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Project Code	
Project Type	

FINAL REPORT 2019

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

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

PROJECT CODE	:	**MSF118**

PROJECT TITLE (10 words maximum)
Identifying nutrient requirements of lentils and chickpeas grown in Mallee sands

PROJECT DURATION

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

Project Start date	**8/5/18**					
Project End date	31/10/19					
SAGIT Funding Request	2019/20		2020/21	$	2021/22	$

PROJECT SUPERVISOR CONTACT DETAILS

The project supervisor is the person responsible for the overall project

Title:	**First Name:**	**Surname:**
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PROJECT REPORT

Provide clear description of the following:

Executive Summary (200 words maximum)

1. Overall nutrition appears to have only a minor role in increasing pulse production with observed increased in biomass less than 25%.
2. The recommendation to growers arising from this project is to maintain starter fertiliser levels on sandy soils and consider compound fertilisers with adequate levels of nitrogen and Sulphur.
3. The data from this project suggests that elaborate combinations of fertiliser inputs are not likely to result in significant improvement in pulse production on Mallee sandy soil types. However, it is recommended that monitoring for potential site-specific nutrient deficiencies through soil testing should be completed.
4. A negative effect of Zinc, Manganese and Copper trace elements applied as chelates was observed in both experiments. The reasons for this are currently unclear, however it is advisable that farmers place liquid trace elements below rather than with the seed if using on Mallee sandy soils.

Project Objectives

The greatest constraint limiting adoption and expansion of pulses in the Mallee is the deep sandy soil that can be found in almost every paddock, with deep sands making up 36% of the agricultural soils in SA (Unkovich, 2014).

The project aimed to determine what nutrients are limiting growth of lentils and chickpeas on deep sands and provide an analysis of the potential nutrient limitations so that growers can improve pulse production on sands through crop nutrition.

Overall Performance

The project achieved its objectives to determine the limitation of nutrients to lentil and chickpea production on SA Mallee sands. This was achieved by conducting two glasshouse trials that were designed by Dr Sean Mason and Michael Moodie and implemented by Michael Moodie and technical staff.

The first experiment followed a nutrient omission design where every nutrient that was highlighted as a potential limitation on deep sands was added apart from the nutrient that was to be tested. Unfortunately, it was quickly discovered that by adding several nutrients to soil types with little chemical buffering we generated a salt effect that suppressed both chickpea and lentil yields.

There is very limited data on EC limits of pulse crops but we were able generate relationships between EC values and decreases in pulse crop yield which as a side benefit to the industry supplies a data pool that currently isn't available but very important regarding fertiliser and pulse seed placements.

Due to the observations from experiment 1 and with consultation between project partners and SAGIT the design for experiment 2 was changed. Instead of response curves for important nutrients highlighted from experiment 1 it was the requirement to still identify pulse nutrient requirements on sandy soil types.

To minimize side effects from adding a cocktail of nutrients a nutrient addition design was put in place which worked more effectively. As a side experiment we also decided to test the effect of standard grower fertiliser practice by placing MAP near the pulse seed at two rates utilising wheat as a control.

Key Performance Indicators (KPI)		
KPI	***Achieved (Y/N)***	***If not achieved, please state reason.***
Collect soils and prepare glasshouse experiments	Yes	
Preform and harvest nutrient omission trial	Yes	
Collate results from trial 1	Yes	
Perform and harvest nutrient response trial	Yes	Methodology was altered as per progress report to undertake nutrient addition trial
Collate results from trial 2	Yes	
Progress report submitted to SAGIT	Yes	

Technical Information

In April 2018 (check) four represented sand dune soil types of the South Australian Mallee region were collected and characterised (Table 1). The cells highlighted represent soil characteristics and nutrition that might limit pulse production.

Table 1. Soil characteristics of the 4 Mallee soils collected for glasshouse experiments. Shaded cells are characteristics which may limit crop growth.

Soil analysis	Loxton	Lameroo	Karoonda	Allawoona
pH (water)	8.21	6.3	5.97	8.12
pH (CaCl2)	7.64	5.63	5.3	7.53
EC (dS/m)	0.11	0.039	0.078	0.053
Boron (mg/kg)	0.29	0.18	0.37	0.17
Exchangeable K (mg/kg)	129	65	105	61
Exchangeable Ca (mg/kg)	1200	290	240	491
Exchangeable Mg (mg/kg)	89	55	69	47
Exchangeable Na (mg/kg)	8	8	32.8	8
DTPA Cu (mg/kg)	0.08	0.12	0.31	0.08
DTPA Cu (mg/kg)	0.71	1.8	0.78	0.14
DTPA Cu (mg/kg)	2.7	2.4	2.9	1.1
DTPA Cu (mg/kg)	3.3	13	19	3
Nitrate N (mg/kg)	5.3	10	20	1.9
Ammonium (mg/kg)	1.5	2	4.3	1.3
Colwell K (mg/kg)	130	73	120	83
MCP S (mg/kg)	3.8	2.2	5.5	2
Organic Carbon (%)	0.32	0.25	0.57	0.14
Colwell P (mg/kg)	14	31	24	5
PBI	17	13	11	14
DGT P (ug/L)	135	347	292	29

The first trial used a nutrient omission approach where the full suite of target nutrients was applied (N, P, K, S, Zn, Mn, Cu, Mo) at optimal rates and each other treatment following eliminated one of the eight targeted nutrients. There was also a control where no nutrients were added. The trial implemented for Lentil and Chickpea grown in each of the four soils (Table 1).

The initial aim was to grow the pulses to the beginning of flowering, however from the early onset of the trial it became evident that the applied nutrients were having a negative effect on pulse establishment and growth. Consistently treatment 1 was visually the best yielding treatments which corresponded to the treatment that had not been manipulated with applied nutrition (Figure 1 and 2). This observation was surprising as the nutrient solutions applied was mixed throughout the soil and therefore no concentrated areas of nutrition was generated which would occur with banding application of fertiliser.

