

IMPROVING CROP PRODUCTION ON HIGHLY CALCAREOUS SANDS OF SOUTHERN YORKE PENINSULA



2024 TRIAL RESULTS

TRENGOVE CONSULTING

ARTICLES

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Site selection and soil properties

Trials one through four were established adjacent to one another in a paddock at Marion Bay, SA (-35.14097, 136.97456). Trial five (foliar experiment) was located approximately 150 m away on a different rise within the same paddock. Trial six and seven (lentils) were located approximately 3 km west of the main site (-35.14001, 136.93916). The soil test results suggest the sites had very high soil available N pre-seeding and high organic carbon at 1.9% (Table 1). However, previous research on highly calcareous soils has shown they have different microbial populations with a high capacity to immobile soil N (GRDC project CSP2009-003RTX). As a result, despite the high soil available N levels pre-seeding these soils are generally responsive to early applications on N.

The site was very highly calcareous with 92% free lime (CaCO_3) in the top 0-10 cm. The soil pH was moderately to strongly alkaline. The site had a high phosphorus buffering index (PBI) of 223 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 15 $\mu\text{g/L}$.

Soil tests for micronutrients generally have a lower reliability than soil tests for macronutrients. Within the current information available, Mn levels at Marion Bay would be categorised as deficient. Critical soil test Mn is <5-10 mg/kg (Brennan et al 2013; Norton 2014). Both Cu and Zn soil levels would be considered adequate at this site.

Table 1. Soil properties for all cereal nutrition trials at Marion Bay sampled pre-seeding, 2024.

Soil properties	Units	0-10 cm	10-40 cm	40-100 cm
pH 1:5 water		8.0		
pH CaCl_2		7.6		
Organic carbon	%	1.92		
Soil available N	kg/ha	89	53	39
CaCO_3	%	92		
Colwell P	mg/kg	92		
PBI + Col P		223		
DGT-P	$\mu\text{g/L}$	15		
Colwell K	mg/kg	120	62	<25
Total sulphur	kg/ha	22	66	94
Zinc	mg/kg	6		
Manganese	mg/kg	3.5		
Copper	mg/kg	0.56		
ECEC	cmol/kg	25		
EC 1:5	dS/m	0.36		

Trial 1. The effect of manganese application timing, rate and product on barley growth and yield

Key messages

- Pre-seeding soil testing showed the site had marginal Mn levels (<5 mg/kg).
- Manganese fertiliser applications (timing, rate and product) however, did not improve crop growth or grain yield this season.
- Tissue testing (GS31) showed Mn concentrations ranged from 14.0 – 16.7 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 14.0 mg/kg in this trial. Manganese concentration increased with increasing rate of foliar Mn applied, but these treatments also reduced P concentration in the plant.

Why do the trial?

The availability of Mn in soil is strongly related to soil pH. Soils with higher pH have lower Mn availability than soils with lower pH. Manganese deficiency is therefore more likely to be a problem on alkaline soils. The availability of Mn is also strongly affected by seasonal conditions and the soil availability is lowest during a dry spring.

Foliar Mn can be more efficient than soil applied Mn. Generally, recommended foliar rates are around 1-5 kg Mn/ha in relatively high-water volumes although a “little (<1 kg/ha) and often” approach may be more effective (Norton 2014) and more common commercial practice in the area. The appropriate timing will depend on the degree of stress, and crops often show good recovery if Mn is applied when symptoms appear and when there is good crop cover.

This trial aimed to evaluate a range of Mn fertiliser strategies including banded and foliar application timings and rates to improve uptake and grain yield.

How was it done?

Stenhouse Bay	Annual 328 mm (449 mm)	Foliar spray	GS14 - 31 st July
rainfall 2024	Growing season	application	GS31 - 22 nd August
(long-term):	254 mm (358 mm)	dates:	GS39 - 10 th September
Sowing date:	3 rd June 2024		
Variety:	Maximus CL barley @ 80 kg/ha		

The trial was a randomised complete block design, consisting of 10 treatments with 3 replicates. Plots were 10 m long with 25 cm row spacing. Plots were sown using knife points and press wheels. All plots received starting fertiliser of MAP Zn at 120 kg/ha and urea at 100 kg/ha incorporated by sowing.

A range of Mn fertiliser strategies were trialled including application timing, rate and product (Table 1). Manganese sulphate (MnSO₄) was the main fertiliser source utilised in the trial, excluding treatment 10 which assessed the effectiveness of a 100% EDTA Manganese Chelate. Incorporated by

sowing MnSO_4 applications were banded under the seed row. Foliar treatments of MnSO_4 were applied at 100 L/ha with a medium droplet size.

Measurements throughout the season included GreenSeeker NDVI (31st July, 22nd August, 10th September and 27th September) and tissue tests at Zadok's Growth stage 31. The trial was harvested for grain yield on the 20th of November. All plots were assessed for grain quality.

Table 1. Manganese fertiliser application timing, rate of elemental Mn and products evaluated in the Mn strategy trial at Marion Bay, SA 2024.

Treatment	Product	IBS	GS14	GS31	GS39	Total applied
		kg Mn/ha				
1	Nil	-	-	-	-	
2	MnSO_4	3.1	-	-	-	3.1
3	MnSO_4	3.1	0.93	0.93	0.93	5.9
4	MnSO_4	-	0.31	0.31	0.31	0.9
5	MnSO_4	-	0.62	0.62	0.62	1.9
6	MnSO_4	-	0.93	0.93	0.93	2.8
7	MnSO_4	-	0.62	0.62	-	1.2
8	MnSO_4	-	0.62	-	0.62	1.2
9	MnSO_4	-	-	0.62	0.62	1.2
10	Mn Chelate	0.12	-	-	-	0.1

MnSO_4 = 31% Mn and Mn Chelate = 6% Mn

Results and discussion

GreenSeeker NDVI and tissue testing

Multiple NDVI assessments prior to and including the 10th of September showed there was no response to Mn fertiliser (product or rate). In late September, the results continued to show no Mn treatment increased NDVI compared to the control (Table 2). However, in some cases there was a negative NDVI response to increasing Mn fertiliser rate. These negative responses were generally observed in treatments where Mn had been applied as a foliar application (Figure 1).

Tissue testing was completed on select treatments at GS31 (youngest emerged blade). There was no difference in Mn tissue concentration according to the ANOVA (Table 2), with samples ranging from 14.0 – 16.7 mg/kg. These tissue Mn values would generally be 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 14.0 mg/kg in this trial. Increasing foliar Mn rates however, increased Mn concentration in the leaf (Figure 2). A broader look at the tissue tests also suggests there is relationship between plant Mn and P uptake (Figure 2). The results show there was a reduction in plant P concentration with increasing Mn concentration.

Later in the season there were some visual differences in the canopy colour among the barley plots (Table 3). Visually treatments which included in-season foliar Mn applications had better plant colour compared to the nil and granular applied Mn at seeding. These untreated plots also appeared to be greener and have slightly delayed maturity compared to the foliar Mn plots (Figure 1), this is not

uncommon with nutrient deficiencies, including trace elements and P deficiency. However, the crop never fully presented 'classic' Mn deficiency symptoms, and the crop visually appeared to be relatively healthy during the growing season.

Table 2. Summary of GreenSeeker NDVI and shoot Mn (mg/kg) sampled at GS31 in the Mn strategy trial at Marion Bay, SA 2024.

Fertiliser treatment	Total applied kg Mn/ha	NDVI 10 th Sep	NDVI 27 th Sep	Shoot Mn* mg/kg	Shoot P %
Nil	-	0.641	0.646 a	14.0	0.27 a
10 kg/ha MnSO ₄ IBS	3.1	0.592	0.574 abc	14.3	0.26 ab
10 kg/ha MnSO ₄ IBS fb 3 kg/ha @ GS14, GS31, GS39	5.9	0.553	0.514 c	16.0	0.24 b
1 kg/ha @ GS14, GS31, GS39	0.9	0.586	0.568 abc	14.7	0.24 b
2 kg/ha @ GS14, GS31, GS39	1.9	0.583	0.525 c	16.0	0.24 b
3 kg/ha @ GS14, GS31, GS39	2.8	0.549	0.505 c	16.7	0.24 b
2 kg/ha @ GS14, GS31	1.2	0.564	0.542 bc	-	-
2 kg/ha @ GS14, GS39	1.2	0.587	0.555 bc	-	-
2 kg/ha @ GS31, GS39	1.2	0.612	0.547 bc	-	-
Mn Chelate 2 L/ha IBS	0.1	0.612	0.625 ab	14.7	0.27 a
Pr(>F)		0.416	0.041	0.32	0.038
LSD		ns	0.084	ns	0.03

* note, only seeding and GS14 applications applied at the time of tissue sampling at GS31.

