Growing pains and how that might affect seed quality

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Sorghum harvest. Credit: Claire Benjamin/Carl R. Woese Institute for Genomic Biology, CC BY 2.0

How healthy a plant matures depends on how well it grows during its early life stages, which is not a surprise to anyone who has raised

children.

And in the face of mounting pressures, like inconsistent temperature patterns or the burden to produce more for us due to the lack of new arable land, plant health might be taking a beating.

Sang-Jin Kim and the Brandizzi lab are interested in making plants more productive and resilient in the face of these challenges so we can meet our own, like feeding a burgeoning global population or powering our cars and airplanes with sustainable biofuels.

In a study published in the journal *Planta*, Sang-Jin and his colleagues show how early stages of plant development, when seeds develop, are a turbulent time for a plant.

How well it can manage internal and environmental pressures is crucial to yield quality later on, and exposure to extreme heat at such a young age could be bad.

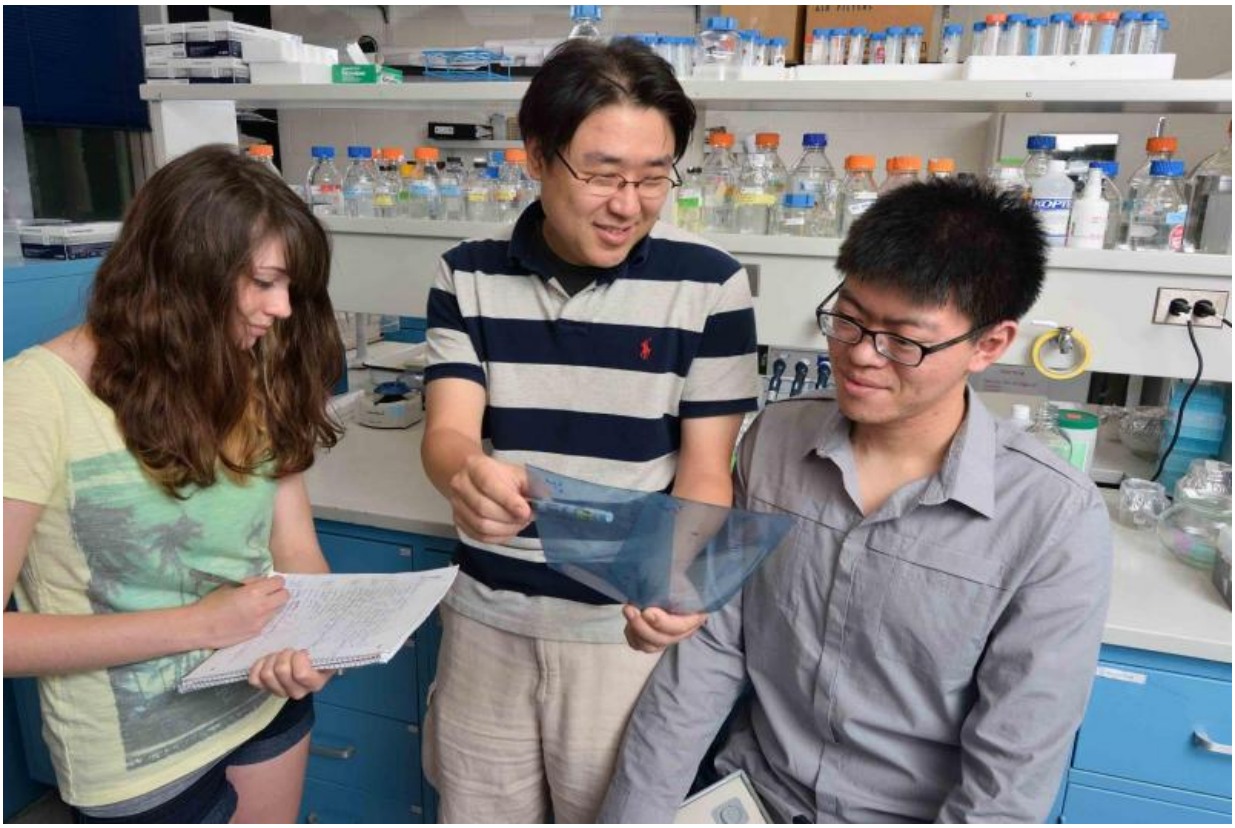
Protecting biofuel plants

Many of the nutrients that we get or the stuff that ends up in biofuels are created by proteins, which, in plant cells, are produced at massive secretory production centers called the endoplasmic reticulum.

"We were interested in the proteins that produce carbs that go into new seeds, specifically in plants targeted for producing biofuels, like sorghum or switch grass. The more you can pack those carbs in a seed, the more the yield later on."

Like any manufacturing center, the endoplasmic reticulum has a control mechanism, known as the unfolded protein response (UPR) when things go wrong.

"The endoplasmic reticulum might produce defective proteins, and that happens for many reasons, like high environmental heat or a heavy load of protein synthesis during early plant development." In those cases, the UPR kicks in to lower the burden of protein production and tells the plant to produce more of the good ones.



Dr. Sang-Jin Kim (center). Credit: Harley J Seeley

With climate change causing temperatures to rise globally, plants will struggle to keep up with hotter temperatures, and Sang-Jin wanted to see how heat affected seed development in sorghum and switch grass.

"But the UPR had been studied in other plants, not these two. We worked with a close relative of these plants, Brachypodium, which is easier to study in the lab. And we indeed confirmed the existence of the UPR."

Sang-Jin then subjected Brachypodium plants to various stresses to gauge their responses. "We treated them with artificial chemicals and also exposed them to hot temperatures they might face in nature, well over 100 degrees Fahrenheit. Both situations caused plants to feel the stress and activate the protective mechanism, possibly because they started cranking out defective proteins."

Seed quality suffers under extreme heat

Crucially, Sang-Jin also found that extreme heat affected how well seeds developed.

"Early on during seed development, the UPR is turned on at all times, even without any of the environmental stresses that usually trigger it."

"Perhaps, since filling the seeds with sugars and other nutrients requires massive amounts of new proteins, more than the usual, production is working at a higher rate. In that case, the UPR control is developmentally turned on as a precaution, or, more likely, because the rate of defects is higher."

When young seeds were exposed to hot temperatures, the already active UPR didn't ramp up much more. "Maybe the UPR is at full capacity at this stage, unable to take any more load."

In a separate observation, heat exposure at early developmental stages led to seed quality taking a hit. The team noted that a crucial carbohydrate for human and livestock consumption, called MLG, was

less present in heat-stressed seeds. "The seeds weighed less, and the genes responsible for making the carb were less abundant."

Sang-Jin is not sure yet whether the high activity rate of the UPR and seed nutritional quality are interrelated during seed development, but he suspects it's the case.

"What we do know is that seed quality decreases with exposure to extreme heat, which affects crop yield later." And as the climate continues to change, plants might need our help in order to stay vigorous. We'll need theirs too.

More information: Sang-Jin Kim et al. In Brachypodium a complex signaling is actuated to protect cells from proteotoxic stress and facilitate seed filling, *Planta* (2017). DOI: 10.1007/s00425-017-2687-7

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