Functional analysis of sugar accumulation in sorghum stems and its competition with grain filling among contrasted genotypes

Sylvain GUTJAHR, Anne CLÉMENT-VIDAL, Gilles TROUCHE, Michel VAKSMANN, Korotimi THERA, Nicole SONDEREGGER, Serge BRACONNIER, Michael DINGKUHN & Delphine LUQUET

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Context

In the context of an inescapable depletion of non-renewable resources and the need to decrease carbon dioxide emission from fossil fuels, biofuel is certainly the best current solution. However, to be viable and to avoid controversies regarding the competition between cultures for food and biofuel the development of FF, FFF (Food, Feed, Fuel) cultures is a major challenge.

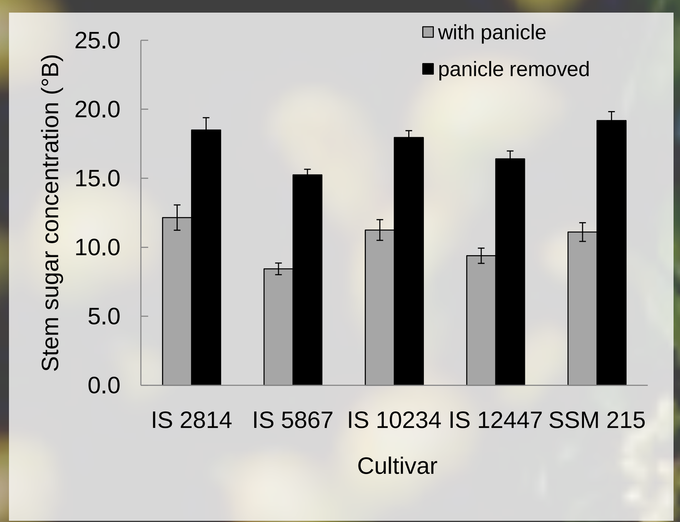
Sweet sorghum (*Sorghum bicolor* (L.) Moench) is one of the best candidates for this purpose (De Vries et al. 2010); it may serve as substrate for bio-alcohol production while producing grain for food and/or feed. Moreover sorghum is drought and heat resistant, thus well adapted to conditions brought about by climate fluctuations. It is a real alternative to sugarcane, particularly for dry areas.

Objectives

Sorghum sweetness is a complex trait. Stem sugar concentration has a moderate heritability (Murray *et al.* 2009) and is highly prone to GxE (Genotype x Environment) interactions that are still poorly understood, as well as its competition with grain filling. Moreover reports on the kinetic of stem sugar accumulation and underlying enzymatic bases are still controversial (McBee and Miller, 1982; Tarpley *et al.* 1994; Hoffmann-Thoma *et al.* (1996).

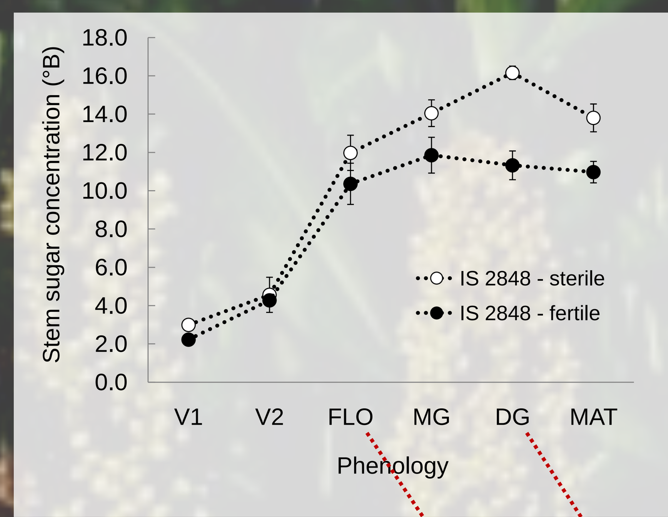
This study is part of the European project, Sweetfuel "Sweet sorghum: an alternative energy crop" (2009-2013) (www.sweetfuel-project.eu). Its aims at studying the morpho-physiological traits (and their genotypic variability) constituting sucrose accumulation in sweet sorghum stems and its competition with grain filling, under various water conditions. This poster presents the first results of this study, focusing on grain / sugar competition under well watered conditions.

