Fertiliser type and placement effects on crop establishment, grain yield and water use efficiency on calcareous soils

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RESEARCH

Location
Piednippie - John Montgomerie
Rainfall
Av. Annual: 378 mm
Av. GSR: 225 mm
2018 Total: 233 mm
2018 GSR: 181 mm
Yield
Potential: 3.0 t/ha (Kirkegaard and Hunt 2012)
Actual: 1.96 t/ha
Paddock History
2017: Pasture
2016: Canola
2015: Pasture
Soil Type
Grey calcareous sand
Plot Size
1.6 m x 10 m 3 reps
Trial Design
Randomised complete block
Yield Limiting Factors
1% grain loss at each plot, late harvest

Location
Nunjikompita - Tim Howard
Rainfall
Av. Annual: 299 mm
Av. GSR: 225 mm
2018 Total: 168 mm
2018 GSR: 128 mm
Yield
Potential: 1.93 t/ha (Kirkegaard and Hunt 2012)
Actual: 1.1 t/ha
Paddock History
2017: Medic pasture
2016: Mace wheat
2015: Medic pasture
Soil Type
Red calcareous sand
Plot Size
1.6 m x 10 m 3 reps
Trial Design
Randomised complete block
Yield Limiting Factors
Poor germination at all trials

Key messages

- **Applying MAP with the seed at sowing resulted in a 25% increase in plant emergence compared to using DAP at Piednippie.**
- **Applying MAP at sowing resulted in higher grain yields and better water use efficiency (WUE) in plots which had high seeding rates at Nunjikompita.**
- **In combination with a high seeding rate, a blend of DAP and triple super phosphate (TSP) applied at sowing at Piednippie and Nunjikompita (plus urea) resulted in grain yields which were closer to the crop yield potential than the control.**

Why do the trial?

On the upper Eyre Peninsula (UEP), calcareous soils constitute a high proportion (more than 1 million hectares) of soils used for agricultural production (Bertrand *et al*. 2003). The website 'Yield Gap Australia' (http://yieldgapaustralia.com.au/maps/) identifies that the average grain yield on western Eyre Peninsula (WEP) and UEP is between 41 and 45% of the water limited yield potential (1.5 t/ha for WEP and 1.8 t/ha for UEP). Closing the grain yield gap for wheat on UEP presents a challenge to growers mostly due to nutrient deficiencies, particularly on calcareous soils (Holloway *et al*. 2001). The majority of landholders in the western and upper Eyre Peninsula currently use granular fertilisers, which require good soil moisture conditions to enable uptake of nutrients. Limitations of water availability during the growing season influences grower decisions regarding fertiliser applications, with associated impacts on crop profitability. Consequently, growers often apply lower rates of nutrients than are required to achieve the water limiting yield potential as a risk management strategy (Sadras and Roget 2004; Monjardino *et al*. 2013). A deeper understanding of the multiple factors influencing the efficacy of applied granular fertilisers such as fertiliser position in relation to seed, fertiliser composition and soil structure and moisture can be used to develop alternative strategies for increasing the effectiveness of fertiliser applications (McLaughlin *et al*. 2011). This study aimed to determine the impact of different fertiliser products and placement relative to the seed on crop emergence, crop WUE and grain yield.

How was it done?

Field trials were sown at two sites (Piednippie and Nunjikompita) on calcareous sandy loam soils. There were two trials at each site, designed to investigate the impacts of fertiliser products and fertiliser placement on wheat establishment and grain yield. The design for all trials was randomised complete block with three replicates.

The crop for all trials was Scepter wheat. National Variety Trials (NVT) protocols were followed for the management of weeds, pests and diseases at all sites. Trial management details are provided in Table 1. Treatments are listed in Table 2 and 3.

Table 1 Trial management details at Nunjikompita and Piednippie in 2018

Trial Details	Nunjikompita	Piednippie
Variety	Scepter wheat	
Sowing rate	60 kg/ha (Normal seeding rate) and 80 kg/ha (High seeding rate)	
Sowing date	8 May 2018	6 June 2018
Fertiliser	50 kg/ha Di Ammonium Phosphate (DAP), 50 kg/ha Mono Ammonium Phosphate (MAP), 50 kg/ha Urea, 100 kg/ha Triple Super Phosphate (TSP), 200 kg/ha Single Super Phosphate (SSP), 200 kg/ha Complete Nutrient Mix	
Herbicide	Boxer gold @ 1.5 L/ha, Avadex @ 1.5 L/ha, Roundup @ 2 L/ha, Hammer @ 1.6 L/ha, Broadstrike @ 800 ml/ha (5/6/18 Nunjikompita, 8/5/18 Piednippie)	
Harvest date	5 December 2018	7 December 2018

