Analysis of continuous water use data for wheat plants grown on a DroughtSpotter platform

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A wheat drought experiment at The Plant Accelerator®

The DroughtSpotter (Phenospex, The Netherlands) is a gravimetric platform enabling continuous weighing and software-controlled watering of potted plants, making it ideal for simulation of drought.

In spring 2016, a DroughtSpotter experiment was conducted at The Plant Accelerator® to assess the effect of drought and heat on wheat during early grain filling. This was a Genotype x Treatment trial:

- 3 modern Australian varieties (Frame, Young, Gladius)
- 3 traditional Australian varieties (Currawa, Koda, Mendos)
- 2 international varieties: Odessa (Ethiopia), Synthetic W7984 (Mexico).

There were 3 treatment groups:

- **WW**: Well-watered at all times
- **Dr**: Well-watered from sowing until 3 days after anthesis (DAA 3), followed by simulated drought until maturity (12%(g/g) soil moisture)
- **D&H**: As for ***Dr***, plus 72-hour heat treatment (DAA 9-12, 37°C maximum).

There were 7 replicates in total (8 x 3 x 7 = 168 pots):

- 3 reps destructively sampled at DAA 12 (end of heat treatment for D&H plants)
- 4 reps grown to maturity for grain harvest.

Each pot contained a single wheat plant positioned on a load cell (**Figure 1**), except for *D&H* plants undergoing heat treatment, which were watered manually in a separate greenhouse.

Pots were weighed at hourly or half-hourly intervals, and water applied as required to the target weight. The DroughtSpotter data log (340K records) enables calculation of both cumulative and real-time water consumption for each pot.

The 3 sampled reps were used for biochemical analysis during grain filling (Elhabti et al, 2019). We now focus on water use in the 4 harvested reps during the 'post-treatment' phase commencing DAA 12.

FIGURE 1: Wheat DroughtSpotter experiment shortly before grain harvest. Each pot contains one wheat plant and is placed on a dedicated weighing cell and watered by a dedicated spout. An environmental sensor (visible at left) records temperature, humidity and light within the greenhouse.

Cumulative water use

Figure 2a plots daily applied water during the post-treatment phase for a single variety (Gladius). Each curve corresponds to one of 4 harvested reps for each of WW (*blue*), Dr (*orange*) and D&H (*red*).

As expected, water consumption is substantially reduced under simulated drought.

To evaluate water use relative to plant size, we calculated Specific Daily Water Use relative to harvest biomass (**Figure 2b**) and final grain yield (**Figure 2c**).