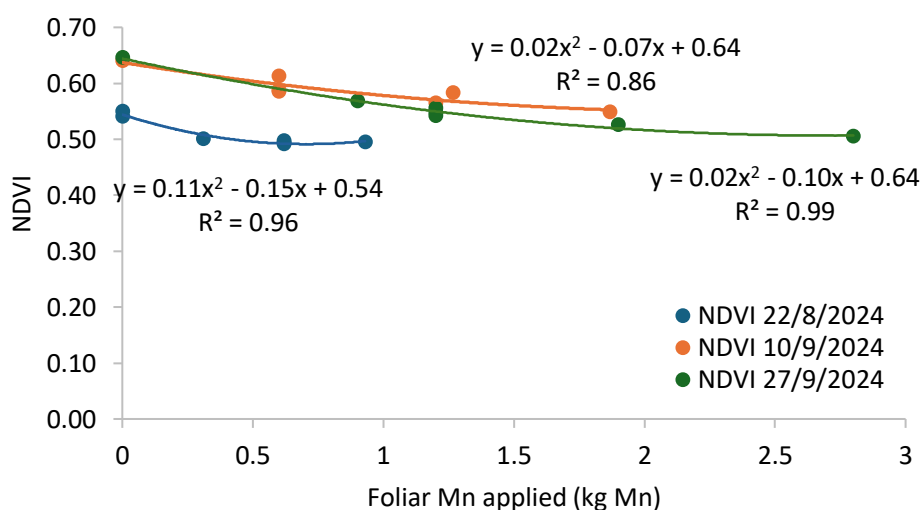


Figure 1. Relationship between GreenSeeker NDVI and foliar applied Mn (mg/kg) at various dates in the Mn strategy trial at Marion Bay, SA 2024.

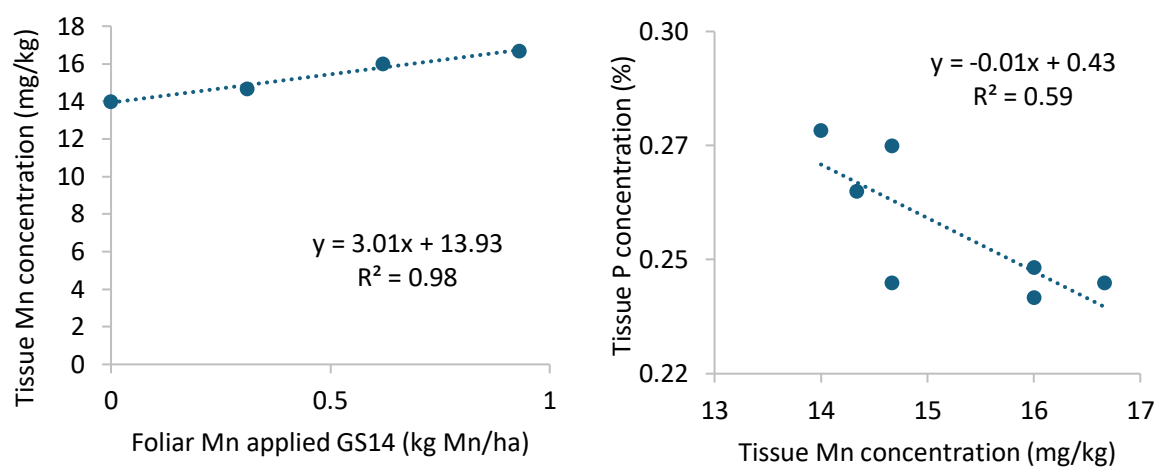


Figure 2. (left) Plant tissue (YEB) Mn concentration in response to foliar Mn application rate and (right) relationship between plant tissue Mn and P concentrations at GS31 in the Mn strategy trial at Marion Bay, SA 2024.



Figure 3. The nil (left plot) was paler and later maturing versus Mn treated (right) which displayed a different canopy colour (brown/purple straw and beard).

Grain yield and quality

Manganese fertiliser strategy had no impact on grain yield or grain quality. Barley grain yields averaged 3.91 t/ha across the trial. Grain protein, test weight and retention averaged 12.1%, 70 kg/hL and 95%, respectively (Table 3). All treatments had screening levels <5% (data not shown). The receival standard for all treatments was either MALT 1 or BAR1 depending on grain protein (12.0% maximum level for malt 1).

Table 3. Summary of barley grain yield and grain quality for the Mn strategy trial at Marion Bay, SA 2024.

Fertiliser treatment	Canopy colour score (1-10)*	Yield (t/ha)	Protein %	Test weight (kg/hL)	Retention %
Nil	6.3 b	3.85	12.4	70.2	93.1
10 kg/ha MnSO ₄ IBS	6.7 b	3.85	12.3	70.4	95.6
10 kg/ha MnSO ₄ IBS fb 3 kg/ha @ GS14, GS31, GS39	8.7 a	3.96	12.2	69.1	95.6
1 kg/ha @ GS14, GS31, GS39	8.3 a	3.94	12.2	69.3	95.0
2 kg/ha @ GS14, GS31, GS39	8.7 a	3.85	12.1	69.2	94.8
3 kg/ha @ GS14, GS31, GS39	8.7 a	3.86	12.0	69.1	94.6
2 kg/ha @ GS14, GS31	8.3 a	3.92	12.0	69.4	95.7
2 kg/ha @ GS14, GS39	8.3 a	3.81	12.0	69.7	95.4
2 kg/ha @ GS31, GS39	8.3 a	4.05	11.9	69.6	96.7
Mn Chelate 2 L/ha IBS	6.3 b	4.01	11.7	70.8	94.8
Pr(>F)	0.003	0.802	0.208	0.279	0.153
LSD	1.4	ns	ns	ns	ns

*1 = light pale straw and beard, green in plot through to 10 = brown/purple straw and beard.

Trial 2. Application rate and placement position of potassium fertilisers

Key messages

- Barley was not responsive to any K fertiliser application rates (0 up to 120 kg K/ha).
- Fertiliser placement (deep banded, with seed or surface applied) had no impact on crop establishment, growth or grain yield this season.
- These results suggest the Colwell K soil test critical limit for barley is lower than 120 mg/kg for the soils at Marion Bay.

Why do the trial?

Most soils in the Southern region contain sufficient potassium (K) levels for crop production however, deficiencies (suspected or confirmed) are increasingly being reported. Deficiency may first appear as poor crop growth between windrows or header tracks from the previous year. Locally recent work by Trengove et al. (2024) has revealed the initial Colwell K for responsive sites were well above the current critical soil value of 45 mg K/kg in the top 0-10 cm. The authors showed for soil types on the Yorke Peninsula, Colwell K values between 98 – 175 mg K/kg were responsive to K fertiliser applications.

This trial aimed to help growers on the southern YP diagnose if K deficiency was limiting their productivity and profitability. It also aimed to identify the most cost-effective applications of K fertiliser, where they are needed the most, and to avoid wasteful applications where K deficiency is unlikely.

How was it done?

Stenhouse	Annual 328 mm	Variety:	Maximus CL barley 80 kg/ha
Bay rainfall:	Growing season 254 mm		
Sowing date:	3 rd June 2024	Fertiliser placements:	1. Deep banded 2. With seed 3. Surface applied IBS + PSPE

The trial was a randomised complete block design, consisting of 7 treatments with 3 replicates (Table 1). Plots were 10 m long with 25 cm row spacing. Plots were sown using knife points and press wheels. All plots received starting fertiliser of MAP Zn at 120 kg/ha and urea at 100 kg/ha incorporated by sowing. Muriate of potash (MoP) was used as the source of potassium (Table 1).

Measurements throughout the season included GreenSeeker NDVI (31st July, 22nd August, 10th September and 27th September) and tissue tests at Zadok's Growth stage 31. The trial was harvested on the 20th of November with grain quality traits measured.

Table 1. Treatments evaluated in the potassium strategy trial at Marion Bay, SA 2024.

Treatment	Timing	Potassium rate (kg K/ha)	Fertiliser position
1	Seeding	0	Deep Banded (30mm below the seed)
2		15	
3		30	
4		60	
5		120	
6		60	With Seed
7	Spread IBS and PSPE	60 IBS + 60 PSPE	Surface

Results and discussion

GreenSeeker NDVI and tissue testing

Rate and placement of potassium fertiliser had had no effect on any NDVI assessment this season (data not shown).

Tissue testing at GS31 (first node) showed there was no increase in K levels for rates up to 120 kg K/ha compared to the nil. All tissues tests averaged 5.0% K (Table 2). While not well-defined, adequate K levels in whole shoot samples at early growth stages (e.g. tillering up until GS31) are generally around 2 – 2.5% (Brennan 2017; Reuter and Robinson, 2008). These levels show the barley crop was not limited by K and had adequate soil reserves.

Gain yield and quality

Potassium strategy had no impact on grain yield or grain quality. Grain yields averaged 3.62 t/ha, with protein, test weight, retention and screenings averaging 12%, 70 kg/hL, 94% and 1.8% respectively (Table 3). The receival standard for majority of treatments was MALT 1 or BAR1 depending if grain protein was >12.0%.

Table 2. Summary of youngest emerged blade (YEB) K, grain yield and grain quality for the K response trial at Marion Bay, SA 2024.

