SA Drought Hub Technical Report

Refining crop nutrition strategies for building drought resilience in highly calcareous soils on southern YP

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Contents

SA Drought Hub Technical Report	**1**
PROJECT SUMMARY	3
EXECUTIVE SUMMARY	4
PROJECT BACKGROUND AND OBJECTIVES	5
METHODOLOGY	6
LOCATION	11
RESULTS	12
CONCLUSION	21
REFERENCES	21
APPENDIX 1: MEL SUMMARY DATA	10

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PROJECT SUMMARY

A series of field trials investigated nutrient constraints on highly calcareous sandy soils in the southern Yorke Peninsula. These soils have a range of constraints that limit crop productivity including; nutritional challenges (low phosphorus (P) and manganese (Mn), poor nitrogen (N) cycling), low water holding capacity, salinity and sodicity. These factors often lead to poor crop establishment, vigour and grain yield.

Three replicated field trials were established at Marion Bay in 2025. Treatments included foliar Mn timing and rate, combinations of Mn and P fertiliser rates and comparisons between chicken litter (CL) and matched synthetic fertiliser. Crop growth was monitored using NDVI, tissue testing at key growth stages and grain yield and grain quality assessments.

Results showed foliar Mn did not increase crop growth or yield, even where tissue Mn levels were considered marginal. Application of P fertiliser rates consistently improved early crop vigour and yield. A reduction in plant P associated with increasing Mn was not consistently observed across trials this season, indicating further investigation is required to understand when and why this interaction occurs. Chicken litter improved early vigour but as the season progressed these differences narrowed and matched NPKS fertiliser treatments were able to achieve similar NDVI. Many synthetic fertiliser treatments matched CL for dry matter, nutrient uptake and grain yield, demonstrating that comparable performance between products can be achieved.

The project has improved grower and adviser nutrient management decision making by demonstrating where inputs are and are not providing yield and economic benefits.

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EXECUTIVE SUMMARY

Highly calcareous soils on the southern YP have a range of constraints that limit crop productivity including; nutritional challenges (low P, Fe and Mn, poor N cycling), low water holding capacity, severe fertiliser toxicity during germination, salinity and sodicity. These factors can reduce fertiliser efficiency and create uncertainty around nutrient management strategies. This project was undertaken to build on initial field trials in 2024 to further improve our understanding of

- Mn nutrition and foliar application timing and rates
- interactions between Mn and P in crop uptake and yield
- whether CL provide benefits beyond matched synthetic fertiliser

Three replicated field trials were conducted during the 2025 season at Marion Bay. Treatments included foliar Mn applications at different timings and rates, combinations of Mn and P fertiliser to explore nutrient interactions and comparisons between CL and equivalent synthetic fertiliser strategies supplying N, P, K and S. Crop performance was assessed using a combination of Greenseeker NDVI, plant tissue testing at key growth stages, biomass cuts, grain yield and grain quality analysis. The key findings from the project have been;

- Foliar Mn applications did not improve NDVI, biomass production or grain yield in barley even where tissue Mn concentrations were considered marginal. This was consistent with results from 2024 and indicates Mn fertiliser applications under these conditions were not yield-limiting and are unlikely to provide an economic return in similar environments.
- Due to the high PBI of these soils P fertiliser applications at moderate to high rates (22–30 kg P/ha) improved early crop vigour and barley grain yield this season. Higher application rates provided minimal additional yield benefits.
- A previously observed negative relationship between plant Mn and P was not consistently expressed across the 2025 trials. This suggests the relationship is strongly influenced by seasonal conditions and timing on Mn and P supply / uptake.
- Chicken litter improved early crop vigour and grain yield compared with unfertilised or partially matched fertiliser treatments. However, when synthetic fertiliser programs were fully matched for N, P, K and S, similar yield outcomes were achieved. This indicates that the primary benefit of CL in the year of application was nutrient supply rather than an additional biological or soil function effect under these conditions.

The findings are directly relevant to growers and advisers managing similar highly calcareous soils, particularly on the southern Yorke Peninsula and parts of the Eyre Peninsula and South East. The project provides valuable information for those seeking to improve fertiliser efficiency while managing financial risk.

For more information regarding the project, any of the following Trengove Consulting personnel can be contacted.

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PROJECT BACKGROUND AND OBJECTIVES

Highly calcareous sandy soils of southern YP are typically low in a range of key plant nutrients, and can be characterised by high pH, high phosphorous buffering index (PBI), low P and Mn and marginal K, S, N and Zn. These nutrient deficiencies can be managed through fertiliser application, but generally at high cost that increases the financial risks of crop and pasture production in the region. This project will seek to test nutrient input strategies to optimise not only productivity, but partial gross margin and return on investment, thereby minimising financial risks.

This project builds on previous work jointly funded through SAGIT and SADH in 2024. It will also further expand the reach of the RiskWi$e project to groups on YP, not currently covered through the Hart RiskWi$e project. The extension component will be delivered through extension activities with farmers to enable more informed soil nutrition decisions, to build drought resilience on farm.

Delivered through this project will be demonstration trials assessing responses to nutrient management strategies including fertiliser applications and combinations thereof, that optimise crop performance and financial returns and will build drought resilience. These trials will build on results from 2024 trials that provided interesting insights into improving crop nutrition on these challenging soils. This will include exploration of response to chicken litter and understanding the drivers of response and insights this provides for optimising commercial fertiliser applications. Investigation into the interaction between phosphorous and manganese fertiliser application will also be undertaken, with both nutrients recognised as important fertiliser inputs in the region.

