Predicting the Perfect Moments in Farming

From Planting to Harvest

KEN HAMMOND (USDA 96CS3051)

ARS began developing growth models for crops like cotton in the 1970s. These computer models can help growers time everything from planting to harvest.

If you think it's a pain to knock on a few cantaloupes in a grocery store or farm market to judge which one is just ripe enough, think of the growers who have thousands of melons to worry about. They have to harvest the crop with almost military precision and at a pace almost as hectic as war.

Growers like David LaGrange, vice president and farm manager of Starr Produce Company in Rio Grande City, Texas, have to schedule a virtual army of trucks and melon pickers so that they can send their melons to market at just the right stage of ripeness and at a pace that allows proper chilling, packing, shipping, and selling. In fact, LaGrange uses a fleet of 18 U.S. Army surplus 10-wheeler trucks to harvest his cantaloupes, honeydews, and watermelons. Seventy trailers stand ready to be attached to the trucks as needed. He has 350 people picking melons in the fields and about 100 more at work in a packing plant. If he times it wrong, he has either fewer, smaller, and less uniform melons or a ton of melons left to rot in a wet field or be sold at bargain-basement prices.

To predict that perfect moment, growers have little to go on other than years of experience and rules of thumb passed down through the generations—plus a lot of guesswork. It would be nice to have something more scientific.

That's exactly what LaGrange got in 1998. At that time, he was growing up to 12 different varieties of cantaloupes in one season. He went to ARS plant physiologist Jeff Baker, then with Texas A&M University, to get a melon growth-simulation computer model that would remove most of the guesswork.

Baker developed the model, called MelonMan, because of problems he saw firsthand when he did research with Rio Grande Valley melon growers. Now with the Alternate Crops and Systems Laboratory in Beltsville, Maryland, Baker continues his crop-modeling research with fellow ARS plant physiologists Vangimalla R. Reddy and Basil Acock.

The model helped LaGrange narrow his choices to the three most predictable cantaloupe varieties and one honeydew. He uses data from model-linked field weather stations to help him time planting and harvesting and predict yields.

"There will always be a place for this cantaloupe model because new varieties come on the market all the time. I'll use the model whenever I try a new variety," LaGrange says. The model also works with watermelon.

Models for horticultural crops, like cantaloupe, are not as common as those for agronomic crops, such as cotton and soybeans. Reddy and Acock have been developing crop growth models for cotton (called Gossym), corn, soybeans (called Glycim), wheat, and potatoes (called 2DSpud) for the past

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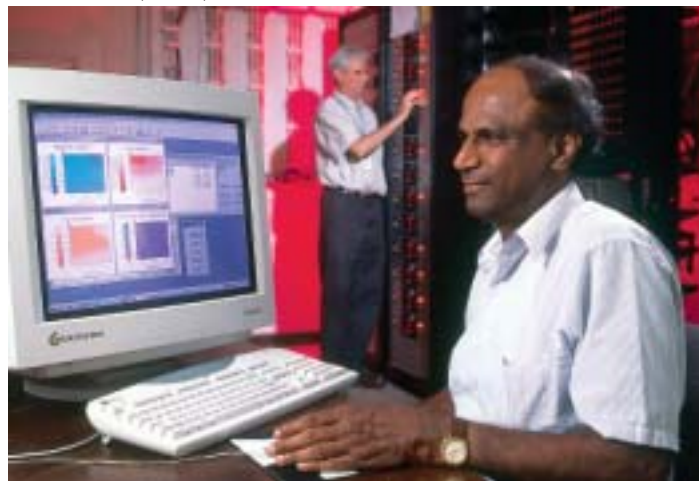
Plant physiologist Vangimalla R. Reddy uses the Glycim computer model to simulate soybean growth while soil scientist Dennis Timlin checks instruments that control conditions and monitor plant growth inside growth chambers. The data gathered in their growth chambers is critical to developing an accurate model.

quarter century. Acock recently retired. They began their research at the former ARS Crop Simulation Research Unit at Mississippi State University, and their cotton model has served as a template for all subsequent ARS crop-growth models.

Strategic Farming

LaGrange's counterpart in the world of field crops, Kenneth Hood, heads Perthsire Farms in the Mississippi Delta, where he grows more than 10,000 acres of 4 different cotton varieties and another several thousand acres of soybeans. He not only has a fleet of large farm vehicles, he even has airplanes to fly over his fields for aerial infrared photography that highlights cotton's vigor—or lack of it.