Fertiliser strategy	YEB K %	Yield (t/ha)	Protein %	Test weight (kg/hL)	Retention %	Screenings %
0 kg K/ha	4.9	3.78	11.7	70.2	94.5	1.7
15 kg K/ha deep banded		3.76	11.8	68.8	94.3	1.9
30 kg K/ha deep banded	5.1	3.51	12.3	70.4	94.3	1.7
60 kg K/ha deep banded		3.58	11.7	69.8	94.1	1.7
120 kg K/ha deep banded	5.1	3.65	11.9	69.4	94.2	1.7
60 kg K/ha with seed		3.56	12.4	69.4	93.5	1.8
60 kg K/ha IBS + 60 kg K/ha PSPE		3.48	12.0	69.1	93.2	1.9
Pr(>F) LSD	ns	ns	ns	ns	ns	ns

Trial 3. Improving crop phosphorus uptake: evaluation of liquid and granular fertilisers and rates

Key messages

- Large yield increases were observed in response to P fertiliser, with barley grain yields across the trial increasing from 2.98 to 4.45 t/ha.
- The performance of liquid P alone shows there was a greater increase in grain yield than for comparable granular rates up to 7.5 kg P/ha.
- The P fertiliser recovery across the P rates and forms trialled ranged from 5 – 44%. The highest P recovery resulted from liquid P alone followed by liquid + granular P and granular alone.

Why do the trial?

Previous research in South Australia has demonstrated more efficient uptake of P and improved yields of wheat when fluid P fertiliser is used on calcareous soils. It appears that, on these highly calcareous soils, P added as granular fertiliser is rapidly precipitated as insoluble calcium phosphates, which are not available to plants (McLaughlin et al. 2008). The fluid P fertiliser is better distributed and may remain in solution longer, with less fixation of insoluble forms of P.

This trial aimed to assess optimum granular and/or liquid P fertiliser rates on a highly calcareous sand on the southern Yorke Peninsula.

How was it done?

Stenhouse Bay Annual 328 mm
rainfall: Growing season 254 mm

Fertiliser: Refer to treatment list.

Sowing date: 3rd June 2024

Variety: Maximus CL barley 80 kg/ha

The trial was a randomised complete block design, consisting of 18 treatments with 3 replicates. Plots were 10 m long with 25 cm row spacing. Plots were sown using knife points and press wheels.

Phosphorus fertiliser treatments consisted of granular, liquid or a combination of both application methods (Table 1). All granular treatments were applied as MAP. The liquid treatments were made up of a blend of phosphoric acid, nitrogen fertiliser and proprietary additives resulting in a N:P:K:S ratio of 8:16:0:1. Nitrogen was matched in all plots at seeding (as urea) to the treatment with the highest N rate (Treatment 18 = 44 kg N/ha).

Measurements throughout the season included GreenSeeker NDVI (31st July, 22nd August, 10th September and 27th September) and tissue tests at Zadok's Growth stage 31. The trial was harvested on the 20th of November for grain yield. All plots were assessed for grain quality.

Table 1. Summary of the phosphorus fertiliser treatments used in the P fertiliser form and rate trial at Marion Bay, 2024.

Treatment	Granular P (kg P/ha)	Liquid P (kg P/ha)	Total P (kg P/ha)
1	0	0	0
2	7.5	0	7.5
3	15	0	15
4	22.5	0	22.5
5	30	0	30
6	50	0	50
7	90	0	90
8	0	3.75	3.75
9	7.5	3.75	11.25
10	15	3.75	18.75
11	0	7.5	7.5
12	7.5	7.5	15
13	15	7.5	22.5
14	22.5	7.5	30
15	0	15	15
16	7.5	15	22.5
17	15	15	30
18	75	15	90

Results and discussion

Greenseeker NDVI

The site was highly P responsive, with growth responses measured up to 90 kg P/ha applied (Figure 1). Barley NDVI for the various P treatments followed a similar trend throughout the season. In general, the liquid P treatments showed a greater growth response per kg P applied compared to the granular treatments (Figure 1), with the steepest response curve. This was also observed in the combined granular plus liquid treatments, where the response curve sits between the liquid only and granular only curves.

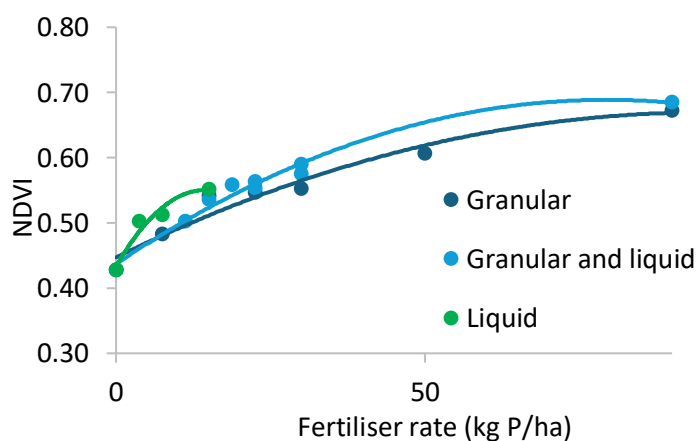


Figure 1. Greenseeker NDVI at GS31 (22 August) in response to P fertiliser rate and form at Marion Bay, 2024.

Tissue testing

Tissue testing at GS31 (youngest emerged blade) showed no increase in P concentration in response to P fertiliser rate or product (Table 2), despite large growth responses observed at the same time (Figure 1). The P concentration averaged 0.26% across all treatments, which is considered marginal-deficient. It indicates that increased P uptake has been diluted through higher dry matter production, resulting in the same P concentration across treatments.

Many other nutrients show a decline in concentration with increasing P rates and increased growth (Table 2). This is due to these nutrients being diluted through greater dry matter, and the crop not being able to increase nutrient uptake to compensate. Nutrients that declined with increasing P rate and crop growth included sulphur, manganese, copper, zinc, molybdenum and potassium. However, all nutrients were in adequate concentration according to industry benchmarks despite these declines, except for manganese. However, the results from Trial 1 suggest the critical Mn concentration for barley at this site is lower than the industry standard of 15 mg/kg.

Table 2. Summary of youngest emerged blade (YEB) GS31 tissue test results for phosphorus and manganese at Marion Bay, SA 2024.

Treatment	Granular P (kg P/ha)	Liquid P (kg P/ha)	Total P (kg P/ha)	Phosphorus (%)	Zinc (mg/kg)	Manganese (mg/kg)
1	0	0	0	0.27	74.7 a	15.7 a
2	7.5	0	7.5	0.26	65.0 ab	16.0 a
3	15	0	15	0.28	64.7 ab	14.7 abc
5	30	0	30	0.25	56.3 bcd	14.7 abc
7	90	0	90	0.28	49.7 cd	13.7 c
11	0	7.5	7.5	0.26	65.0 ab	15.3 ab
12	7.5	7.5	15	0.25	58.0 bcd	13.7 c
14	22.5	7.5	30	0.25	61.3 bc	14.7 abc
15	0	15	15	0.27	56.7 bcd	16.0 a
17	15	15	30	0.27	52.0 bcd	14.0 bc
18	75	15	90	0.27	47.3 d	14.0 bc
Pr(>F)				ns	0.012	0.021
LSD					13.1	1.53

Grain yield and quality

Large yield increases were observed in response to P fertiliser, with barley grain yields across the trial increasing from 2.98 to 4.45 t/ha (Table 3). The performance of liquid P alone shows there was a greater increase in grain yield than for comparable granular rates up to 7.5 kg P/ha (Figure 2). For example, for a total P application rate of 7.5 kg P/ha grain yield was lower for granular P at 3.30 t/ha compared to 3.72 t/ha for liquid P alone (Table 3). However, at the 15 kg P/ha rate the grain yields were similar for both liquid and granular P. While earlier in the season there was still an increase in biomass at this P rate, it did not translate to grain yield.

For the granular P treatments, grain yields increased up to rates of 50 kg P/ha. At this point no further grain yield increase was observed with higher P rates. Across all granular + liquid combinations there is a trend for slightly higher yield than straight granular treatments (Figure 2).

This ranges from 1.4-2.1% higher yield for P rates of 5-30 kg P/ha, but the yield increase is smaller than the NDVI response observed earlier in the season (Figure 1). According to the trend lines (Figure 2), 20 kg P/ha applied as granular MAP fertiliser would have produced 3.70 t/ha, whereas the same rate applied as a combination of granule and liquid would have produced 3.77 t/ha. To achieve the same yield using only granular P would have required 23 kg P/ha to be applied.

Another way to evaluate fertiliser performance is to look at the phosphorus use efficiency (PUE). The most common way of calculating the recovery by crops of fertiliser P applied is using the difference method ((P removal fertilised – P removal nil) / P rate). The P fertiliser recovery across the P rates and methods trialled ranged from 5 – 44%. The highest P recovery resulted from liquid P rates 3.75 kg P/ha and 7.5 kg P/ha at 44% and 30%, respectively. In comparison all granular P treatments had PUE ranging from 5-14%. In general, the granular + liquid P recovery rates were similar to the granular alone, ranging from 5 – 18%. This is consistent with the outcomes from the grain yield results.

Grain quality across the site was high (data not shown) with the majority of samples meeting MALT 1 classification (depending on protein). Grain protein ranged from 10.7 – 12.9%. Test weight and retention average 69.6 kg/hL and 94.5%, respectively. Screening levels were <5% for all samples.