Results will be shared through site visits from local agricultural groups, including the Weavers ag bureau and advertised to local growers. Deliverables will include:

- in crop monitoring and assessment
- harvest and collation of soil and crop results
- in season crop walks
- farmer, adviser and industry discussion groups
- extension of results through the post-harvest meetings

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METHODOLOGY

Site selection and soil properties

The trials were established together in a barley paddock at Marion Bay, SA (-35.12179, 136.9652). The Southern YP area is very highly calcareous with >80% free lime ($CaCO_3$) often measured in the top 0-10 cm. The soil pH at both sites was strongly alkaline (Table 1). The site had a high phosphorus buffering index (PBI) of 201 indicating a strong potential for "tie up" and a significant proportion of P fertiliser applied will be unavailable to plants. This contributed to the very low DGT-P level of ≤9 µg/L. The site had adequate levels of sulphur and potassium. EC_e suggest the salinity level at Marion Bay were high enough that it may affect many crop types.

Table 1. Soil properties for all cereal and lentil trials at Marion Bay sampled pre-seeding, 2025.

Soil properties	Units	Barley trial site
		Marion Bay
Depth	cm	0-10
pH	$CaCl_2$	7.61
	H_2O	8.08
Organic Carbon	%	2.22
Phosphorus Colwell	mg/kg	66
PBI		201
DGTP	ug/L	9
Colwell K	mg/kg	170
Sulfur	mg/kg	32
	kg/ha	42
Conductivity	EC1:5 dS/m	0.48
	ECe	4.56
Exchangeable Cations (cmol/kg)	Al	<0.02
	Ca	23.2
	Mg	1.4
	K	0.5
	Na	0.6
	ECEC	25.6
	ESP	2.3%

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Trial 1. The effect of foliar manganese application timing on barley growth and yield

Stenhouse Bay rainfall: Annual 438 mm
Growing season 383 mm

Variety: Maximus CL 80 kg/ha barley

Sowing date: 28th May 2025

Fertiliser at seeding: MAP + Zn1% @ 120 kg/ha + SOA @ 110 kg/ha

The trial was a randomised complete block design, consisting of five treatments with three replicates. Plots were 10 m long with 25 cm row spacing. Plots were sown using knife points and press wheels.

A range of foliar Mn rates and application timings were trialled (Table 2). Manganese sulphate ($MnSO_4$) was used as the Mn source in this trial with a concentration of 31%. Foliar treatments of $MnSO_4$ were applied at GS14 (7 July), GS31/32 (28 July) and GS39 (22 August).

Measurements throughout the season included GreenSeeker NDVI (7 July, 22 August, 17 September and 8 October) and tissue tests at Zadok's growth stage 39 on 22 August. The trial was harvested for grain yield on the 3 December and all plots were assessed for grain yield and quality.

Table 2. Manganese foliar fertiliser application timing and rate of elemental Mn evaluated in the foliar Mn trial at Marion Bay, SA 2025. Application of 0.62 kg Mn/ha = 2 kg/ha $MnSO_4$.

Treatment	Product	GS14	GS31	GS39	Total applied
		kg Mn/ha			
1	Nil	-	-	-	
2	$MnSO_4$	0.62	0.62	0.62	1.9
3	$MnSO_4$	0.62	0.62		1.2
4	$MnSO_4$	0.62		0.62	1.2
5	$MnSO_4$		0.62	0.62	1.2

Trial 2. Manganese and phosphorus interactions and the impact on crop nutrient uptake

Stenhouse Bay rainfall: Annual 438 mm
Growing season 383 mm

Variety: Maximus CL 80 kg/ha barley

Sowing date: 28th May 2025

Fertiliser at seeding: Treatment list + SOA @ 110 kg/ha all plots

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The trial was a randomised complete block design, consisting of 22 treatments with 3 replicates. Plots were 10 m long with 25 cm row spacing. Plots were sown using knife points and press wheels.

A range of Mn and P rates were trialled to achieved different concentrations within the crop (Table 3). All P rates were applied as MAP at seeding. Two sources of Mn were assessed; MnSO4 (31% Mn) and EDTA Mn (13% Mn). Both Mn products were applied as foliar applications on 7 July (GS14).

Measurements throughout the season included GreenSeeker NDVI (7 July, 5 August, 22 August and 8 October) and tissue tests at Zadok's Growth stage 39 on 22 August. The trial was harvested for grain yield on the 3 December and all plots were assessed for grain yield and quality.

Table 3. Foliar Mn and P applied at seeding treatments, Marion Bay 2025.

Mn product and rate (g Mn/ha)	**P rate (kg P/ha)**
Nil	0
Nil	11
Nil	22
Nil	44
$MnSO_4$ - 300	11
$MnSO_4$ - 300	22
$MnSO_4$ - 300	44
$MnSO_4$ - 700	11
$MnSO_4$ - 700	22
$MnSO_4$ - 700	44
$MnSO_4$ - 1500	11
$MnSO_4$ - 1500	22
$MnSO_4$ - 1500	44
EDTA Mn - 150	11
EDTA Mn - 150	22
EDTA Mn - 150	44
EDTA Mn - 300	11
EDTA Mn - 300	22
EDTA Mn - 300	44
EDTA Mn - 700	11
EDTA Mn - 700	22
EDTA Mn - 700	44

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Trial 3. Unravelling the crop nutrient response to chicken litter

Stenhouse Bay rainfall: Annual 438 mm
Growing season 383 mm

Variety: Maximus CL 80 kg/ha barley

Sowing date: 28th May 2025

Fertiliser: See treatments below.