Table 2 Seeding fertiliser type and placement trial (Trial 1) list of treatments

Treatment #	Treatment Description
1	50 kg/ha DAP + with seed + Normal seeding rate (control)
2	50 kg/ha DAP + 3 cm below seed + Normal seeding rate (control)
3	50 kg/ha DAP + with seed + High seeding rate
4	50 kg/ha DAP + 3 cm below seed + High seeding rate
5	50 kg/ha MAP + with seed + Normal seeding rate (control)
6	50 kg/ha MAP + 3 cm below seed + Normal seeding rate (control)
7	50 kg/ha MAP + with seed + High seeding rate
8	50 kg/ha MAP + 3 cm below seed + High seeding rate.

Table 3 Fertiliser combinations and placement trial (Trial 2) list of treatments

Treatment #	Treatment Description
1	Normal seeding rate (control treatment)
2	High seeding rate
3	50 kg/ha Urea + Normal seeding rate
4	50 kg/ha Urea + High seeding rate
5	100 kg/ha TSP + Normal seeding rate
6	100 kg/ha TSP + High seeding rate
7	100 kg/ha TSP + 50 kg/ha Urea + Normal seeding rate
8	100 kg/ha TSP + 50 kg/ha Urea + High seeding rate
9	200 kg/ha SSP + Normal seeding rate
10	200 kg/ha SSP + High seeding rate
11	200 kg/ha complete nutrient mix (N, P, K, S, Ca, Cu, Zn, Mn, Mo, Fe) + Normal seeding rate

What happened?

Plant establishment was assessed at emergence for all trials. Plant counts were undertaken either side of a 50 cm ruler placed at random between two central crop rows at three locations within the plot. This data was extrapolated to plants per square metre.

At all trials, gravimetric soil moisture was measured on three random replicates within each block at sowing and per plot at maturity. Soil sampling at Piednippie was hindered by limestone below 30 cm, whilst 60 cm was the maximum sampling depth at Nunjikompita.

Water use efficiency (WUE) was benchmarked against water limiting yield potential.

At sowing, soil moisture content was significantly higher at Piednippie compared to Nunjikompita (Table 4). Soil nutrients and exchangeable cations were also higher at Piednippie (Table 5), particularly organic matter and exchangeable calcium (93% and 40% higher than Nunjikompita, respectively). The trials at Piednippie had significantly higher crop establishment and grain yield (Figures 1a and 1b) compared to Nunjikompita, which might have resulted in part from higher soil nutrient levels and rainfall (181 mm at Piednippie vs. 128 mm at Nunjikompita, Table 5).

Trial 1

Establishment

At both Piednippie and Nunjikompita, crop emergence was affected by seeding rate, type of fertiliser and fertiliser positioning at sowing (Figures 2a and 2b). Where DAP was positioned below the seed at Piednippie, there was a significant (25%) increase in emergence counts compared to DAP with the seed (Figure 2a). This might result from the hygroscopic nature and high salt index of DAP, whereby the granule attracts moisture away from nearby seeds. At Nunjikompita, the effect of MAP and DAP fertilisers on crop establishment was not significant (Figure 2a) and might result from the lower levels of soil moisture at this site compared to Piednippie (Table 4).

Where MAP was used in combination with high seeding rates, emergence was 16% higher at Piednippie compared to using DAP and 25% higher at Nunjikompita (Figure 2b). At normal seeding rate, emergence was not affected by the type of fertiliser at either site (Figure 2b, 60% and 44% establishment rate at Piednippie and Nunjikompita, respectively).

Grain yield and water use efficiency

At Piednippie, the negative effects of DAP on seed germination were independent from final grain yield. Plots with 50 kg/ha of DAP did not have significantly different grain yield and WUE to plots with 50 kg/ha of MAP (Figures 3a and 3b). The percentage of crop yield potential achieved also did not significantly differ between treatments (Figure 3c). Low fertiliser application rates and dry conditions might have contributed to poor WUE, resulting in poor grain yields compared to the water limited yield potential.