Table 3. Grain yield, P fertiliser recovery and partial gross margin (PGM) for the P form and application rate trial at Marion Bay, 2024. Assumptions, barley = \$300/t, granular P = \$4.2/kg P, liquid P = \$7.2/kg P, no application costs considered.

Treatment	Granular P (kg P/ha)	Liquid P (kg P/ha)	Total P (kg P/ha)	Yield t/ha	P fertiliser recovery	PGM (\$/ha)
1	0	0	0.0	2.98 g		894
2	7.5	0	7.5	3.30 fg	13	959
3	15	0	15	3.70 def	14	1046
4	22.5	0	22.5	3.73 cdef	10	1025
5	30	0	30	3.96 bcde	10	1062
6	50	0	50	4.25 abc	8	1064
7	90	0	90	4.44 ab	5	955
8	0	3.75	3.8	3.53 def	44	1033
9	7.5	3.75	11.3	3.65 def	18	1037
10	15	3.75	18.8	3.94 cde	15	1093
11	0	7.5	7.5	3.72 cdef	30	1062
12	7.5	7.5	15	3.48 efg	10	957
13	15	7.5	22.5	3.89 cde	12	1049
14	22.5	7.5	30	4.02 abcd	10	1058
15	0	15	15	3.67 def	14	994
16	7.5	15	22.5	3.83 cde	11	1009
17	15	15	30	3.88 cde	9	993
18	75	15	90	4.45 a	5	913
Pr(>F)				<0.001		
LSD				0.399		

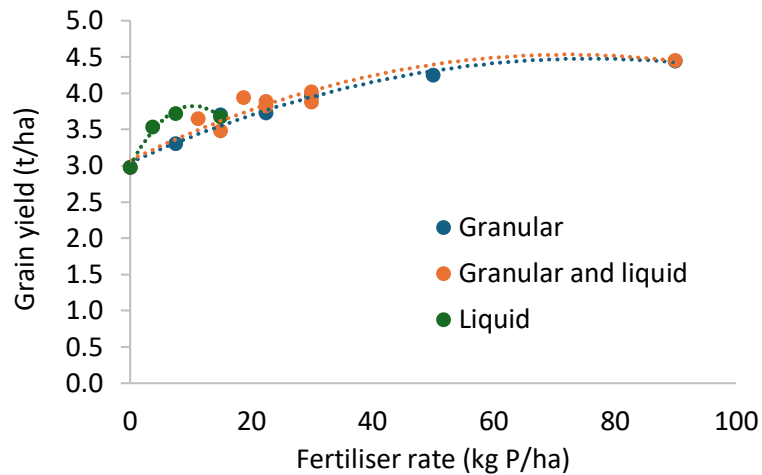


Figure 2. Grain yield response to P fertiliser rate and form at Marion Bay, 2024.

Partial gross margin

Across all P fertiliser treatments, the lowest and highest partial gross margin differed by \$164/ha (Table 3). The highest PGM at the site was achieved by applying 15 kg P/ha as granular with 3.75 kg P/ha as liquid (treatment 10, Table 2). The addition of liquid in this treatment increased PGM by \$47 compared to 15 kg P/ha as granular (treatment 3). Other high performing treatments were those including liquid P at 7.5 kg P/ha, or high rates of granular P at 30-50 kg P/ha. Based on the predicted PGM, the granular P rate that optimises PGM is 34 kg P/ha (155kg MAP/ha) (Figure 3).

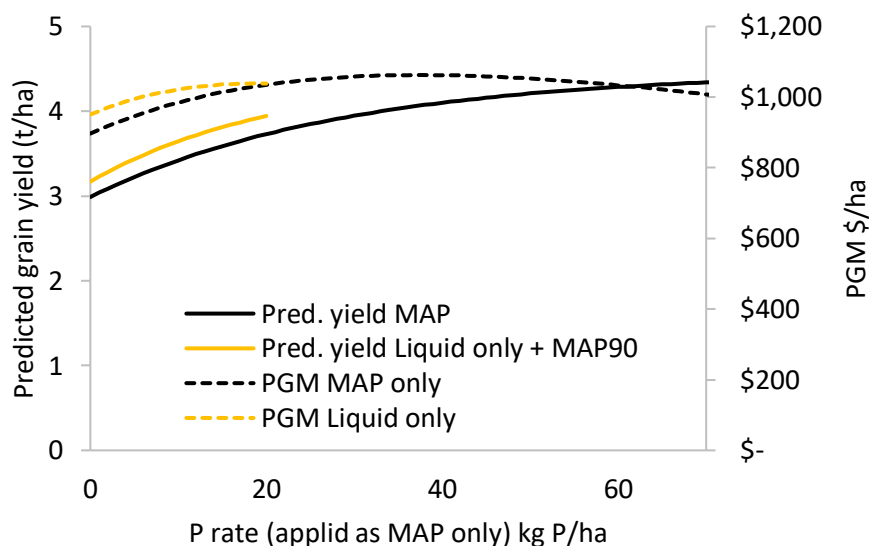


Figure 3. Predicted grain yield response and partial gross margin for P fertiliser rates and form at Marion Bay, 2024.

Trial 4. Evaluation of alternative nutrient products

Key messages

- Chicken litter was the only alternative nutrient source to outperform synthetic fertilisers yielding 4.69 t/ha. This was an increase of 0.61 t/ha (15%) when compared to the matched MAP treatments.
- The application of biochar and biosolids had lower grain yields compared to the matched MAP treatments. While these alternative products contain comparative levels of nutrients, the results suggest they may be less available, or their release may be slower and over a longer timeframe.

Why do the trial?

Organic amendments such as manures and biosolids are used in farming systems as alternatives to inorganic fertiliser to supply nutrients, to improve poor performing soils and to ameliorate subsoil constraints. Fertiliser inputs are the single largest variable cost for grain growers and the use of / interest in alternative nutrient sources is increasing. In the Mid-North and Yorke Peninsula biosolids and chicken litter (CL) are commonly applied to paddocks because of the proximity to Bolivar Sewage Treatment Works and a network of local chicken farms. There are also more products coming onto the market for example, biochar and nano technologies.

Crop yield and quality improvements from the application of organic amendments can be due to a range of factors such as amelioration of soil constraints and/or plant nutrient input. Where positive crop responses to organic amendments have been reported, they are often attributed to the presence of nutrients in more bioavailable forms, nutrient release patterns better matched to seasonal conditions, increase in organic matter and microbial activity, or providing nutrients not supplied by the current fertilizer strategy. However, the exact mechanisms behind the yield improvement from organic amendment applications are still unclear.

This trial aims to compare crop performance from different nutrient sources (e.g. synthetic fertilisers versus alternative products).

How was it done?

Stenhouse	Annual 328 mm	Variety:	Maximus CL 80 kg/ha barley
Bay rainfall:	Growing season 254 mm		
Sowing date:	3 rd June 2024		

The trial was a randomised complete block design, consisting of 9 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 and biosolids used within these trials are summarised in Table 1. The biosolids, CL, biochar at 350 kg/ha and the gypsum dispersion product were spread prior

to seeding. Biochar at 500 kg/ha was deep banded prior to seeding. Foliar trace elements were applied to treatment 3 on 22nd August containing 2 kg/ha MnSO₄, 300 g/ha CuSO₄, 2 kg/ha ZnSO₄, 100g/ha Boron, 8.4 kg/ha Iron EDDHA and 100g/ha sodium molybdate. The gypsum dispersion with Aqua-Sil was applied by hand at 2 t/ha with approximately 5% phosphoric acid. Excluding the chicken litter treatment (148 kg N/ha), nitrogen was matched across all treatments at 69 kg N/ha.

Table 1. Nutrient concentration of the chicken litter and biosolids and the total nutrient applied with each product at 4.12 t/ha chicken litter and 3.47 t/ha biosolids.

Product		Nitrogen	Phosphorus	Potassium	Sulphur	Calcium	Magnesium	Iron
Chicken Litter	%	3.43	0.85	2.79	0.59	1.29	0.69	0.20
	kg/ha	141.2	34.9	114.9	24.1	53.0	28.3	8.4
Biosolids	%	0.89	1.01	0.84	0.41	3.35	0.97	1.97
	kg/ha	30.9	34.9	29.0	14.3	116.2	33.7	68.3
Product		Aluminium	Boron	Copper	Manganese	Molybdenum	Zinc	
Chicken Litter	%	0.31	0.007	0.04	0.05	0.0008	0.03	
	kg/ha	12.6	0.3	1.5	1.9	0.032	1.2	
Biosolids	%	3.58	0.005	0.02	0.02	0.0005	0.02	
	kg/ha	124.0	0.2	0.6	0.7	0.017	0.8	

Measurements throughout the season included GreenSeeker NDVI (31st July, 22nd August, 10th September and 27th September) and tissue tests (youngest fully emerged leaf) at Zadok's GS31 (first node). Biomass cuts were completed at anthesis on 27th of September and tissue tests were also taken from these samples (whole tops). The trial was harvested for grain yield on the 20th of November. All plots were assessed for grain yield and quality.