The trial was a randomised complete block design, consisting of 12 treatments with 3 replicates. Plots were 10 m long with 25 cm row spacing. Plots were sown using knife points and press wheels. All granular fertiliser was deep banded below the seed.

The nutrient content of the chicken litter used in these trials are summarised in Table 4. The CL was spread prior to seeding. All urea, MAP, MoP and SoA was applied in-furrow at seeding (Table 5). The only exception were treatments 9, 10 and 12 where some fertiliser was spread pre-seeding and some was applied in-furrow at seeding. This was due to the large quantity of product required per plot.

Foliar trace elements were applied to treatments 11 and 12 on 28th July containing 4 kg/ha Mn $ZnSO_4$, 200 g/ha $CuSO_4$, 100g/ha Boron, 2 kg/ha Iron EDTA and 400g/ha sodium molybdate.

Table 4. Nutrient concentration of the CL used at Marion Bay, 2025.

Nutrient	Nitrogen	Phosphorus	Potassium	Sulphur	Calcium	Magnesium	Iron
	%w/w	%w/w	%w/w	%w/w	%w/w	%w/w	%w/w
	3.1	0.8	1.7	0.4	1.8	0.5	0.1
kg nutrient/ ha in 1 t/ha CL	31	7.7	17	4.4	18	5.2	0.86

Nutrient	Aluminium	Boron	Copper	Manganese	Molybdenum	Zinc
	%w/w	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
	0.1	36	83	385	8.5	292
kg nutrient/ ha in 1 t/ha CL	0.73	0.04	0.08	0.39	0.01	0.29

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Table 5. Chicken litter and synthetic fertiliser treatments.

Treatment	Urea	MAP	CL	MoP	SoA	N	P	K	S
	kg/ha								
1. N only, 0 kg P/ha	150					69			
2. 30 kg P/ha	120	136				69	30		
3. 50 kg P/ha	100	227				69	50		
4. 90 kg P/ha	61	409				69	90		
5. Chicken Litter @ 15 kg P/ha + starter P 15 kg P/ha = (30)		68	2000			69	30	34	8
6. Chicken Litter @ 35 kg P/ha + starter P 15 kg P/ha (50)		68	4667			152	50	79	19
7. Chicken Litter @ 75 kg P/ha + starter P 15 kg P/ha (90)		68	10000			317	90	170	40
8. N, P, K and S matched to treatment 5	103	136		68	37	69	30	34	9
9. N, P, K and S matched to treatment 6	241	227		158	86	152	50	79	21
10. N, P, K and S matched to treatment 7	516	409		338	183	317	90	169	44
11. N + 50 kg P/ha with early foliar trace (Cu, Zn, B, Fe, Mo)	100	227		68		69	50		
12. N, P, K and S matched to treatment 6 with early foliar trace (Cu, Zn, B, Fe, Mo)	241	227		158	86	152	50	79	21

Measurements throughout the season included GreenSeeker NDVI (7 July, 5 August, 22 August, 17 September and 8 October). Biomass cuts were completed at GS39 on 22nd August and tissue tests were also taken from these samples (whole tops). The trial was harvested for grain yield on the 3rd of December and all plots were assessed for grain yield and quality.

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LOCATION

Site # and name	Latitude (decimal degrees)	Longitude (decimal degrees)	LGA
Trial 1. The effect of foliar manganese application timing on barley growth and yield	-35.12179	136.9652	Yorke Peninsula
Trial 2. Manganese and phosphorus interactions and the impact on crop nutrient uptake	-35.12179	136.9652	Yorke Peninsula
Trial 3. Unravelling the crop nutrient response to chicken litter	-35.12179	136.9652	Yorke Peninsula

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RESULTS

Trial 1. The effect of foliar manganese application timing on barley growth and yield

Key messages

- Foliar Mn fertiliser applications did not improve crop growth or grain yield this season.
- Tissue testing (GS39) showed Mn concentrations ranged from 13.0 – 16.0 mg/kg which is generally categorised as deficient to marginal. However, the lack of growth response indicates the critical tissue Mn level was lower than 13.0 mg/kg in this trial.
- Across two seasons of field trials (2024 and 2025) on a highly calcareous sand at Marion Bay, no growth or yield response to Mn fertiliser applications has been observed.

Results and discussion

Greenseeker NDVI and tissuee testing

Multiple NDVI assessments from July through to October showed there was no NDVI response to foliar Mn fertiliser timing or total rate applied (Table 6).

Tissue testing was completed on select treatments at GS39 by sampling the youngest emerged blade (YEB). These samples were collected prior to GS39 applications and therefore only reflect nutrient uptake from GS14 and GS31 Mn applications. The Mn tissue concentration ranged from 13.0 – 16.0 mg/kg (Table 6). In general, the tissue Mn values are considered deficient (<15 mg/kg) to marginal (15-20 mg/kg). However, the lack of growth response indicates the critical Mn level was lower than 13.0 mg/kg in this trial.