Hood's computer guidance comes from the cotton model called Gossym. "It's a dual reference, along with my aerial photography and other precision farming techniques," he says. "Both give me the big picture and warn me about drought or nitrogen deficiencies before they're visible and while I still have time to turn on the irrigation water or apply more nitrogen. I go back and forth between the imagery and Gossym to help me make decisions. And now that precision farming has brought me on-the-go yield monitors, I have all the pieces in place. When I get that yield data, I can go back and correlate it with predictions from Gossym plus information from my aerial imagery to see what caused my high or low yields.

Hood also correlates his aerial imagery with an insect pest component of Gossym called rbWHIMS (short for rule-based Wholistic Insect Management Systems). "With these two layers together, I can spray for certain pests only in parts of the fields where needed. This saves money and has environmental benefits," he says.

Hood was one of the 20 farmers who formed the second wave of Gossym users in 1986, 2 years after Hood's neighbor, Frank M. Mitchener, and another farmer pioneered its use. In 1991, Hood became the first farmer to test Glycim, the soybean counterpart. As his cotton operation expanded and got even more time consuming, he contracted for the consultant services of Jeff Baker's father, Don, who helped develop Gossym and Glycim before retiring from ARS at Mississippi State. Don Baker not only runs both models for Hood now, but also does other consulting services, such as taking leaf samples for lab analysis of nitrogen content.

Hood likes to get as much usable information as possible— considering each an overlay—so that when he views them together, he gets a more complete picture for more accurate decisions. When he started using Gossym, cotton sold for 55 cents a pound, and now he barely gets 40 cents. "At that low a price, you don't recover from a mistake," Hood says. "Gossym gives me very accurate information."

Reddy says that since the models have proven themselves successful on large farms such as Hood's, it's time to test them on small farms. To do that, ARS recently signed a cooperative agreement with Florida A&M University in Tallahassee, a historically Black university, to field-test the crop growth models on small farms owned by minority farmers.

What Exactly Is a Crop-Growth Model?

Crop-growth models simulate a different growing-season scenario very quickly, often every second or faster. Reddy says that technically the melon model is a simple one because it predicts only yields and harvest timing. The more complex models like Gossym and Glycim also predict timing of water, fertilizer, and chemical applications.

"All crop-growth models package scientific research and rules of thumb, supplementing or replacing farmers' rules of thumbs, habits, and guesswork," Reddy says. "Because these are scientific models that have principles of plant physiology and soil physics built into them, they can be used not only to help farmers, but also for other applications, like studying the effects of global climate change on crop yields or lowering nitrogen levels in bodies of water like the Chesapeake Bay." Reddy, Dennis J. Timlin, a soil scientist at Beltsville, and Jeff Baker work with colleagues around the world on these types of environmental uses.

"The models 'learn' from years of computer monitoring of crops grown in hard-wired outdoor growth chambers as well as from years of field trials on farms around the country," Reddy says. "All the models are programmed into software that can be downloaded from the Internet or a CD."

Biological science aide Meredith Bilek maps corn roots on a glass panel of one of the Soil-Plant Atmosphere Research (SPAR) chambers to evaluate the rooting pattern in response to changes in temperature and carbon dioxide.

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The Cotton Production Model (CPM), a successor to Gossym, was released in 2002 on the ARS Office of Technology Transfer's Internet site (http://ott.ars.usda.gov/) for further research and commercial development. "It predicts the timing of all cotton-farming operations," Reddy says. The CPM—along with Glycim, the melon model, and an earlier version of the potato model—is available on the Internet or on CD.

A new rice crop-growth model will soon be available at this site, and a corn model will be available within the next few years. A wheat model is in the planning stages.

Don't Forget the Soil

In 1996, Timlin and Yakov A. Pachepsky, another ARS soil scientist at Beltsville, helped develop 2DSOIL, a soils component for the models—along with soil physicists Jirka Simunek and Rien van Genuchten at ARS' Salinity Laboratory in Riverside, California. They used parts of various models, including Glycim. Timlin worked closely with Pachepsky and Reddy—as well as with Frank D. Whisler, a now retired professor of soil science at Mississippi State University—in moving Glycim into on-farm use.

Reddy says that by working with farmers, researchers gained valuable insights on how to design models for practical use. For example, Pachepsky and ARS computer programmer Eugene Mironenko developed GUICS (Graphical User Interface for Crop Simulators), a generic interface that makes all ARS crop models easier to use. They had substantial help from farmers who were using the soybean model.