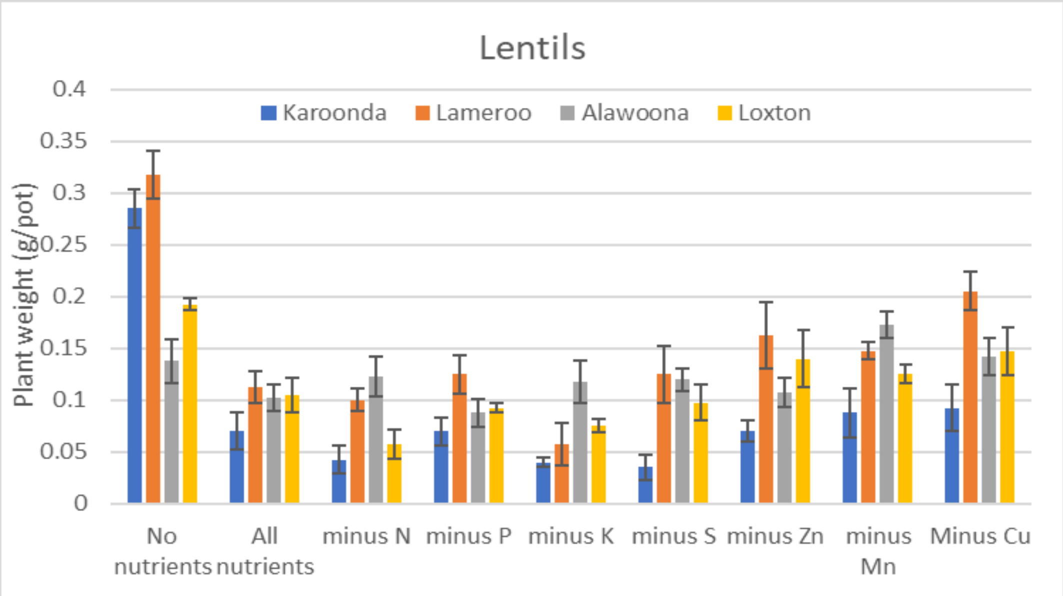

Figure 1: Lentil response to each nutrient when omitted from the trial.

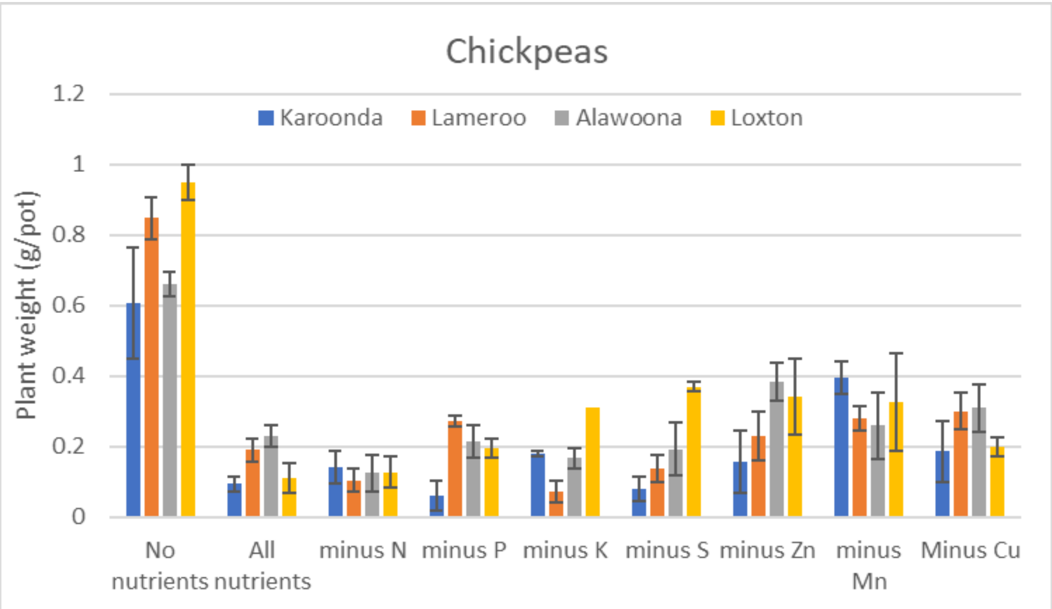

Figure 2: Chickpea response to each nutrient when omitted from the trial.

Analysis from this point forward focused on determining what caused the reduced pulse yields from applied nutrients. Pot soils were analysed for pH, EC and chloride concentrations in addition to the pH and EC levels of each nutrient solution prepared to deliver the required nutrient rate. The effect of delivering high salt solutions at these ratios was assessed by analysing selected treatments after harvest for various soil constraints. Treatments were selected based on their varying effects on crop growth which were as follows; No nutrients (no effect), all nutrients (greatest effect), Minus S (moderate effect), Minus Cu (overall least effect). The best relationship with pulse yield across the four soil locations was EC. There was little change in pH with the applied treatments and therefore this couldn't explain the poor yields from applied treatments.

A second experiment followed on from experiment one where nutrients were applied by themselves (nutrient addition) so no other influence of other products would occur. MAP was applied to all treatments at 40 kg/ha apart from the Nil. We also included a wheat as a control for the Nil, MAP and MAP x 2 treatments which are the typical treatments growers would apply on these soil types and crops.

Nutrient additions can improve pulse vegetative crop growth significantly in the appropriate circumstances with yield increases generally less than 25%. The main positive treatment was applying Nitrogen only (as Urea) which yielded significant increases in pulse biomass for 4 of the 8 combinations (soil x crop) (Table 2). Sulphur applications produced yield increases in 3 scenarios (Table 2).

Nutrient requirements generally match soil test results with Lameroo and Loxton both having relatively low starting N amounts (Table 1). The positive response of chickpeas in the Karoonda (Table 2) was unexpected as decent levels of N existed and the non-response of both crops to applied N for the Alawoona soil (Table 2) was unexpected given the very low N levels present (Table 1).

Positive responses to sulphur were expected for Lameroo and Loxton with low starting S levels (Table 1). Karoonda (positive response of Lentils on moderate S levels) and Alawoona (No response on low S levels) were again the exception (Table 2).

Both experiments (1 & 2) has shown that chickpeas and lentils are very sensitive to micronutrient applications in chelate form when placed near the seed. Copper, Manganese and Zinc applied treatments caused a significant yield reduction in 5, 7 and 5 scenarios (soil x crop) respectively (Table 2).

The sub experiment which assessed the impact of applying MAP at 40 and 80 kg/ha close to pulse seeds showed there was no significant impact on pulse growth compared to the nil treatment (Table 3). This is the typical form and application rates that growers are using in their fertiliser programs for pulses. Positive growth responses to MAP did occur for both pulse crops in the Loxton soil (but not wheat) and in the Lameroo soil (wheat only) which could be mainly attributed to the application of N as seen with the main experiment.

Table 2. Statistical summary of the significant ($p < 0.05$) negative or positive impact of nutrient additions to Chickpea and Lentils for the four soils used compared to the nil treatment.

		Nutrient impact compared to Control							
Soil	Crop	Copper	Manganese	MAP	MAPx2	Molybdenum	Nitrogen	Potassium	Sulphur	Zinc
Alawoona	Chickpea	Negative	Negative			Negative			Negative	Negative
	Lentils		Negative						Negative	
Karoonda	Chickpea	Negative	Negative				Positive			Negative
	Lentils	Negative	Negative	Positive					Positive	Negative
Lameroo	Chickpea	Negative	Negative				Positive		Positive	Negative
	Lentils	Negative	Negative			Negative	Positive	Negative		Negative
Loxton	Chickpea				Positive		Positive	Positive	Positive	Positive
	Lentils		Negative		Positive					

Table 3. Statistical summary of significant differences ($p < 0.05$) of MAP treatments compared to the control for Chickpea, Lentil and Wheat in the four soils used.