There were small differences in YEB Mn among fertiliser treatments (Table 6). The GS14 application alone did not improve Mn uptake compared to the nil control. Whereas GS31 application increased Mn levels, both when applied alone and in combination with GS14. These results suggest the GS31 foliar timing was more effective than GS14 for increasing Mn uptake.

Table 6. Summary of GreenSeeker NDVI and shoot Mn (mg/kg) sampled at GS39 in the foliar Mn trial.

Foliar Mn timing	NDVI 7 July	NDVI 22 Aug	NDVI 17 Sept	NDVI 8 Oct	YEB P (%)	YEB Mn (mg/kg)
Nil	0.210	0.663	0.820	0.697	0.31 a	13.0 b
1.9 kg Mn/ha @ GS14, GS31, GS39	0.217	0.647	0.803	0.686		
1.2 kg Mn/ha @ GS14, GS31	0.217	0.690	0.823	0.693	0.28 ab	15.3 ab
1.2 kg Mn/ha @ GS14, GS39	0.220	0.697	0.833	0.718	0.31 a	13.3 b

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1.2 kg Mn/ha @ GS31, GS39	0.210	0.593	0.763	0.643	0.26 b	16.0 a
Pr (>F)	0.714	0.259	0.507	0.738	<0.001	<0.001

While not the focus of this trial there was a negative relationship (R^2=0.95) observed between plant Mn and P uptake (Figure 1). The results show there was a reduction in plant P concentration with increasing Mn concentration. This is consistent with previous results from a similar trial in the area (Trengove 2024) and explored further in Trial 2.

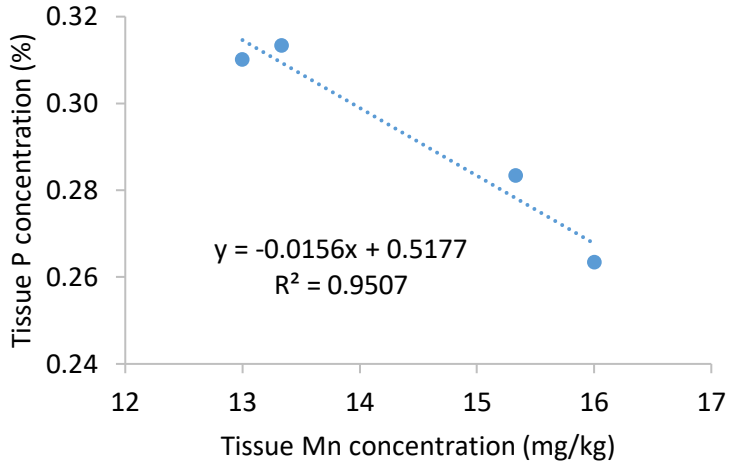

Figure 1. Relationship between plant tissue Mn and P concentrations at GS39 in the foliar Mn trial.

Grain yield and quality

Foliar Mn applications had no impact on grain yield or quality. Barley grain yields averaged 4.75 t/ha across the trial. Grain protein, test weight and retention averaged 11.1%, 67.4 kg/hL and 89%, respectively (Table 7). All treatments had screening levels <5%. The receival standard for all treatments met MALT 1 classification.

Table 7. Barley grain yield and grain quality for the foliar Mn trial.

Foliar Mn timing	**Grain yield (t/ha)**	**Protein (%)**	**Test weight (kg/hL)**	**Retention (%)**	**Screenings (%)**
Nil	4.41	11.4	66.8	88.8	2.6
1.9 kg Mn/ha @ GS14, GS31, GS39	4.82	11.1	67.7	91.2	2.4
1.2 kg Mn/ha @ GS14, GS31	4.94	11.2	67.6	89.5	2.6
1.2 kg Mn/ha @ GS14, GS39	4.91	11.0	67.6	85.0	2.5
1.2 kg Mn/ha @ GS31, GS39	4.66	11.0	67.2	90.9	2.3
Pr (>F)	0.643	0.514	0.624	0.102	0.176

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Trial 2. Manganese and phosphorus interactions and the impact on crop nutrient uptake

Key messages

- Tissue testing showed no clear P - Mn relationship in this trial. While observed previously, this interaction appears inconsistent and likely influenced by seasonal conditions and timing of Mn and P supply / uptake.
- Foliar Mn applications (rate or form) did not increase NDVI, tissue Mn levels or grain yield.
- Higher P fertiliser rates increased early NDVI and crop vigour with most yield response achieved by 11 kg P/ha.

Results and discussion

Greenseeker NDVI and tissue testing

Greenseeker NDVI increased across all treatments throughout the season with the biggest differences occurring early in the season. Higher P rates (44 kg P/ha) improved early crop vigour (Figure 2). However, these differences narrowed as the season progressed and all treatments reached a similar NDVI by early October. Using the 22 kg P/ha treatment as an example, the addition of Mn did not improve NDVI, with all Mn rates performing similarly to 22 kg P/ha alone (Figure 2 and Figure 3). Overall, P increased early crop growth but Mn application did not improve NDVI.