Table 2. Summary of treatments implemented in the alternative products trial at Marion Bay, SA 2024.

Trt	MAP (kg/ha)	MoP (kg/ha)	MnSO ₄ (kg/ha)	Urea (kg/ha)	Treatment description	Total P kg P/ha	Total N kg N/ha
1	-	-	-	150	Synthetic fertiliser – N only	0	69
2	227	50	11.6	100	Synthetic fertiliser – N, P, K, Mn	50	69
3	227	50	11.6	100	Synthetic fertiliser (N, P, K, Mn) + foliar trace (Cu, Zn, B, Fe, Mo)	50	69
4	-	-	-	150	Biochar + phos acid 10% @ 500 kg/ha deep banded + N	50	69
5	-	50	11.6	150	Biochar + phos acid 10% @ 500 kg/ha deep banded + N + Mn + K	50	69
6	-	50	11.6	150	Gypsum dispersion with Aqua-Sil @ 2 t/ha + phos acid 5%	100	69
7	68	50	11.6	135	Biochar + phos acid 10% @ 350 kg/ha pre-spread + N + starter P, K, Mn	50	69
8	68	-	-	0	Chicken Litter @ 4118 kg/ha pre-spread + starter P	50	148
9	68	-	-	68	Biosolids @ 3465 kg/ha pre-spread + starter P	50	69

Results and discussion

Crop vigour and GreenSeeker NDVI

Early crop vigour was improved by the application of CL, which was slightly better compared to biosolids (Table 3). There was minor difference in crop vigour among the remaining treatments.

Across all NDVI assessments, CL also returned the highest values and this could visually be seen (green, larger biomass) within the trial during the growing season (Table 3). Treatments 2 and 3 which included 227 kg/ha of MAP also had consistently high NDVI values compared to the nil (urea only) from late July to late September. The gypsum dispersion product also had similarly high NDVI by the end of September. Early in the season NDVI for the biochar and biosolid treatments was higher. However, these differences were no longer observed later in the season (equal to the nil).

Table 3. Crop vigour and NDVI assessments for the alternative nutrient source trial at Marion Bay, SA 2024.

Trt#	Description	Vigour 27 June		NDVI 31 July		NDVI 22 Aug		NDVI 10 Sept		NDVI 27 Sept	
1	N Fert only (Nil)	2.7	d	0.194	d	0.363	d	0.557	c	0.613	bc
2	N + P + K + Mn Fert	3.0	cd	0.258	b	0.593	b	0.681	b	0.677	ab
3	N + P + K + Mn Fert + Foliar trace	3.0	cd	0.261	b	0.584	b	0.681	b	0.679	ab
4	N Fert + Biochar P	3.0	cd	0.225	c	0.477	c	0.603	c	0.610	bc
5	N Fert + Biochar P + K + Mn	3.3	c	0.224	c	0.505	c	0.620	bc	0.610	bc
6	N Fert + Gypsum disp + P	2.7	d	0.191	d	0.479	c	0.684	b	0.714	a
7	N Fert + Biochar P + Starter P	3.0	cd	0.225	c	0.479	c	0.628	bc	0.655	abc
8	Chicken litter (N+P) + Starter P	8.0	a	0.357	a	0.752	a	0.768	a	0.710	a
9	N Fert + Biosolid P + Starter P	5.0	b	0.236	bc	0.512	c	0.597	c	0.575	c
	Pr(>F)	<0.001		<0.001				<0.001		0.036	
	LSD	0.527		0.026				0.074		0.088	

Crop biomass and tissue testing

Tissue test results at GS31 show a large increase in P concentration for the CL treatment at 0.38%, compared to all other treatments averaging 0.27% (Table 4). This is despite a large increase in biomass, as indicated in the NDVI measurement on 22 August (Table 3). In comparison the P concentration did not change at GS31 in response to 50 kg P/ha applied as MAP, though it did increase NDVI. This result is consistent with the outcomes from the P rate and form trial discussed previously. The CL treatment, supplying the same rate of P, increased both tissue P concentration and NDVI.

There were also differences in other nutrient concentrations at the GS31 sampling time. For example, the molybdenum concentration increased in response to both CL and biosolids (Table 4). Several nutrients, including calcium, sodium and zinc, showed declines in concentration from the application of CL at this growth stage (Table 4). This is most likely a result of nutrient dilution due to increased crop growth. None of these nutrient concentrations are considered deficient.

Table 4. Nutrient concentration for youngest fully emerged leaf sampled at GS31 (22 August) for selected treatments.

Trt	Description	K %	P %	Na %	Zn mg/kg	Mo mg/kg	Mn mg/kg	Fe mg/kg
1	N Fert only (Nil)	4.9	0.27 b	0.21 a	77.3 a	0.33 c	17.3	75
2	N + P + K + Mn Fert	5.1	0.27 b	0.18 a	55.3 bc	0.48 c	15.3	74
5	N Fert + Biochar P + K + Mn	4.7	0.25 b	0.18 a	61.7 b	0.28 c	14.3	66
8	Chicken litter (N+P) + Starter P	5.0	0.38 a	0.09 b	47.0 c	1.93 a	14.3	70
9	N Fert + Biosolid P + Starter P	5.0	0.28 b	0.20 a	65.0 b	1.27 b	15.6	72
	Pr(>F)	ns	0.003	0.019	0.001	<0.001	ns	ns
	LSD		0.05	0.07	10.1	0.26		

Chicken litter resulted in the highest crop biomass at anthesis (Table 6). The CL treatment had an 80% increase when compared to the nil and 37% higher than the synthetic fertiliser treatment. The remaining two treatments tissue tested (N + P + K + Mn and biosolids) also increased crop biomass by 31 and 17%, respectively. These results are consistent with NDVI measurements (Table 3). No difference in P concentration was measured at anthesis for the CL treatment, which is not consistent with the increase measured at GS31. However, given the biomass increase, the total P uptake was increased to 11.9 kg/ha from CL and to 8.8 kg/ha for the N + P + K + Mn treatment compared to 6.9 kg/ha for untreated (Table 6). This increase in P uptake equates to 10% and 4% of the 50 kg P/ha applied in these treatments. Greater P uptake from the CL maybe be due to better timing of P availability from the CL with crop demand. There are a range of P forms within CL and many require soil microbes to convert them into plant available forms. Therefore, CL may not have high soil P availability up front but smaller and slower amounts may be released over the growing season. Biosolids did not increase P uptake at all. The P in biosolids is largely in unavailable forms and is not a good P fertiliser source, at least in the short term.

It was hypothesised that the large growth increases observed in the CL treatments may be due to more N applied (148 kg N/ha) in this treatment, where all other treatments were balanced to 69 kg N/ha (Table 2). However, N uptake at anthesis was the same for both the N + P + K + Mn treatment and the CL (Table 6), indicating they had similar N availability. Similarly, at harvest these treatments were removing similar quantities of N in the grain as protein (Table 7).

At anthesis, similar to the GS31 sampling time, several nutrients showed concentration declines in better performing treatments. This included nitrogen, calcium, sulphur and zinc (Table 5), but total nutrient uptake for these still increased, relative to the untreated control (Table 6). Molybdenum concentration and uptake was increased in response to CL and biosolids, in line with the molybdenum contained within these products (Table 1).

Aluminium and iron (Fe) concentration increased in response to CL at anthesis (this was not observed at GS31). A nearby trial in lentil showed a 30% yield increase in response to an application of EDDHA Fe, therefore increasing Fe availability in the CL treatment may also be important in the barley

response. However, treatment 3 included an application of EDDHA Fe and no improvement in NDVI or grain yield was observed following application. Interestingly, biosolids apply much greater quantities of Al and Fe (Table 1) compared to CL however, it does not appear to be taken up by the plant. Sewage waste streams typically contain ions of Fe^{++} and Al^{+++} . Treatment to remove these ions from the liquid stream into the solids can include the addition of ferric chloride and aluminium sulphate to the sludge, causing the metals to flocculate and settle out. This likely explains their high concentration in the resulting product but, also lower plant availability. Reactions between P and Fe and Al may produce insoluble precipitates and explain why the P in biosolids also has low availability.

Table 5. Nutrient concentration of whole barley tops for selected treatments at anthesis 27 September, 2024.

Trt	Description	N %	P %	K %	S %	Cu mg/kg	Zn mg/kg	Al mg/kg	Fe mg/kg	Mo mg/kg	Mg %	Mn mg/kg	Ca %
1	N Fert only (Nil)	2.1 a	0.20	2.7	0.18 a	4.6 a	30.7 a	20.0 b	45.0	0.17 c	0.14	7.5	0.46 a
2	N + P + K + Mn Fert	1.9 a	0.18	2.5	0.14 b	3.8 b	23.7 b	17.3 b	40.0	0.22 c	0.14	7.2	0.44 ab
8	Chicken litter (N+P) + Starter P	1.6 b	0.19	2.7	0.14 b	4.0 ab	25.3 b	36.7 a	52.0	0.60 a	0.14	8.0	0.38 b
9	N Fert + Biosolid P + Starter P	1.7 b	0.17	2.3	0.14 b	3.8 b	24.7 b	19.7 b	40.0	0.43 b	0.13	6.8	0.39 b
	Pr(>F)	0.01	ns	ns	0.04	0.05	0.04	0.00	ns	0.00	ns	ns	0.046
	LSD	0.25			0.03	0.61	4.76	8.15		0.15			0.06

Table 6. Dry matter production at anthesis and nutrient uptake (dry matter x nutrient concentration) for selected treatments sampled 27 September, 2024.

