Final Technical Results Report

2023

Carryover of Nitrogen after Crop Failure – Western Region Case Studies

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REPORT SENSITIVITY

Does the report have any of the following sensitivities?

Intended for journal publication	YES ☐ NO ☒
Results are incomplete	YES ☐ NO ☒
Commercial/IP concerns	YES ☐ NO ☒
Embargo date	YES ☐ NO ☒ If Yes, Date: <Choose date>

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ABSTRACT

In September 2021 a widespread frost significantly reduced the grain yield of crops in the Geraldton and Kwinana East port zones. This left growers and agronomists with a gap in their knowledge, will the N applied to crops that got frosted carryover to benefit the 2022 crop? To answer this question 40 farm scale trials were established across the Kwinana East and Geraldton Port Zones. The results indicated that relying on carryover N in cereals led to a grain yield penalty of 500 kg/ha and an economic loss of $84/ha. Growers and agronomists should not rely on N applied to crops that get frosted to carryover and deliver a grain yield or economic benefit to the following crop.

EXECUTIVE SUMMARY

In September 2021 a widespread frost significantly reduced grain yields across large areas of the Western Region. It was particularly devasting for some growers, who, anticipating above average grain yields, due to a very favourable start to the growing season, applied additional nitrogen (N) fertiliser. This left growers and agronomists with a gap in their knowledge, will the N applied to crops that got frosted in 2021 carryover to benefit the 2022 crop? This was seen as a high-priority issue going into 2022 because of the high-priced N fertiliser.

To answer this question, 40 farm scale trials were established across the Kwinana East and Geraldton Port Zones. Paddocks were soil sampled before the 2022 growing season, mid-season, and at the end of the growing season. In addition, leaf tissue samples were taken mid-season and grain yield and quality at harvest.

Soil sample results showed soils were N deficient all the way down the profile to 60cm. Therefore, these results did not support the assumption that N applied to crops that get frosted is stored in the soil.

On average, relying on carryover N in cereals led to a grain yield penalty of 500 kg/ha and an economic loss of $84/ha. Therefore, growers and agronomists should not rely on N applied to crops that get frosted to carryover and deliver a grain yield or economic benefit.

These results need to be considered in the context that was the 2022 season in Western Australia when many growers grew yields well above average.

BACKGROUND

In 2021, favourable seasonable conditions early in the growing season led to above-average yield potential across much of the Geraldton and Kwinana East Port Zones. As a result, growers applied nitrogen (N) mid-season, in some cases well above budget, to capture the higher yield potential. However, in September, a significant frost impacted crops and reduced grain yield potential. At harvest, it became clear that frost had had a significant impact on grain yield; many paddocks yielded <500 kg/ha.

This posed a question, will the N applied in 2021 carryover and benefit the crop in 2022? This was particularly relevant given the high price of N fertiliser going into the 2022 season.

Research on the carryover effects on N has been studied in Eastern Australia. In a droughted wheat crop near Wagga Wagga, Sandral et al. (2019) studied the impact of carryover N and concluded that N recovery is low; recovery rates ranged from 1% to 18%. In southern NSW, Hunt et al. (2021) explored the concept of an 'N' bank and concluded that unused N carries over and is available to subsequent crops on most soils. Little research on the carryover effects on N after frosted crops has been done under Western Australian farming systems.