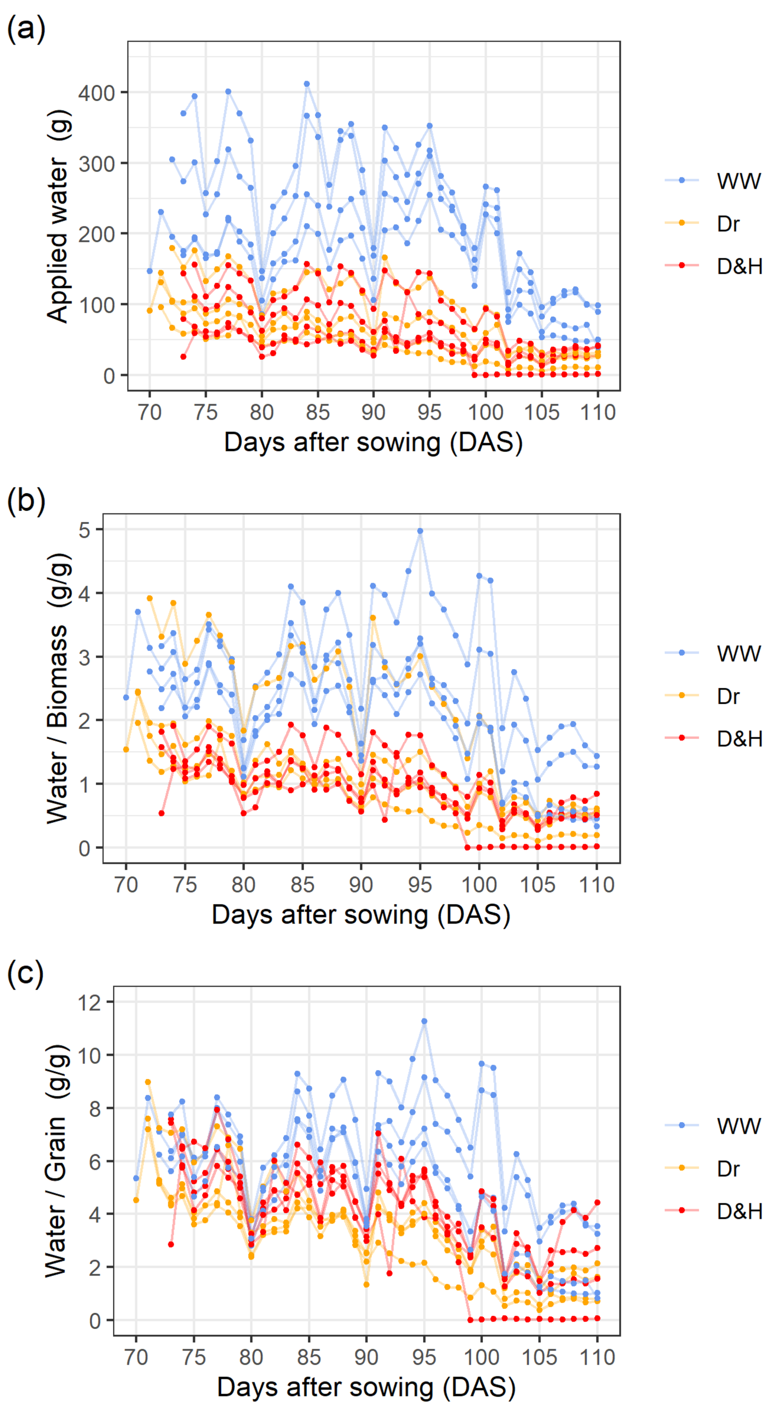

FIGURE 2:
(a) Daily water use (grams or mL) for Gladius (4 reps x 3 Treatments = 12 plants) commencing 12 days after anthesis (DAA 12).
(b) Daily water use normalised by harvest biomass (g/g dry weight excluding grain).
(c) Daily water use normalised by harvest grain weight (g/g).

Real-time water use

It was hypothesised that water use efficiency under drought would (a) vary by variety and (b) be correlated with real-time water consumption ('transpiration rate'). It was decided to focus on midday transpiration rate (approx. noon to 2pm).

Figure 3 plots midday transpiration rate (TR, mL/h) for the Gladius plants, superimposed with time-series plots of temperature (*red*), Vapour Pressure (VP, *black dashed*) in units of kilopascals (kPa), and Vapour Pressure Deficit (VPD, kPa, *solid black*). VPD is a simple measure of the drying power of air, based on temperature *T* and relative humidity *RH:*

$$\mathrm{VC} = 0.611\exp\left(\frac{17.62T}{T+243}\right)$$

$$\mathrm{VPD} = \left(1 - \frac{\mathrm{RH}}{100\%}\right)\mathrm{VC}$$

where *VC* is the vapour capacity of air in kPa, and *T* is measured in degrees Celsius.

Figure 3 indicates that VPD:

- is a highly sensitive function of temperature
- is highly correlated with transpiration rate.

Figure 4 pools the post-treatment transpiration data, plotting midday TR against VPD for each variety (Genotype). The relationship appears approximately linear up to 1.5kPa.