Soil	Crop	MAP	MAP x 2
Alawoona	Chickpea	NS	
	Lentil		
	Wheat		
Karoonda	Chickpea	NS	
	Lentil		
	Wheat		
Lameroo	Chickpea	NS	NS
	Lentil	NS	NS
	Wheat	Positive	Positive
Loxton	Chickpea	NS	Positive
	Lentil	NS	Positive
	Wheat	NS	NS

Conclusions Reached &/or Discoveries Made

Our hypothesis was that the addition of nutrients may have a significant impact on lentil and chickpea growth on Mallee sandy soil types, however the data from this project would suggest that overall nutrition appears to have only a minor role in increasing pulse production with observed increased in biomass less than 25%.

The main nutrients to improve yields were the addition of nitrogen and sulfur. The recommendation to growers arising from this project is to maintain starter fertilizer levels on sandy soils and consider compound fertilizers with adequate levels of nitrogen and Sulphur. The data from this project suggests that elaborate combinations of fertilizer inputs is not likely to result in significantly improve pulse production on Mallee sandy soil types. However, it is recommended that monitoring for potential site-specific nutrient deficiencies through soil testing should be completed.

Experiment 1 showed that the two pulse crops used in this project are highly sensitive to treatments placed near the seed that causes an increase in EC values of the soil. The soils selected in this project have high sand contents and therefore cannot buffer any EC changes with the introduction chemical fertilisers. Data from this project show that the critical ECse values for chickpeas appear to be around 0.6 ds/m and 0.85 ds/m for Lentils. Corresponding critical ECse values for wheat are 6 ds/m which puts lentils and chickpeas in the very sensitive class.

A negative effect of Zinc, Manganese and Copper trace elements applied as chelates was observed in both experiments. The reasons for this are currently unclear, however it is advisable that farmers place liquid trace elements below rather than with the seed if using on Mallee sandy soils.

Intellectual Property

NA

Application / Communication of Results

This project was a lab based experiment therefore farmer extension activities have not been factored into the project. The results will be developed into an MSF research compendium that will be published in February 2020 and made freely available on the MSF website.

POSSIBLE FUTURE WORK

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

The positive benefit in terms of Pulse growth of applying N (as Urea) on low N soils could be investigated. There is a common message that keeping soil N levels low will drive pulse production, nodulation and N fixation but do these crops need a kick start of N to make the whole system more efficient?

Other research questions include: what is the tipping point of applying N in sandy soils with pulse growth and nodulation, how much N is required and how much N causes the system to fall apart in terms of nodulation and N fixation?

The negative response to Zinc, Manganese and Copper Chelate in both experiments is perplexing and warrants further investigation. Liquid injection of trace elements is becoming more common practice as farmers add liquid injection capabilities to their seeding systems and could provide a solution.

Identifying nutrient requirements of Lentil and Chickpea crops when grown on Mallee sands

Reporting on Experiment 2 – Nutrient addition

Activities and Methodologies:

In order to maximise funding dollars, the project team plans undertake a one-year project to test pulse nutrient requirements in the glasshouse before moving into more elaborate and expensive nutrition response field trials (pending the outcome of the pot trials). It is proposed that the glasshouse work will be performed in two phases:

1) Nutrient omission trials assessing the response of lentil and chickpea +/- Potassium, Sulphur, Phosphorus, Nitrogen, Zinc, Copper, Manganese and Molybdenum using four sandy soils from the SA Mallee where pulse crops have performed poorly in the past and;
2) Nutrient response trials where optimal rates of each nutrient are assessed for selected treatments identified from the outcome of the first trial.

With the results from experiment 1 where significant negative effects of fertiliser treatments were found the design of experiment 2 changed after discussions within the project team and the inclusion of SAGIT.

Experiment 2 followed on from experiment 1 but nutrients were applied by themselves so no other influence of other products would occur. MAP was applied to all treatments at 40 kg/ha apart from the Nil. We also included a wheat as a control for the Nil, MAP and MAP x 2 treatments which are the typical treatments growers would apply on these soil types and crops.

Progress against KPI

Soils from experiment 1 were used for experiment 2

Treatment design:

Soil = 4 (Alawoona, Karoonda, Lameroo, Loxton)

Treatments = 10 (Copper (5), Manganese (5), MAP (40 = 8.8P), MAP x 2 (80 = 17.6P), Molybdenum (5), Nitrogen (30), Potassium (20), Sulphur (10), Zinc (5). (Numbers in brackets represent application rates as kg/ha).

Replicates = 3

Results: Presented per soil type

Alawoona

Table 1: Alawoona soil test results (Shading = potential nutrient limitations

pH	EC	OC	B	Exch K	DTPA Cu	DTPA Zn	DTPA Mn	Nitrate N	Amm N	Col K	MCPS	Col P	PBI	DGT P
CaCl2	dS/m	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg		ug/L
7.53	0.053	0.14	0.17	61	0.08	0.14	1.1	1.9	1.3	83	2	5	14	29

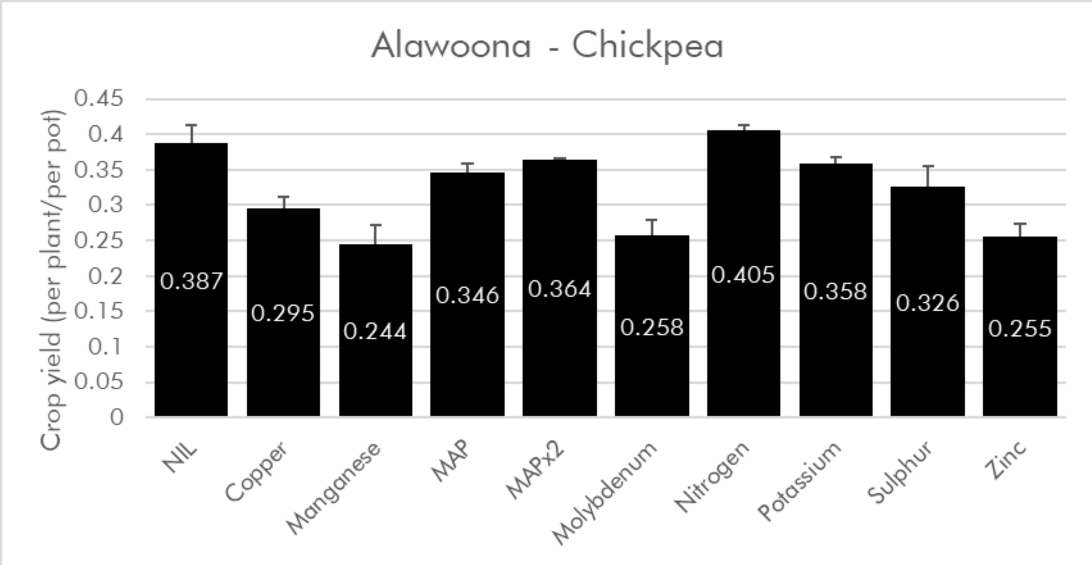

Figure 1: Mean chickpea weights (per plant) for each of the 10 treatments applied in the Alawoona soil. Error bars represent standard errors from three replicates. Please see statistical table for significant differences.