Trt	Description	Dry matter t/ha	N uptake kg/ha	P uptake kg/ha	K uptake kg/ha	S uptake kg/ha	Cu uptake g/ha	Zn uptake g/ha	Al uptake g/ha	Fe uptake g/ha	Mo uptake g/ha	Mg uptake kg/ha	Mn uptake g/ha	Ca uptake kg/ha
1	N Fert only (Nil)	3.5 b	74 b	6.9 b	92 c	6.1	15.9 b	106 b	69 b	156 b	0.6 c	5.0 c	26.0 b	15.9 b
2	N + P + K + Mn Fert	4.6 b	96 a	8.8 b	126 b	7.2	18.7 b	118 b	86 b	200 b	1.1 bc	6.8 b	36.3 b	21.7 a
8	Chicken litter (N+P) + Starter P	6.3 a	101 a	11.9 a	166 a	8.8	25.2 a	159 a	232 a	327 a	3.8 a	8.6 a	50.3 a	24.1 a
9	N Fert + Biosolid P + Starter P	4.1 b	67 b	6.9 b	91 c	5.7	15.3 b	100 b	81 b	162 b	1.7 b	5.2 c	27.6 b	15.9 b
	Pr(>F)	0.009	0.008	0.004	0.004	ns	0.011	0.018	0.003	0.003	<0.001	0.002	0.005	0.003
	LSD	1.32	17.5	2.2	32.2		5.1	32.9	67.3	71.0	1.0	1.4	10.7	3.6

Grain yield and quality

The application of CL was the highest yielding treatment at 4.7 t/ha (Table 7). The next best yielding treatments were those with synthetic fertilisers (treatments 2 and 3). All remaining alternative nutrient products (3.46 t/ha average) evaluated were lower yielding compared to the district practice (treatment 2).

The lowest grain protein was in the CL treatment (Table 7). This reduction in protein is a yield dilution effect (higher yield = lower protein) for the CL, despite higher total N application. Given higher N application but similar N removal to other high yielding treatments it indicates lower recovery or nitrogen use efficiency of the N in CL. The biosolid treatment also had lower protein but lower grain yield, producing low N removal. Biosolids supplied 31 kg N/ha, with the remaining 38 kg/ha supplied from urea and MAP, the same as treatments 1-7. Similar to CL, it appears the N supply from biosolids is less available and less efficient, at least in the short term.

Test weight, retention, and screenings average 69 kg/hL, 94% and 2%, respectively. For these quality parameters all samples met MALT 1 classification.

Table 7. Grain yield and quality for the alternative products trial at Marion Bay, SA 2024.

Trt	Description	Grain yield t/ha	Protein %	Test weight kg/hL	N removal kg/ha
1	N Fert only (Nil)	2.73 d	12.6 ab	66.9 c	55 c
2	N + P + K + Mn Fert (District Prac)	4.08 b	12.0 c	69.7 ab	79 a
3	N + P + K + Mn Fert + Foliar trace	4.11 b	12.4 abc	69.8 ab	82 a
4	N Fert + Biochar P	3.45 c	12.1 bc	69.9 ab	68 b
5	N Fert + Biochar P + K + Mn	3.46 c	11.8 c	68.7 abc	66 b
6	N Fert + Gypsum disp + P	3.31 c	13.0 a	68.7 abc	69 b
7	N Fert + Biochar P + Starter P	3.59 c	12.0 bc	68.6 bc	70 b
8	Chicken litter (N+P) + Starter P	4.69 a	10.7 d	70.7 a	81 a
9	N Fert + Biosolid P + Starter P	3.50 c	11.1 d	69.6 ab	62 bc
	Pr(>F)	<0.001	<0.001	0.045	<0.001
	LSD	0.38	0.60	2.00	8.8

Trial 5: The potential for in-season foliar phosphorus fertiliser applications

Key messages

- Application of foliar P fertilisers did not increase biomass (NDVI), grain yield or quality.
- Given the very low soil P levels (DGT-P 15 µg/L) and high potential for crop response at this site, the results show foliar P was not suitable as in-season tactical application to increase grain yield.

Why do the trial?

The ability to utilise foliar applied phosphorus (P) as a strategy to increase the P status and yield of grain crops would be beneficial. Crops have a high P demand early in the season and while foliar P is not replacement for starter P, it could potentially be a 'top-up' application later in the season. There has been a large amount of research on wheat foliar P in both controlled and field conditions however, the responses have not been consistent.

This trial aimed to assess the potential use of foliar P fertilisers for increasing grain yield on a highly calcareous soil.

How was it done?

Stenhouse	Annual 328 mm	Fertiliser:	At seeding - 100 kg/ha MAP + 5 kg/ha MnSO ₄ In-season – 100 kg/ha urea
Bay rainfall:	Growing season 254 mm	Foliar application date:	22 nd August 2024
Sowing date:	31 st May 2024		
Variety:	Maximus CL 80 kg/ha barley		

The trial was a randomised complete block design, consisting of 7 fertiliser treatments with 3 replicates. Plots were 10 m long and 1.7 m wide. Plots were sown using knife points and press wheels. All plots received a starting blend fertiliser of 80% DAP and 20% MoP with NPK ratio of 14.4:16:10 at 120 kg/ha incorporated by sowing. This was followed by post emergent applications of MoP at 60 kg/ha and urea at 80 kg/ha.

In-season foliar P fertilisers were applied on the 22nd August at crop growth stage GS32. The fertilisers used in the trial (Table 1) include Haifa MKP (0-22.7-28.2), Haifa Bonus (13-0.9-36.5) and Haifa Polyfeed GG (11-18-9.1).

Measurements throughout the season included GreenSeeker NDVI on 10th September. The trial was harvested on the 20th of November for grain yield. All plots were assessed for grain quality.

Table 1. Foliar fertilisers and rates used in the foliar P trial at Marion Bay, SA 2024.

No.	Haifa MKP (kg/ha)	Haifa Bonus (kg/ha)	Haifa Polyfeed GG (kg/ha)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
1	-	-	-	0	0	0
2	13	-	-	0	3.0	3.7
3	-	-	16.5	1.8	3.0	1.5
4	13	13	-	1.7	3.1	8.4
5	26	-	-	0	6.0	7.4
6	-	-	33	3.6	5.9	3.0
7	26	26	-	3.4	6.2	16.8

Results and discussion

The foliar fertilisers trialled (products and rates) did not improve crop growth, grain yield or quality compared to the nil. Barley grain yields ranged from 4.14 t/ha – 4.53 t/ha across the trial. Protein, test weight, retention and screenings averaged 11.6 %, 69 kg/hL, 95.3% and 1.4% respectively.

Given the very low P levels at this site (DGT-P15 µg/L), the results show foliar P applications could not be used as an in-season tactical application to increased grain yield.

Table 2. Summary of in-season crop assessments for the foliar phosphorus fertiliser trial at Marion Bay, SA 2024.

Fertiliser treatment	NDVI Sept 10	Grain yield t/ha	Protein %	Test weight kg/hL	Retention %	Screenings %
Nil	0.66	4.50	11.9	69.3	96.1	1.2
MKP 13 kg/ha	0.62	4.31	11.4	68.4	95.6	1.3
Polyfeed 16.5 kg/ha	0.60	4.14	11.5	68.3	94.6	1.6
MKP 13 kg/ha + Haifa Bonus 13 kg/ha	0.63	4.30	10.7	68.2	94.8	1.7
MKP 26 kg/ha	0.61	4.47	12.2	68.0	95.5	1.3
Polyfeed 33 kg/ha	0.61	4.37	11.9	69.7	95.3	1.4
MKP 26 kg/ha + Haifa Bonus 26 kg/ha	0.64	4.53	11.4	69.6	95.1	1.5
Pr(>F)	0.73	0.534	0.835	0.427	0.556	0.380
LSD	ns	ns	ns	ns	ns	ns

Trial 6. Lentil micronutrient nutrition

Key messages

- Foliar application of EDDHA Fe resulted in increased NDVI and lentil grain yields of up to 28%.
- Applications of Cu, Mo and B did not improve lentil growth or grain yield, suggesting they were in adequate supply in the soil.

Why do the trial?

Calcareous soils are strongly alkaline, contain free lime (calcium carbonate) and are particularly common in subsoils on SA's lower Yorke Peninsula, upper Eyre Peninsula, Mid North and the Mallee. Calcareous soils exist in other parts of Australia, but mainly in the subsoil, which restricts root growth after crop establishment and tillering.

Very highly calcareous soils on the Eyre and Yorke Peninsulas and in the South-East of SA contain large amounts (>40%) of calcium carbonate in the topsoil and this often increases with depth. Crops often struggle before they can get established and this is further exacerbated if the topsoil is sandy and dries out quickly.

