QnAs with Elizabeth Ainsworth

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The atmosphere of today will be increasingly different in the coming decades as it continues to respond to human influences. Elizabeth Ainsworth, of the US Department of Agriculture (USDA) Agricultural Research Service (ARS), recently received the 2019 National Academy of Sciences Prize in Food and Agriculture Sciences for her efforts to explore how increasing carbon dioxide and ozone affect crucial food crops like soy and corn. As lead investigator of SoyFACE Global Change Research Facility in Urbana, Illinois, Ainsworth runs an open-air laboratory that allows researchers to simulate atmospheric conditions in the year 2050 and beyond. She recently spoke to PNAS about her prize-winning research.

PNAS: Have you always been interested in science and agriculture?

Ainsworth: I discovered plant biology and ecology at UCLA [University of California, Los Angeles] and spent 2 semesters doing fieldwork abroad. In Thailand, I measured photosynthesis for the first time. That was exciting, and my first introduction to a process that I continue to study.

Elizabeth Ainsworth. Reprinted with permission from the RIPE project.

My interest in agriculture goes back even further. I grew up in a small town in Illinois and come from generations of farmers and corn breeders. My first job was working in a cornfield, but I never really thought agriculture would be my career path.

Then, I joined Steve Long's laboratory at the University of Illinois. He studied photosynthesis and climate change as well. It merged fields of environmental sciences with biology and an emphasis on photosynthesis; that was just a great fit for me. Those disciplines have been what I built my career around.

PNAS: In your prize acceptance speech, you listed 3 grand challenges of agriculture: adapting crops to climate change, reducing the environmental impacts of agriculture, and nutritiously feeding a growing population. Can you elaborate on these challenges?

Ainsworth: If we look out into the future, many of our growing environments will be so different from what they are today that we don't really have a good analog for future growing conditions.

There's also a social challenge, especially in this country. There are loud voices that deny climate change and the role that humans play, which leads to inaction. The climate is already changing in ways that negatively impact agriculture.

For example, the floods this year across the US Midwest have made it incredibly challenging to plant crops. Increased spring precipitation is shortening the planting window in one of the most productive growing regions in the world. At the same time, later this summer, farmers will probably face drought and high temperatures. These stresses have challenged agriculture since its inception, but the speed at which we're changing the environment is new.

If we think about the remarkable growth of yields in agriculture, much of that has come from using resources [that] are not renewable and have had negative environmental consequences. Sustainability has never been a major goal; productivity has been a goal, and that priority needs to change.

Giving the public a voice in each of these challenges is really important to later adoption of potential solutions. I think addressing some of the social aspects

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of these challenges, as well as doing the research to really find solutions, is important.

PNAS: What is the SoyFACE partnership and how does it differ from other methods used to study plant responses?

Ainsworth: FACE stands for Free Air CO_2 Enrichment. It's a technology to release carbon dioxide or air that's enriched with ozone across a field in a totally open-air situation. There's no greenhouse, and there's no growth chamber; you're just out in a field. SoyFACE basically looks like any other farmer's field except that we have the capacity to grow the plants in the atmospheres that we expect in the future.

If you grow a crop like soybean in a greenhouse in a pot, it often doesn't really look like a soybean in the field. The phenotype of the plant in terms of leaf display, stem strength, or seed yield is totally different. FACE technology is as close as it gets to a real-world farmer's field with a future atmospheric environment.

Our FACE experiment is jointly supported by the University of Illinois and the USDA ARS, and provides a facility where faculty from around the world have collaborated to ask questions about how crops respond to global climate change.

PNAS: Has your ability to fast-forward atmospheric conditions revealed anything unexpected?

Ainsworth: Stomata are pores on the leaf's surface, and, as they open and close, CO_2 enters and water is lost. Under high CO_2, stomata close, which in theory would improve the water use efficiency of the plant, leave more water in the soil, and make plants more tolerant to drought. What we expected, from many decades of work, is that the benefits of elevated CO_2 would be greater under dry conditions. We found the opposite in the FACE experiment. Yield responses of soybean were greatest under ample water supply. This was a surprise and a reminder to revisit basic assumptions about the hypotheses we're testing (1, 2).

PNAS: How do you look for the underlying mechanisms of these responses and what is your ultimate goal?

Ainsworth: We've done gene expression analysis so that we can identify some of the genes that are involved in the response to CO_2 and to ozone pollution (3, 4), and we've looked at different [plant] tissues to try to understand whether the genes that are changing are specific to different tissues. Do flowers respond the same way as, say, developing seeds or leaves? The answer there is "no," which is intriguing. There are independent mechanisms of sensing changes in the environment and stress (5).

The other thing that we are currently doing is using metabolomics approaches to try to identify the initial molecules that are formed in ozone stress. That level of information can be used to identify transgenic solutions.

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2 S. B. Gray *et al.*, Intensifying drought eliminates the expected benefits of elevated carbon dioxide for soybean. *Nat. Plants* **2**, 16132 (2016).

3 K. M. Gillespie *et al.*, Greater antioxidant and respiratory metabolism in field-grown soybean exposed to elevated O3 under both ambient and elevated CO2. *Plant Cell Environ.* **35**, 169–184 (2012).

4 A. D. B. Leakey *et al.*, Genomic basis for stimulated respiration by plants growing under elevated carbon dioxide. *Proc. Natl. Acad. Sci. U.S.A.* **106**, 3597–3602 (2009).

5 C. P. Leisner, R. Ming, E. A. Ainsworth, Distinct transcriptional profiles of ozone stress in soybean (*Glycine max*) flowers and pods. *BMC Plant Biol.* **14**, 335 (2014).