For statistical analysis, it was decided to focus on the first 20 days post-treatment (DAA 12-32). **Figure 5** pools this data up to a maximum of 1.5kPa. The trend lines correspond to a trend regression model fitted to this restricted dataset. The full statistical model incorporates (a) Genotype x Treatment interaction, (b) differential variance by Treatment, (c) adjustment for spatial variation within the greenhouse and (d) a random term for differences between pots. For Pot i (of Genotype k and Treatment m) on day j of the experiment, the transpiration model is:

$$\mathrm{TR}_{ij} = (\mathrm{Gen}_k * \mathrm{Tr}_m) + (\mathrm{VPD}_j * \mathrm{Gen}_k * \mathrm{Tr}_m) + \mathrm{spatial}_i + \mathrm{Pot}_i + \mathrm{e}_{ij}$$

where the variance of the residuals e_{ij} is assumed to depend on the Treatment.

The model was fitted in R using the R package ASReml-R4 (Butler et al, 2018) and the three-way interaction term was found to be significant ($p < 0.001$).

This model was separately fitted to Specific Transpiration Rate (TR normalised to harvest biomass), with the three-way interaction again proving significant ($p < 0.001$).

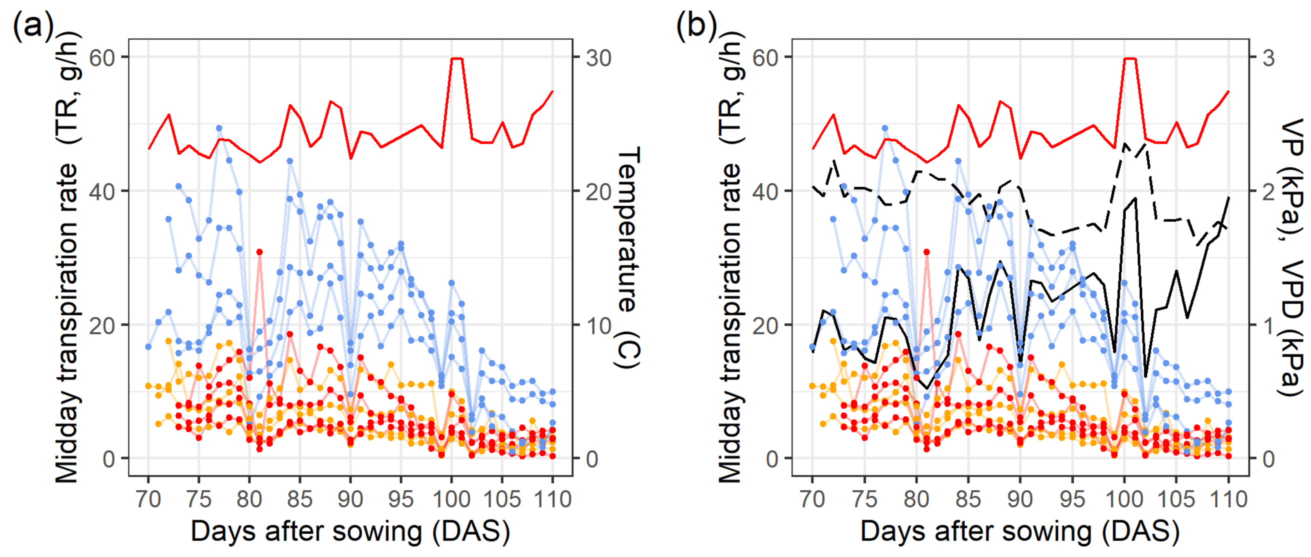

FIGURE 3: **(a)** Midday real-time water use (transpiration rate) for each Gladius plant (**TR**, g/h, LHS axis), superimposed with midday ambient temperature (RHS). **(b)** As in (a), but superimposed with Vapour Pressure (**VP**, *dashed black* – kPa, RHS) and Vapour Pressure Deficit (**VPD**, *solid black*, kPa, RHS).