Competition for carbohydrates between grain and sugar yield is obvious



Panicle pruning (F1 experiment) enhanced sugar storage in stems

Sucrose accumulation internodes can start before flowering and the sucrose synthase (Susy) seems to be the most active enzyme (G1 experiment)



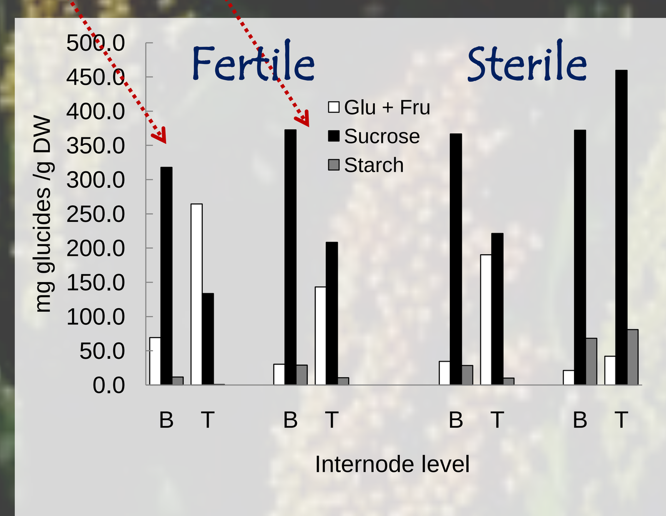
At flowering, total sugar concentration and content already reached a plateau

At FLO

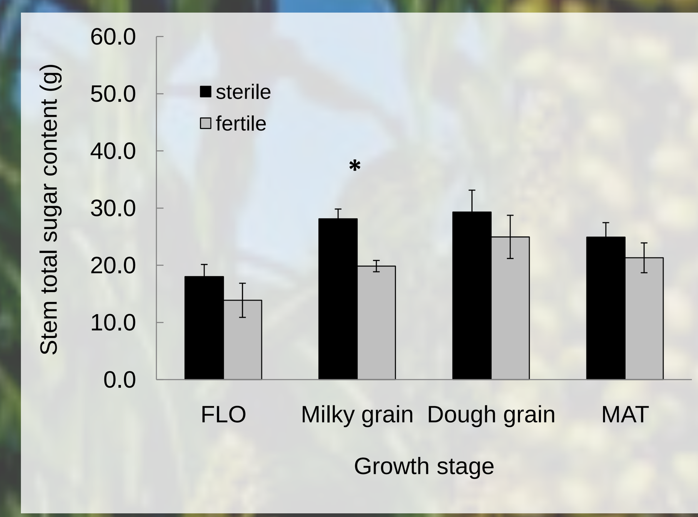
Level	Enzyme	Fertile	Sterile
Bottom	SPS	N.S.	N.S.
	Susy	65.5 ± 6.5	127.5 ± 48.9
	SAI	N.S.	N.S.
Top	SPS	32.4 ± 7.1	62.0 ± 31.9
	Susy	79.7 ± 13.2	138.3 ± 22.8
	SAI	7.1 ± 2.8	N.S.

