Impact of the experimental setup on wheat response to heat stress

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Background and Methodology

Introduction

- Previous experiments testing the response of wheat to heat stress around anthesis suggested dissimilar impacts of heat on yield and yield components (Ferris et al., 1998; Liu et al., 2016).
- The results of previous studies performed under controlled conditions are extremely diverse regarding the response of wheat yield to different levels of heat (Figure 1).

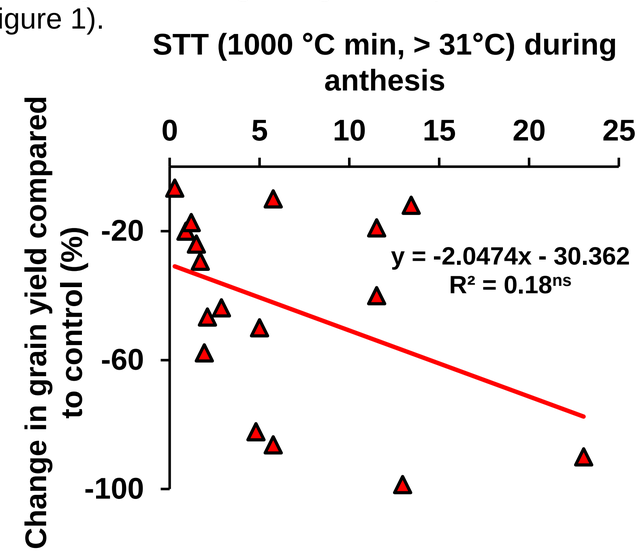

Figure 1. The relationship between relative yield reduction and stress thermal time (STT) for 8 published studies about heat stress effects around anthesis on crop yield which provided detailed information of soil, experimental setup and applied treatments.

- The objective of the current study was to assess the influence of differences in experimental setup about heating methods, temperature measurement and soil substrate on the response of wheat to heat and combined heat and drought stress around anthesis (HSA) by series of experiments under controlled conditions.

Methodology

- Six pot experiments were conducted from 2013 to 2015 under controlled conditions in Braunschweig, Bonn and Halle to study the effect of heat (H) and combined heat and drought stress (HD) on wheat yield and yield components (Table 1).
- Crop heat stress called subsequently stress thermal time (STT), was calculated as temperature sum above a critical threshold set to 31 °C.
- The STT was calculated by using temperature measurements of the ambient air (Tair) in Bonn and Braunschweig experiments and of the ear surface (Tear) in the Halle experiments. Sandy soil substrate was used at Bonn and Halle while clay soil was used at the Braunschweig experiments.
- Table 1. Summary of experimental setup and arrangement of sole heat and combined heat and drought stress treatments in Bonn, Halle and Braunschweig experiments.

Location	Experiment	Treatment	Start of heating (BBCH)	Heat dose (STT, °C min)	Heating method	Set-point drought intensity (SAW)	Temperature measurement point
Bonn	E1 (2014)	Control	-	-	-	-	Air
		Heat	60	12000	Growth chamber	-	
		Heat + Drought	60	12000		40	
	E2 (2015)	Control	-	-	-	-	
		Heat	60	12000	Growth chamber	-	
		Heat + Drought	60	12000		40	
Halle	E1 (2013)	Control	-	-	-	-	Ear
		Heat	60	1400	Infrared heater	-	
		Heat + Drought	60	800		35	
	E1 (2015)	Control	-	-	-	-	
		Heat1	60	500	Infrared heater	-	
		Heat2	60	1900		-	
		Heat + Drought	60	2600		35	
Braunschweig	E1 (2014)	Control	-	-	-	-	Air
		Heat1	50	13000	Growth chamber	-	
		Heat2	60	8000		-	
		Heat3	68	10000		-	
	E2 (2014)	Control	-	-	-	-	
		Heat1	50	12000	Growth chamber	-	
		Heat2	60	12000		-	
		Heat3	68	16000		-	

Results

Effects of heat and drought on yield and yield components

- Growth chamber experiments performed at different sites showed that increasing of the ambient air temperature at anthesis corresponding to a temperature sum of 12000 °C min above 31 °C resulted in a significant yield reduction of -24 % for plants grown on sandy soil substrate but not for those grown in a soil with high soil water holding capacity (Figure 2).
- An almost similar reduction in grain yield of -16 % was observed for sandy soil substrate at a much lower level of heat stress when the temperature of the ears increased by infrared heaters (a temperature sum of 1900 °C min above 31 °C). The yield reduction was increased significantly under combined heat and drought compared to sole heat stress (Figure 2).
- The yield reduction was increased significantly under combined heat and drought compared to sole heat stress. Grain number significantly reduced in all experiments by heat stress and combined heat and drought stress at anthesis (Figure 2).
- The single grain weight increased by heat stress around anthesis and partly compensated for lower grain numbers for pots containing a soil with high soil water holding capacity but not in experiments with sandy soil substrate.

