# Eavesdropping on Plants To Save Water on Crops

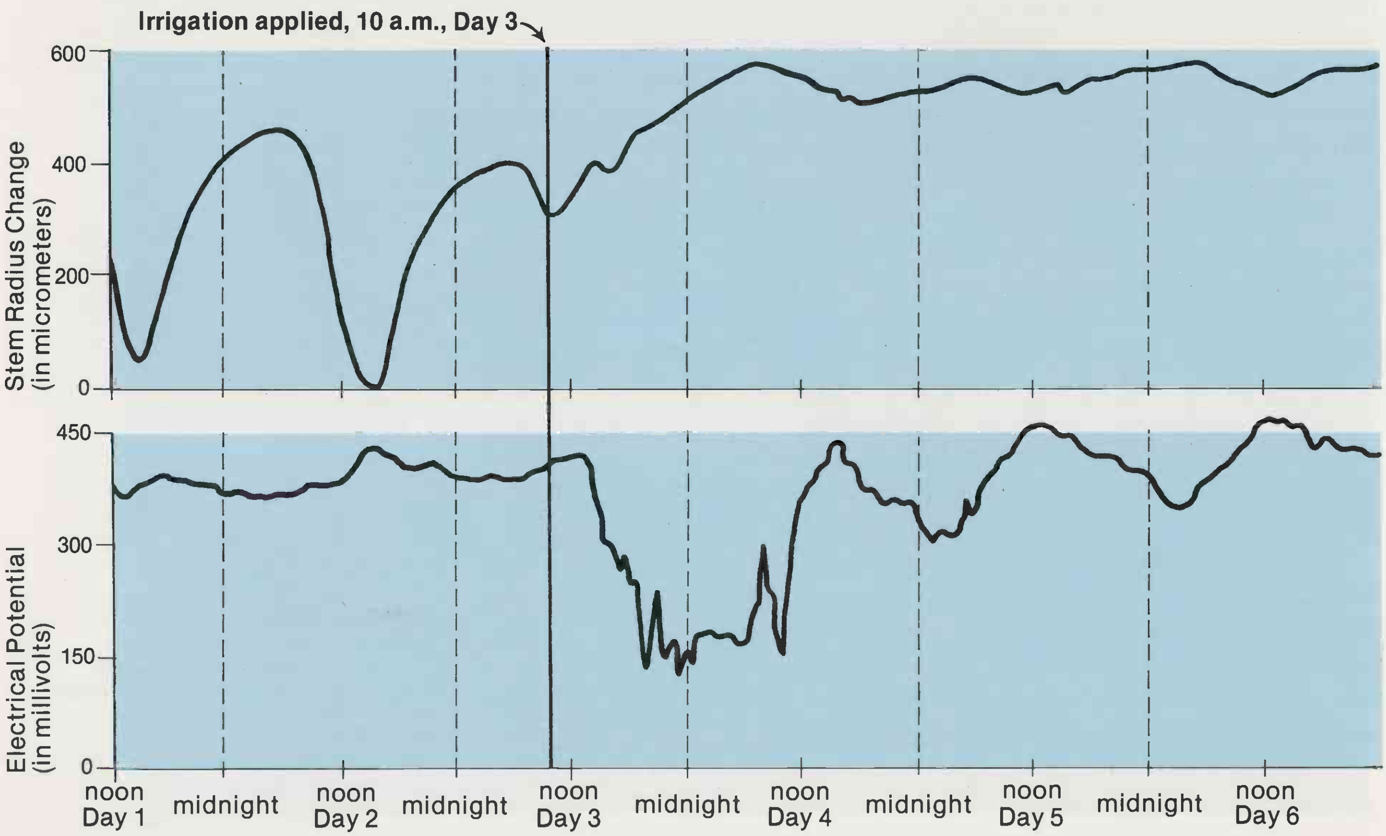
If you listen right, the plants are talking.

A field of cotton plants sends out messages. If we can learn their language, the field's farmer might know when the plants need water or fertilizer, or feel other distress.

Electrical engineer Dr. William G. Gensler and co-workers in the UA College of Engineering have developed two types of minature devices to pick up plants' signals. One measures changes in the electric charges that build up in plant tissues. The other measures tiny fluctuations in the diameter of a plant's stem.

The researchers have worked with Avra Valley Farmer Herb Kai and other cooperators.

Last summer, measuring devices fastened to scattered plants in Kai's cotton automatically took readings every 15 minutes. The readings were fed into a solar-powered transmitter that radioed the information 25 miles back to a computer at the University of Arizona.




Cotton plants respond to irrigation. Graphs of plants' stem radius and electrical potential for days 1 and 2 show typical day-night cycles. After more than a week without watering, plants were irrigated at 10 a.m. on day 3. Stem thickness increased. Its day-night cycle became less exaggerated while soil moisture was plentiful. The electrical potential dropped and fluctuated within hours after irrigation was applied. In following days, the day-night cycle of electrical potential was different than in the days beforehand.

With the computer, Gensler has found patterns in the cotton plants' signals that appear to correspond to their water needs. This year, he is checking the reliability of those patterns on a test field at a UA research farm in northwest Tucson. He plans to use the cotton plants' signals to schedule late-season irrigation.

"It's a matter of reducing 10,000 or 15,000 data points down to one index number that tells a grower either it's time to irrigate or it's not," said Gensler.