At DG

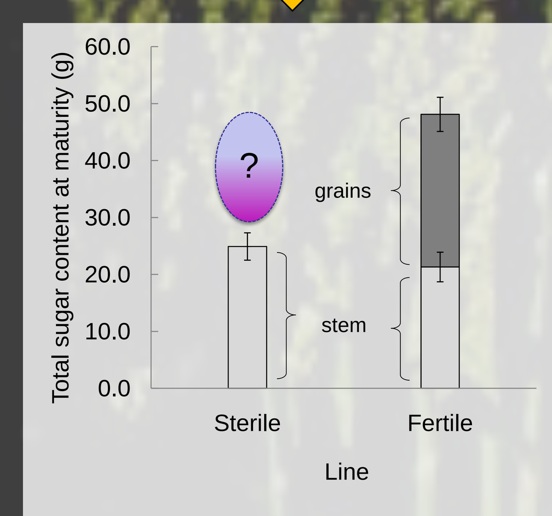
Level	Enzyme	Fertile	Sterile
Bottom	SPS	47.2 ± 5.0	53.6 ± 18.4
	Susy	97.5 ± 44.8	51.1 ± 22.5
	SAI	9.6 ± 1.7	N.S.
Top	SPS	21.0 ± 2.7	77.7 ± 16.8
	Susy	123.7 ± 27.0	82.9 ± 21.9
	SAI	N.S.	N.S.

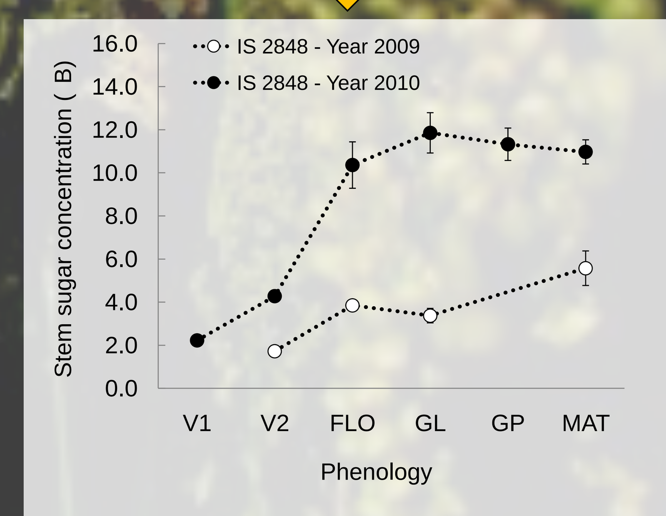


However sugar storage is not only a question of competition among sinks (G1 & F1 experiments)



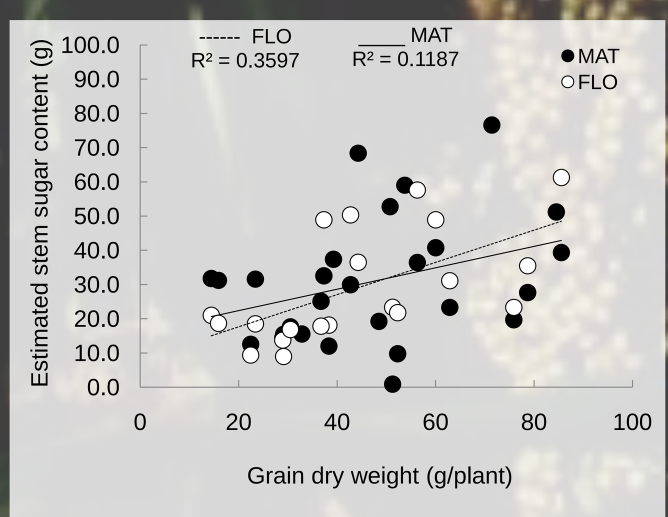
Growth conditions seem to have more impact on sugar storage in stems than variation in panicle sink strength

