing N rates applied at sowing only (left) and split between sowing and GS30 (right) for the Karoonda site.

Nitrogen uptake (Grain):



Statistical output

Category	P value	LSD
N Product	0.071	ns
N rate	0.281	ns
N Product x Rate	0.688	ns

Figure 13: Nitrogen uptake into the grain for each treatment applied at the Karoonda trial site. Uptake was calculated by multiplying the grain yield obtained for each treatment with the grain N concentration obtained.

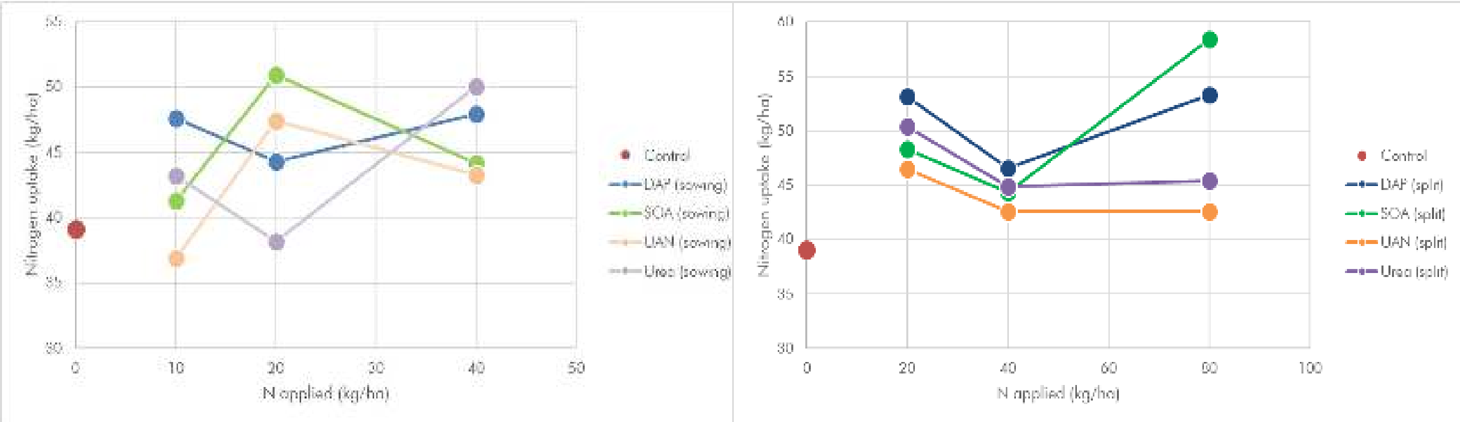


Figure 14: Overall N uptake into the grain with increasing N rates applied at sowing only (left) and split between sowing and GS30 (right).

Nitrogen Use Efficiency of applied N:

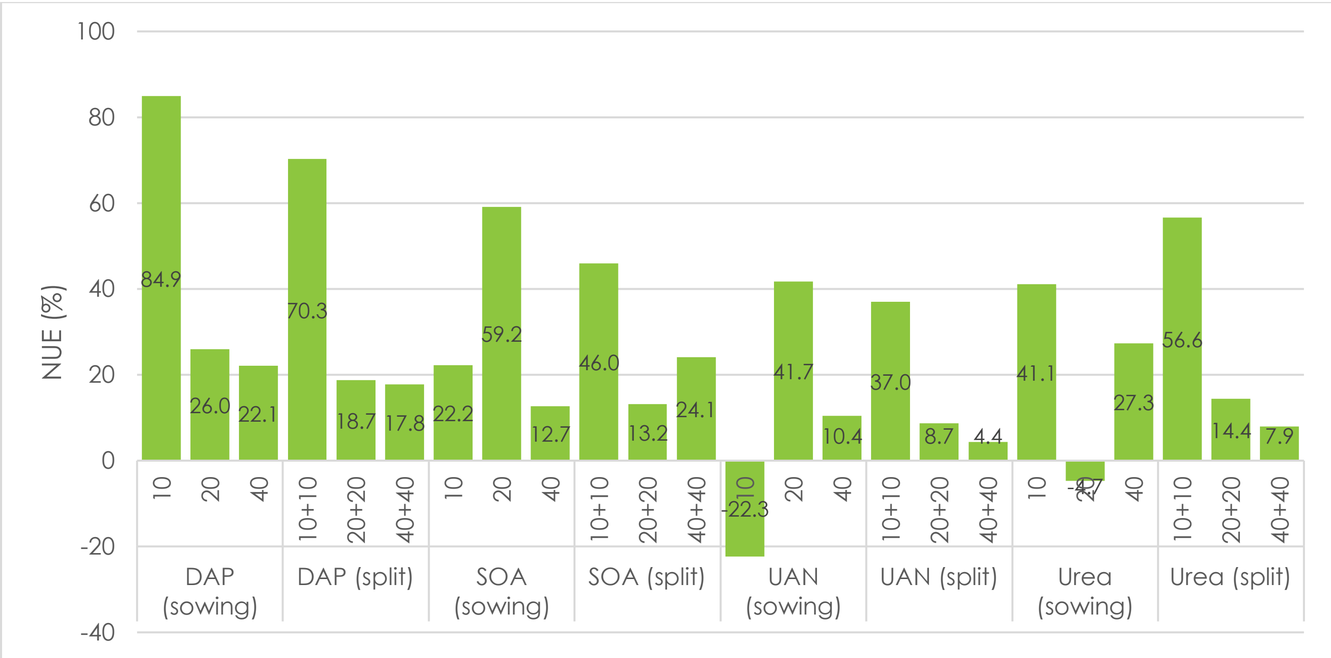


Figure 15: Nitrogen use efficiency (NUE) results for each applied N treatment at the Karoonda trial site. NUE was calculated by subtracting the soil N supply to the grain as measured by the control off the grain N uptake for each N treatment.

Gross Margins:

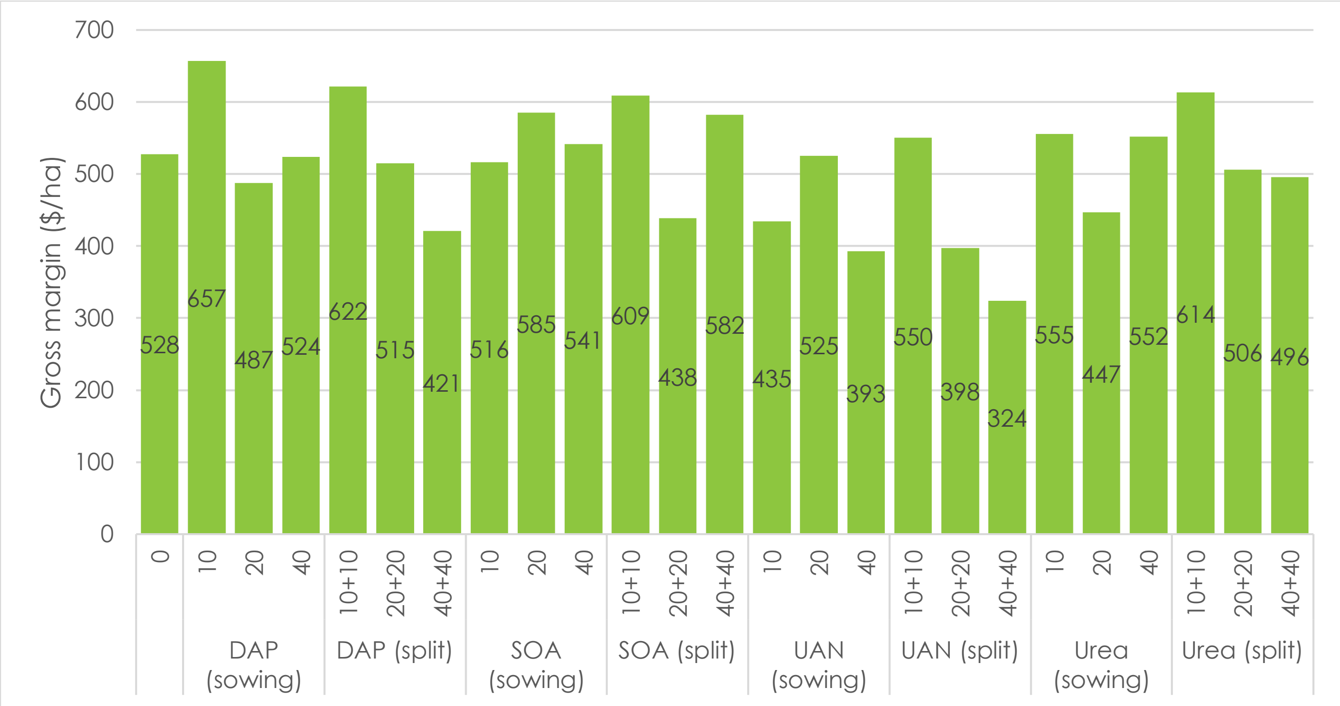


Figure 16: Gross margin analysis factoring in returns from grain yield (price determined by grade) minus the cost of the fertiliser treatments applied. See appendix for values used.