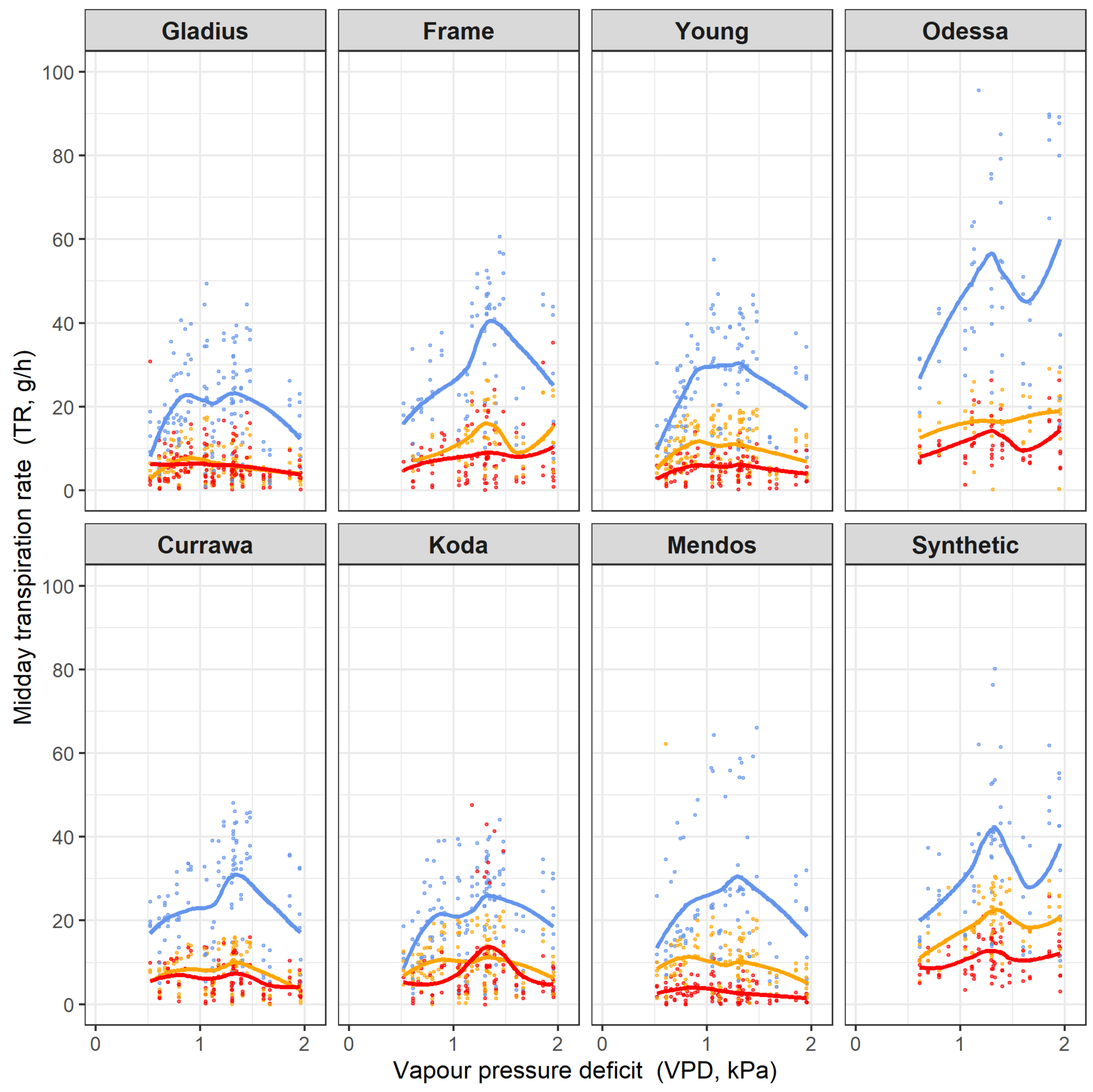

FIGURE 4: Midday transpiration rate (TR, g/h) vs VPD for each plant and variety for the post-treatment period commencing DAA 12. Coloured curves are loess averages.