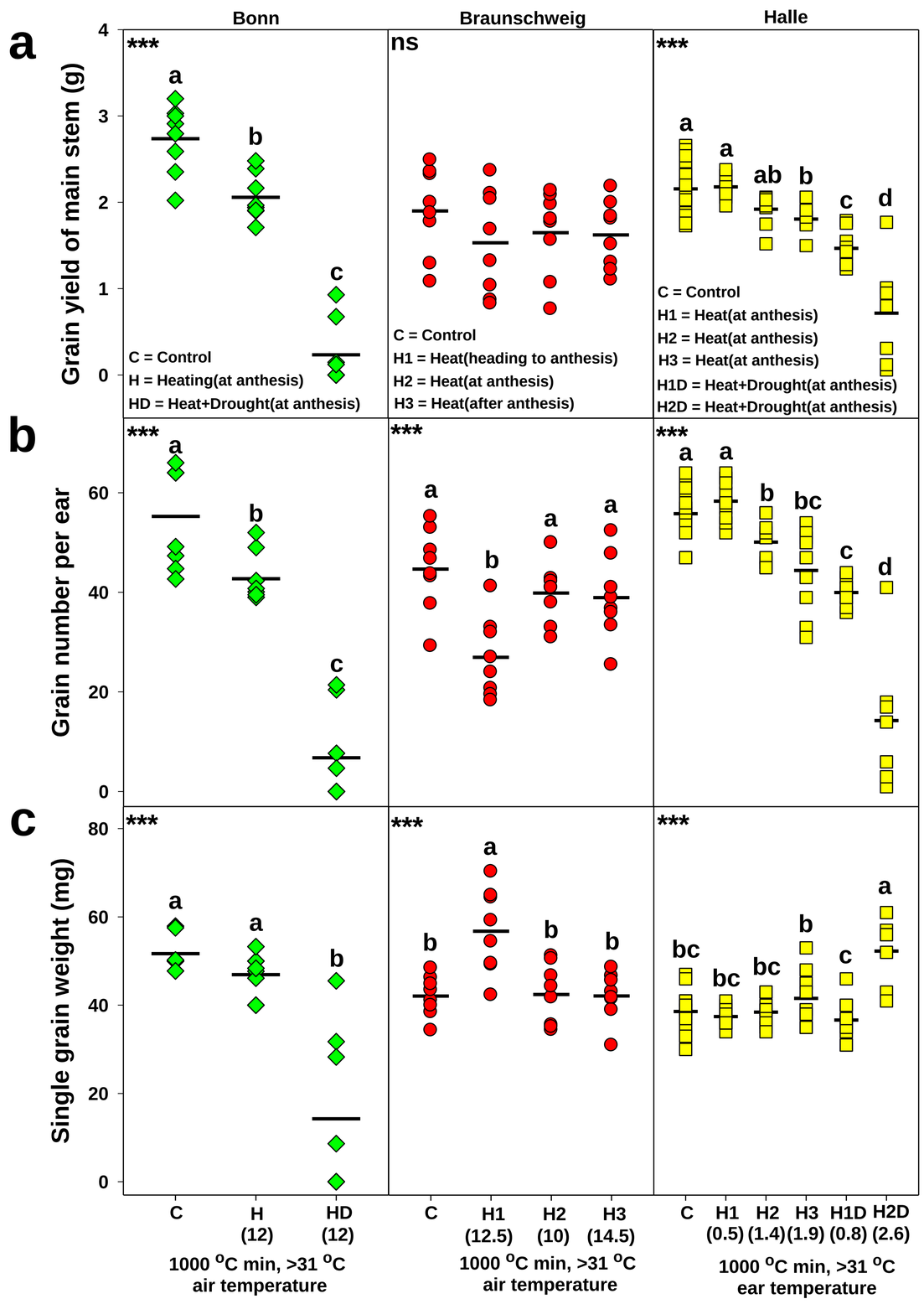

Figure 2. The observed grain yield (a), grain number (b) and single grain weight (c) of wheat under control, different levels of heating and combined heat and drought stress in Bonn, Braunschweig and Halle experiments. Each point represents one replication; the black line indicates the mean value. ns = non-significant trend and *** = significance at 0.1% probability level, respectively. Differences between treatments were obtained using Fisher's Least Significant Difference (LSD) test. Different letters indicate statistically significant difference (P < 0.05) between treatments. C = control, H = sole heat, and HD = combined heat and drought

Conclusion and outlook

- We conclude that the differences in the experimental setup of heat stress experiments substantially influence the crop response to heat stress and need to consider when using the data to parameterize crop models used in climate change impact assessments.

References

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