At Nunjikompita, grain yields reflected the trends observed at emergence (Figure 2). The MAP treatment had 6% more plants at emergence compared to the DAP treatment (Figure 3a). Grain yield was significantly higher (more than 8%) on the plots with high seeding rates compared to normal seeding rate (Figure 3a), and this trend was also reflected in significantly higher WUE (Figure 3b) and percentage of potential yield achieved (9%, Figure 3c). Fertiliser placement (with or below the seed) did not significantly affect grain yield and WUE at either trial, suggesting that plants may have been able to recover from the negative impact of fertiliser placement on crop emergence.

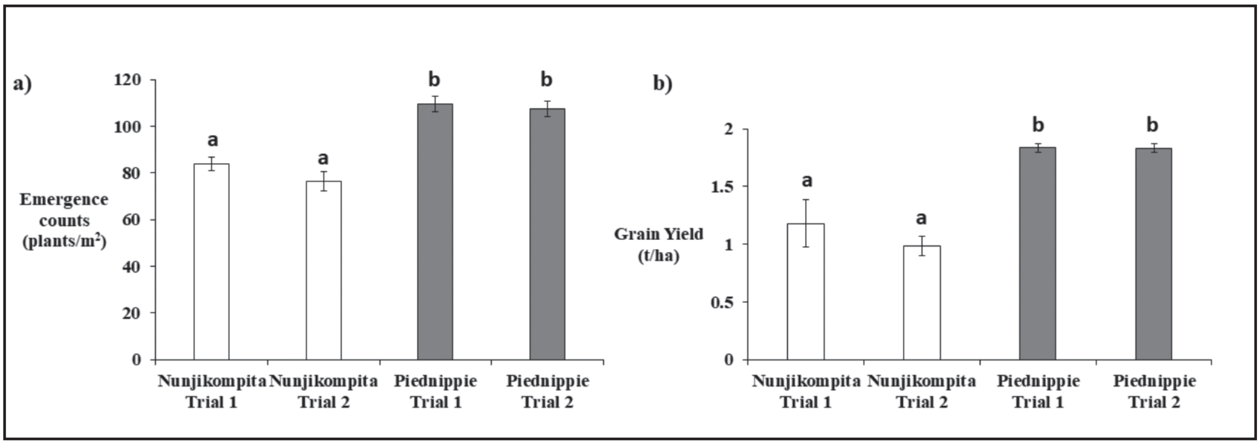

Figure 1 Differences in average emergence counts (a) and grain yield (b) between Nunjikompita and Piednippie at trials 1 and 2

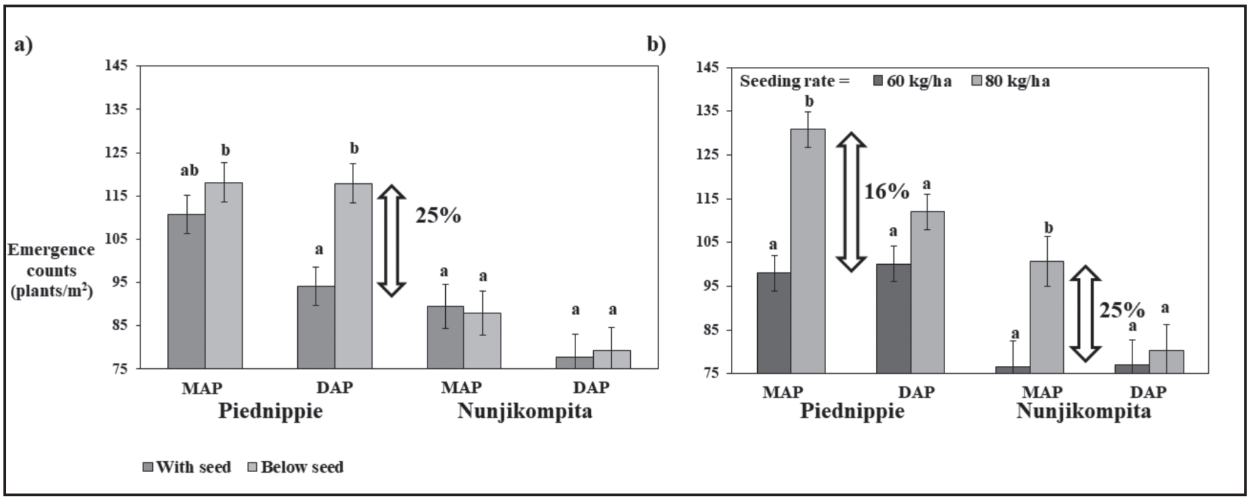

Figure 2 Effect of type of fertilisers (a-b), fertilisers positioning (a) seeding rate (b) on emergence counts at Piednippie and Nunjikompita Trial 1