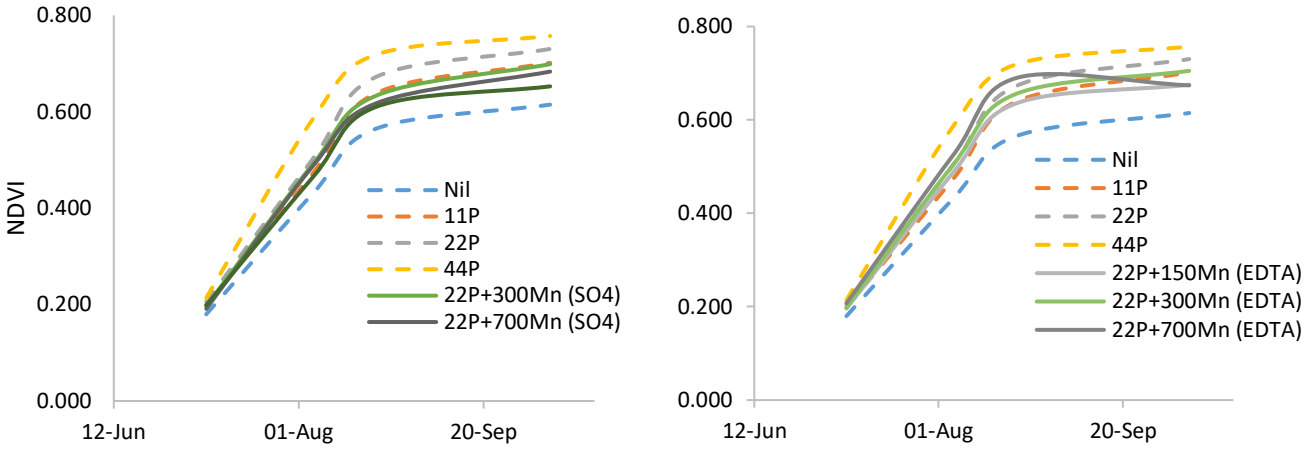

Figure 2. Summary of GreenSeeker NDVI for (left) $MnSO_4$ and (right) Mn EDTA Marion Bay, SA 2024.

Despite applying a range of Mn and P rates to alter plant nutrient status, tissue testing at GS39 showed no significant differences in either Mn or P concentration between treatments. Tissue P ranged from 0.30 – 0.32% and Mn ranged from 11.4 – 13.1 mg/kg for all treatments.

There was no observable relationship between Mn and P in plant tissue ($R^2 = 0.04$) in this trial. This is in contrast to 2024 where a moderate negative relationship was observed (Figure 3). This shows the interaction between P and Mn is not always seen and it is likely to depend on season conditions. In dry years, it would be expected that Mn deficiency is more pronounced and more likely to see a negative P - Mn interaction. The 2024 season at Marion Bay received 254 mm of growing season rainfall, 129 mm less than in 2025 which may have contributed to the stronger interaction observed.

However, seasonal conditions alone do not fully explain the different outcomes between the two adjacent trials in 2025. In Trial 2, tissue P concentrations were consistent (0.30–0.32%) across all treatments, which may have limited the ability to detect any relationship with Mn. In comparison, Mn was applied at staggered timings in Trial 1, compared to a single application timing in the current trial. This may have created greater variation in Mn availability and uptake allowing the interaction with P to be expressed more clearly in Trial 1 than in the current trial.

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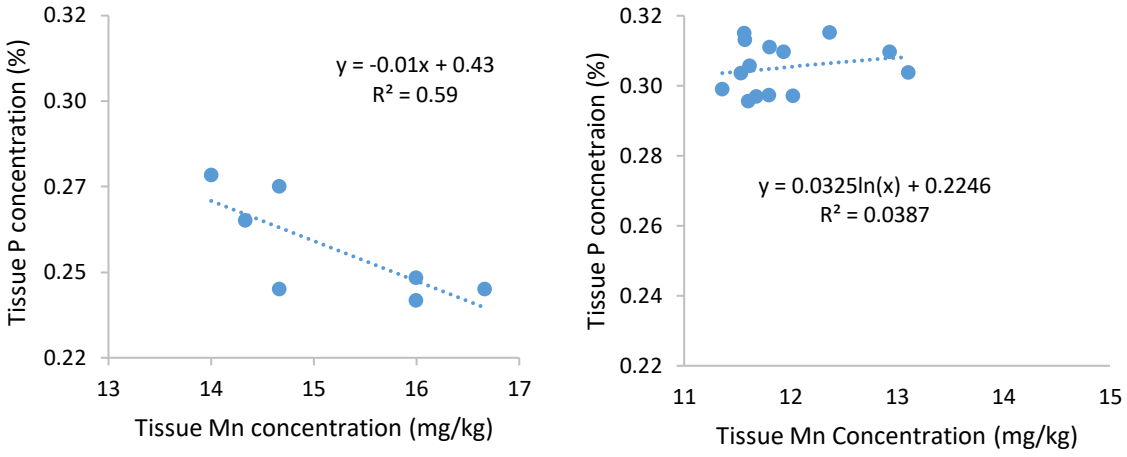

Figure 3. Relationship between plant tissue Mn and P concentrations (left) at GS31 in 2024 and (right) GS39 in 2025 in foliar Mn trials at Marion Bay.

Grain yield and quality

Grain yield increases were driven by P fertiliser with no response to foliar Mn applications (Figure 4). The nil treatment had the lowest yield (3.67 t/ha). Most of the yield response was achieved with 22 kg P/ha (4.55 t/ha) and no gains from higher rate of 44 kg P/ha. The different Mn strategies (rate and form) had minimal impact on yield. For example, using 22 kg P/ha alone as a baseline, all Mn treatments performed similarly and did not increase grain yield (Figure 4).