PROJECT OBJECTIVES

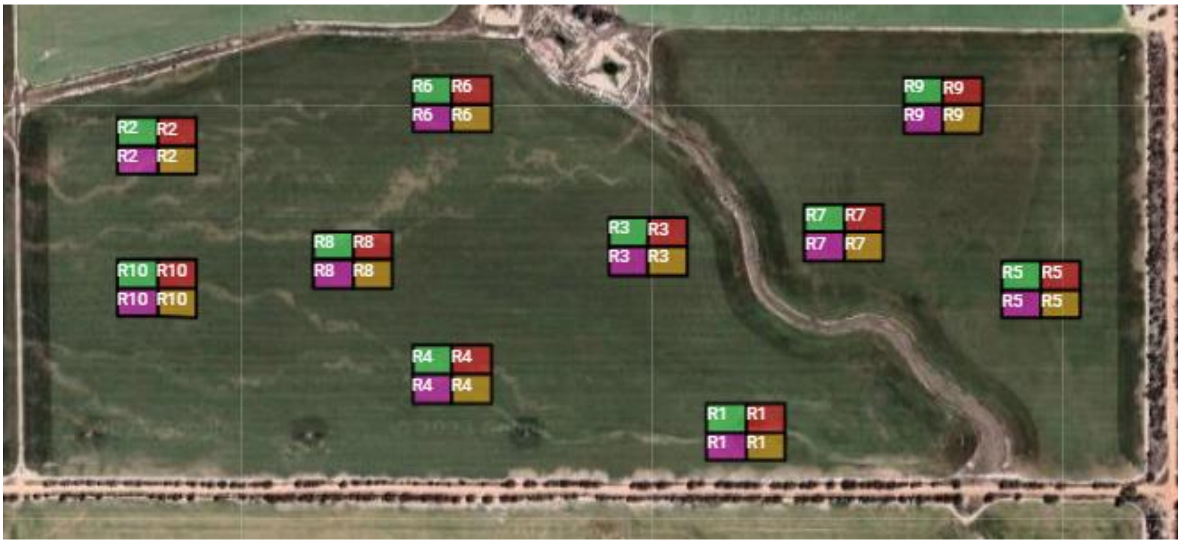
1. To determine if N applied in 2021, carries over into 2022, and has a positive grain yield and economic benefit.

METHODOLOGY

Twenty growers (10 each from Geraldton and Kwinana East port zones) established 40 farm scale trials (2 trials/farm, one paddock=1 trial) to measure the impact of carryover N. There were 32 trials in wheat, four in barley and four in canola.

The Laconik Combine™ trial design randomly locates a 'swarm' of replicates across the paddock (Image 1). Individual plots were 50m long x 36m wide. The number of replicates per trial was governed by the paddock size and ranged from 10 to 35. Each grower was provided with a prescription containing the trial design uploaded to the variable rate controller in the machine (boomspray, cultivar bar or fertiliser spreader); as the machine went across the paddock, different rates of N fertiliser were applied.

Image 1: Laconik Combine™ trial design used in this project.



Each replicate contained four treatments arranged in a square, Treatment 1 – Nil N (green plots in Image 1), Treatment 2 - half grower rate N fertiliser (red plots in Image 1), Treatment 3 – grower rate of N fertiliser (yellow plots in Image 1) and Treatment 4 – twice the grower rate of N fertiliser (pink plots in Image 1). Treatment 1 – Nil N is the treatment against which other treatments have been compared to measure the impact of carryover N from 2021. It was not possible to have an accurate Nil N treatment because N can be found mixed with other fertilisers. Therefore, all efforts were made to minimise the amount of N applied in Treatment 1. The amount of N (kg/ha) applied in 2021 and 2022 is shown in Table 1.

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Table 1: Amount of N (kg/ha) applied in 2021 and 2022.

Treatments	2021	2022	Total
Treatment 1	61	22	78
Treatment 2	61	37	94
Treatment 3	62	51	109
Treatment 4	62	81	139

All data were analysed using ANOVA (P=0.1).

LOCATION

Where field trials have been conducted, provide the following location details in the table below: latitude and longitude or nearest town. (Add additional rows as required.)

Site #	Latitude (decimal degrees)	Longitude (decimal degrees)	Nearest town
Trial Site #1	-28.056801°	114.629342°	Binnu
Trial Site #2	-28.072665°	114.631578°	Binnu
Trial Site #3	-28.079002°	114.917955°	Binnu
Trial Site #4	-28.092156°	114.901254°	Binnu
Trial Site #5	-28.045157°	114.989546°	Binnu
Trial Site #6	-28.049667°	114.983161°	Binnu
Trial Site #7	-28.384361°	114.959525°	Yuna
Trial Site #8	-28.390983°	114.958176°	Yuna
Trial Site #9	-28.485441°	115.512839°	Mullewa
Trial Site #10	-28.472646°	115.443876°	Mullewa
Trial Site #11	-28.761506°	115.275391°	Mullewa
Trial Site #12	-28.839500°	115.308472°	Mullewa
Trial Site #13	-29.205010°	115.251714°	Mingenew
Trial Site #14	-29.211400°	115.250740°	Mingenew
Trial Site #15	-29.457029°	115.360869°	Arrino