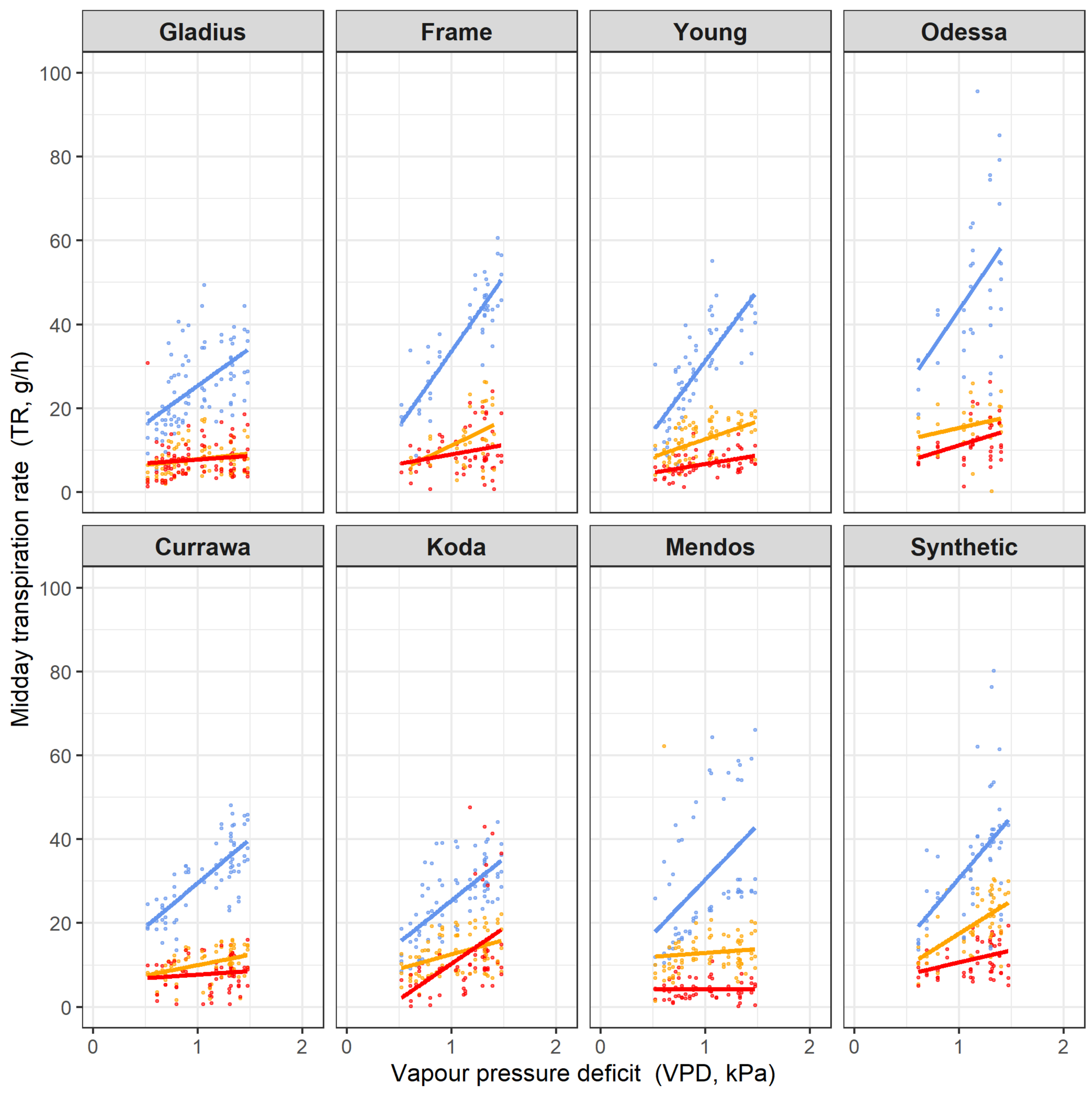

FIGURE 5: Midday transpiration rate (TR, g/h) vs VPD for each plant and variety for the 20-day period DAA 12-32, up to a maximum VPD of 1.5kPa. Coloured lines correspond to the fitted trend regression model.

References

Butler DG, Cullis BR, Gilmour AR, Gogel BJ, Thompson R (2018). *ASReml-R reference manual. Version 4.* Retrieved from http://asreml.org.

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