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Quinoa research punctures 100-year-old theory of odd little 'water balloons'

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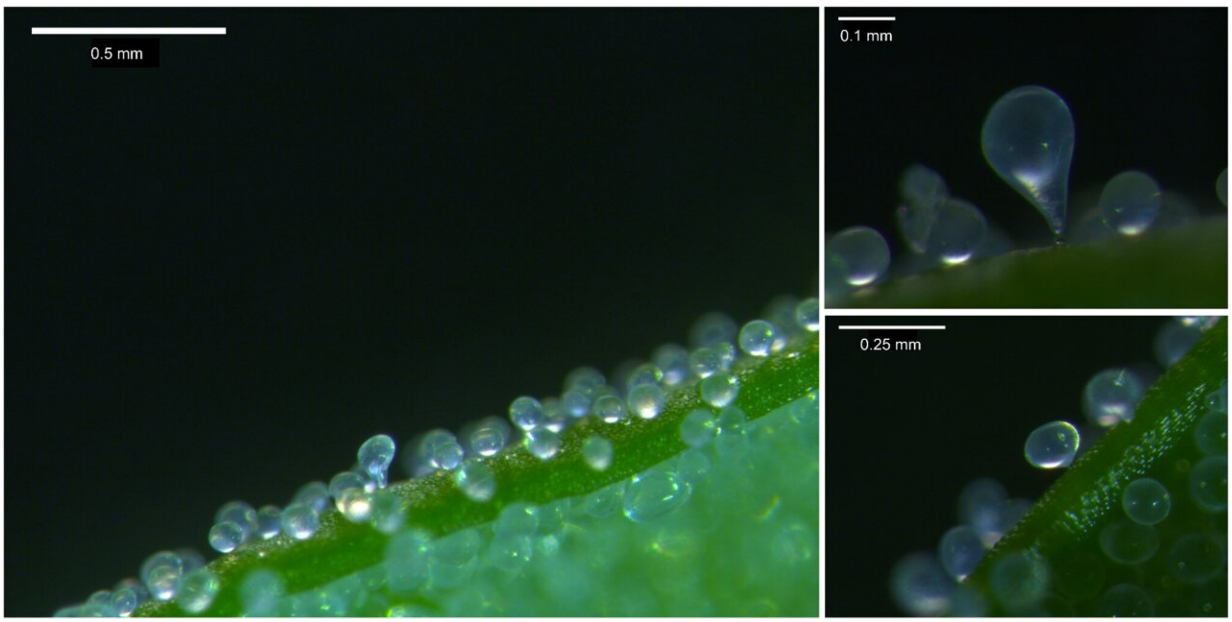


The bladders, with which the surfaces of many quinoa varieties are completely covered, look like small balloons on a stem. Credit: University of Copenhagen

Quinoa and many other extremely resilient plants are covered with strange balloon-like "bladders" that for 127 years were believed to be responsible for protecting them from drought and salt.

Research results from the University of Copenhagen reveal this not to be the case. These so-called bladder cells serve a completely different though important function. The finding makes it likely that even more resilient quinoa plants will now be able to be bred, which could lead to the much wider cultivation of this sustainable crop worldwide. The findings are published in the journal *Current Biology*.

Looking through a microscope, it resembles a water balloon. Or a piece of glass art. But it's just a so-called bladder cell. If you wondered what it was for, you wouldn't be the first. For 127 years, even the brightest minds in plant biology believed that the fluid-filled bladders covering the leaves, clustered flowers and stems of a range of hardy plants were something completely different from what they now turn out to be.

The discovery was made thanks to a new piece of research from the University of Copenhagen that completely contradicted the researchers' expectations. The new insight can probably be used to expand the cultivation of a particularly nutritious and climate-resilient crop.

"Quinoa has been touted as a future-proof crop because it is rich in proteins and highly tolerant of drought and salt, and thus climate change. Scientists believed that the secret to quinoa's tolerance was in the many epidermal bladder cells on the surface of the plant. Until now, it was assumed that they served as a kind of salt dump and to store water. But they don't, and we have strong evidence for it," says Professor Michael Palmgren from the Department of Plant and Environmental Sciences.

Bulwark against pests

Three years ago, a research group led by Ph.D. student Max Moog and his supervisor Michael Palmgren began studying the epidermal bladder cells of quinoa plants in ways that had never been used before. The hope was to understand the plant's mechanisms for making it resilient to salt and drought.

To this end, the researchers cultivated mutant plants without bladder cells to compare their reactions to salt and drought with those of wild quinoa plants covered with bladder cells.

To their surprise, the researchers discovered that bladder cells have no positive influence on the plant's ability to tolerate salt and drought. On the contrary, they seem to weaken tolerance. Instead, bladder cells serve as a barrier against pests and disease.

