# Achieving water limited yield frontiers more profitably

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**Key findings**

- A new GRDC project focuses on connecting crop agronomy practices to maximise grain number production and yield potential.
- Modern genetics and advanced crop management are delivering higher water use efficiencies, achieving transpiration efficiencies greater than 25 kg/ha/mm and evaporation losses below 60 mm.
- An extra 30 mm of water in the critical period increased wheat yield by 0.6–1 t/ha at Hart, a transpiration efficiency for grain yield of 20–33 kg/ha/mm.
- Barley suffered greater yield loss than wheat in 2024 at Hart and requires more analysis of water use patterns.

## Introduction

A new GRDC project (CSP2404-020RTX - Profitable Yield Frontiers) is focused on supporting tactical agronomy decisions in low to medium rainfall zones to achieve water-limited yield potentials. In these rainfall zones, early season decisions often account for most of the crop expenditure. While higher inputs or adjusted timings can influence yield under different seasonal scenarios, knowing when and how to react, and the likely return, is challenging. Agronomic interventions must address the fundamentals of crop growth to deliver a yield response. Beyond sowing date, genetics, and nitrogen (N), opportunities to influence yield potential in season are limited. Our goal is to develop a responsive agronomic system that increases yields without significantly raising risk or costs.

We conducted a series of experiments across South-eastern Australia to:

1. Link tactical agronomy to physiological changes in the critical period and yield.
2. Identify key benchmarks (crop and soil traits) for actionable decisions during the season.
3. Lift water-limited yield potential in low to medium rainfall zones.

The 2024 season was defined by summer rainfall, a late break, low in-season rainfall, and September frost stress. Our work focused on understanding the crop canopy, how this influences grain yield formation (during the critical period) and refining agronomic benchmarks. This will help to better position crops for success and adapt to seasonal water supply fluctuations.

## Methodology

A factorial plot experiment was carried out at Hart in 2024 (Table 1), utilising sowing date, genetics and nitrogen to create different canopy structures. Supplementary water (30 mm) was applied to a subset of treatments at the start of the critical period (flag leaf emergence) to determine the value of extra water and the response of different agronomy strategies.

Sowing date and emergence targets were April 25–May 10, and approximately three weeks later (or with the break). There were two times of sowing (TOS): May 24, emerging on June 11 and June 13 which emerged on June 25. Supplementary irrigation of 30 mm was applied at the onset of the critical period for Shotgun wheat on August 27 (TOS 1) and September 4 (TOS 2) via dripper irrigation.

*Table 1. Trial details for Hart, SA.*

| | | | |
|---|---|---|---|
| **Plot size** | 1.75 m x 10.0 m | **Fertiliser** | Seeding: MAP Zn 1% @ 120 kg/ha |
| **Harvest plot width** | 0.92 m x 5.0 m | | |
| **Seeding date (TOS 1)**<br>**Seeding date (TOS 2)** | April 24, 2024<br>June 13, 2024 | | |
| **Previous crop** | Kingbale oaten hay | | |
| **Harvest date** | December 4, 2024 | | |

Growing season rainfall (GSR) received at Hart in 2024 was 176 mm (Figure 1) with 240 mm annual rainfall.