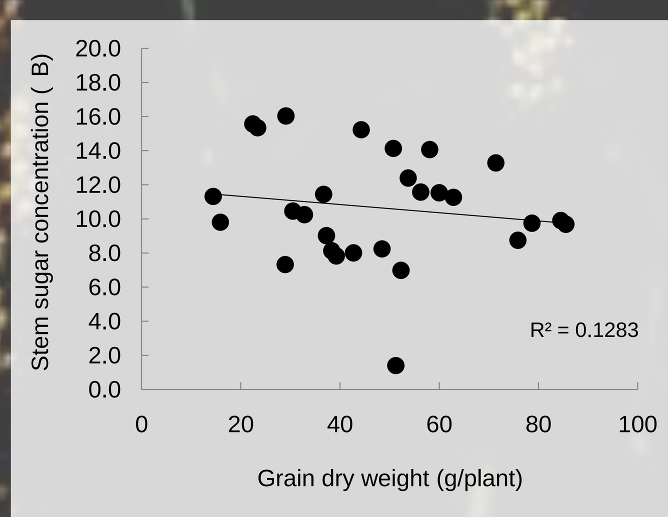


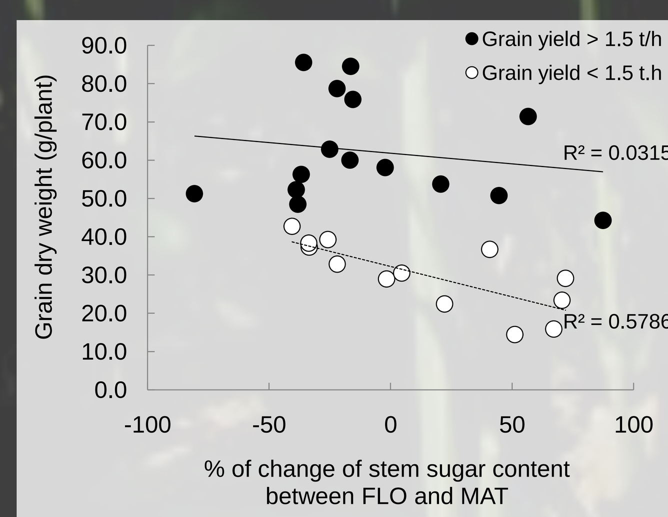


Nevertheless, sorghum may offer a real opportunity for dual purposes (F1 experiment)

Grain dry weight positively correlated to stem sugar content at FLO and MAT across the 14 genotypes studied in Mali







Cultivars with highest grain yield not necessarily those associated with the highest reduction of sugar content in stems between FLO and MAT.

Material and methods

A greenhouse, pot (G1) and field (F1) experiment in 2009.

G1 (Montpellier, France):
- 1 sweet sorghum genotype IS2848, sterile (A) and fertile (B) version
- 4 replicates (plants), completely randomized design.
- Measurements: at 6 dates until maturity MAT, plant growth (height, fresh & dry weight (fw, dw) and development (leaf, tiller and internode number on the main stem) sugar content (soluble, starch), related enzyme activity, °Brix (refractomer index of sucrose content) at 3 levels on main stem

F1 (Cinzana, Mali):
- 14 contrasted genotypes (morphology, grain & sugar yield)
- Split-plot design with 3 replicates. Well irrigated.
- On 4 genotypes, 4 plants per block with panicle pruned at flowering FLO
- Measurements at FLO and MAT, similar to G1 (no sugar analyses), on 4 plants per block
-Computation of an equivalent soluble sugar content of plant main stem:

Eq: [stem water content (g) x Brix (°B)]/100

Discussion

This study suggests that the competition between sorghum grain filling and sugar accumulation in stems is significant but may not represent a physiological or even genetic limit to breed for dual purpose sorghums. Grain dry weight was positively correlated with stem sugar content at FLO. No negative correlation was found between plant grain dry weight and stem sugar content at maturity; moreover sugar content reduction in stems between FLO and MAT was poorly correlated to final plant grain dry weight. Finally, both pruning and sterility treatments of IS2848 genotype did not result in a significant increase of stem sugar content, suggesting sucrose accumulation might be limited by an inherent sink capacity of the internodes and strongly regulated by the environment.

These results are preliminary but suggest that the design of dual purpose sorghum ideotype should be possible. This functional analysis will be completed and a conceptual model provided once integrated results on gas exchanges, enzyme activities (related to sugar metabolism) and related gene expressions (G1). The integration of such concepts into crop growth models will help in designing ideotypes for targeted environments.

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