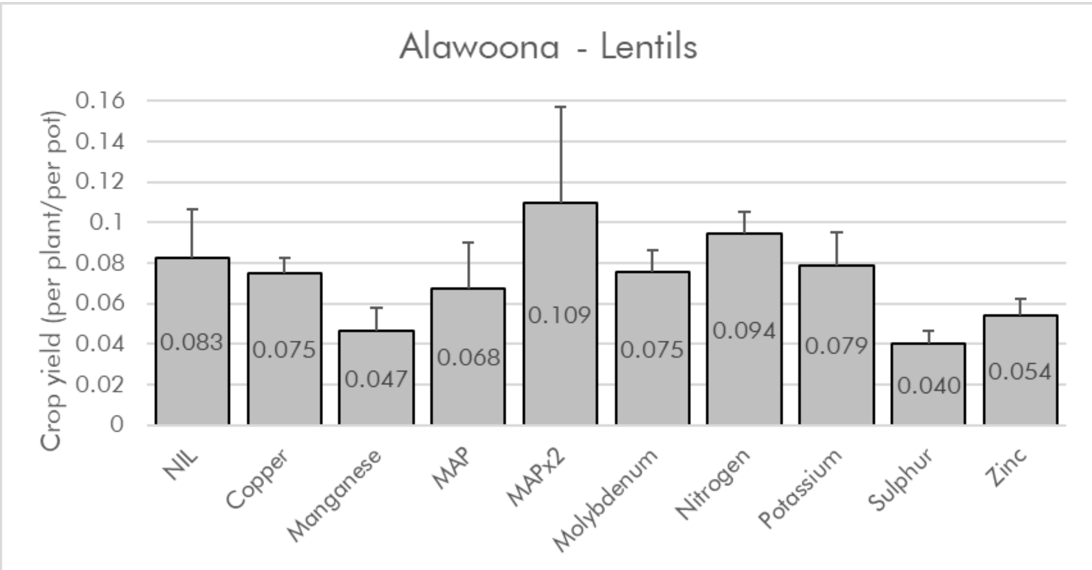

Figure 2: Mean lentil weights (per plant) for each of the 10 treatments applied in the Alawoona soil. Error bars represent standard errors from three replicates. Please see statistical table for significant differences.

Table 2: Statistical output for two-way ANOVA analysis for the Alawoona soil

Source of variation	P value	LSD
Crop	< 0.001	0.0178
Treatment	< 0.001	0.0399
Crop.Treatment	0.01	0.0563

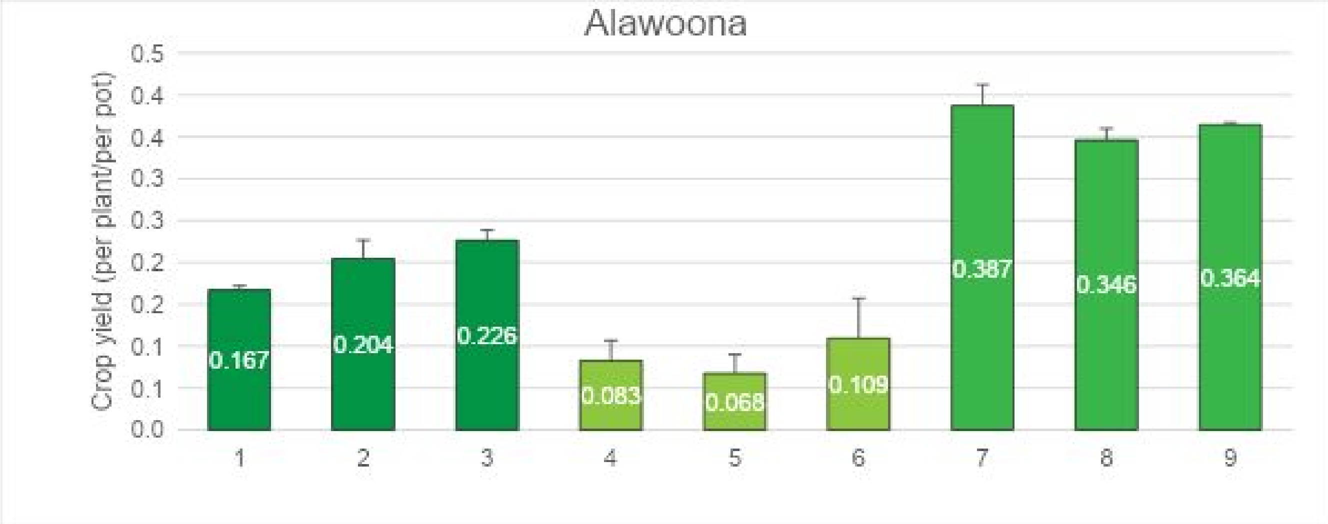

Figure 3: Mean crop weights for Chickpea, Lentil and Wheat with increasing MAP treatments in the Alawoona soil. Error bars represent standard errors from three replicates. Please see statistical table for significant differences.

Table 3: Statistical output for two-way ANOVA analysis for the MAP treatments in the Alawoona soil

Source of variation	P value	LSD
Crop	<.001	0.0399
Treatment	0.345	NS
Crop.Treatment	0.402	NS

Karoonda

Table 4: Karoonda Soil test results (Shading = potential nutrient limitations)

pH	EC	OC	B	Exch K	DTPA Cu	DTPA Zn	DTPA Mn	Nitrate N	Amm N	Col K	MCP S	Col P	PBI	DGT P
CaCl2	dS/m	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg		ug/L
5.3	0.078	0.57	0.37	105	0.31	0.78	2.9	20	4.3	120	5.5	24	11	292