Site #	Latitude (decimal degrees)	Longitude (decimal degrees)	Nearest town
Trial Site #16	-29.371908°	115.694533°	Arrino
Trial Site #17	-29.792720°	115.898017°	Carnamah
Trial Site #18	-29.728995°	116.020250°	Carnamah
Trial Site #19	-29.766282°	116.439661°	Latham
Trial Site #20	-29.867469°	116.393522°	Latham
Trial Site #21	-30.344383°	116.885579°	Kalannie
Trial Site #22	-30.364549°	116.865791°	Kalannie
Trial Site #23	-30.689629°	117.943558°	Bencubbin
Trial Site #24	-30.658986°	117.961061°	Bencubbin
Trial Site #25	-30.482197°	118.180475°	Wialki
Trial Site #26	-30.471775°	118.180562°	Wialki
Trial Site #27	-30.521955°	118.503378°	Bonnie Rock
Trial Site #28	-30.535112°	118.513625°	Bonnie Rock
Trial Site #29	-31.210406°	117.707620°	Yelbeni
Trial Site #30	-31.198611°	117.682360°	Yelbeni
Trial Site #31	-31.074100°	118.138255°	Mukinbudin
Trial Site #32	-31.081293°	118.133011°	Mukinbudin
Trial Site #33	-31.185358°	118.116301°	Nungarin
Trial Site #34	-31.189695°	118.115487°	Nungarin
Trial Site #35	-31.502378°	118.851953°	Bodallin
Trial Site #36	-31.512192°	118.874593°	Bodallin
Trial Site #37	-31.551377°	119.234236°	Dulyalbin
Trial Site #38	-31.601902°	119.194600°	Dulyalbin
Trial Site #39	-32.036019°	118.812361°	Mt Walker
Trial Site #40	-32.038484°	118.867450°	Mt Walker

If the research results are applicable to a specific GRDC region/s (e.g. North/South/West) or GRDC agro-ecological zone/s, indicate which in the table below:

Research	Benefiting GRDC region (select up to three)	Benefitting GRDC agro-ecological zone	
Carryover of Nitrogen after Crop Failure – Western Region Case Studies	Western Region Choose an item. Choose an item.	☐ Qld Central ☐ NSW NE/Qld SE ☐ NSW Vic Slopes ☐ Tas Grain ☐ SA Midnorth-Lower Yorke Eyre x WA Northern ☒ WA Eastern ☐ WA Mallee	☐ NSW Central ☐ NSW NW/Qld SW ☐ Vic High Rainfall ☐ SA Vic Mallee ☐ SA Vic Bordertown-Wimmera ☐ WA Central WA Sandplain

RESULTS

Soil Nitrogen

In March and July 2022 and January 2023, soil samples were collected from each site at 0-10cm, 10-30cm, and 30-60cm. Samples were tested for nitrate (method - 2 M KCI) and ammonia (method – 2 M KCI), and the results are presented in Table 2. The results show that the soils were low in N (desired level Nitrate = 10-50 mg/kg, Ammonia 2-10 mg/kg) before, early in the growing season, and after the growing season.

The theory that N applied to crops that get frosted is stored in the soil and then becomes available to the following crop is not supported by these results.

Table 2: Soil nitrate and ammonia (mg/kg) across all sites at three timings.