2018 trial summary

Full analysis of these trial results highlights the importance of a season finish in order to make full use of applied N particularly in season applications. Both sites had non-significant responses to applied N in terms of grain yield but there was significant ($p < 0.05$) increase in grain protein and overall grain N uptake which meant that applied N was getting into the wheat crop. There was no effect of which source of N was applied, however. Nitrogen management was important in terms of grain protein levels and the ensuing wheat grade, but this wasn't reflected in the gross margin analysis as the differences between prices for varying wheat grades is quite small (see appendix). As expected from the small insignificant increases in grain yield with applied N the lower rates of N generally resulted in the highest Nitrogen Use Efficiencies (NUE). The treatment which resulted in the highest gross margin at Brinkworth was 20 kg N/ha applied as Urea at sowing closely followed the split application of Urea at 20 kg N/ha both at sowing and GS30 which was driven by higher yields. At Karoonda the lowest rates of DAP generated the highest gross margins again due to high relative yields which were 10 kg N/ha applied at sowing closely followed by 10 kg N/ha applied at both sowing and GS30.

Other nutrient interactions

There was no significant ($p > 0.05$) effect of applying N through various forms on any other nutrient uptake into the grain.

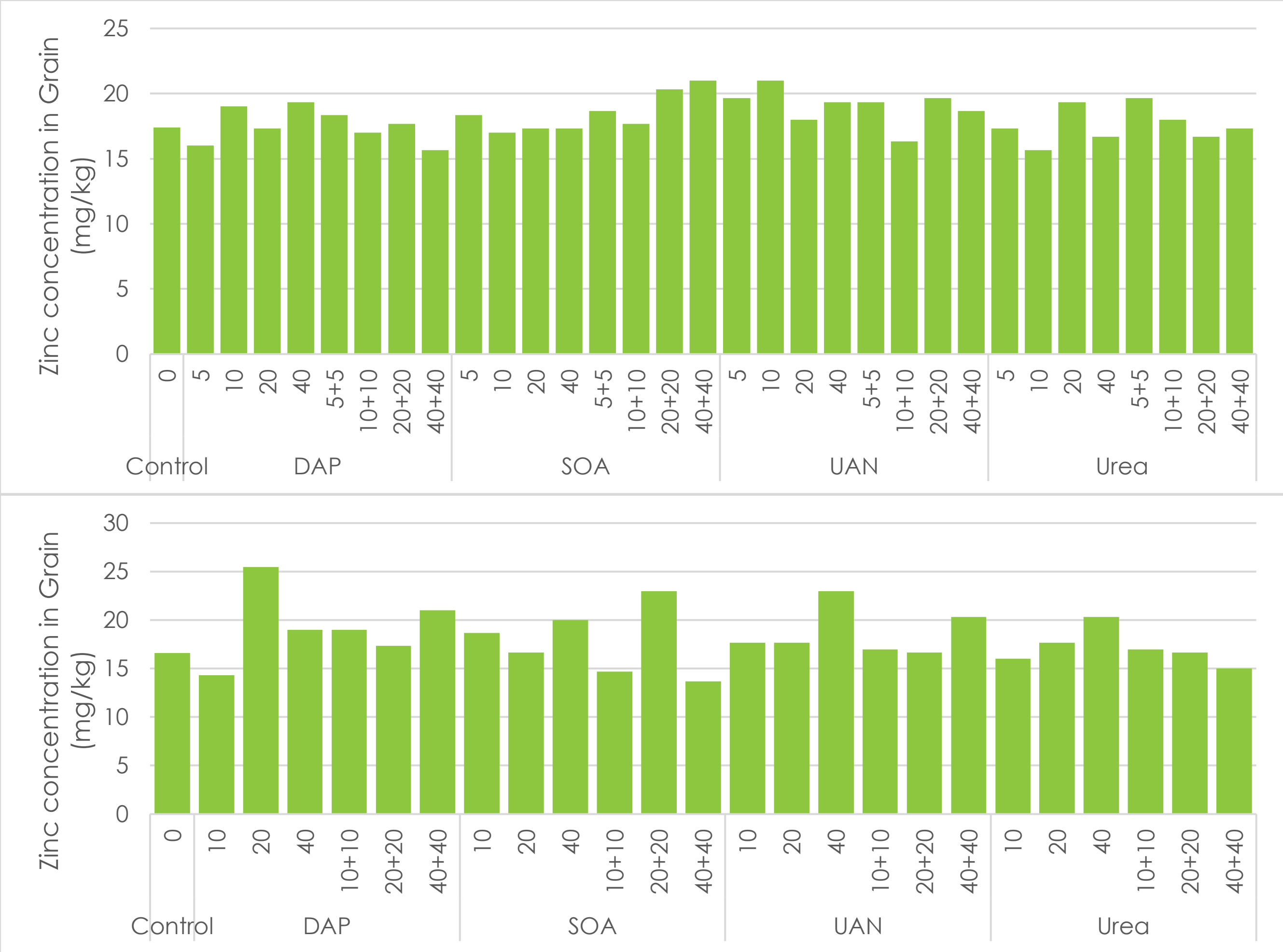


Figure 16: Grain Zinc concentrations for each N treatment at Brinkworth (top) and Karoonda (bottom). There was no significant ($p > 0.05$) differences between treatments.

8 Conclusions and recommendations

This project outlines while there might be some interactions with different N products causing lower efficiencies for crop N uptake and growth these differences are not consistent and there appears to be no benefit of choosing one N product over the other when considering NUE.

