Benchmarking water limited yield of cereal crops on major soil types across Eyre Peninsula

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Key messages

- **Positive relationships (R^2=0.6) were observed between water and grain yield (t/ha) across 14 Eyre Peninsula (EP) paddocks.**
- **Yeelanna (Pooh Bear paddock, clay loam over light clay) had the highest grain yield (5.8 t/ha) across the 14 EP paddocks and 100% of yield potential achieved.**
- **Karkoo, Yeelanna (South West) and Witera had similar grain yield (3.82-4.70 t/ha), but only Witera had over 100% yield potential achieved.**
- **Paddock yields were also affected by soil constraints and other abiotic stresses.**

Why do the trial?

This research aims to determine in which situations extra fertilisation can bring benefits to growers in 14 different Eyre Peninsula (EP) environments.

Every season, growers need to make choices over limited resources in order to optimise their profitability. Soil type and water represent two of the key limiting resources which define the grain yield potential of a paddock. The unpredictability of growing season rainfall patterns restricts in-season fertiliser applications for EP growers, due to the associated high economic risks. As a risk management strategy, growers often apply lower rates of nutrients than required to achieve the water limiting yield potential (Sadras and Roget 2004, Monjardino *et al*. 2013). Therefore, less than optimum nutrient rates are applied in many instances, and maximum grain yield gains are not reached on occasions where opportunities have existed. Understanding soil water and nutrient dynamics can be useful to determine when in-season extra fertiliser applications are worth the investment in EP dryland farming systems.

This study used a subset of the Eyre Peninsula Agricultural Research Foundation (EPARF) soil moisture probe network locations to benchmark the water limited yield potential and determine the achievable grain yield of cereals crops across major soil types of EP.

How was it done?

From the 37 sites, 14 sites were selected to represent major soil types of EP (Table 1). At pre-sowing and post-harvest, three soil cores per paddock were collected to 100 cm and divided in four depth intervals: 0-10, 10-30, 30-60 and 60-100 cm. Each soil core at each depth interval was split in two sub-samples. One subsample was used to calculate soil moisture and the other one was sent to the CSBP laboratory for nutrient testing. The subset of soil samples that was taken for testing nutrient content was dried in an oven (35°degrees until constant weight), sieved and sent to the CSBP laboratory.

Soil moisture was measured using the gravimetric method. A volumetric estimate was calculated considering the bulk density information from the nearest APSOIL sites, then the volumetric estimates were converted into mm of water.

Three harvest biomass cuts of 1 m^2 were collected in each paddock near the moisture probe for estimating grain yield and thousand grain weight. Benchmarking grain yield was performed following the formulae from Hunt and Kirkegaard 2012:

- Crop water use (CWU) was calculated as: CWU= Growing season rainfall + (soil moisture at sowing - soil moisture at maturity).
- Potential yield (kg/ha) = 22 (water use efficiency) x (CWU - 60* (evaporation)).
- % yield potential achieved = (Actual grain yield (kg/ha)/ Potential yield (kg/ha) x 100.

**Low evaporation rate benchmark updated by Angus and Sadras (2006) to allow for the introduction of semi-dwarf wheats, increases in atmospheric carbon dioxide and crops grown on sandy soils where evaporation is very low.*

When using this formula, care must be taken when considering particular soil types. Crops in some heavy soils will rarely come close to the benchmark or can go over the benchmark in case of some loam soils (Hancock *et al*. 2006).

Statistical analyses were performed using R software. The least significant difference (LSD) test was applied to assess differences between paddocks.

Table 1. Location, crop type, soil type, sowing date, seeding rate and harvest cut date of 14 selected paddocks across EP in 2019.

Location	Crop	Soil	Sowing date	Seeding rate (kg/ha)	Harvest cut date
Minnipa (Condada)	Scepter wheat	sand over sandy loam	22 May	65	11 Dec
Pygery	Scepter wheat	loam over clay loam	12 May	60	21 Oct
Elliston	Scepter wheat	calcareous loam	9 May	60	5 Nov
Karkoo	Emu Rock and Scepter (50:50) wheat	sandy loam over sand	6 May	100	23 Nov
Yeelanna (Pooh Bear)	Scepter wheat	clay loam over light clay	29 Apr	100	27 Nov
Yeelanna (South west)	Scepter wheat	sandy clay loam over heavy clay	6 May	100	27 Nov
Mt Damper	Scepter wheat	sandy loam over loam	29 May	65	5 Nov
Ungarra	Scepter wheat	clay loam over red sodic clay	14 May	100	27 Nov
Witera	Scepter wheat	clay loam	20 May	75	5 Nov
Port Kenny	Scepter wheat	clay loam	12 May	75	5 Nov
Minnipa (MAC)	Scepter	loam over clay loam	10 Jun	65	23 Oct
Wudinna	Spartacus barley	silty loam over loam	2 May	55	9 Oct
Cungena	Mace wheat	calcareous loam	10 May	65	23 Oct
Streaky Bay	Mace/Axe (35:35) wheat	calcareous loam	3 May	70	23 Oct

What happened?