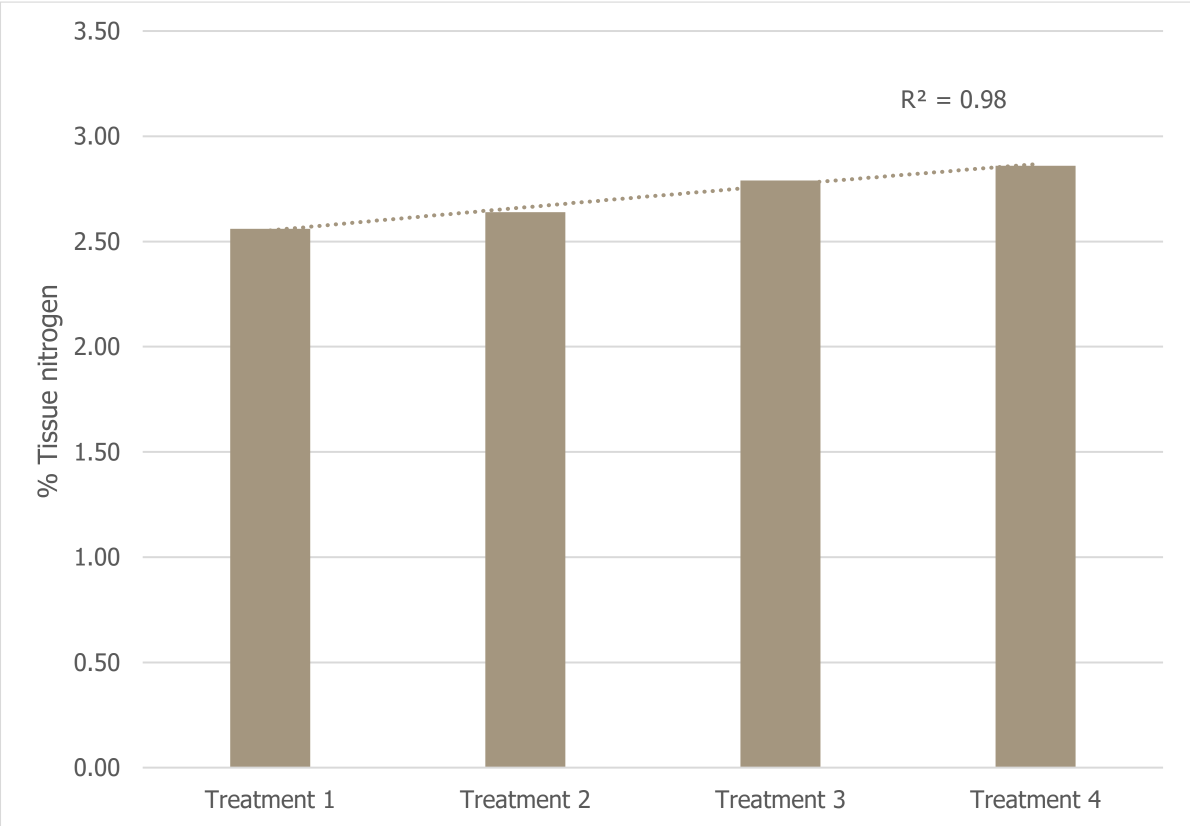
	March 2022		July 2022		January 2023	
Depth	Nitrate	Ammonia	Nitrate	Ammonia	Nitrate	Ammonia
0-10cm	9	2	8	2	3	2
10-30cm	4	1	5	2	2	1
30-60cm	2	2	1	1	1	1
Average	5	2	5	2	2	1

Tissue Nitrogen

To determine the effect different treatments had on tissue N, leaf samples from wheat were collected from one replicate, across 15 trials, at late stem extension (Zaddocks 34-40) and analysed using the DUMAS combustion method. The results are presented in Figure 1.

While not statistically significant (P=0.87), there is a trend towards higher tissue N in the treatments which received more N. Treatment 1 recorded 2.56% N compared to Treatment 3 at 2.79% N.

Figure 1: Tissue nitrogen in wheat taken at Z34-40 from 15 sites.