Applying relatively high amounts of N in various forms (40 kg N/ha) with the seed didn't affect early crop growth or ensuing grain yields even in susceptible soil types found at the Lameroo and Karoonda trial sites.

Unfortunately, product interactions and NUE were not tested under severe N deficiency or high crop yields demanding higher N demand from various N sources. Most sites were either non-responsive to N applications (Lameroo – 2017, Brinkworth – 2018, Karoonda - 2018) or marginally responsive (Condowie - 2017).

The climatic conditions at all sites in 2017 and 2018 meant that yields generally below 2t/ha didn't drive the demand for N and the starting soil N available in the soil profile was able to fulfill the majority of crop N demand.

Despite the lack of responsiveness, we did show that there potentially might be some issues with placing DAP near the seed in a soil type like Lameroo. Further trials are required to confirm this result.

In line with this observation trials being run by Therese McBeath (CSIRO) has shown benefits of placing DAP below the seed (~ 5cm) compared to with the seed at field sites in the Mallee region. It is speculated that the cause of this might be that more of the soil area where roots access nutrients are enriched with N due to the deeper placement. It also cannot be ruled out that yields are reduced due to potential hostile soil conditions generated by DAP placement near the seed

Applied N significantly ($p < 0.05$) increased grain protein levels and high NUE values were obtained at low applied N rates at sowing for Brinkworth and Karoonda (apart from UAN applied at 10 kg N/ha).

9 Appendix

Full economic analysis outputs

Prices used ($/t grain – source: www.awb.com.au/daily-grain-prices

Wheat grade	Brinkworth (Snowtown)	Karoonda
H1	306	298
H2	301	293
APW1	301	293
ASW1	286	278

Fertiliser prices used:

Pasture King (source of P with no N applied as basal) - $370/t

Urea - $366/t, DAP - $538/t, SOA - $380/t, UAN - $0.65/L

Brinkworth:

	N rate	Yield	Protein	N uptake	NUE	Wheat grade	Wheat price	Fertiliser cost	Return	Gross margin
Treatment	kg/ha	t/ha	%	kg/ha	%		$/t	$/ha	$/t	$/ha
Control	0	1.34	9.67	22.4		ASW1	286	75	385	310
DAP (split)	5+5	1.44	10.43	25.8	35	ASW1	286	91	413	322
	10+10	1.41	10.73	25.8	17	APW1	301	107	425	319
	20+20	1.80	11.37	34.7	31	APW1	301	139	542	403
	40+40	1.49	11.47	29.2	9	H2	301	239	447	208
DAP (sowing)	5	1.56	9.93	26.2	76	ASW1	286	76	446	370
	10	1.33	10.90	24.7	23	APW1	301	77	401	324
	20	1.45	11.47	28.7	31	H2	301	79	437	358
	40	1.41	12.70	30.9	21	H2	301	120	423	304
SOA (split)	5+5	1.30	11.00	24.6	22	APW1	301	93	392	299
	10+10	1.57	11.37	30.6	41	APW1	301	111	472	361
	20+20	1.64	11.73	33.2	27	H2	301	147	495	348
	40+40	1.19	13.97	28.5	8	H1	306	220	364	145
SOA (sowing)	5	1.54	10.50	27.7	107	APW1	301	84	464	381
	10	1.17	11.37	22.8	4	APW1	301	93	351	258
	20	1.20	12.00	24.9	13	H2	301	111	361	250
	40	1.55	10.73	28.7	16	APW1	301	147	466	318
UAN (split)	5+5	1.35	10.93	25.5	32	APW1	301	90	407	317
	10+10	1.65	10.27	29.2	34	ASW1	301	106	497	391
	20+20	1.50	11.77	30.5	20	H2	301	137	453	316
	40+40	1.40	12.90	30.5	10	H2	301	199	421	222
UAN (sowing)	5	1.42	10.60	25.9	70	APW1	301	82	426	344
	10	1.32	11.70	26.1	37	H2	301	90	397	307
	20	1.26	11.47	25.0	13	H2	301	106	380	274
	40	1.55	12.47	33.3	27	H2	301	137	468	331
Urea (split)	5+5	1.21	10.70	22.6	2	APW1	301	83	365	283
	10+10	1.33	11.37	26.2	19	APW1	301	91	400	310
	20+20	1.76	11.07	33.8	29	APW1	301	107	531	**424**
	40+40	1.57	12.37	33.6	14	H2	301	138	473	335
Urea (sowing)	5	1.31	10.47	23.5	22	APW1	301	79	394	315
	10	1.62	10.80	29.5	71	APW1	301	83	487	405
	20	1.72	11.20	33.0	53	APW1	301	91	517	**426**
	40	1.37	11.53	27.3	12	H2	301	107	413	306

Karoonda:

	N rate	Yield	Protein	N uptake	NUE	Wheat grade	Wheat price	Fertiliser cost	Return	Gross margin
Treatment	kg/ha	t/ha	%	kg/ha	%		$/t	$/ha	$/t	$/ha
Control	0	2.00	11.4	39.1		APW	291	55	583	528
DAP (sowing)	10	2.46	11.2	47.6	84.9	APW	291	58	714	**657**
	20	1.85	14.0	44.3	26.0	H1	296	60	547	487
	40	2.17	13.0	47.9	22.1	H1	296	120	643	524
DAP (split)	10+10	2.44	12.6	53.1	70.3	H2	291	87	709	**622**
	20+20	2.18	12.5	46.6	18.7	H2	291	120	634	515
	40+40	2.23	13.9	53.3	17.8	H1	296	239	660	421
SOA (sowing)	10	2.03	11.8	41.3	22.2	H2	291	73	590	516
	20	2.33	12.8	50.9	59.2	H2	291	92	677	585
	40	2.26	13.1	44.2	12.7	H1	296	128	669	541
SOA (split)	10+10	2.41	11.6	48.3	46.0	H2	291	92	701	609
	20+20	1.91	13.4	44.4	13.2	H1	296	128	566	438
	40+40	2.69	12.6	58.4	24.1	H2	291	200	782	582
UAN (sowing)	10	1.74	12.3	36.9	-22.3	H2	291	71	505	435
	20	2.10	12.4	47.4	41.7	H2	291	86	612	525
	40	1.72	14.6	43.2	10.4	H1	296	117	510	393
UAN (split)	10+10	2.19	12.3	46.5	37.0	H2	291	86	637	550
	20+20	1.74	13.1	42.6	8.7	H1	296	117	515	398
	40+40	1.70	14.7	42.6	4.4	H1	296	179	503	324
Urea (sowing)	10	2.13	11.8	43.2	41.1	H2	291	63	619	555
	20	1.78	12.4	38.2	-4.7	H2	291	71	518	447
	40	2.16	13.4	50.0	27.3	H1	296	87	639	552
Urea (split)	10+10	2.35	12.6	50.4	56.6	H2	291	71	685	614
	20+20	2.00	13.1	44.8	14.4	H1	296	87	593	506
	40+40	2.11	12.5	45.4	7.9	H2	291	119	615	496