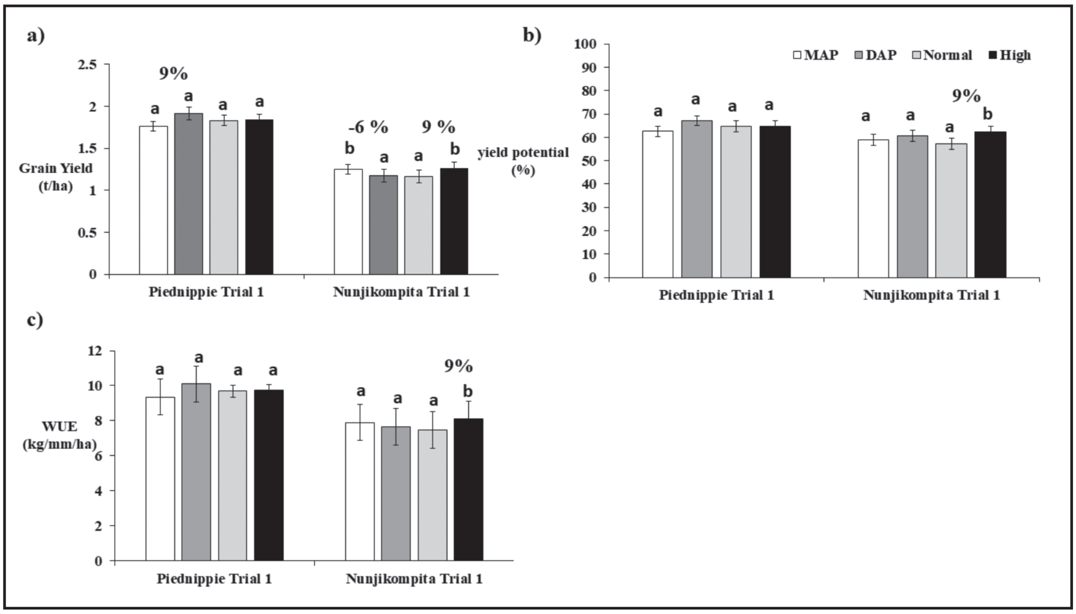

Figure 3a-c Effect of type of fertilisers, and seeding rate on grain yield (a), water use efficiency (WUE) and % yield potential achieved (c) at Piednippie and Nunjikompita Trial 1

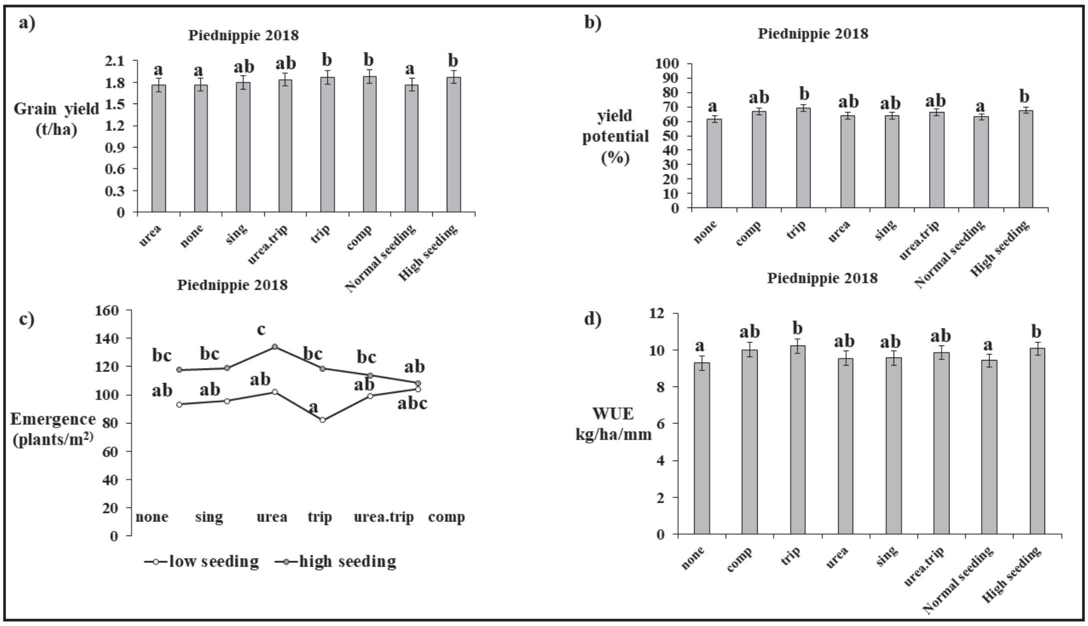

Figure 4a-d. Effect of type of fertilisers, and seeding rate on emergence counts (a), grain yield (b), % yield potential achieved (c) and water use efficiency (WUE, d) at Piednippie Trial 2