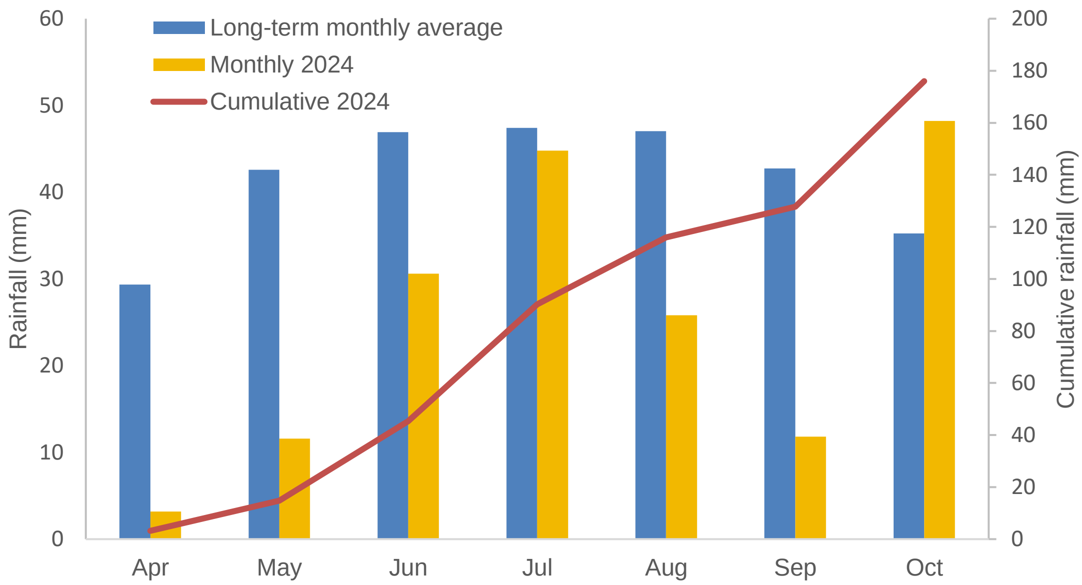


*Figure 1. Long-term and 2024 monthly GSR rainfall for April–October.*

The crop types and varieties included:

- Spring barley – Neo, Cyclops, Beast
- Winter barley – AGTB1007, AGTB1009
- Wheat – Shotgun, Rockstar
- Winter wheat – Mohawk

Nitrogen was seasonally adjusted to achieve two possible yield outcomes based on anticipated seasonal rainfall outlooks, a more conservative Decile 2-3, and a more aggressive Decile 7-8 yield. These were applied as split applications prior to stem elongation. A third treatment was applied to Neo barley and Shotgun wheat only where it low N levels were applied prior to stem elongation and then topped up to the higher N strategy (Table 2).

*Table 2. Nitrogen rates (kg N/ha) and dates for treatments applied as urea.*

| N treatment | Timing 1<br>June 28 | Timing 2<br>August 7 | Timing 3<br>TOS 1: August 27<br>TOS 2: September 4 | Total N applied |
|---|---|---|---|---|
| Low N (Decile 2) | 20 | 30 | - | 50 |
| High N (Decile 8) | 60 | 90 | - | 150 |
| Delayed N (Decile 8) | 20 | 30 | 100 | 150 |

A linear mixed model was fit to the data using ASReml-R, and treatment predictions were extracted for subsets of treatments. Treatment yield predictions were grouped by Tukey's Honestly Significant Difference.

## Results and discussion

### *Understanding grain yield*

Grain yield is primarily determined by the number of grains produced, making processes that determine grain number worth focusing on (Fischer 2008). The most sensitive part of the critical period for wheat and barley occurs just prior to flowering, when grain number (and therefore, yield) is most sensitive to environmental factors like water, temperature, and nutrients. Water deficits during the critical period greatly influence grain number and yield. Aligning this phase with periods of minimal water stress or access to more water can enhance yield potential. Cossani and Sadras (2021) showed that reducing the duration of the critical period from 90 to 30 days can lead to a linear decline in yield from ~6 t/ha to <0.5 t/ha in low to medium rainfall zones (LRZ, MRZ), driven mainly by temperature. Porker et al. (2025) found that conditions during the critical period explained over 70% of yield variation in high rainfall zones (HRZ) due to sowing date, temperature and radiation, emphasising the importance of aligning agronomic practices with this critical phase.

### *Drivers of yield – Hart, 2024*

The experiment at Hart in 2024 will add to a database of experiments that aim to maximise water use and grain number (yield potential) using tactical agronomy. Due to the late break, the time of emergence had little influence on grain yield in 2024 (Table 3). The biggest factor was crop type, with wheat performing up to 0.6 t/ha greater than barley. Nitrogen strategy had little impact on grain yield at this site in 2024 and there was little evidence of negative effects of high N despite the dry season, although there is some evidence of smaller grain size in barley from higher N strategies in Neo barley (Table 4). The reasons for the poor relative performance of barley require more investigation, however its likely related to timing of water use prior to anthesis.

The results also reaffirm the importance of understanding agronomic practices that influence grain number, while the differences in grain weight are not insignificant the key drivers of grain yield are grain number, for example an increase 30 mm of water in wheat almost increased grain number two-fold and had little to no impact on grain weight (Figure 2).