Grain Yield

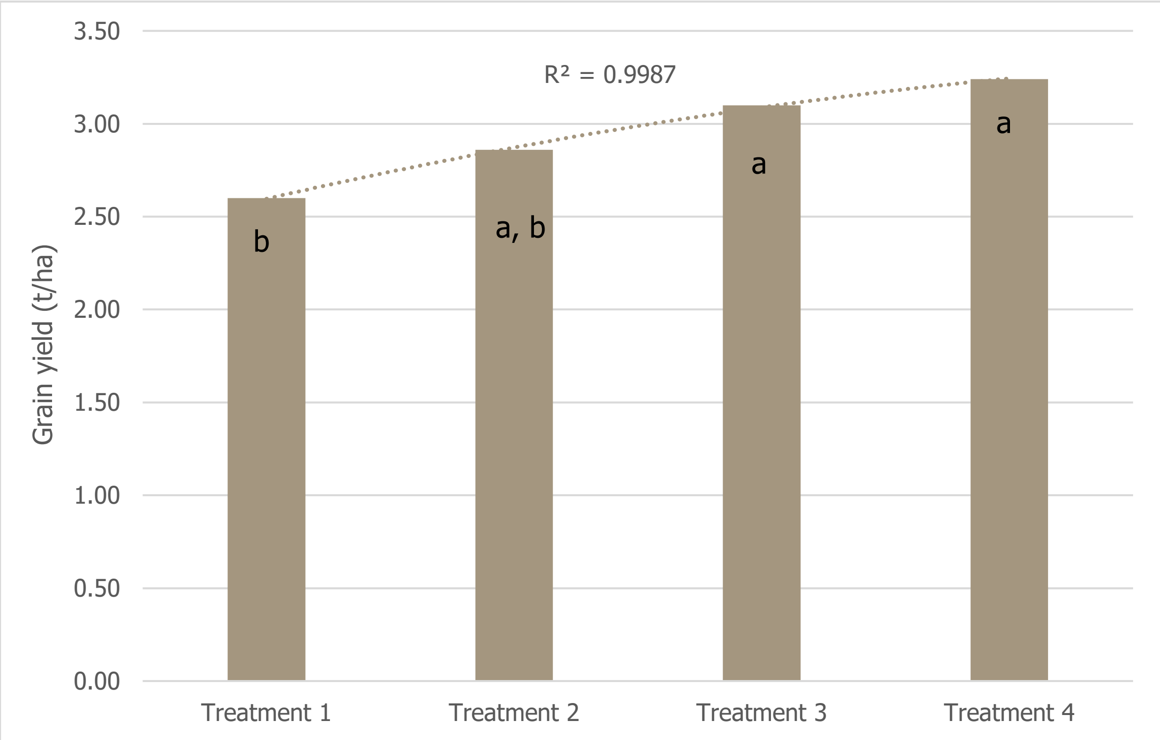
Cereals

A significant (P=0.09) difference was recorded between treatments for grain yield in cereals (Figure 2). Treatment 1 recorded a grain yield of 2.60 t/ha compared to Treatment 3 at 3.10 t/ha. Treatment 4 recorded the yield grain yield of 3.24 t/ha. The results show that cereal crops needed additional N to maximise grain yield in 2022. Therefore, relying on N to carryover from 2021 was insufficient to meet crop demands.

Canola

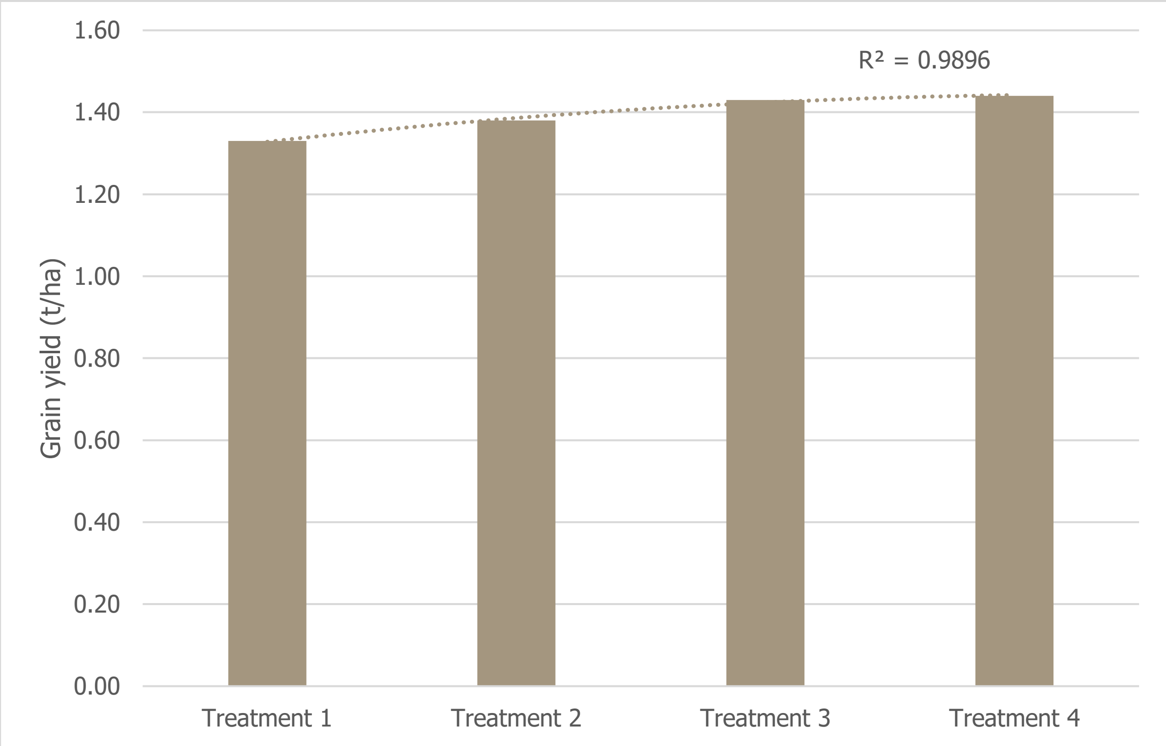
While not statistically significant (P=0.97), there was a trend to higher canola yields with higher rates of N. Treatment 1 recorded a grain yield of 1.33 t/ha compared to Treatment 3 at 1.43 t/ha. Like wheat, these results indicate that there has not been enough N carrying over from 2021 to meet crop demand in 2022, and grain yield was reduced.