Some of the major constraints to crop production on highly calcareous soils are poor uptake of nutrients, sodicity, nutrient toxicity, poor water holding capacity, persistence of residual herbicides, low soil biological activity, root diseases, weeds and snails. These factors combined with dry conditions often result in poor crop establishment, vigour, and grain yield.

The aim of this trial was to determine best practice micronutrient management on a highly calcareous soil on the southern Yorke Peninsula. A field trial was established in lentil and the main micronutrients under evaluation were copper (Cu), molybdenum (Mo), boron (B) and iron (Fe).

How was it done?

Stenhouse Bay	Annual 328 mm	Sowing date:	3 rd June 2024
rainfall:	Growing season 254 mm		
Variety:	GIA Thunder lentil @ 50 kg/ha	Seeding	MnSO ₄ 12 kg/ha,
		fertiliser:	MoP 35 kg/ha,
			MAP Zn2% 120 kg/ha

Soil properties

The soil test results suggest the site had high organic carbon at 2.08 % (refer to soil test results at the start of this report). The site was very highly calcareous with 90% free lime (CaCO₃) in the top 0-10 cm. The soil pH was classified as slightly alkaline. The site had a moderate phosphorus buffering index (PBI) of 173, indicating strong potential for "tie up" and a significant portion of the P fertiliser applied will be unavailable to plants. This contributed to a very low DGT-P level of 14 µg/L.

This site was also sampled for soil micronutrient concentrations (Table 1). Soil tests for micronutrients generally have a lower reliability than soil tests for macronutrients. However, within

the current information available, Mn levels at Marion Bay would be categorised as deficient. Critical soil test Mn is <5-10 mg/kg (Brennan et al 2013; Norton 2014). For the remaining micronutrients Cu, B and Fe the soil levels would generally be considered adequate at this site.

Table 1. Soil micronutrient concentrations measured pre-seeding at Marion Bay, SA 2024.

Micronutrient	Units	0-10 cm
Manganese	mg/kg	4.5
Copper	mg/kg	0.44
Boron	mg/kg	2.1
Iron	mg/kg	5.0

Trial details

The trial was a randomised complete block design consisting of three replicates and seven micronutrient treatments (Table 2). All micronutrient treatments were applied as foliar fertilisers on the 5th August. Treatments were applied in 100 L water/ha using 015LD nozzles at 1.8 Bar.

Table 2. Micronutrient treatments applied to lentil in Marion Bay crop nutrition trial, 2024.

Foliar fertiliser	Product application rate (g, kg or L/ha)	Nutrient applied (g/ha)
Nil		
Propriety blend (Cu, Co, Mo, B)	4.0 L/ha	
Loveland Nutrisync D (Mo 0.9%, B 0.7%, P 1%, K 1%)	1.0 L/ha	9 g Mo/ha, 7 g B/ha, 10 g P/ha, 10 g K/ha
Sodium Molybdate (39% Mo)	100 g/ha	39 g Mo/ha
Borax (10.5% B)	100 g/ha	10.5 g B/ha
EDDHA Fe (4.8% Fe)	8.4 kg/ha	403 g Fe/ha
Copper Sulfate (25% Cu)	300 g/ha	75 g Cu/ha

Measurements in season included NDVI (23 August, 10 and 27 September) and tissue testing in selected treatments. All plots were harvested for grain yield.

What happened?

The only foliar micronutrient application to have a consistent effect on crop growth and grain yield was EDDHA Fe. The visual response to the application of EDDHA Fe was a clear indication that there was an Fe deficiency at the site. This response was first noted on 22nd August, 17 days after application (DAA) and Figure 1 shows the greening effect from the application of Fe.



Figure 1. Lentil canopy colour 10 September (36DAA) in response to EDDHA Fe (right foreground) compared to untreated (left foreground) on a highly calcareous soil at Marion Bay. The remaining two replicates of EDDHA Fe treatments can be seen to the left in the middle bay and to the right in the rear bay of the trial.

Greenseeker NDVI measured the day after this photo was taken (18 DAA), was not able to identify differences between treatments with an average reading of 0.266 (data not shown). Later in the season (36 DAA) NDVI showed the EDDHA Fe application had increased biomass production with an increase in NDVI of 26% (Table 3). By 53 DAA, at the end of September the increase in NDVI over the control remained high at 25%. The application of Cu sulfate also had similar NDVI readings compared to EDDHA Fe however, it was no different to the control (Table 3).

Table 3. Greenseeker NDVI and grain yield in the lentil micronutrient trial at Marion Bay, 2024. Treatments that share a common letter are statistically similar

Foliar fertiliser	Nutrient applied (g/ha)	NDVI 10 Sept 36DAA		NDVI 27 Sept 53DAA		Grain yield (t/ha)	
Nil		0.344	bcd	0.478	bc	1.06	b
Proprietary blend (Cu, Co, Mo, B)		0.305	d	0.443	c	0.97	b
Loveland Nutrisync D (Mo 0.9%, B 0.7%, P 1%, K 1%)	9 g Mo/ha, 7 g B/ha, 10 g P/ha, 10 g K/ha	0.374	bc	0.545	ab	0.98	b
Sodium Molybdate (39% Mo)	39 g Mo/ha	0.320	cd	0.478	bc	1.01	b
Borax (10.5% B)	10.5 g B/ha	0.339	bcd	0.483	bc	1.06	b
EDDHA Fe (4.8% Fe)	403 g Fe/ha	0.433	a	0.600	a	1.36	a
Copper Sulfate (25% Cu)	75 g Cu/ha	0.380	ab	0.540	ab	1.06	b
Pr(>F)		0.005		0.028		0.008	
LSD		0.054		0.09		0.18	

Later in the season plots treated with EDDHA Fe were observed to be maturing quicker (Figure 2) and this may be attributed to the higher plant biomass or an advancement in maturity due to the alleviation of Fe deficiency. Similar advances in maturity are often observed where other deficiencies have been rectified.

The NDVI/biomass response from the application of foliar EDDHA Fe translated into an increase in lentil grain yield of 28% compared to the untreated. This treatment produced the highest yield at 1.36 t/ha compared to the remaining treatments which averaged 1.02 t/ha. These results show there was a response to foliar Fe on this highly calcareous soil at Marion Bay. There was no grain yield response to the remaining micronutrients (Cu, Mo and B) suggesting they were in adequate supply in the soil.



Figure 2. The EDDHA Fe plot (right) maturing quicker compared to the remaining treatments.

Trial 7. Lentil varieties and herbicide tolerance

Key messages

- The trial was affected by salt spray from severe winds early in the growing season which impacted the accuracy of herbicide damage scores.
- PBA Highland XT was severely affected by diuron treatments, although this was not reflected in the scores. Other herbicides applied to PBA Highland XT were less damaging.
- In general, the metribuzin treatments trialled to GIA Metro provided high levels of control for scarlet pimpernel, cape weed, milk thistle and canola.
- The highest lentil yields were observed in GIA Metro for any of the metribuzin treatments averaging 0.86 t/ha.
- The highest yielding PBA Highland XT treatments were diflufenican 200 ml/ha POST at 0.72 t/ha and Intercept 600 ml/ha POST at 0.65 t/ha. All other herbicide treatments were not different to the nil at 0.4 t/ha.
- PBA Highland XT was also impacted by iron deficiency however, GIA Metro did not appear to be affected, suggesting some genetic variation between the two varieties.

Why do the trial?

To assess a range of herbicides for crop tolerance and weed control in lentil varieties with novel herbicide traits.

How was it done?

Stenhouse Bay	Annual 328 mm	Sowing date:	3 June 2024
rainfall:	Growing season 254 mm		
Varieties:	PBA Highland and GIA Metro at 120 plants/m ²	Seeding	MnSO ₄ 12 kg/ha,
		fertiliser:	MoP 35 kg/ha, MAP Zn2% 120 kg/ha

The trial was a randomised complete block design consisting of three replicates and twelve herbicide treatments (Table 1). All IBS herbicides applications were applied immediately prior to sowing on the 3 June. Post applications of diflufenican were applied on 4 July. Post applications of metribuzin and Intercept were both applied on 31 July.

Measurements in season included leaf bleaching and stunting (21 June), leaf necrosis (31 July) and Greenseeker NDVI (22 August and 10 September). Weed counts were conducted at harvest on 20 November. All plots were harvested for grain yield.

Results and Discussion:

Herbicide tolerance and crop safety

Early assessments showed no or minor crop damage from the herbicide treatments. There was no visible crop bleaching in any lentil plots on June 21. Crop stunting scores ranged from 7 to 9, with the majority of plots achieving 9 (data not shown), indicating strong crop establishment across treatments.

