Plant response to a late heat stress can be modified by an earlier one. A case study on sorghum grain production

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Introduction

Global climate change is today a reality and the observable effects include higher temperatures and in particular longer and recurring periods of heat waves. Sorghum is a promising cereal in the climate change context (Hermuth et al., 2016), and a major staple crop in several developing countries in which almost half a billion people depends on its production. Heat stress during reproductive stage is known to impact grain production (quality and quantity) but a few researches were completed on this issue on sorghum and in particular on recurring heat stresses.

In this preliminary study, we analysed the effects of isolated and recurrent heat waves on sorghum grain production considering both quantity and quality. This stress scenarios were imposed at specific stages of grain development, allowing comparison of different genotypes on robust bases. We aimed at answering the following questions :

i. What is the effect of isolated and recurrent heat stress scenarios on grain yield components and quality?
ii. Do plants exposed to a primed stress respond differently than those encountering heat stress for the first time ?

Experimental design

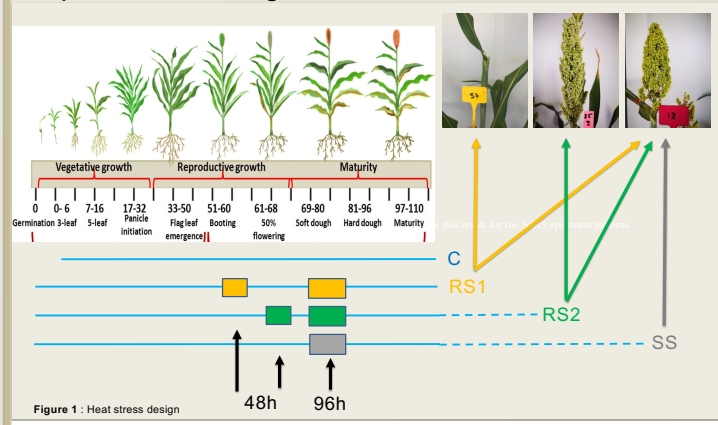


Figure 1 : Heat stress design

Figure 2 : Btx623 panicle

- Plants of Btx623 genotype have been grown in the Abiophen greenhouse in optimal temperature conditions 30°C day/23°C night
- 4 different temperature scenarios were imposed at specific stages :
  - Control (C) over all growing period
  - Recurrent heat stress at heading (priming) and grain filling (primed) (RS1)
  - Recurrent heat stress at flowering (priming) and grain filling (primed) (RS2)
  - Single heat stress at grain filling (SS)
- During heat stress periods, plants were moved into the Abiophen phytotrons with 38°C day/26°C night (Prasad et al., 2014; Singh et al., 2015)

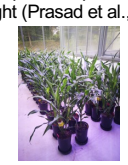



Figure 3 : Green house device

- n=15 plants/scenario
- Yield and Morphological related traits were measured on mature panicles
- Spectral and biochemical analyses were performed on mature seeds after harvest

Results

1.Yield components are not affected by isolated and recurrent heat stresses but morphological traits are affected

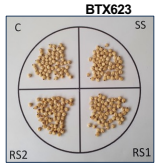


Figure 4 : Picture of 60 seeds for each treatment

Visually, seeds don't seem to be affected by heat stress scenario.

The 3 heat stress scenarios did not significantly affect grain number per panicle.

None of the heat stress scenario significantly affected the weight of 1000 grains.

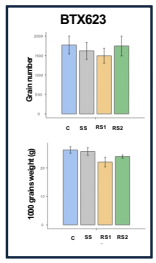
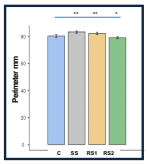


Figure 5 : Yield related traits 4 thermal scenario (n=10 plants).** pvalue<0.05



The two recurrent stresses present contrasting results, indeed the value of the perimeter for RS1 increases in the same way that SS, whereas it decreases significantly for RS2.