Figure 2: Grain yield response in cereals.



Grain yield followed by the same letter do not significantly differ. P=<0.1, LSD = 0.45 t/ha

Figure 3: Grain yield response in canola.



Grain Quality

At harvest, a 600g grain sample of wheat was collected for each treatment, from one replicate, at 21 sites and sent for grain quality analysis. The results are presented in Table 3. While not statistically significant (P=0.21), there was a trend to higher grain protein as N rates increased. Treatment 1 recorded a grain protein of 7.93% compared to Treatment 3 at 8.25%. Based on the grain quality results, irrespective of treatment, the wheat would achieve a quality classification of ASW1.

Table 3: Grain quality results in wheat.

	Grain Protein (%)	Hectolitre Weight (kg/hl)	Screenings (%)
Treatment 1	7.93	81.69	1.90
Treatment 2	7.98	82.64	1.24
Treatment 3	8.25	82.11	1.68
Treatment 4	8.57	82.78	1.71
LSD	NSD	NSD	NSD

Economics

The economic returns for the different treatments are presented in Table 4. For cereals, financial returns ranged from $786/ha for Treatment 1 to $834/ha for Treatment 4. The loss from relying on N to carryover from 2021 to 2022 was $84/ha (Treatment 3 $870/ha – Treatment 1 $786/ha). For canola, there was no significant difference between treatments for grain yield indicating no differences in economic returns between treatments. Treatment 4 recorded the highest grain yield for cereals and canola, however, the increased cost of applying higher rates of N fertiliser, in some cases, resulted in a lower gross margin when compared to other treatments.

Table 4: Grain yield (t/ha) and gross margin ($/ha) by crop type.

	Cereals		Canola	
	t/ha	$/ha	t/ha	$/ha
Treatment 1	2.60	786	1.33	872
Treatment 2	2.86	830	1.38	866
Treatment 3	3.10	870	1.43	863
Treatment 4	3.24	834	1.44	789
LSD	0.45		NSD	

Assumptions for economics = Grain yield * Grain Price (wheat $355/t, canola $700/t, barley $305/t) – (N rate in 2022 (see Table 1) * $2.7/unit N).

DISCUSSION OF RESULTS

In September 2021, frost affected large areas of the Kwinana East and Geraldton port zones. Compounding the issue was the rapidly rising price of N fertiliser; between mid-2021 and early 2022, N fertiliser prices increased from $650/t to $1,200/t. Consequently, growers and agronomists wanted to know if N applied to frosted crops in 2021, would carryover and have a grain yield and economic benefit to the 2022 crop.

Soil samples collected in this project indicated deficient levels of N in the soil profile down to 60 cm (Table 2). The theory that N applied to crops that get frosted is stored in the soil and then becomes available to the following crop is not supported by these results. Over the past 5-10 years, there has been a focus by the grains industry and supported by numerous GRDC funded projects to identify and remove sub-soil constraints. This focus on removing constraints allows crops to access moisture and nutrients deeper in the soil profile, this could be the reason for the low levels of N recorded in this study. Growers and agronomists should consider soil testing to 60 cm when making N fertiliser recommendations to understand better the total amount of N available in the soil profile.