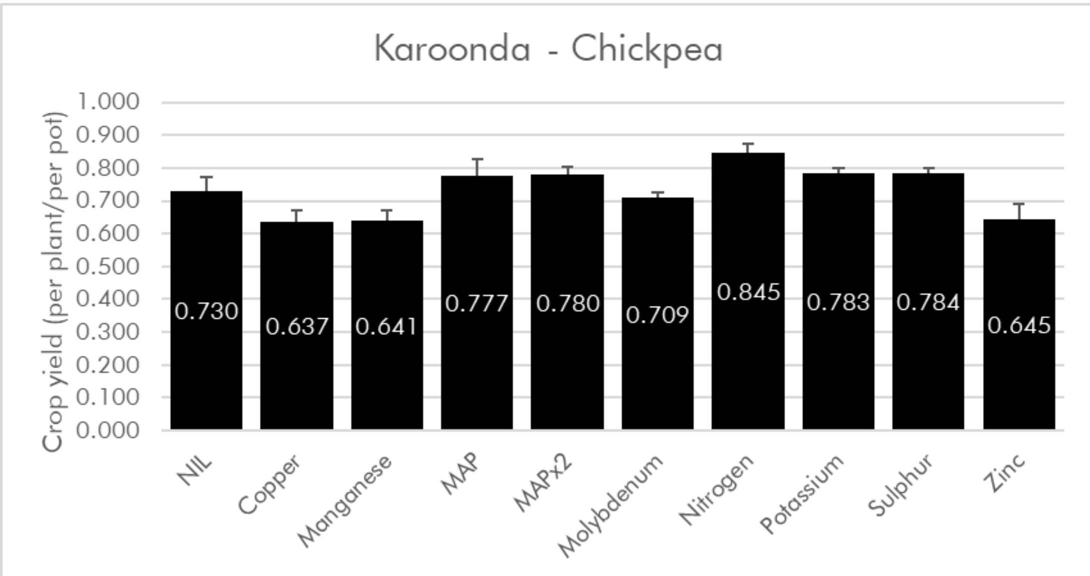

Figure 4: Mean chickpea weights (per plant) for each of the 10 treatments applied in the Karoonda soil. Error bars represent standard errors from three replicates. Please see statistical table for significant differences.

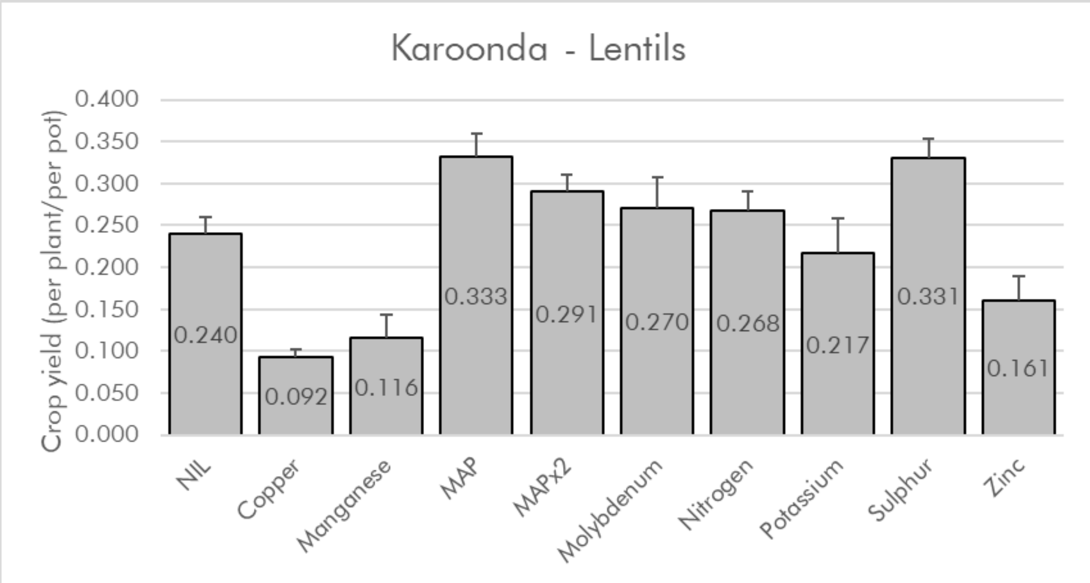

Figure 5: Mean lentil weights (per plant) for each of the 10 treatments applied in the Karoonda soil. Error bars represent standard errors from three replicates. Please see statistical table for significant differences.

Table 5: Statistical output for two-way ANOVA analysis for the Alawoona soil

Source of variation	P value	LSD
Crop	<.001	0.0274
Treatment	0.01	0.0613
Crop.Treatment	0.46	NS

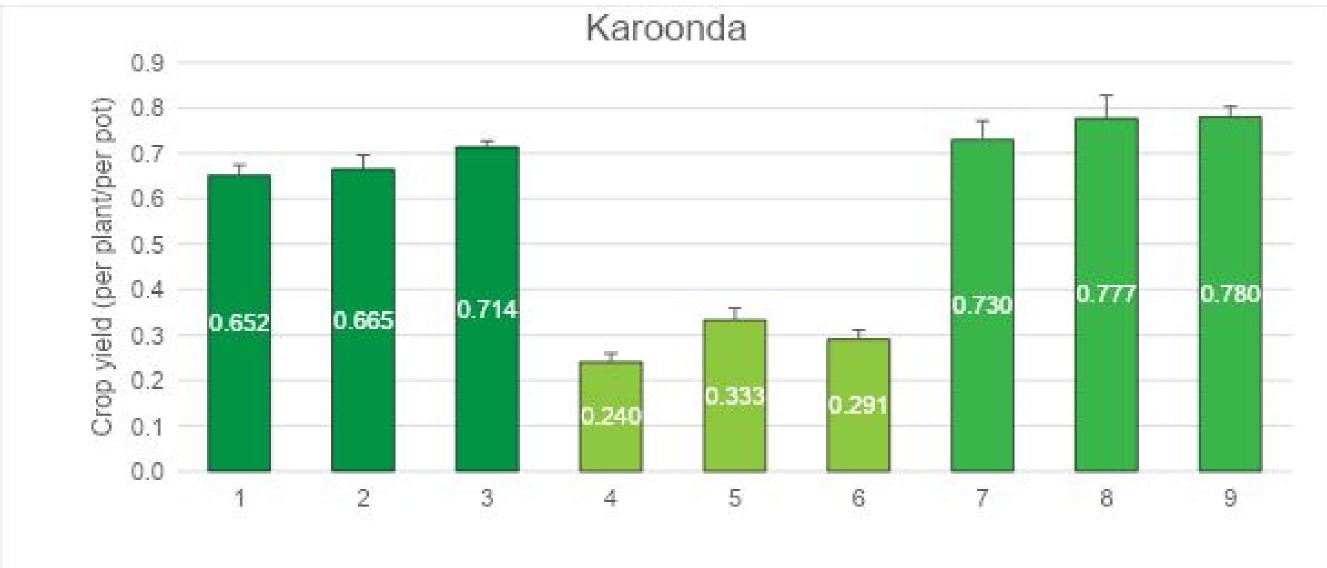

Figure 6: Mean crop weights for Chickpea, Lentil and Wheat with increasing MAP treatments in the Karoonda soil. Error bars represent standard errors from three replicates. Please see statistical table for significant differences.

