Engineering study examines sunflower stem growth

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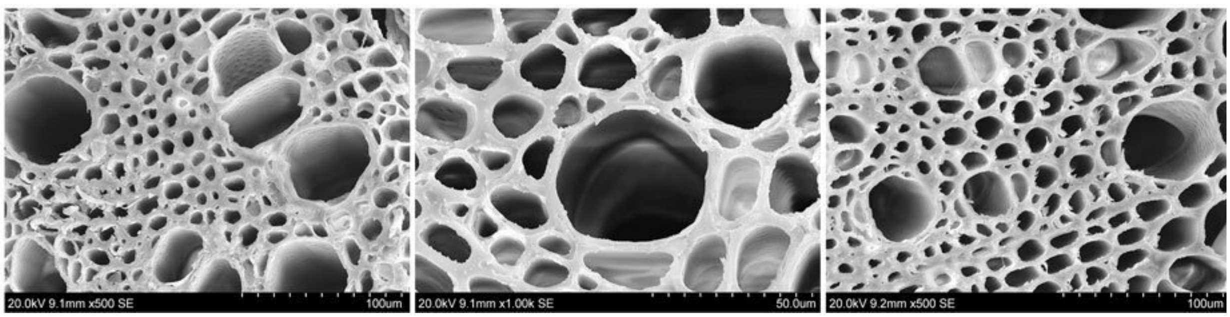

These microscope images show the cylindrical vascular tissue in a sunflower stem at six weeks, from left, eight weeks and 10 weeks of growth. With growth, the cross-section of vascular tissue becomes a more uniform circle, with an increase in cell diameter and cell wall thickness. Credit: South Dakota State University

Examining the structure of a sunflower stem as it matures can help both the plant scientist and biomaterials engineer. That's the premise that Anamika Prasad, an assistant professor in South Dakota State University's Department of Mechanical Engineering, is putting into practice.

"This is the first study to quantify structural and compositional changes in the sunflower stem at multiple stages of crop development," said Prasad, noting most of the literature from the engineering side on plants is on wood. Results will be published in the August 2020 issue of *Materialia*.

Prasad, whose expertise is in materials science and biomechanics, has done research on the structure and mechanics of bone and cardiovascular tissue in collaboration with medical doctors for more than 10 years.

Doctors use CT scans of healthy and diseased human tissues "to identify what is going wrong," she explained. "These techniques have been studied to diagnose plant diseases, but they are not commonly used." Prasad hopes to work with plant scientists to bring an engineering perspective to crop production issues including plant diseases.

That goal led her to collaborate with field crops pathologist Febina Mathew, an associate professor of agronomy, horticulture and plant science. Mathew's research at SDSU focuses on diseases of soybean, corn, sunflower and other broadleaf crops.

"This study gives us a different perspective on what is happening within a healthy plant and can be applied to study diseased plants," Mathew said. Plant diseases are usually diagnosed using laboratory tests, such as DNA/RNA-based identification methods. Spectroscopy-based techniques can complement these identification methods to confirm diagnosis of plant diseases and, possibly, asymptomatic infections of the crops.

The sunflower plants Prasad studied were cultivated under Mathew's supervision in the greenhouse to protect them from biotic stressors, such as diseases, weeds and insects.

Prasad's work was supported by the SDSU Research and Scholarship Fund. Doctoral student Mukesh Roy worked on the project through funding from the Department of Mechanical Engineering.

Examining stem structure

"Annual plants are a good template to design flexible polymer composites," Prasad said. Though trees grow radially outward once matured, annual plants, such as sunflowers, grow longitudinally during their short life cycle. To see how the vascular tissues within the plant stem change as they grow, the researchers examined a non-oilseed sunflower variety, collecting samples at four, six, eight and 10 weeks, which is when the plant begins flowering.

"At week four, we could only measure the girth because the stem was too soft for sectioning," Prasad said, noting that she and Roy also had to figure out how to analyze the tissues.

Surprisingly, the number of vascular tissue cells do not increase, but the shape and thickness of the cell walls change considerably to accommodate mechanical and biological demands, Prasad explained. At first, the cells are non-uniform cylinders, but as the plant grows, they take on a uniform circular cross-section, with their diameter and wall thickness also increasing. Correspondingly, the internal soft food storage cells in the stem pith decrease and the vascular tissues widen to accommodate the flow of water and nutrients.

"All of these internal modifications influence the load-carrying capacity and flow conduction properties," Prasad said.

Inspiring composite material design

"We are looking at the plant cell wall as inspiration for composite design and the cellulose within as biomaterial for manufacturing," said Prasad, whose research group is developing the infrastructure to incorporate cellulose nanofibers into structural engineering materials and biomaterials for medical applications.

This summer, Prasad is using her research on plant structure as a basis for designing composite materials for aerospace and defense applications through a U.S. Air Force Research Laboratory Summer Faculty Fellowship.

"The stem is a fiber-reinforced structure and cellulose is the building block of that fiber," she noted. Determining how the cell's structure handles strain may help engineers use those mechanics to design flexible composites.

Furthermore, different layers within the cell wall grow in unison, touching one another without breaking apart, Prasad pointed out. Understanding the underlying structural basis of this adhesive contact can provide inspiration for the design of composite materials.

Next, she is examining structural changes in soybeans based on the amount of water and nutrients they receive. To do this, Prasad is working with SDSU associate professor Sen Subramanian, whose expertise is in plant genetics and molecular biology.

More information: Mukesh Roy et al. Biomechanics of vascular plant as template for engineering design, *Materialia* (2020). DOI: 10.1016/j.mtla.2020.100747

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