Growing season rainfall, soil water and nutrient levels at sowing

Karkoo, Ungarra, Yeelanna South West and Pooh Bear had the highest soil moisture levels (223, 202, 149 and 125 mm) compared to the other EP sites (Table 2). As expected, growing season rainfalls were the highest at lower EP sites (Yeelanna and Karkoo) and the lowest at upper EP sites (Wudinna and Cungena). Port Kenny, Cungena, Streaky Bay, Elliston, Yelanna South West and Ungarra had moderate to high phosphorus buffer index (PBI), suggesting that phosphorus is quickly bound to the soil and thus less available to the plant.

However, high levels of Colwell P were observed in those soil profiles (Table 2). Growers' fertiliser applications and seeding rates (Table 1) reflected the regional area, soil type and nutrition, for example: Yeelanna sites and Karkoo had 100 kg/ha seeding rate and received three different urea applications during the season to increase yield potential, while Cungena had 65 kg/ha of seeding rate and 50 kg/ha of DAP blended with sulphur (Table 2).

Relationship between grain yield and water

A linear relationship between grain yield and water supply (growing season rainfall plus soil water used) was observed across all 14 sites (Figure 1). The increase of one millimetre of water either used by cereal crops during the season (Figure 1b) or from growing season rainfall (Figure 1a) was associated with an increase of 20 kg/ha of grain yield. This result underlines the importance of water as one of the drivers of grain yield in EP environments and closely matches the potential yield model of 22 kg/ha per mm.

Benchmarking water limiting yield potential

Given the moderate linear relationship between water supply and grain yield across EP sites, potential grain yield and % of potential yield achieved was also determined (Figure 2a-b). Yeelanna (Pooh Bear) paddock had the highest grain yield across the EP paddocks with 5.8 t/ha (Figure 2a) and 100% of potential yield achieved (Figure 2b).

Table 2. Location, growing season rainfall (GSR), soil moisture, N and P rates at sowing and fertilisers type applied to each paddock in 2019.

Location	GSR (Apr-Oct) (mm)	Soil moisture 0-100 cm (mm)	Soil N 0-100 cm (kg/ha)	Colwell P 0-10 cm (mg/kg)	PBI 0-10 cm	Fertiliser applications at seeding	In crop fertiliser applications
Minnipa (Condada)	234	47	44	22	*	65 kg/ha DAP + 50 kg/ha urea	
Pygery	187	83	63	25	104	60 kg/ha Granuloc ® + 40 kg/ha urea	
Elliston	283	83	117	66	254	80 kg/ha DAP	15 July and 15 September: Zn, Mn and Cu
Karkoo	346	223	56	29	20	77 kg/ha Zincstar ® (10:22:0:0:1 plus Zn) + 50 kg/ha urea	14 June: 75 kg/ha urea 9 July: 75 kg/ha urea, 27 July: 50 kg/ha urea
Yeelanna (Pooh Bear)	346	125	63	41	52	113 kg/ha Zincstar ®	7 June: 100 kg/ha urea 31 July: 100 kg/ha urea + 1% zinc
Yeelanna (South west)	346	150	90	94	174	120 kg/ha Zincstar ®	28 June: 100 kg/ha urea 27 July: 100 kg/ha urea
Mt Damper	242	61	35	27	77	80 kg/ha DAP + 40 kg/ha urea	
Ungarra	213	203	57	33	178	UAN at 20 L/ha + 55 kg/ha of Double super (0:15:10:10)	
Witera	255	100	70	23	81	80 kg/ha 50% Urea/50% Sulphur of Ammonium	20 June: 50 kg/ha urea
Port Kenny	255	89	68	46	183	80 kg/ha MAP + 40 kg/ha urea	17 July: 50 kg/ha urea
Minnipa (MAC)	234	67	77	27	77	70 kg/ha Granuloc ® and 1% zinc	
Wudinna	187	52	79	31	113	50 kg/ha MAP + 25 kg/ha urea	
Cungena	185	59	86	49	127	50 kg/ha DAP (blend 19:16:0:6 Sulphur)	
Streaky Bay	262	68.8	64.74	52	184	70 kg/ha DAP	18 August: application of Zn, Mn and Cu