Table 6: Statistical output for two-way ANOVA analysis for the MAP treatments in the Karoonda soil

Source of variation	P value	LSD
Crop	<.001	0.144
Treatment	0.358	NS
Crop.Treatment	0.631	NS

Lameroo

Table 7: Lameroo Soil test results (Shading = potential nutrient limitations)

pH	EC	OC	B	Exch K	DTPA Cu	DTPA Zn	DTPA Mn	Nitrate N	Amm N	Col K	MCP S	Col P	PBI	DGT P
CaCl2	dS/m	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg		ug/L
5.63	0.039	0.25	0.18	65	0.12	1.8	2.4	10	2	73	2.2	31	13	347

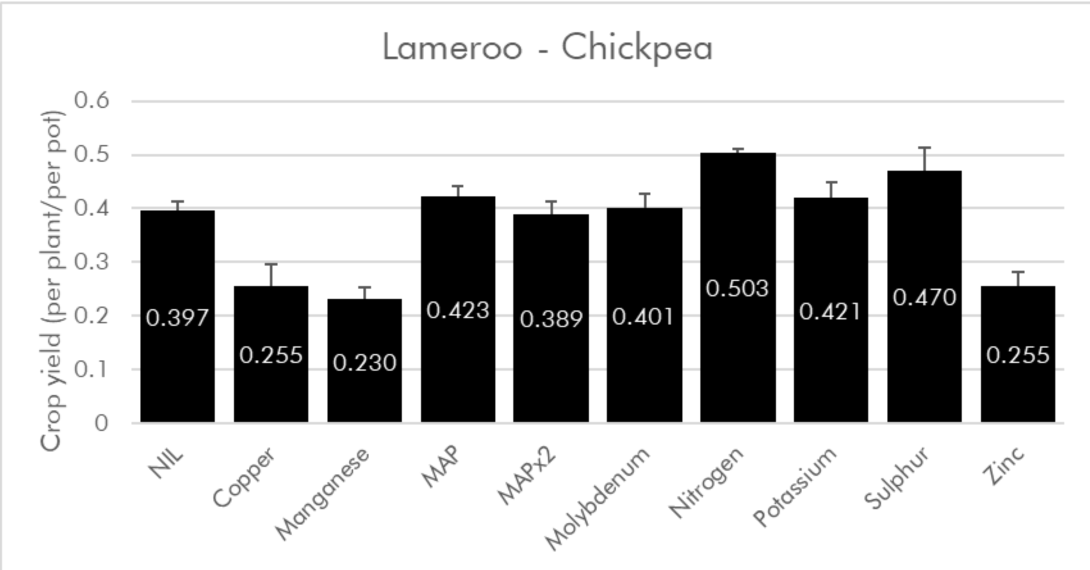

Figure 7: Mean chickpea weights (per plant) for each of the 10 treatments applied in the Lameroo soil. Error bars represent standard errors from three replicates. Please see statistical table for significant differences.

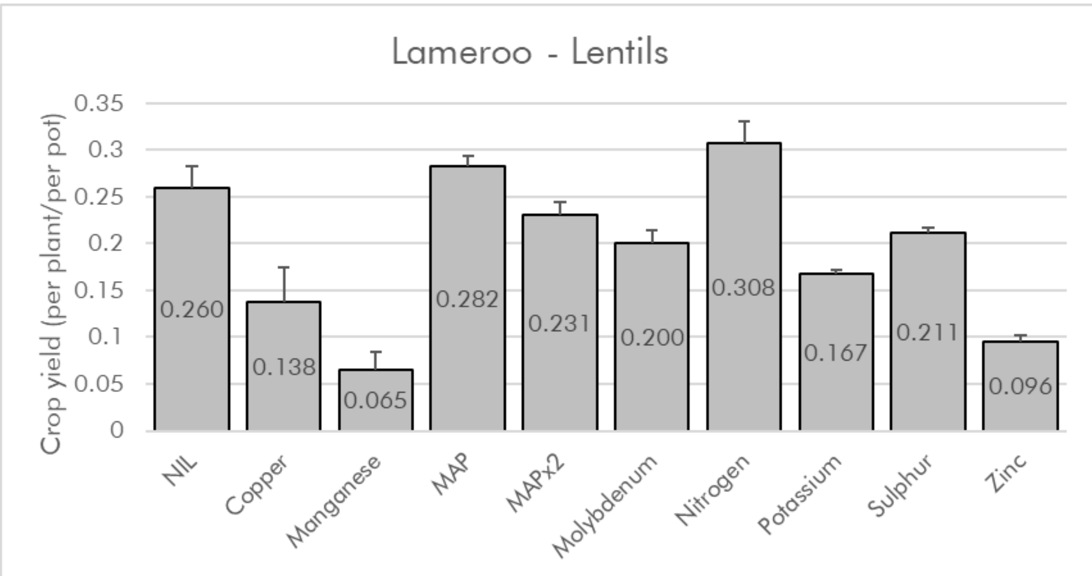

Figure 8: Mean lentil weights (per plant) for each of the 10 treatments applied in the Lameroo soil. Error bars represent standard errors from three replicates. Please see statistical table for significant differences.

Table 8: Statistical output for two-way ANOVA analysis for the Lameroo soil

Source of variation	P value	LSD
Crop	<.001	0.020
Treatment	<.001	0.046
Crop.Treatment	0.039	0.065

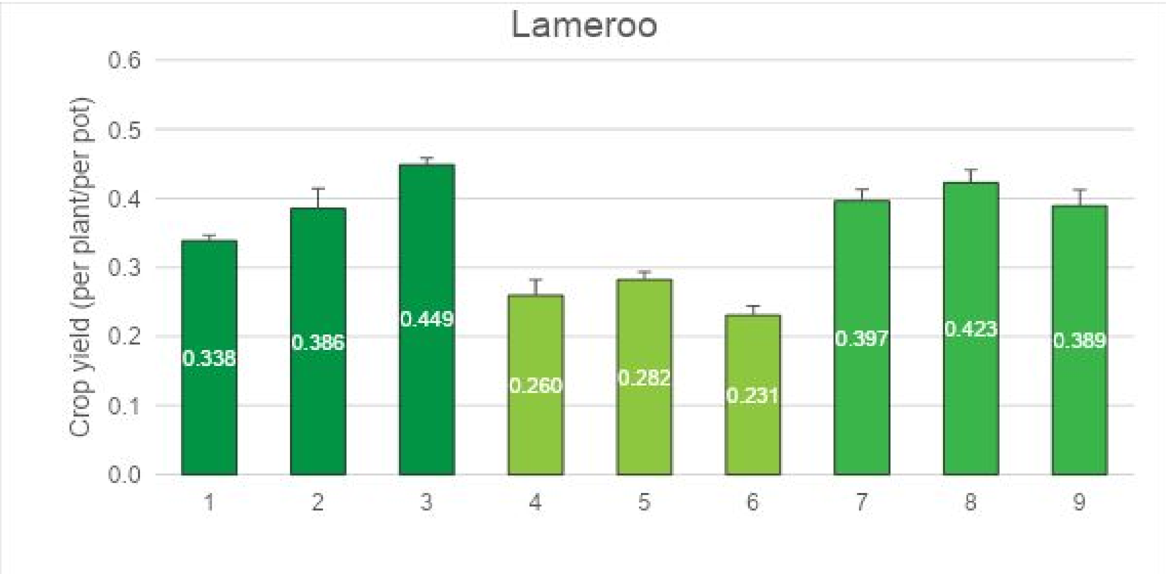

Figure 9: Mean crop weights for Chickpea, Lentil and Wheat with increasing MAP treatments in the Lameroo soil. Error bars represent standard errors from three replicates. Please see statistical table for significant differences.