"Whether we poured salt water on the mutant plants without bladder cells or exposed them to drought, they performed brilliantly and against expectations. So, something was wrong. On the other hand, we could see that they were heavily infested with small insects—unlike the plants covered with bladder cells. That's when I realized that bladder cells must have a completely different function," says Max Moog, now a postdoc at the Department of Plant and Environmental Sciences and first author of the study.

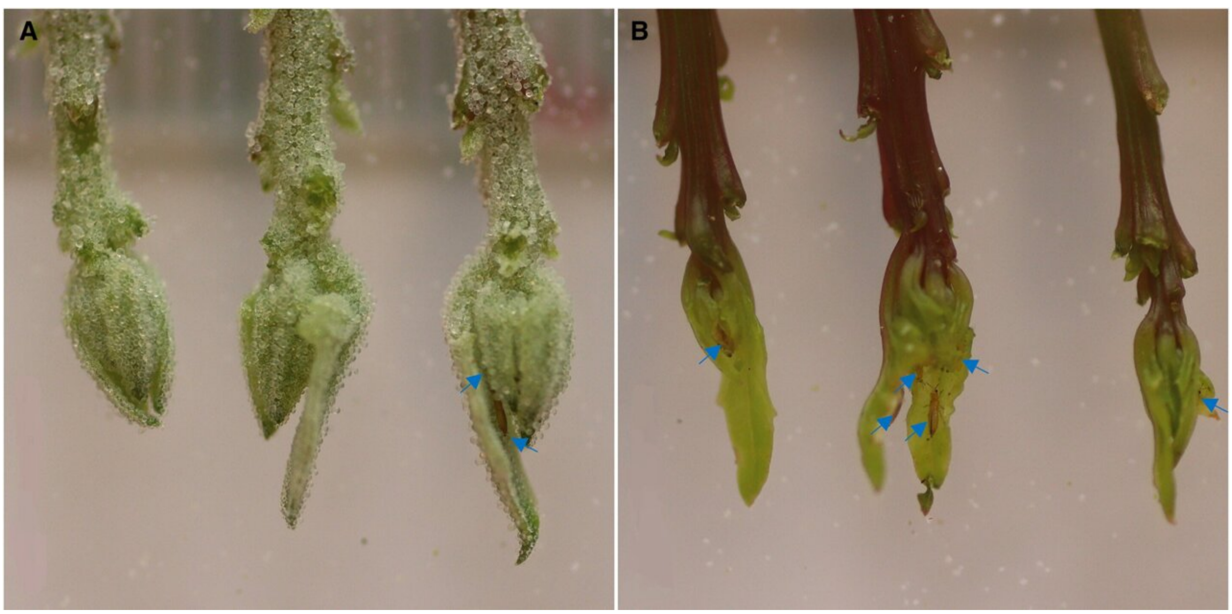
When the researchers analyzed what is hidden inside the bladder cells, they did not find salt as expected—despite having added extra salt to the plant. Instead, they found compounds that repel intruders.

"We discovered that bladder cells act as both a physical and chemical barrier against hungry pests. When tiny insects and mites trudge around on a plant covered with bladder cells, they are simply unable to get to the juicy green shoots that they're most interested in. And as soon as they try to gnaw their way through the bladder cells, they find that the contents are toxic to them," says Michael Palmgren.

Among other things, the epidermal bladder cells of quinoa contain oxalic acid, a compound also found in rhubarb, which acts as a deadly poison on pests.

The experiments also demonstrated that the bladder cells even protect quinoa against one of the most common bacterial diseases in plants, Pseudomonas syringae. This probably happens because the bladder cells partially cover the stomata on the plant's leaves, a point of entry for many bacterial invaders.

"Our hypothesis is that these bladder cells also protect against other plant diseases like downy mildew, a fungal disease which severely limits quinoa yields," says Max Moog.



Juicy shoots of the quinoa plant are covered with small bladders (left). To the right is a mutant plant completely free of bladder cells. Blue arrows point to thrips—small insects that are serious pests and by which the mutant is attacked more severely. Credit: University of Copenhagen