** PBI was not measured*

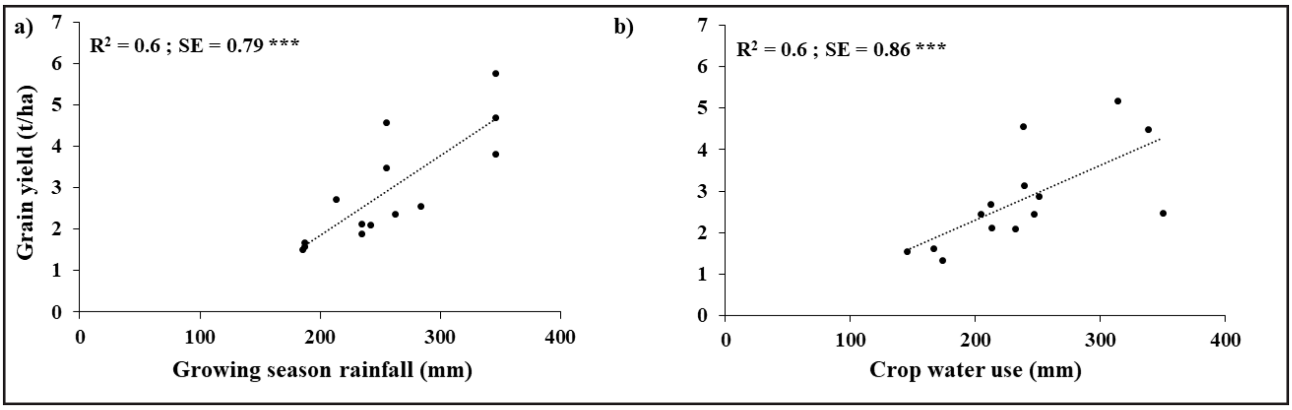

Figure 1. Relationship between wheat grain yield (t/ha) and water supply (growing season rainfall (mm))(a) and crop water use (b)) across 14 locations on Eyre Peninsula in 2019.

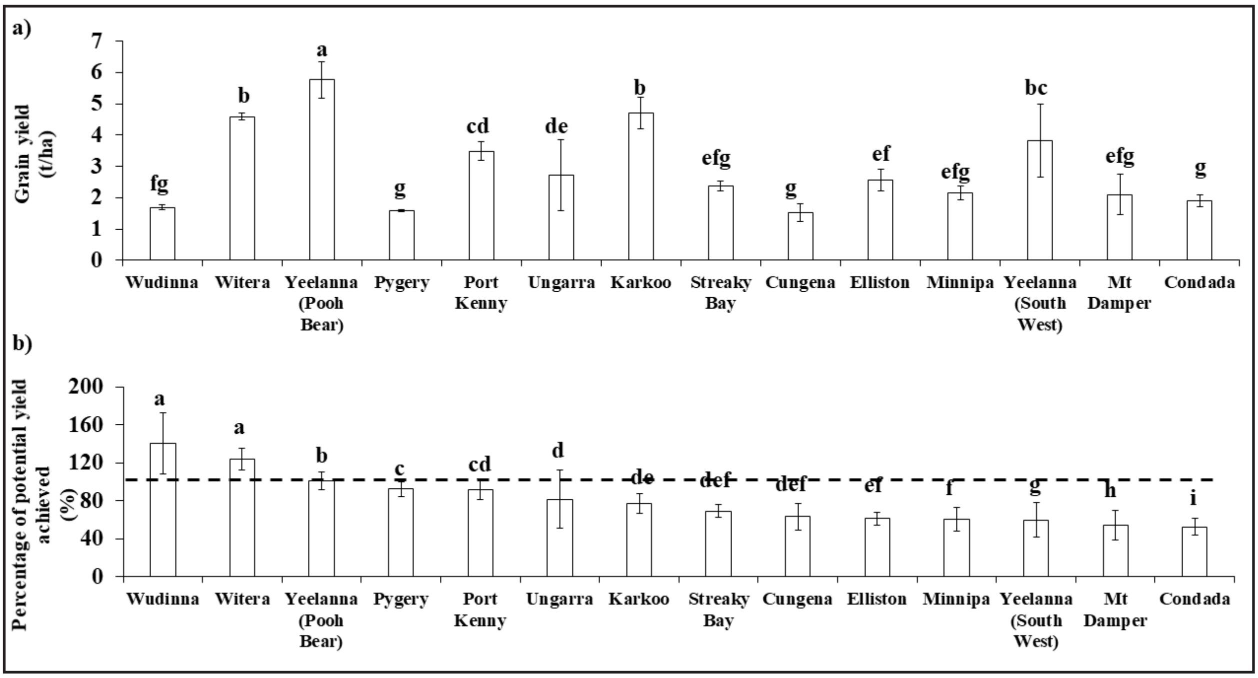

Figure 2. Grain yield (a) and percentage of potential yield achieved (b) of 14 locations on Eyre Peninsula in 2019. Dotted line indicates 100% of yield achieved. Sites followed by the same letter are not statistically different (P=0.05).