Table 9: Statistical output for two-way ANOVA analysis for the MAP treatments in the Lameroo soil

Source of variation	P value	LSD
Crop	<.001	0.449
Treatment	0.105	NS
Crop.Treatment	0.008	0.339

Loxton

Table 10: Loxton Soil test results (Shading = potential nutrient limitations)

pH	EC	OC	B	Exch K	DTPA Cu	DTPA Zn	DTPA Mn	Nitrate N	Amm N	Col K	MCP S	Col P	PB I	DGT P
CaCl 2	dS/ m	%	mg/k g	mg/k g	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/k g	mg/k g	mg/k g		ug/L

7.64	0.11	0.32	0.29	129	0.08	0.71	2.7	5.3	1.5	130	3.8	14	17	135

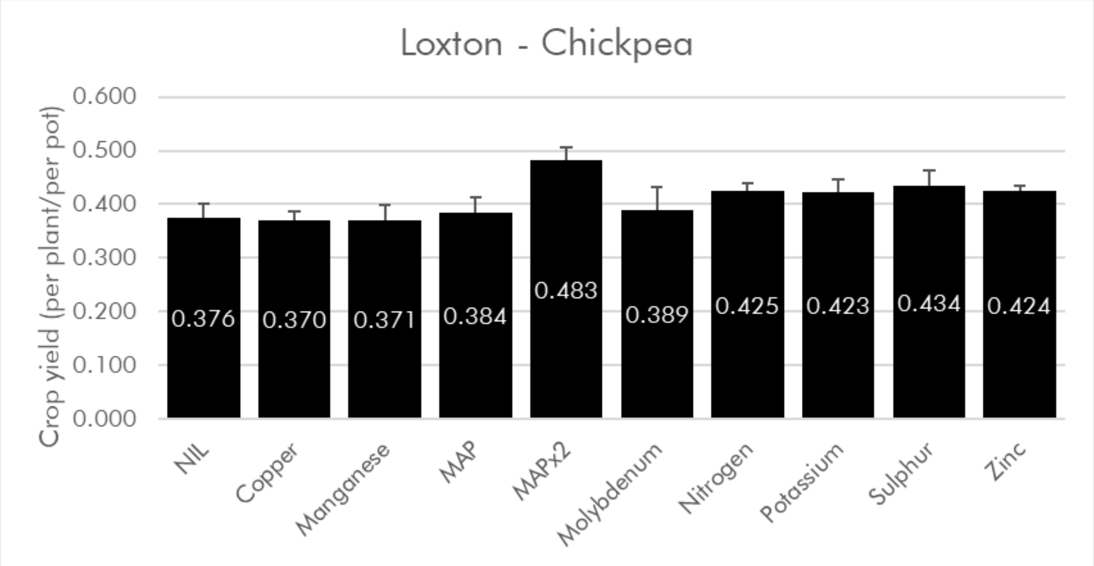

Figure 10: Mean chickpea weights (per plant) for each of the 10 treatments applied in the Loxton soil. Error bars represent standard errors from three replicates. Please see statistical table for significant differences.

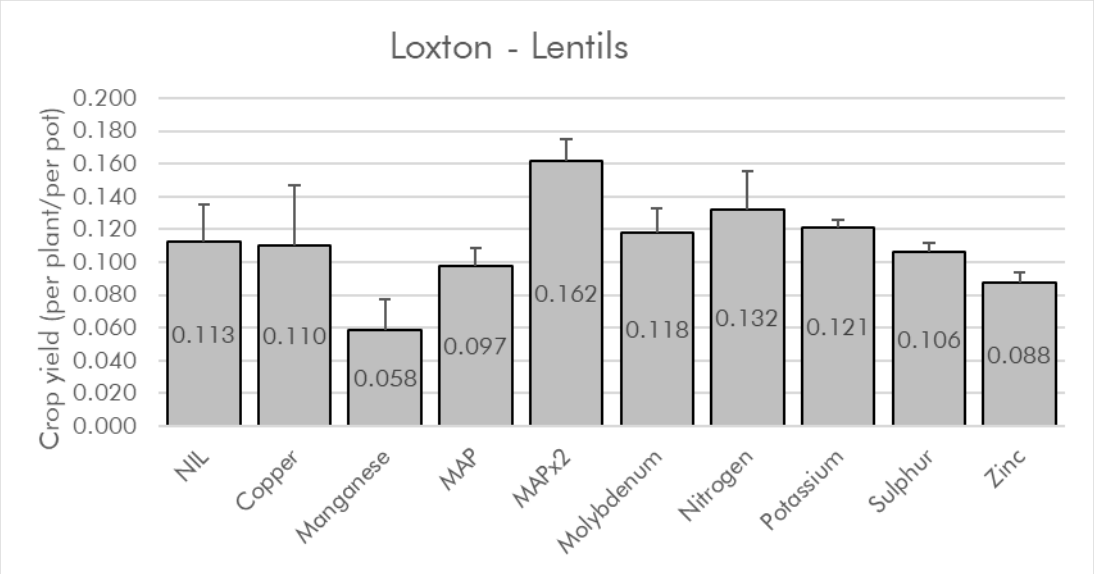

Figure 11: Mean lentil weights (per plant) for each of the 10 treatments applied in the Loxton soil. Error bars represent standard errors from three replicates. Please see statistical table for significant differences.

Table 11: Statistical output for two-way ANOVA analysis for the Lameroo soil

Source of variation	P value	LSD
Crop	<.001	0.0190
Treatment	0.001	0.0424
Crop.Treatment	0.585	NS

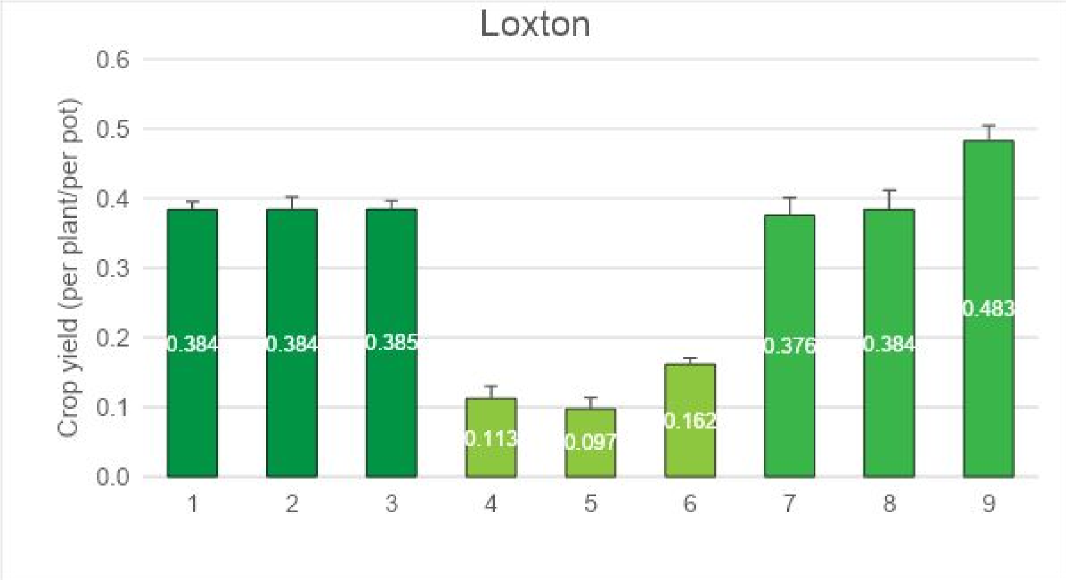

Figure 12: Mean crop weights for Chickpea, Lentil and Wheat with increasing MAP treatments in the Loxton soil. Error bars represent standard errors from three replicates. Please see statistical table for significant differences.