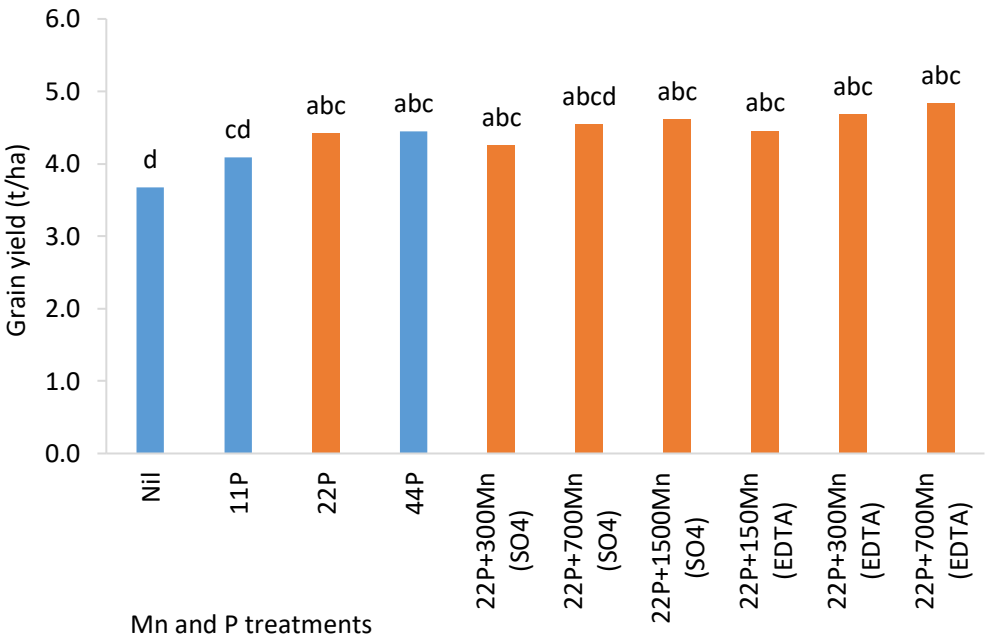

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Figure 4. Barley grain yield for Mn and P treatments at Marion Bay, 2025.

Trial 3. Unravelling the crop nutrient response to chicken litter

Key messages

- Chicken litter (CL) improved early crop vigour but, as the season progressed these differences narrowed and matched NPKS fertiliser treatments were able to achieve similar NDVI.
- Many synthetic fertiliser treatments matched CL for dry matter, nutrient uptake and grain yield, demonstrating that comparable performance between products can be achieved.
- In terms of grain quality, CL applications resulted in reduced protein levels (dilution effect), reinforcing the need to manage N.
- Micronutrient additions (Cu, Zn, B, Fe, Mo) provided limited benefit at this site.

Results and discussion

Greenseeker NDVI

NDVI responses showed that CL treatments consistently improved early crop vigour compared to synthetic fertiliser alone, with the highest NDVI values observed in July (Table 8). The effect was visible even at comparable P and NPKS rates, suggesting CL supported early vigour beyond just nutrient supply (likely due to nutrients release timing or organic matter effects).

However, as the season progressed differences between treatments narrowed and matched rates of synthetic fertiliser (with or without trace elements) were able to achieve comparable or higher NDVI by later August through to October. The inclusion of trace elements did not further enhance NDVI in synthetic fertiliser treatments, indicating that the response was driven by NPKS. Overall CL provided an early crop vigour advantage, but synthetic fertiliser strategies were able to replicate these benefits later in the season.

Table 8. Greenseeker NDVI for CL and synthetic fertiliser response trial.

Treatment	NDVI July 7	NDVI Aug 22	NDVI Sep 17	NDVI Oct 8
1. N only, 0 kg P/ha	0.163 e	0.445 f	0.790 c	0.613 bd
2. 30 kg P/ha	0.184 bcd	0.558 cdef	0.779 c	0.669 abcd
3. 50 kg P/ha	0.174 de	0.557 def	0.800 bc	0.676 abcd
4. 90 kg P/ha	0.191 bc	0.661 abcde	0.842 abc	0.721 abcd
5. Chicken Litter @ 15 kg P/ha + starter P 15 kg P/ha = (30)	0.224 a	0.706 ab	0.810 bc	0.601 cd
6. Chicken Litter @ 35 kg P/ha + starter P 15 kg P/ha (50)	0.223 a	0.684 abcde	0.807 bc	0.629 abcd
7. Chicken Litter @ 75 kg P/ha + starter P 15 kg P/ha (90)	0.225 a	0.709 ab	0.856 ab	0.691 abcd

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8. N, P, K and S matched to treatment 5	0.179 cd	0.543 ef	0.818 abc	0.671 abcd
9. N, P, K and S matched to treatment 6	0.219 a	0.692 abcd	0.808 bc	0.725 ac
10. N, P, K and S matched to treatment 7	0.193 b	0.696 abc	0.876 a	0.725 a
11. N + 50 kg P/ha with early foliar trace (Cu, Zn, B, Fe, Mo)	0.179 cd	0.624 bcde	0.786 c	0.700 abcd
12. N, P, K and S matched to treatment 6 with early foliar trace (Cu, Zn, B, Fe, Mo)	0.224 a	0.766 a	0.841 abc	0.731 ab
	<0.001	<0.001	<0.001	<0.001

Dry matter and nutrient uptake

At matched nutrient rates the lowest application rate (30 kg P/ha) was the only rate where CL produced higher dry matter compared to the equivalent P and NPKS treatments (Table 9). At higher rates (50 and 90 kg P/ha), there were no differences in biomass production between CL, synthetic P or NPKS treatments.