sing=single super phosphate, trip=Triple super phosphate, comp=Complete nutrient mix, urea.trip=urea plus triple superphosphate

Trial 2

Establishment

At Piednippie, high seeding rates, in combination with either urea (32%) or TSP (45%), had significantly higher plant numbers at emergence compared to normal seeding rates (Figure 4c). This might have resulted from the placement of fertilisers below the seed, minimising fertiliser "burn".

At Nunjikompita, urea and TSP had an inverse effect on crop establishment. Plant numbers on the Urea treatment were less than all other treatments, (Figure 5c), while TSP and the control had the highest plant numbers. The ammonia released by the urea fertiliser might have had a negative impact on germination.

Grain yield and water use efficiency

At Piednippie, the high plant numbers observed at crop emergence on the high seeding rate treatment carried through to higher grain yield and WUE, irrespective of fertiliser treatment (Figure 4ab-d). This might present an opportunity to increase crop ground cover, which in some years might result in higher grain yields and WUE. TSP and Complete Nutrient Mix gave the highest grain yield response (7% more than the control), of all fertiliser treatments. Higher WUE and percentage of potential grain yield achieved were also measured on these treatments (10% and 12% higher than the control respectively, Figure 4b-d). It is suggested that these products (TSP and Complete Nutrient Mix) might have had some benefit in providing nutrients to the crop in a plant available form.

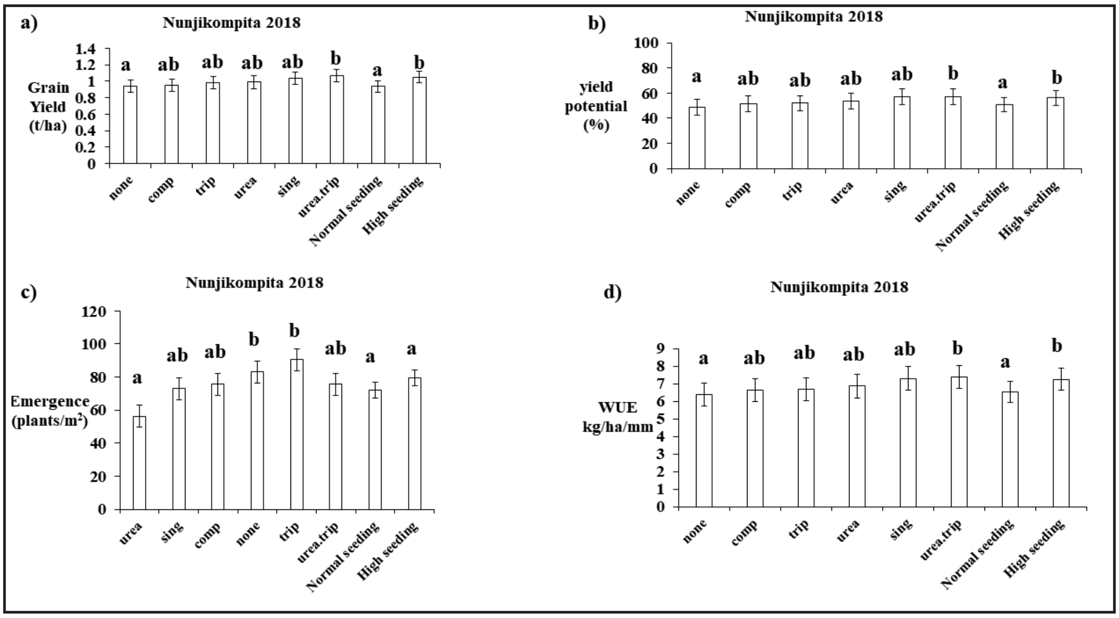

Figure 5a-d Effect of type of fertilisers, and seeding rate on emergence counts (a), grain yield (b), % yield potential achieved (c) and water use efficiency (WUE, d) at Nunjikompita Trial 2
sing=single super phosphate, trip=triple super phosphate, comp=complete nutrient mix, urea.trip=urea plus triple superphosphate