Table 12: Statistical output for two-way ANOVA analysis for the MAP treatments in the Loxton soil

Source of variation	P value	LSD
Crop	<.001	0.032
Treatment	0.003	0.032
Crop.Treatment	0.072	NS

Table 13: Statistical summary of the significant ($p < 0.05$) negative or positive impact of nutrient additions to Chickpea and Lentils for the four soils used compared to the nil treatment.

		Nutrient impact compared to Control								
Soil	Crop	Copper	Manganese	MAP	MAPx2	Molybdenum	Nitrogen	Potassium	Sulphur	Zinc
Alawoona	Chickpea	Negative	Negative			Negative			Negative	Negative
	Lentils		Negative						Negative	
Karoonda	Chickpea	Negative	Negative				Positive			Negative
	Lentils	Negative	Negative	Positive					Positive	Negative
Lameroo	Chickpea	Negative	Negative				Positive		Positive	Negative
	Lentils	Negative	Negative			Negative	Positive	Negative		Negative
Loxton	Chickpea				Positive		Positive	Positive	Positive	Positive
	Lentils		Negative		Positive					

Table 14: Statistical summary of significant differences ($p < 0.05$) of MAP treatments compared to the control for Chickpea, Lentil and Wheat in the four soils used.

Impact of MAP compared to Control			
Soil	**Crop**	**MAP**	**MAPx2**
Alawoona	Chickpea	NS	
	Lentils		
	Wheat		
Karoonda	Chickpea	NS	
	Lentils		
	Wheat		
Lameroo	Chickpea	NS	NS
	Lentils	NS	NS
	Wheat	Positive	Positive
Loxton	Chickpea		Positive
	Lentils		Positive
	Wheat		

Table 15: Overall statistical analysis of the Chickpea and Lentil dataset grouped by Soil, Crop and Treatment

Soil	Mean	P value	LSD
Alawoona	0.198	<0.001	0.015
Karoonda	0.483		
Lameroo	0.285		
Loxton	0.259		
Crop			
Chickpea	0.460	<0.001	0.01
Lentils	0.153		
Treatment			
Nil	0.323	<0.001	0.023
Copper	0.247		
Manganes	0.222		
MAP	0.339		
MAP x 2	0.351		
Molybdate	0.303		
Nitrogen	0.373		
Potassium	0.321		
Sulphur	0.338		
Zinc	0.247		

Table 16: Mean results and overall statistical analysis of the Chickpea and Lentil dataset without any grouping.

		Treatment									
Soil	Crop	Nil	Copper	Manganese	MAP	MAPx2	Molybdenum	Nitrogen	Potassium	Sulphur	Zinc
Alawoona	Chickpea	0.387	0.295	0.244	0.346	0.364	0.258	0.405	0.358	0.326	0.255
	Lentil	0.083	0.075	0.047	0.068	0.109	0.075	0.094	0.079	0.040	0.054
Karoonda	Chickpea	0.730	0.637	0.641	0.777	0.780	0.709	0.845	0.783	0.784	0.645
	Lentil	0.240	0.092	0.116	0.333	0.291	0.270	0.268	0.217	0.331	0.161
Lameroo	Chickpea	0.397	0.255	0.230	0.423	0.389	0.401	0.503	0.421	0.470	0.255
	Lentil	0.260	0.138	0.065	0.282	0.231	0.200	0.308	0.167	0.211	0.096
Loxton	Chickpea	0.376	0.370	0.371	0.384	0.483	0.389	0.425	0.423	0.434	0.424
	Lentil	0.113	0.110	0.058	0.097	0.162	0.118	0.132	0.121	0.106	0.088
						P value	LSD				
				Soil x Crop		<.001	0.021				
				Soil x Treatment		<.001	0.046				
				Crop x Treatment		0.011	0.033				
				Soil x Crop x Treatment		0.05	0.065				

Key Messages:

Nutrient additions can improve pulse vegetative crop growth significantly in the appropriate circumstances with yield increases generally less than 25%.

The main positive treatment was applying Nitrogen only (as Urea) which yielded significant increases in pulse biomass for 4 of the 8 combinations (soil x crop). Sulphur applications produced yield increases in 3 scenarios.

Nutrient requirements generally match soil test results with Lameroo and Loxton both having relatively low starting N amounts. The positive response of chickpeas in the Karoonda was unexpected as decent levels of N existed and the non-response of both crops to applied N for the Alawoona soil was unexpected given the very low N levels present.

Positive responses to sulphur were expected for Lameroo and Loxton with low starting S levels. Karoonda (positive response of Lentils on moderate S levels) and Alawoona (No response on low S levels) were again the exception.

Both experiments (1 & 2) has shown that Chickpeas and Lentils are very sensitive to micronutrient applications in chelate form when placed near the seed. Cooper, Manganese and Zinc applied treatments caused a significant yield reduction in 5, 7 and 5 scenarios (soil x crop) respectively.

The sub experiment which assessed the impact of applying MAP at 40 and 80 kg/ha close to pulse seeds showed there was no significant impact on pulse growth compared to the nil treatment. This is the typical form and application rates that growers are using in their fertiliser programs for pulses. Positive growth responses to MAP did occur for both pulse crops in the Loxton soil (but not wheat) and in the Lameroo soil (wheat only) which could be mainly attributed to the application of N as seen with the main experiment.

Experiment 1 showed that the two pulse crops used in this project are highly sensitive to treatments placed near the seed that causes an increase in EC values of the soil. The soils selected in this project have high sand contents and therefore cannot buffer any EC changes with the introduction chemical fertilisers. Caution should be used when deciding on nutrient strategies for pulse crops.

Future work:

The positive benefit in terms of Pulse growth of applying N (as Urea) on low N soils could be investigated. There is a common message that keeping soil N levels low will drive pulse production, nodulation and N fixation but do these crops need a kick start of N to make the whole system more efficient. What is the tipping point of applying N in these soils with pulse growth and nodulation, how much N is required and how much N causes the system to fall apart in terms of nodulation and N fixation?