Nutrient uptake was generally similar across treatments when matched for P rate (Table 9). There were no significant differences in N, P, or S uptake between CL, P only, and NPKS treatments. For example, at 50 kg P/ha, P uptake was 3.2 kg/ha for the synthetic P treatment, 5.3 kg/ha for CL, and 4.8 kg/ha for the matched NPKS treatment, with no statistical difference between them. The only exception was K, where P application alone was not able to increase K uptake similar to levels of CL or NPKS treatments.

While statistical analysis did not show differences, there was a consistent trend of reduced N, P, K and S uptake where CL treatments were matched with P fertiliser only (Figure 5). A balanced nutrient package (NPKS) more closely matched both dry matter production and nutrient uptake compared with a P only approach.

Table 9. Dry matter and nutrient uptake for CL and synthetic fertiliser response trial.

	Dry matter (kg/ha)	**N uptake (kg N/ha)**	**P uptake (kg P/ha)**	**K uptake (kg K/ha)**	**S uptake (kg S/ha)**
1. N only, 0 kg P/ha	713 d	35.2 c	2.4 c	42.5 d	2.9 c
2. 30 kg P/ha	1033 bcd	48.6 abc	3.6 bc	64.7 bcd	3.8 abc
3. 50 kg P/ha	997 bcd	47.7 abc	3.2 bc	56.7 cd	3.5 abc
4. 90 kg P/ha	1192 abcd	59.1 abc	4.2 abc	71.2 bcd	4.5 abc
5. CL @ 15 kg P/ha + starter P 15 kg P/ha = (30)	1867 a	77.1 ab	5.8 ab	112.6 ab	6.1 ab

6. CL @ 35 kg P/ha + starter P 15 kg P/ha (50)	1634 ab	65.5 abc	5.3 abc	103.6 abc	5.5 abc
7. CL @ 75 kg P/ha + starter P 15 kg P/ha (90)	1838 a	80.0 a	6.6 a	135.4 a	6.2 a
8. N, P, K and S matched to treatment 5	850 cd	41.3 bc	3.0 bc	53.4 bcd	3.2 bc
9. N, P, K and S matched to treatment 6	1543 ab	68.2 abc	4.8 abc	88.5 abcd	5.1 abc
10. N, P, K and S matched to treatment 7	1435 abc	75.2 ab	5.5 ab	103.3 abc	5.5 abc
11. N + 50 kg P/ha with early foliar trace	1036 bcd	53.5 abc	3.6 bc	64.6 bcd	4.1 abc
12. N, P, K and S matched to treatment 6 with early foliar trace	1778 a	68.6 abc	5.1 abc	107.2 abc	5.4 abc
	<0.00	<0.001	<0.001	<0.001	<0.001

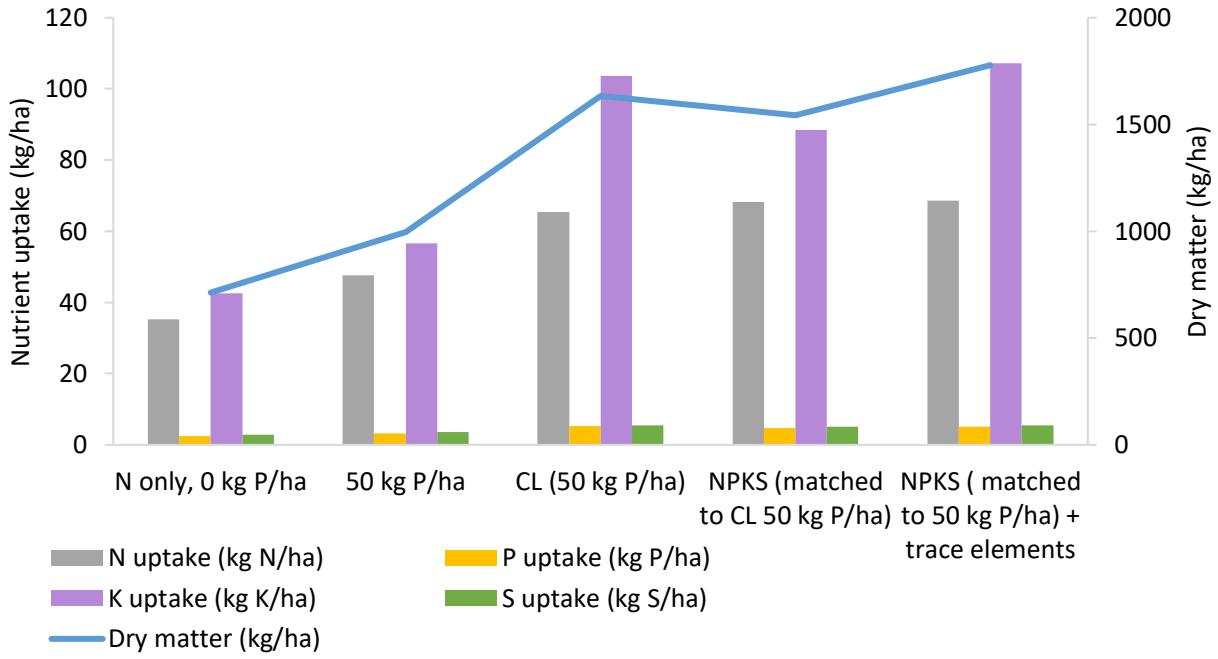

Figure 5. Dry matter and nutrient uptake for the 0 kg P/ha treatment compared with all CL and fertiliser treatments targeting a common application rate of 50 kg P/ha.