He expects to refine his equation for that index number over the next growing season or two by comparing the irrigation timing it implies with timing indicated by traditional methods.

"The next step is to send the index back to the grower," said Gensler. He foresees growers using telephone hookups between their farm computers and the university computer. Kai is also interested in telemetric readings from irrigation pumps – such as their oil pressure, operating temperature and speed – to help irrigate efficiently.

**Water Stress and Irrigation Timing**

Kai said growers could benefit from an improved method for judging plants' need for water, to help in determining when to irrigate.

"Now, it's just the farmer walking through the field and looking at the color of the plant, sometimes feeling the temperature of the leaves," said Kai. "You can tell when they're stressed for water by their color, and by the curl of the leaves."

Some water stress is desirable for getting cotton plants to set bolls instead of just growing more stem and leaves. With more sensitive measurement of stress, said Kai, "We might be able to apply water soon enough to keep from shocking the plants too much, but not so soon that we would just promote vegetative growth by not stressing the plant at all."

He and Gensler both expect that more precise scheduling of irrigations would save water.

Measurement of soil moisture provides one way to refine the scheduling of irrigation. Some test systems even feed soil-moisture information automatically through a computer. Another method uses infrared measurement of plants' temperature. Plants warm up when stressed by lack of water.

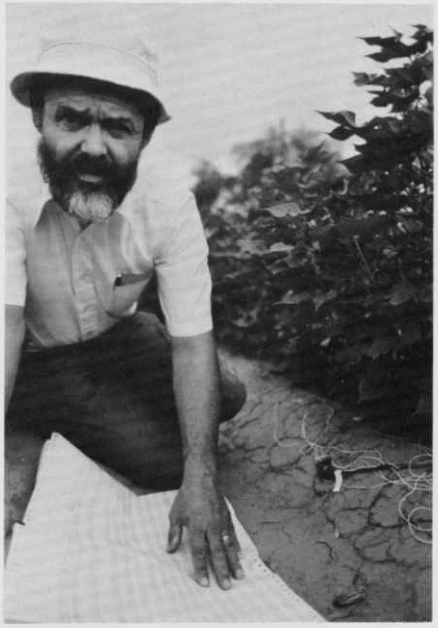
Gensler figures that the best way is to use direct sensing of the plants' physiological signals, ones that show up even without stressing the plants.

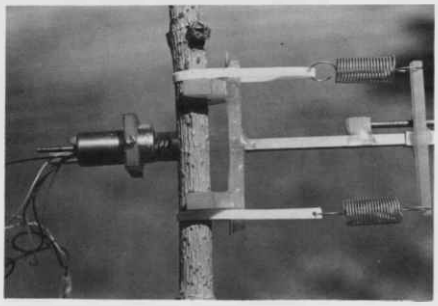
In 6 years of laboratory work, he developed and tested electrodes installed on plants. His resulting design uses tiny palladium rods inserted into the stems of plants. He has used them in laboratory and field tests to monitor the electrical changes in several types of plants, including tomatoes, pecan trees and cotton.

The electrodes can detect changes in voltages as small as a few millivolts. The fluctuations in plants are often in the range of several hundred millivolts. "For example," said Gensler, "You get an incredibly active response when you irrigate."

However, to correlate the electrode readings with the plants' need for more water, Gensler needed a separate way to evaluate plants' water status. For that, he has developed a sensitive gauge of stem diameter. It can be clamped onto a young plant for a whole season of readings.

"When a plant is drawing up water through its stem, the stem con-





Top: Dr. William Gensler checks sensors and readouts in a Tucson cotton field row.
Bottom: Sensors such as this automatically measure miniscule changes in stem diameter every few minutes throughout the growing season.

tracts," he explained. "It can change as much as 400 microns in a 4-hour period. . . .When it has plenty of water, it doesn't contract as much."

After an irrigation, the stem expands, simutaneously with a burst of electrical activity in the plant (see graph).

Combining the two types of signals from plants has helped him interpret each type better. Both show correlations to time of day and other variables besides water status. In future tests, Gensler plans to settle on whichever method provides cheaper and more reliable monitoring, probably the electrical measurement.

**Not for State-of-the-Art's Sake**

"We're not doing this just for the sake of making measurements," he said. "We have to deliver meaningful information to a grower in an economical way. . . . I figure we have to make the measurements and deliver the analyzed information for about $500 for the whole season for an 80-acre plot. I think we will be able to do that."

Much of the cost is installation of the electrodes. Each takes 4 or 5 minutes. Fifteen to 25 sensors in a field are wired to a small, buried transmitter. The transmitter cuts labor costs for the rest of the season by minimizing the number of trips to the field.

For 4 years, Gensler has hooked up sensors to cotton grown at the UA research farm along Interstate 10 in northwestern Tucson. There he can manipulate irrigation timing to study the system. Farm supervisor Glen F. Barney, cotton specialist Dr. B. Brooks Taylor and county agent Jim F. Armstrong have provided help from the College of Agriculture, said Gensler.

He began working with Kai and with the Farmers' Investmemt Company pecan orchards 2 years ago to be sure that the system could operate under commercial farming conditions.

"The measuring and the telemetry can work right now," said Gensler. "This is absolutely state-of-the-art electronics. . . . The emphasis now is on understanding the biological criteria responsible for these changes that we're measuring."

Gensler refines field-site recording equipment between growing seasons.