Crop Stress Bulletin

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Stress Steals Yield Before You See It

Tom Sinclair
North Carolina State University

Even when everything is right...the optimum seedbed, nutrients and crop protection...yields can still fall short of expectations if the weather doesn't cooperate. Abiotic stress, including temperature extremes, drought and excess soil moisture as well as salts, toxins and even excess light, can all impact yield. The most common and greatest stress is water related, advises Tom Sinclair, adjunct professor, Dept. of Crop Science, North Carolina University.

"When we talk about abiotic stress in the Midwest and West, 80 to 90 percent of the time we're talking about water and how the plant uses it," says Sinclair. "In soybeans we can have severe nitrogen (N) deficiency due to drought before we even know the plant is getting dry. We don't see stress until the plant wilts, but by then we've lost at least half the N fixation capability. And a lot of other things have started to shut down as well, including photosynthesis and leaf growth."

Water or the lack of it is only one of many stresses crops deal with each year. High temperatures, especially at night, can steal up to a bushel of corn a day from potential yields, points out Fred Below, professor, Crop Physiology, University of Illinois. While 86° is the optimum daytime temperature for corn and 98° or above causes heat stress during the day, 73° is the tipping point for nighttime temperatures.

"The plant has no way to cool itself at night with the stomates closed," explains Below. "Without transpiration, it is like putting the plant in an oven."

During the day, the opening of the stomates cools the plant. In the case of drought, the stomates close to conserve moisture. That too can be a problem, observes Below.

"I believe plants over respond to stress," he says. "When it is dry, you want the stomates to close, but not too soon or for too long."

Fred Below
University of Illinois

Plant stress response timing can be a problem, allows Sorina Popescu, assistant professor, Boyce Thompson Institute for Plant Research (BTIPR), Cornell University. "Protein receptors in cell membranes are sentinels that continuously monitor the environment; when they perceive a stress signal they become active and recruit other proteins in an enzymatic cascade that transmits the stress signal all the way to the cell nucleus. In the nucleus, where gene transcription takes place, the stress signals changes the gene expression to prepare the plant for a response. This begins to affect the plant," she explains. "This signaling pathway is triggered seconds after the receptors perceived the stress signal; however, the changes in gene expression can last for days or weeks and strengthen the plant ability to withstand stress, considerably."

In fact, the gene expression can last the rest of the season, suggests Sharon Clay, agronomist, South Dakota State University. Clay's research team has found that stress can permanently down regulate the genes responsible for immune response, for insect damage response and for phosphorous uptake, as well as for photosynthesis.

Sorina Popescu
Cornell University

"The genetic response takes place before any obvious signs of stress are seen," says Clay. "The crop doesn't have to be severely stressed before the down regulation occurs, and it can occur at early as well as later stages."

Under optimum conditions, the down regulation may not noticeably impact yield. However, should the crop be stressed later in the season, yield loss could occur. An affected plant may be less able to handle a stress-induced build-up of reactive oxygen species (ROS). These chemically reactive molecules containing oxygen include peroxides and oxygen ions that are constantly being produced in a healthy plant as part of oxygen metabolism. Normally, plant enzymes break them down to be used in plant growth. In plant tissue faced with an invading stress, ROS may initially act as a plant protectant such as forming hydrogen peroxide that strengthens the plant cell wall. However, too much ROS can damage surrounding cells or lead to plant death.

"The commonality to all abiotic stress is that it leads to increased accumulation of ROS," says Popescu. "Depending on the stress, the receptors and the signaling pathways, ROS can accumulate in different places, in the chloroplast of the cell, outside the cell in the apoplast or even in the mitochondria or cytoplast."

Differences in how much and where ROS locates, as well as how it affects gene expression, creates a specific response, such as the leaf rolling associated with drought stress. Such visible signs are often not seen until late in the stress response, perhaps long after the short or even long term damage to yield has been done.

Abiotic Stress Research Showcase

(Editor's note: Periodically, we will showcase a leading research center working on abiotic stress response in plants.)

The Boyce Thompson Institute for Plant Research (BTI) at Cornell University has as its goals, improving agriculture, protecting the environment and enhancing human health. Copper magnate and philanthropist William Boyce Thompson established the institute in 1920 in response to hunger and suffering he had witnessed while on a Red Cross relief mission to Russia in 1917.

Thompson determined the institute should study, "why and how plants grow, why they languish or thrive, how their development maybe stimulated by the regulation of the elements which contribute to their life."

For the past 95 years the institute affiliated with Cornell University since 1978, continues to work towards Thompson's goals. Research discoveries include:

- Plant disease resistance
- Salicylic acid pathway for systemic acquired resistance
- Plant and bacterial proteins effects on immunity
- Plant insect resistance – plant genes and small signaling molecules
- Natural small molecules in plant and human health
- Plant-based vaccines
- Vaccine and other protein production in insect cell lines

In recent years, recognition that reactions of plants to pathogens and abiotic stress may utilize similar cellular pathways and biological processes, has led to expanded research in Plant Stress. Researchers explore how plants respond and adapt to adverse environmental factors, such as extremes in water supply, light, temperature and soil nutrients. They recognized that the key to unravelling the complexity of plant stress responses is signaling – a communication systems which mediates the dialog between plant cells and their surroundings. Discovery of signaling molecules that alert and help plants defend themselves against multiple stresses is a tangible goal with tremendous benefits for the agriculture.

Researchers share expertise in diverse fields of plant signaling, molecular systems biology, insect resistance, photosynthesis, biotic/abiotic stress tolerance and utilize advanced approaches in bioinformatics, small molecule chemistry, proteomics, plant transformation and cell culture. Overlap and interaction of research areas and researchers encourage a holistic approach to understanding plants and their relationships to the environment and other organisms.

William Boyce Thompson could not have envisioned the technological tools being used today, nor could he have imagined the advances that have been made in understanding plants and related organisms. However, he certainly would approve of the role of his institute in discovering new fundamentals which can be applied to fulfill the humanitarian goals he first identified nearly a century past.

For soybean growers, hidden cost of climate change tops $11 billion

Even during a good year, soybean farmers nationwide are, in essence, taking a loss. That's because changes in weather patterns have been eating into their profits and taking quite a bite: $11 billion over the past 20 years.

This massive loss has been hidden, in effect, by the impressive annual growth seen in soybean yields thanks to other factors. But that growth could have been 30 percent higher if weather variations resulting from climate change had not occurred, according to a study by University of Wisconsin-Madison agronomists published last month in Nature Plants.

"We are still making yield gains because of breeding and other strategies, but those numbers aren't as big as they could be," says lead author Shawn Conley, a UW-Madison agronomy professor and UW-Extension soybean and wheat specialist.

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About The Writer

For more than 30 years, Jim Ruen has specialized in technical writing within the agricultural industry, from basic and applied research to on-farm application and management of technology. Jim serves as a contributing editor to publications including Corn & Soybean Digest, Ag Professional, and Progressive Farmer.

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About Crop Microclimate Management

Crop Microclimate Management is based in Apex, N.C. and is one of the few companies in the world that focuses exclusively on research and development of products to help crops handle abiotic stressors to improve plant health and yield.

Learn more at www.cropstress.com