Grain yield and quality

Any application of CL trialled or where NPKS was matched to ≥50 kg P/ha treatments resulted in higher barley grain yields averaging 4.32 t/ha (range 4.16 – 4.57). P application alone was unable to achieve grain yields comparable to the CL treatments (Table 10). The addition of trace elements also

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did not result in any grain yield benefit. This is consistent with NDVI, dry matter and nutrient uptake results.

The lowest grain protein levels were observed in the CL treatments (Table 10). This is likely due to a yield dilution effect, where higher grain yield results in lower protein concentration. Although CL and synthetic fertiliser treatments received similar N rates and comparable total N removal, the higher yield under CL resulted in dilution of grain protein. This is consistent with results from Marion Bay in 2024 (Trengove 2024).

Ther were minor differences in test weight and screenings across all treatments. Test weight and screenings averaged 65 kg/hL and 3.6%, respectively. For these quality parameters all samples met MALT 1 classification.

Table 10. Grain yield and quality for CL and synthetic fertiliser response trial.

	Grain yield (t/ha)	Protein (%)	N removal (kg N/ha)	Test weight (kg/hL)	Screenings (%)
1. N only, 0 kg P/ha	2.82 f	11.8 bc	54	64.3 ab	3.6 ab
2. 30 kg P/ha	3.47 def	12.0 ab	67	65.0 ab	3.2 ab
3. 50 kg P/ha	3.39 ef	12.2 ab	66	65.0 ab	3.7 ab
4. 90 kg P/ha	3.76 bcde	12.1 ab	73	65.1 ab	4.1 a
5. CL @ 15 kg P/ha + starter P 15 kg P/ha = (30)	4.25 abc	10.9 d	74	64.8 ab	3.7 ab
6. CL @ 35 kg P/ha + starter P 15 kg P/ha (50)	4.33 abc	11.1 cd	77	66.1 ab	3.2 ab
7. CL @ 75 kg P/ha + starter P 15 kg P/ha (90)	4.57 a	11.6 bcd	85	67.0 a	2.2 b
8. N, P, K and S matched to treatment 5	3.65 cde	11.9 abc	70	64.9 ab	3.6 ab
9. N, P, K and S matched to treatment 6	4.21 abc	11.8 abc	80	64.4 ab	3.6 ab
10. N, P, K and S matched to treatment 7	4.16 abcd	12.6 a	84	65.3 ab	4.4 a
11. N + 50 kg P/ha with early foliar trace (Cu, Zn, B, Fe, Mo)	3.63 cde	11.7 bc	69	63.9 b	4.0 a
12. N, P, K and S matched to treatment 6 with early foliar trace (Cu, Zn, B, Fe, Mo) 50 kg P	4.43 ab	11.8 b	84	65.2 ab	4.3 a
Pr (>F)	<0.001	<0.001		0.02	<0.001

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CONCLUSION

Key findings

Across three nutrition trials on a highly calcareous sand on the southern YP, P fertiliser applciaitons had the largest impact on crop response at moderate to high rates (22–30 kg P/ha). In comparison, Mn applications did not provide yield or crop growth benefits. Foliar Mn applications had no consistent effect on NDVI, tissue Mn response or grain yield. There were also inconsistent effects of Mn application on P uptake in 2025. Results from the previous season suggest this interaction can occur however, when combined with this season's results, it indicates that further investigation is required to understand when and why it may be observed.

Previous work at Marion Bay has shown that CL can achieve up to 15% higher grain yields than matched MAP fertiliser when both supply 50 kg P/ha. In 2025, many synthetic fertiliser treatments (which included NPKS) matched CL for dry matter, nutrient uptake and grain yield, demonstrating that comparable performance between products can be achieved. This is a positive outcome for growers as the grain yield improvement from CL in 2024 was high but, the cost of the product and freight can limit its economic viability on the southern Yorke Peninsula. These results demonstrate that fertiliser programs may be able to achieve similar production outcomes more cost-effectively.

Benefits to industry

These findings improve confidence in fertiliser decision-making on highly calcareous soils by identifying where inputs do and do not provide return on investment. The work demonstrates that routine foliar Mn applications are unlikely to be economically beneficial under similar soil and seasonal conditions, helping reduce unnecessary input costs. It also reinforces the importance of P management in these systems.

Future adoption opportunities

The results can be adopted immediately by growers and advisers to refine nutrient strategies, particularly by prioritising P management and using more evidence-based triggers for Mn applications. Adoption of nutrient budgeting approaches is also supported when looking at the comparative results of CL and fertiliser programs.

Further work is required to better understand the conditions under which Mn–P interactions occur, including the role of seasonal rainfall and timing of nutrient uptake. This presents an opportunity for targeted follow-up trials to improve predictive tools for micronutrient management in high pH, calcareous systems.

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