Figure 6 : Morphological trait (n=10 plants).
** pvalue<0.05

2. Grain quality related traits are affected by isolated and recurrent stresses

RS1 and RS2 heat stress scenario resulted in a significant increase of the sucrose concentration.

All 3 stress scenario caused reduction in grain starch concentration in Btx623.

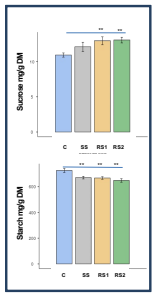


Figure 6 : Sucrose and starch grain contents in mature grains f (n=5 plants).** pvalue<0.05

3. Data from Near InfraRed Spectroscopy on grains or flours show differences between C and the stress scenarios.

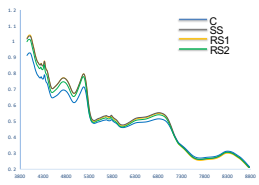


Figure 7 : Near InfraRed spectroscopy of grains (n=15 plants).

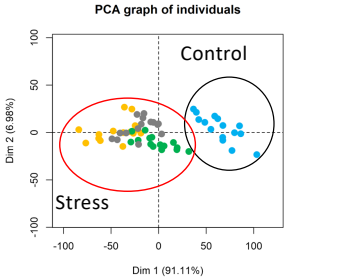


Figure 8 : PCA of Near InfraRed spectroscopy Data of flour (n=15 plants).

The spectral analysis highlights contrasting differences between thermal scenarios event since the control data are grouped together, whereas the data from the three stress scenarios are closed.

Conclusion

Heat stress scenarios imposed in our study didn't affect yield related traits but affected grain quality and morphology. In addition, the two different recurrent stress scenario did not affect the same traits. It can reflect different effects of priming stress (interaction between the first stress wave and the second one) or different recovery strategies (plant response between the two stresses).

These results paved the way for further experiments, which started in 2023 in the PARSEMA (INRAE) and RICOCHETS (ANR) funded projects. We are now studying the effects of 3 single stresses and 2 recurrent stresses on 2 sorghum genotypes, still considering final grain yield and quality. However, plant physiological status is also measured during each period of stress and between each period of stress to decipher the respective effects of heat during each stressing period and the recovery period. To amplify the effects on plant traits, the temperature during heat waves is increased at 40°C at day and 28°C at night; the early stress (priming stress) is imposed at flowering time and late stresses (primed) occurs 2 or 7 days after the end of the priming one. This project combines an original ecophysiological with multi-scale phenotyping to decipher mechanisms involved in heat stress response and heat stress recovery. It will be completed in a third phase by an in-depth molecular analysis

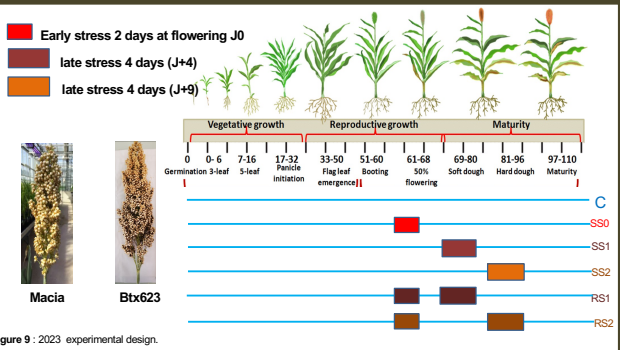


Figure 9 : 2023 experimental design.

Acknowledgements : A. Leon for the pictures. F. De Bellis for seeds. AGAP greenhouse growers (C.Chaine, S. Melliti, R. Michel)

References : Hermuth et al., 2016. http://dx.doi.org/10.5772/62642
Prasad et al., 2014. Funct. Plant Biol. 41, 1261–1269.
Singh et al., 2015. Field Crops Research 171 (2015) 32–40.

sources of funding

Sorghum conference, 5-9 june 2023, Montpellier