The high water input across the season was successfully matched with multiple urea applications by stem elongation (Table 2). Karkoo, Yeelanna (South West) and Witera had similar high grain yield (3.8-4.7 t/ha), however, only Witera had 123% of yield potential achieved (Figure 2b). Yeelanna (South West) and Karkoo had 60-77% of yield potential achieved, possibly due to soil constraints (Table 2, PBI) and frost during the season. Wudinna had the highest % of potential yield achieved (140%, Figure 2b) across all EP sites. However, the potential grain yield at Wudinna was associated with lower levels of grain yield (1.7 t/ha, Figure 2a), which were similar to Pygery (1.6 t/ha), Streaky Bay (2.4 t/ha), Cungena (1.5 t/ha), Minnipa (2.1 t/ha), Mt Damper (2.1 t/ha) and Condada (1.9 t/ha, Figure 2a). Port Kenny and Ungarra had comparable grain yields (2.7-3.5 t/ha) and % of potential yield achieved (82-92%, Figure 2b). At the Elliston paddock, grain yield reached 2.6 t/ha, however, the % of yield potential was only 61% (Figure 2b), possibly due to soil constraints (high levels of P fixed in the soil).

What does this mean?

In this study, our findings suggest:

1. Water supply (growing season rainfall) is one of the main drivers of grain yield. Water use explained at least 50% of the variation associated with grain yield across 14 EP paddocks. These results support the findings of Sadras *et al*. (2002).
2. An example of successful matching of water and nitrogen to maximise yield potential was observed at Yeelanna (Pooh Bear). An extra 100 kg/ha of N was added by stem elongation in three separate applications to match the seasonal water input and 100% of potential yield was achieved. These findings support the work of Sadras and Cossani on co-limitation of water and nitrogen in cereal crops (Cossani *et al*. 2019, Cossani and Sadras 2018, Sadras 2002-2006, and Arsego *et al*. 2018).
3. Water limited yield was also affected by subsoil constraints, such as moderate to high P fixation in the soils as previously observed by Sadras *et al*. (2002) and also frost damage in 2019.

Further research would need to focus on defining the soil moisture holding capacity or 'bucket size' of major soils of EP.

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References

Arsego, F., *et al*. "Nitrogen application at stem elongation, is it worth the investment?". Eyre Peninsula Farming Systems Summary (2018):180-184

Cossani, Cesar Mariano, and Victor O. Sadras. "Water-nitrogen co-limitation in grain crops." Advances in Agronomy 150 (2018): 231-274.

Cossani, C. Mariano, and Victor O. Sadras. "Increasing co-limitation of water and nitrogen drives genetic yield gain in Australian wheat." European Journal of Agronomy 106 (2019): 23-29.

Hancock, J. "Water use efficiency of crops and pasture". Eyre Peninsula Farming Systems Summary (2006): 87-90

Hunt, J. R., and J. A. Kirkegaard. "A guide to consistent and meaningful benchmarking of yield and reporting of water-use efficiency." (2012).

Monjardino, M., *et al*. "Are farmers in low-rainfall cropping regions under-fertilising with nitrogen? A risk analysis." Agricultural Systems 116 (2013): 37-51.

Sadras, Víctor. "Interaction between rainfall and nitrogen fertilisation of wheat in environments prone to terminal drought: economic and environmental risk analysis." Field Crops Research 77.2-3 (2002): 201-215.

Sadras, Víctor O. "Yield and water-use efficiency of water-and nitrogen-stressed wheat crops increase with degree of co-limitation." European Journal of Agronomy 21.4 (2004): 455-464.

Sadras, Víctor O., and David K. Roget. "Production and environmental aspects of cropping intensification in a semiarid environment of South eastern Australia." Agronomy Journal 96.1 (2004): 236-246.

Sadras, Victor O., and John F. Angus. "Benchmarking water-use efficiency of rainfed wheat in dry environments." Australian Journal of Agricultural Research 57.8 (2006): 847-856.