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Steroids Could Add Bulk to Crop Harvests



Image Title: One of the broad goals of HHMI investigator Joanne Chory is to identify the mechanisms by which plants respond to changes in their light environment. - Mark Harmel

Taking steroids is a definite no-no for human athletes, but treating plants with steroids could offer performance enhancement of a more desirable nature by boosting the biomass and seed yields of crops. Unfortunately, plant steroids are complex, expensive chemicals, and the biological mechanisms by which they alter plant growth and development have remained largely a mystery.

Now, however, two research articles by Howard Hughes Medical Institute investigator Joanne Chory and her colleagues open a new pathway to understanding how plant steroids work at the molecular level. The discoveries made by Chory's team may one day lead to less expensive ways to trigger growth enhancement of plants.

“The common theme of these two articles is that we are now beginning to unravel the molecular mechanisms by which steroid hormones regulate gene expression in plants,” said Chory, who is at The Salk Institute for Biological Studies.

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- Joanne Chory

The first study reveals how plant steroid hormones, called brassinosteroids, plug into and activate receptor proteins on the surface of plant cells. Receptor activation is the first step in triggering processes, such as growth, development, the stress response and senescence—the deterioration of plants at the end of a growing season. In a second study, the researchers identified and clarified the function of specific transcription factors, which are proteins that regulate genes involved in the cell's response to steroids.

The researchers reported their findings in articles published in the January 13, 2005, issue of the journal *Nature* and in the January 28, 2005, issue of the journal *Cell*. Chory and her Salk Institute colleagues collaborated on the studies published in *Nature* with Japanese researchers at Kyushu University and the RIKEN research institute. They collaborated with researchers from RIKEN on the studies published in *Cell*.

“Before this work we had a genetic model for what we thought was going on with steroid signaling in plants,” said Chory. This model resulted from studying the effects of mutations in genes that were believed to be part of the steroid signaling machinery.

Those experiments hinted that one important steroid-related gene coded for a receptor protein called BRI1 that bound to the cell membrane. Their experiments indicated that another protein, a kinase called BIN2, appeared to act negatively in the steroid pathway to modify BES1 and BZR1 proteins, which targeted these proteins for turnover. In the presence of the steroids, BIN2 becomes inactivated by an unknown mechanism, thereby allowing BES1 and BZR1 to accumulate in the nucleus of the plant cell.

“Although we've known about BRI1 for almost eight years, we hadn't shown that it was actually a steroid receptor and not just part of a bigger complex,” said Chory. To determine whether BRI1 was indeed the steroid receptor, co-author Hideharu Seto of RIKEN constructed synthetic versions of a functional steroid molecule that carried a telltale chemical tag. This synthetic steroid could also form a tight chemical bond with its natural target molecule

when exposed to ultraviolet light. Experiments done in the Chory lab demonstrated that this synthetic steroid interacted directly with BRI1 and allowed her team to define a small region of BRI1 that is outside of the cell as the part of the molecule responsible for steroid binding. “These experiments enabled us to show definitively that BRI1 was actually binding to the steroid itself and wasn't just part of a bigger complex”, said Chory.

Chory said that demonstrating that the steroid binds to BRI1 will open the way to new studies of the structural details of the interaction. “We will aim to obtain a three-dimensional structure of this receptor both with and without the steroid attached,” she said. “And once we do that, we can begin to understand how this binding transmits signals inside the cell.”

In the article published in *Cell*, Chory and her colleagues discovered important new details about how steroids transmit a chemical signal to the interior of plant cells. “Our genetic studies had identified the proteins BES1 and the similar protein BZR1 as two that accumulate in the nucleus as a result of steroid action,” said Chory. However, despite the fact that the proteins were in a location and in a form that suggested they could regulate gene activity, they did not appear to possess any of the known structures found in transcription factors seen in either plant or animal cells, said Chory.

But the researchers' experiments showed that BES1 does, indeed, bind to and interact with DNA in a way that one would expect if it were a transcription factor. The experiments also revealed that BES1 joins with another transcription factor called BIM1 to activate genes known to be regulated by steroid hormones.

“So, in these two papers we have established a precise function for proteins that were known from genetic experiments to be important in steroid signaling, but we didn't know exactly what they were doing,” concluded Chory.

“These findings open the way to understanding the molecular mechanism of one of the key plant growth hormones; and this will offer the prospect for actively increasing the biomass and yield in crop plants,” she said. “Understanding this mechanism is important because, although the steroids themselves do affect plants, they are prohibitively expensive. If we can find simpler ways of manipulating these biosynthetic response pathways in plants, it could have a very significant impact on crop yields, as well plant response to stress and to senescence programs,” said Chory.