Table 4 Tukey's test of soil moisture at sowing in Piednippie and Nunjikompita at both Trials 1 and 2

Sites/Trial number	Soil moisture at sowing (mm)
Piednippie/1	29.6 a
Piednippie/2	28.0 a
Nunjikompita/1	22.7 b
Nunjikompita/2	22.5 b
Significant Sites difference	*P<0.05, P<0.01*
LSD (P=0.05)	*4.04*
Trials WU difference	*P value*
Nunjikompita/1 vs. Nunjikompita/2	*ns*
Piednippie/1 vs. Piednippie/2	*ns*
Nunjikompita/1 vs.Piednippie/1	**
Nunjikompita/1 vs. Piednippie/2	*
Nunjikompita/2 vs.Piednippie/1	**
Nunjikompita/2 vs.Piednippie/2	*

*The letters a and b indicate a significant difference of: *=P<0.05 and **=P<0.01. ns stands for not significant.*

Table 5 Comparison at sowing time of soil nutrient and exchangeable cations to 60 cm depth between Piednippie and Nunjikompita

Trials	Piednippie	Nunjikompita	Difference (%)
Nitrogen (kg/ha)	65.8	50.0	31.5
Phosphorous (kg/ha)	80.0	65.8	21.5
Sulphur (kg/ha)	23.5	17.6	33.5
Organic carbon (%)	2.4	1.3	92.9
Exchange calcium (%)	37.5	27.5	36.3
Exchange magnesium (%)	3.2	2.9	9.3
Exchange potassium (%)	2.3	1.7	35.9
Exchange sodium (%)	1.1	0.8	39.7

Despite no significant impact of seeding rate on crop emergence at Nunjikompita, high seeding rates gave significantly higher (12%) grain yields (compared to the control). This might have been due to the very low soil moisture levels at seeding, which could have delayed plant emergence (Figure 5a). Grain yields were also significantly higher than the control on the urea plus TSP treatment (14% compared to the control, Figure 5a). Consequently, these treatments also had significantly higher percentages of yield potential achieved and WUE (Figure 5b-d). Given the poor soil fertility of Nunjikompita at sowing the extra nitrogen and phosphorous supplied by the urea and TSP treatments might have been beneficial for canopy closure and increased grain yield and WUE (Table 5).

What does this mean?

The results of Trial 1 suggest that differences in soil moisture and soil fertility at sowing may have an effect on the efficacy of MAP or DAP starter fertilisers on calcareous sites. When lower rates (50 kg/ha) of fertiliser (either DAP or MAP) are applied at sowing, the benefits from applying one fertiliser product over the other on grain yield and WUE are marginal (between 62 and 67% grain yield potential achieved, with WUE increased by 0 to 9% only, Figure 3a and c).

The results from Trial 2 at both sites suggest that a high seeding rate is the best treatment for improving grain yield and WUE (Figure 4-5a-d). The differences in response to fertiliser application at Piednippie compared to Nunjikompita are perhaps attributed to differences in soil moisture and nutrient levels at sowing (Table 4-5, Figure 1). Apart from the seeding rate responses described, only the addition of TSP (at Piednippie) and TSP plus urea (at Nunjikompita) resulted in higher grain yield and WUE. It is possible that microsite differences in pH were created through the application of a combination of fertilisers resulting in improved phosphorous diffusion and availability. Low soil nutrient levels at Nunjikompita, might have resulted in improved grain yields and WUE from the fertiliser treatments compared to the control (Figure 5b-d).

Future research on calcareous soils should focus on validating different rates of MAP/DAP, TSP and urea to identify the maximum grain yield and WUE response that might be achieved.

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Additional Information

Crop water use (CWU) was calculated as: CWU=Growing season rainfall + (Soil moisture at sowing– Soil moisture at maturity (Soil bulk density was extracted from ApSoil).

Water use efficiency (WUE) was calculated as: WUE=grain yield (kg/ha)/CWU.

Benchmark of grain yield was performed following the formulas from Hunt and Kirkegaard 2012.

Statistical analyses were performed using the R software and the R package asreml to estimate treatments variability and adjust for spatial trends in the trials. Tukey's test was applied to assess differences between treatments.

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