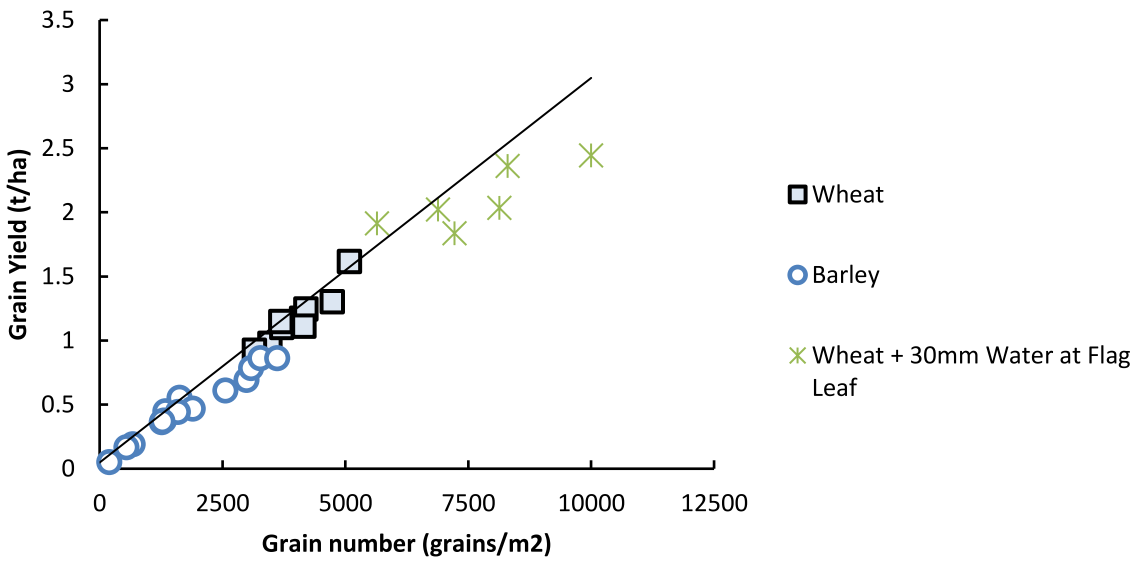


*Figure 2. Relationship between grain number and yield across all treatments at Hart 2024.*

The most interesting results occurred from the extra application of water. The critical developmental period for wheat and barley yield spans from late stem elongation to one week after flowering. Our main focus was that management of water use, and crop canopy needs to better consider this phase. For example, if we received more rain in the critical period, how could we use tactical agronomy to convert this into more yield. At Hart in 2024 an extra 30 mm of water in the critical period increased wheat yield by 0.6–1 t/ha, a transpiration efficiency for grain yield of 20–33 kg/ha/mm. (Table 3). This increased occurred irrespective of N strategy and sowing date.

*Table 3. Grain yield (t/ha) and grain size of Neo, Shotgun and Shotgun with 30 mm irrigation at flag leaf emergence. Predicted values are across all N treatments (NS), letters are groups determined by Tukey's Honestly Significant Difference (HSD). Shaded values indicate best performing treatments.*

| Emerged | Variety | Grain yield (t/ha) | g/1000 grains |
|---|---|---|---|
| June 11 | Shotgun + 30 mm | $2.0^{a}$ | $32.0^{c}$ |
| | Shotgun | $1.4^{b}$ | $31.8^{c}$ |
| | Neo | $0.6^{cd}$ | $38.5^{ab}$ |
| June 26 | Shotgun + 30 mm | $2.1^{a}$ | $39.0^{a}$ |
| | Shotgun | $1.0^{bc}$ | $34.3^{bc}$ |
| | Neo | $0.3^{d}$ | $32.0^{c}$ |

*Table 4. Grain yield (t/ha) and grain size of spring barley varieties at two sowing dates and nitrogen rates. Shaded values indicate best performing treatments.*

| Emerged | Variety | Nitrogen | Grain Yield (t/ha) | g/1000 grains |
|---|---|---|---|---|
| June 11 | Beast | N1 | 0.7 | $41.9^{ab}$ |
| | Beast | N2 | 0.8 | $39.0^{a\text{-}g}$ |
| | Cyclops | N1 | 0.7 | $32.7^{d\text{-}i}$ |
| | Cyclops | N2 | 0.4 | $31.8^{ehi}$ |
| | Neo | N1 | 0.7 | $41.4^{abc}$ |
| | Neo | N2 | 0.3 | $34.8^{d\text{-}i}$ |

**Summary**

Results from 2024, a very dry season, emphasise the potential of new genetics. These results will be best interpreted when combined with more in depth understanding of soil water use across a wider range of season types. It’s clear from other experiments and this on it is possible to continue to increase grain yield through maximising resource efficiency by focusing on the critical period's sensitivity to environmental and management factors. We plan to develop new benchmarks that can assist in maintaining profitability in challenging low to medium rainfall zones.

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*Photo: Taken at the Hart field site on September 4 of TOS 1 post-irrigation.*