While not statistically significant, there is a trend in the results showing higher levels of tissue N with increasing rates of N (Figure 1). This trend is consistent with other research on N; as the rate of N fertiliser rises, so does tissue N. For example, the desired level of tissue N in wheat at Z34-40 is 1.50-2.40%. Tissue N in Treatment 1 is above the desired range

(2.56%), however, it is well below Treatment 3 (2.79%). This result shows that the carryover N treatment (Treatment 1) cannot supply as much N to the plant as the grower practice treatment (Treatment 3).

Grain yield and economic returns from this project are consistent with previous N fertiliser research. As the rate of N fertiliser increased, so too did grain yield and financial return (Figures 2 and 3, while the result for canola is not statistically significant, there is a clear trend, Table 4). There was a 500 kg/ha response for cereals between Treatment 1 and Treatment 3 worth $84/ha. The results show crops needed N to maximise grain yield and economic returns in 2022. For cereals relying on N to carryover from 2021 was insufficient to meet crop demands. When making N fertiliser decisions after frosted crops growers and agronomists should budget on and apply enough N to achieve yield potential and not rely on N to carry over from the frosted crop.

The lack of a significant response to increasing rates of N fertiliser for grain protein is inconsistent with previous research on N (Table 3). Typically, grain protein increases when more N fertiliser is applied. However, the results of this project are aligned with grower expectations and their experience in applying N fertiliser and trying to increase grain protein. Growers have been increasing the amount of N they are using to wheat to achieve grain protein levels to achieve premium wheat classifications and finding it very difficult. The results from this project suggest that additional N has been used to maximise yield and not used for grain protein.

The results of this project need to be considered in the context that they have been determined based on one year of field trials conducted in 2022. Many growers who hosted the trials experienced favourable seasonal conditions and recorded grain yields well above their five-year average. Consequently, the magnitude of the responses recorded in this project may not be as significant in a more 'average' season.

CONCLUSION

This project was established to determine the grain yield and economic benefits of carryover N after frosted crops. The results show that, on average, there was a 500 kg/ha yield penalty for cereals and a $84/ha economic loss.

To maximise grain yield and economic returns in 2022, crops needed N, relying on N to carryover from 2021 was not sufficient to meet crop demands. Growers and agronomists should not rely on N after frosted crops to carryover and deliver a grain yield or economic benefit to the following crop.

The theory that N applied to crops that get frosted is stored in the soil was not supported by the soil test results from this project. Soil N was well below desired levels across all depths sampled. Growers and agronomists should be aware of this when making fertiliser decisions for 2023.

The conclusions from this project need to be considered in the context that they have been determined based on one year of field trials conducted in 2022.

IMPLICATIONS

Assuming the average area of frosted crops in Western Australia is 750,000 ha per year and an economic loss of $84/ha from relying on carryover N, the cost to industry would be around $63 million.

RECOMMENDATIONS

If GRDC considers further research on the issue of carryover N, consider establishing a three-year project to incorporate the effects of different seasons on the results.

Feedback from industry gathered from the presentation of this project at the Perth Research Updates and at regional Update events was that 1-year of research is not enough to provide enough confidence to use the results to change recommendations. Moreover, feedback indicated that the ~60 kg N/ha (Table 1) that was applied by growers in 2021 to crops that got frosted was low and any carryover effects were unlikely to be detected in the following crop. Agronomists and researchers suggested that to detect the effect of carryover N significantly higher rates of N need to be applied in the first year of the project.

The first year of a new 3-year project would involve establishing trials in frost-prone paddocks and applying higher rates of N fertiliser than used in this project (e.g., Treatment 1 = Grower Practice, Treatment 2 = 2 x grower practice, Treatment 3 = 3 x grower practice and Treatment 4 = 4 x grower practice). The second and third years of the project would involve studying the carryover N effects.

GLOSSARY AND ACRONYMS

DPIRD	Department of Primary Industries and Regional Development
DAP	di ammonium phosphate
DArT	Diversity Arrays Technology
DAT	days after treatment
Db	bulk density

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