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Mechanical Stimulation Increases Sorghum Stem Strength and Flexibility and is Associated with Altered Transcriptome Expression and Hormone Homeostasis

Statement of the Problem: Like most crops, sorghum [Sorghum bicolor (L.) Moench] is susceptible to stem lodging (the bending or breakage of stems) due to severe mechanical forces generated by weather-related phenomena like wind and rain, which is a major limiting factor in sorghum production worldwide, especially in taller cultivars suitable for use as bioenergy feedstocks. However, in response to less severe mechanical stimulation, plants may exhibit alterations in growth and development known as thigmomorphogenesis that enhance the plant's ability to withstand stronger forces. Stem lodging is expected to occur when thigmomorphogenic acclimation is insufficient to meet the challenge of the mechanical forces experienced. Understanding the physiological and molecular mechanisms behind sorghum stem thigmomorphogenic responses is a necessary step in developing lodging-resistant lines. While there is a substantial amount of information available regarding thigmomorphogenesis in plants, there are very limited studies in sorghum with many gaps. For instance, how the stem's developmental stage and duration of mechanical stimulation influence plant responses at transcriptomic level to mechanical stimulation have not been reported in sorghum. The current study investigated the effect of mechanical stimulation on the morphology, anatomy, biomechanical properties, transcriptome expression and endogenous hormones of sweet sorghum stems and if this effect was dependent on the developmental stage of the internodes or the duration of treatment.

Methodology: An automated apparatus was used to apply moderate mechanical stimulation on the stems of sorghum, Della. Four-point bending tests were used to measure biomechanical properties while hormone levels were quantified by LC-MS/MS. RNA-Sequencing of internodes was performed to study how mechanical stimulation affects gene expression.

Findings: Mechanical stimulation led to reduced length and increased diameter of internodes, and younger internodes experienced a more pronounced reduction in length. Mechanically-stimulated internodes exhibited lower elastic modulus and flexural stiffness but higher strength (more flexible, stronger) compared to control internodes. Mechanical stimulation also appeared to increase internode vascular bundle size and density as well as the lignification level and a more noticeable increase in lignin content was observed in younger internodes. Transcriptome profiling by RNA-Sequencing of internode rind revealed that mechanical stimulation altered the expression of over 900 genes, including a large number of transcription factors and genes related to cell wall biology and hormone signaling. The abundances of IAA, GA1 and ABA generally declined following mechanical stimulation, while JA was elevated. Weighted Gene Co-expression Network Analysis (WGCNA) identified three modules highly correlated with mechanical stimulation and morphological and biomechanical traits, which were significantly enriched in pathways associated with cell wall modifications, hormone signaling and general stress responses. Additionally, mechanical stimulation-triggered responses were found to be developmental stage- and dose-dependent.

Conclusion & Significance: Mechanical stimulation increases the strength and flexibility of sorghum stems, which is associated with altered transcriptome and hormone homeostasis. The critical biological processes and hub genes of sorghum stems in response to mechanical stimulation discovered in this study may offer opportunities to improve lodging resistance in sorghum and other crops.

Recent Publications:

1. SLi Q, Zargar O, Park S, Pharr M, Muliana A and Finlayson S A. Mechanical Stimulation Reprograms the Sorghum Internode Transcriptome and Broadly Alters Hormone Homeostasis. Plant Science (2022).

2. Zargar O, Li Q, Nwaobi C, Pharr M, Finlayson S A, and Muliana A. Thigmostimulation alters anatomical and biomechanical properties of bioenergy sorghum stems. Journal of the Mechanical Behavior of Biomedical Materials (2022).

Biography

Qing Li works in Department of Soil and Crop Sciences, Texas A&M University, USA. Her research interests are genetic engineering, plant science, anatomy.

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