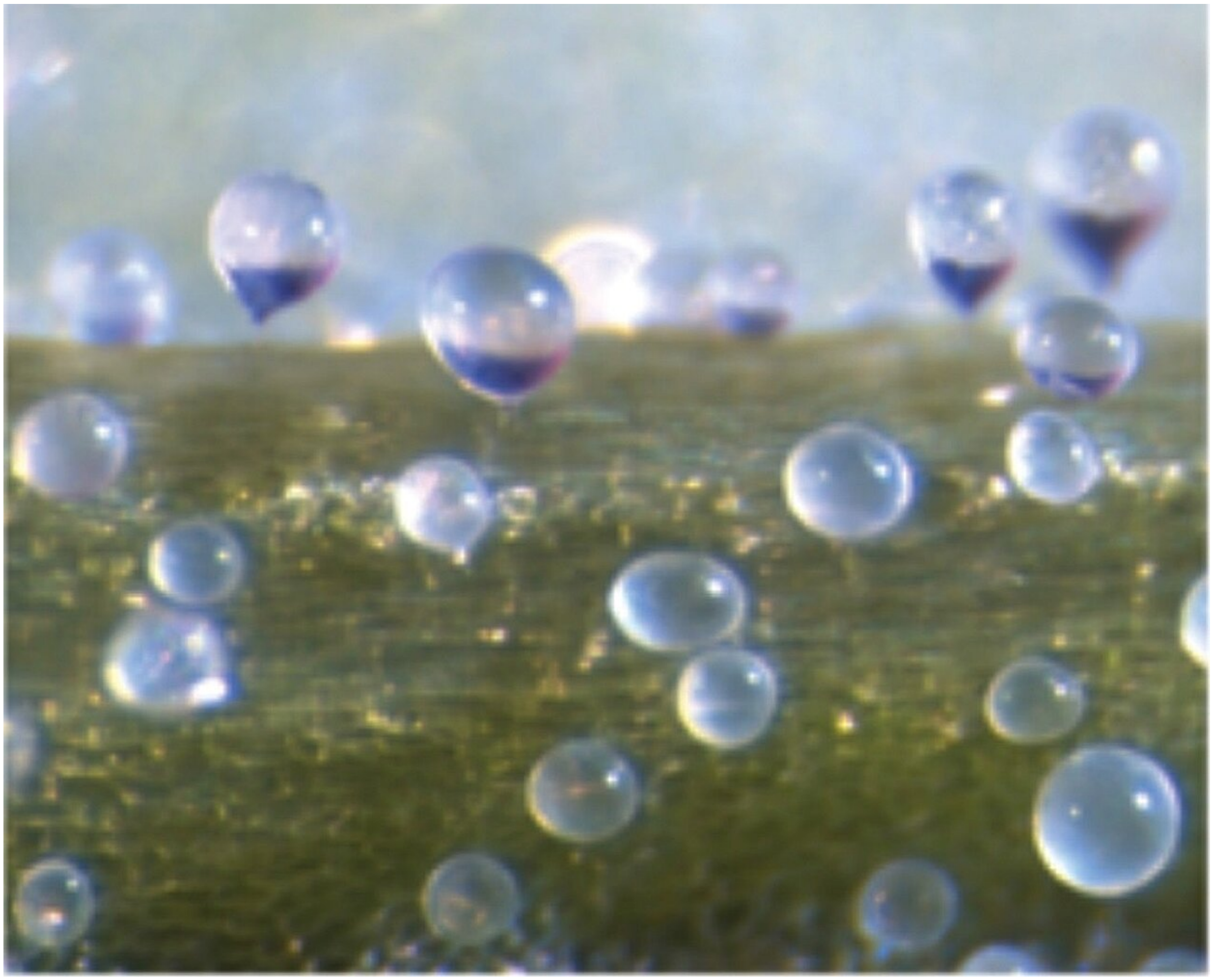
The key to extra tolerant 'super-quinoa'

There are thousands of varieties of the South American crop, and the density of bladder cells on the plant's surface varies from variety to variety. But there is much to suggest that density determines how effective a safeguard the bladder cells are.

"Quinoa varieties with a higher density of bladder cells are most likely more robust against pests and diseases. On the other hand, they may be slightly less tolerant of salt and drought. And vice versa. These variations don't change the fact that quinoa is generally very resistant to salt and drought. But the explanation must be found somewhere other than in the bladder cells," says Max Moog.

"Due to efforts to expand quinoa cultivation around the world, the new knowledge can be used to adapt the crop to various regional conditions. For example, southern Europe has very dry conditions, while pests are a bigger problem than drought in northern Europe. Here in northern Europe, it would make sense to focus on quinoa varieties that are densely covered with bladder cells."

According to Michael Palmgren, the new results provide a concrete recipe for how to breed "super-quinoa" relatively easily. "Thus far, these bladder cells have been ignored in the breeding of quinoa. If you want a crop that is extra resistant to pests and diseases, but is still tolerant of salt and drought, one can opt to breed varieties that are densely covered with bladder cells. So, we may now have a tool that allows us to simply cross-breed our way to an extra tolerant 'super-quinoa,'" says Michael Palmgren.



Epidermal bladder cells seen through a microscope. Credit: University of Copenhagen

Michael Palmgren and Max Moog from the University of Copenhagen. Credit: University of Copenhagen

The research results add a new dimension to our knowledge about quinoa. Until now, very little was known about how the plant defends itself against attacks from hostile organisms.

"Now we know, quinoa isn't just tolerant of non-biological stressors like drought and salt, but also of biological influences such as pests and pathogenic bacteria. And at the same time, we've found the secret of these odd-looking bladder cells. This research is an example of how what's established doesn't always turn out to be what's true," concludes the professor.

More information: Max W. Moog et al, Epidermal bladder cells as a herbivore defense mechanism, *Current Biology* (2023). DOI: 10.1016/j.cub.2023.09.063

Provided by University of Copenhagen