By late July, some variation in leaf necrosis was noted in the trial (Table 1). Overall, GIA Metro showed fewer symptoms of leaf damage compared to PBA Highland XT. However, it was evident that strong winds had resulted in salt spray (from the nearby coast) and this caused significant leaf necrosis, masking the herbicide damage. This was particularly the case for PBA Highland XT with less necrosis recorded in the untreated GIA Metro compared to PBA Highland XT. Other visual observations that were consistent with salt damage, was more damage on the crop rows closest to the sea and on the seaward side of the lentil plants. Field notes from the time indicated that the diuron treatments in PBA Highland XT were causing significant damage and reduced vigour which is not reflected in the necrosis scores or NDVI data due to the apparent salinity damage. There was no damage noted in GIA Metro from the application of metribuzin at any time.

Where herbicides had been applied there was a reduction in NDVI for all herbicide treatments (Table 1) when compared to the nil for each variety. This is a result of reduced weed biomass within the plots and not a reflection of the herbicide affects as demonstrated in Figure 1.

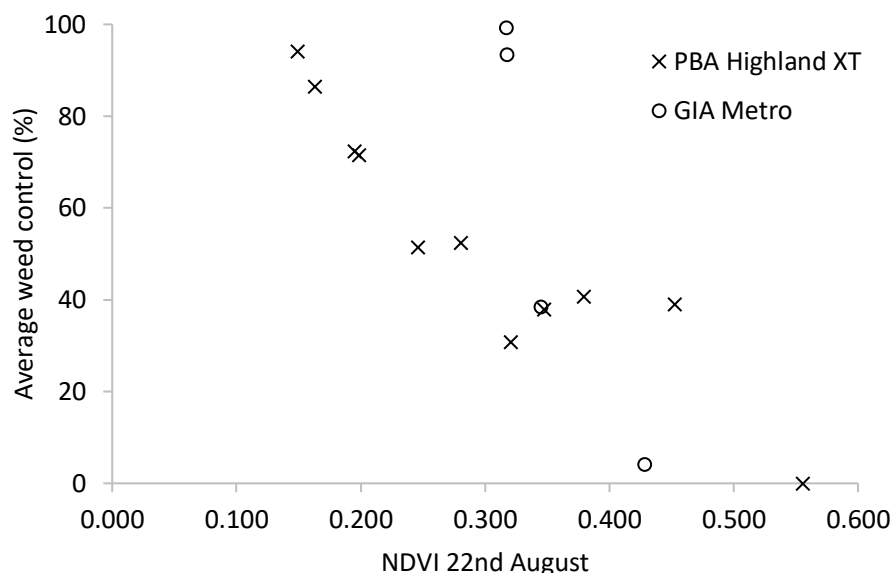


Figure 1. GreenSeeker NDVI and average weed control for PBA Highland XT and GIA Metro across a range of herbicide treatments at Marion Bay, 2024.

For PBA Highland XT lentil the herbicide treatments with the smallest reduction in biomass (NDVI) were Reflex 500 mL/ha IBS and Intercept 600 mL/ha POST (Table 1). For example, the nil had an NDVI of 0.556 in September compared to these herbicides which ranged from 0.379 to 0.452. Diuron and diflufenican applied on their own reduced NDVI further. The lowest NDVI (<0.200) was measured in treatments which contained diuron in combination with diflufenican, Intercept and/or Reflex.

For GIA Metro the safest application of metribuzin was 380 g/ha PSPE. The metribuzin 380 g/ha POST was not consistent in terms of performance compared to PSPE (either the same or lower).

Weed control

There were a range of herbicide treatments applied to PBA Highland XT which provided high levels of weed control (Table 2). The level of control for scarlet pimpernel ranged from 72 – 100% for all herbicides. Treatments 7 – 9 (combinations of diuron, diflufenican, Reflex and Intercept) provided the highest level of control (>93%). Similarly, these treatments also provided high levels of cape weed control (>95%) compared to the nil.

The background medic population was low (3 plant/m²) and there were no significant differences in weed control for any herbicide applied to PBA Highland XT due to site variation.

Diflufenican 200 ml/ha applied alone or in combination with other herbicides provided the highest level of milk thistle and canola control in PBA Highland XT (Table 2).

In general, all the metribuzin treatments trialled on GIA Metro provided high levels of control for scarlet pimpernel, cape weed, milk thistle and canola (Table 2). The only exception was metribuzin 750 applied PSPE at 380 g/ha resulted in poorer control (35%) of milk thistle compared to the POST application. As above the background medic population was low and there were no significant differences in weed control for GIA Metro.

Grain yield

The highest lentil yields were observed in GIA Metro for any of the metribuzin treatments averaging 0.86 t/ha (Table 2). This was a 61% increase in grain yield compared to the GIA Metro nil at 0.53 t/ha.

The highest yielding PBA Highland XT treatments were diflufenican 200 ml/ha POST at 0.72 t/ha and Intercept 600 ml/ha POST at 0.64 t/ha (Table 2). All other herbicide treatments were not different to the nil at 0.4 t/ha. There was one herbicide treatment to yield less than the nil at 0.17 t/ha which was Reflex + Diuron IBS fb diflufenican POST fb Intercept POST. This treatment achieved strong weed control, but the herbicide damage was severe, resulting in greater yield loss than in the less effective treatments.

Table 1. Leaf necrosis and Greenseeker NDVI for herbicide treatments in the lentil crop tolerance and weed control trial at Marion Bay, 2024.

Treatment	Variety	Herbicide	Leaf Necrosis (0-10) 31 July	NDVI 22 Aug	NDVI 10 Sept
1	PBA Highland XT	Nil	3.7 cd	0.309 c	0.556 b
2		Diuron900 500 g/ha (IBS)	3.8 cd	0.215 fg	0.320 fg
3		Reflex 500 mL/ha (IBS)	4 cd	0.263 d	0.452 cd
4		Diflufenican500 200 mL/ha (POST)	4.3 cd	0.222 f	0.280 gh
5		Intercept 600 mL/ha (POST)	3.7 cd	0.253 de	0.379 def
6		Diuron900 500 g/ha (IBS) fb Intercept 600 mL/ha (POST)	4.3 cd	0.177 hi	0.195 ij
7		Diuron900 500 g/ha (IBS) fb Diflufenican 200 mL/ha fb Intercept 600 mL/ha (POST)	5.0 d	0.166 hi	0.163 j
8		Reflex 500 mL/ha (IBS) + Diuron900 500 g/ha (IBS) fb Intercept 600 mL/ha (POST)	4.0 cd	0.188 gh	0.199 ij
9		Reflex 500 mL/ha (IBS) + Diuron900 500 g/ha (IBS) fb Diflufenican 200 mL/ha fb Intercept 600 mL/ha (POST)	5.0 d	0.155 i	0.149 j
11	GIA Metro	Nil	1.8 a	0.428 a	0.677 a
11		Metribuzin750 @ 380 g/ha (PSPE)	2.0 ab	0.345 b	0.496 bc
12		Metribuzin750 380 g/ha (POST)	1.3 a	0.318 bc	0.399 de
Pr(>F)			<0.001	<0.001	<0.001
LSD			1.49	0.028	0.073

Table 2. Weed control and grain yield in the lentil crop tolerance and weed control trial at Marion Bay, 2024. Background weed populations in the nil were scarlet pimpernel 39 plant/m², cape weed 7.3 plants/m², medic 3 plants/m², milk thistle 5.8 plants/m² and canola 1.9 plants/m².

Trt	Variety	Herbicide	Scarlet Pimpernel	Cape weed	Medic	Milk thistle	Volunteer canola	Grain yield (t/ha)
				% control				
1	PBA Highland XT	Nil	0 ab	0 ab	0	0 a	0 a	0.40 efg
2		Diuron900 500 g/ha (IBS)	90 a-e	64 a-e	0	63 bcd	4 bc	0.35 fg
3		Reflex 500 mL/ha (IBS)	72 a	0 a	22	66 bcd	7 cd	0.44 ef
4		Diflufenican500 200 mL/ha (POST)	100 a-e	77 a-e	0	98 f	99 d	0.72 bc
5		Intercept 600 mL/ha (POST)	81 abc	9 abc	22	36 ab	0 d	0.65 cd
6		Diuron900 500 g/ha (IBS) fb Intercept 600 mL/ha (POST)	100 abcd	45 abcd	89	64 bcd	39 d	0.28 gh
7		Diuron900 500 g/ha (IBS) fb Diflufenican 200 mL/ha fb Intercept 600 mL/ha (POST)	93 e	100 e	33	93 ef	100 d	0.40 efg
8		Reflex 500 mL/ha (IBS) + Diuron900 500 g/ha (IBS) fb Intercept 600 mL/ha (POST)	100 de	95 de	44	78 cd	11 d	0.29 fgh
9		Reflex 500 mL/ha (IBS) + Diuron900 500 g/ha (IBS) fb Diflufenican 200 mL/ha fb Intercept 600 mL/ha (POST)	100 e	100 e	78	94 f	93 d	0.17 h
10	GIA Metro	Nil	0 a	0 a	0	25 ab	41 ab	0.53 de
11		Metribuzin750 @ 380 g/ha (PSPE)	60 cde	86 cde	0	35 abc	52 cd	0.82 ab
12		Metribuzin750 380 g/ha (POST)	100 de	95 de	78	91 f	100 d	0.89 a
Pr(>F)			0.008	0.008	ns	<0.001	0.044	<0.001

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