Customizing the Model

Farmers localize a crop-growth model by choosing their field soil types, local weather, and crop variety and typing in some simple measurements of their crops' growth.

The models are typically coupled with field weather stations that send data to desktop computers over phone lines. The weather data is automatically updated every 10 minutes or so.

Baker says that for the melon model, all farmers have to do is "download the air temperature data and make simple measurements for each melon variety—such things as the rate at which their vines grow new leaf nodes."

When Reddy and Acock were in Mississippi, they saw firsthand that knowing the moment to harvest is just as critical to cotton farmers as it is to melon farmers. They saw farmers' army of harvest vehicles lined up across the horizon, rushing to beat storm clouds that loomed in the distance and that threatened to knock cotton bolls down into a sea of mud. Like melon growers, if they harvest too early, they will have less cotton; if they wait too long, the quality and price go down, sometimes dramatically if the weather turns bad.

The threat of damage from severe rainstorms is much higher for Mississippi cotton farmers than for melon growers in the dry Rio Grande Valley. On the other hand, produce has a much shorter shelf life—and higher individual crop values—than field crops. In the end, the pressures of horticultural crop and field crop farming are more similar than they are different.

The Heart of Crop Models

Growth chambers are the heart—or brains—of crop-growth models. They are where the models gain an intimate knowledge of crop growth—a knowledge that can easily surpass a farmer's. That's partly because the chambers monitor plant growth every 10 seconds or so, 24 hours a day, along with hidden root growth, soil moisture, temperature, and other conditions. From this data, crop models can "see" things before they are visible to the human eye.

Soil scientist Dennis Timlin (left) and plant physiologist Soo Hyung Kim collect soil respiration measurements in one of the Soil-Plant Atmosphere Research (SPAR) chambers.

Mississippi State acquired the first such chambers in the world. Their 10 bubble-top containers have been monitoring cotton and other plants since 1974, providing the knowledge base for Gossym and Glycim. Reddy and Acock went to Beltsville in 1989 and set up 12 similar units there.

Plant physiologist Jeffrey Baker inspects rice plants grown in day-lit growth chambers under controlled temperatures and carbon dioxide to allow precise measurements of photosynthesis and growth.

Kambham R. Reddy, a plant physiologist and colleague of V.R. Reddy's while at Mississippi State, has been working with the chamber facility since arriving at the university 14 years ago. From the growth-chamber data, he and his associates have developed mathematical equations for Gossym to simulate over 200 different cotton growth functions.

No Time for Models?

Don Baker has seen farming from both sides now—as a scientific researcher and as a farm consultant. He toured farms and worked with farmers during his 25 years of Gossym research. But it was only after he retired from ARS and began working daily with farmers that he was really struck by the fast pace of farming—one so hectic during the growing season that farmers had no time to run models.

"We had Gossym on 300 farms at one point, and we couldn't give the farmers all the assistance they needed," Baker says. "I knew farmers were busy, but you just can't fully appreciate how busy until you work with them daily, as I do now."

As a consultant for cotton and soybean farmers in the Mississippi Delta, Baker sees the issues they face in the field—personnel, procurement, weather, equipment breakdowns, and fertilizer and chemical decisions. "There are many times when farmers just can't sit at a desk computer; they're too busy directing the battle," Baker says.

Sam Turner, an ARS computer specialist at Mississippi State, worked with Baker, V. R. Reddy, and Acock on the Gossym and Glycim models. He points out that "All farmers work with models—it's just that some are in their heads. Their experience and common sense give them a conceptual model that frames their farming decisions. But a computer model is a nice supplement to the model in their heads because, unlike the human mind, it never forgets, and it contains all the knowledge scientists have learned about crops and farming."

Despite the time limitations, Baker agrees with Turner that farmers can't farm without a model, whether in their heads or on a computer. "It would be like flying a plane without visual sighting or instruments," he says.

The Bottom Line

Crop-growth models can save farmers a lot of money and worry. The cotton model, for example, earns farmers an average $60 to $80 an acre in additional profits. Mitchener says that in 1984, Gossym would have saved him hundreds of thousands of dollars of cotton had he listened to the model during early tests. He lost about 200 pounds of cotton an acre because he didn't harvest exactly when the cotton was ready. The cotton fell to the ground during rains.

Reddy says a survey by Mississippi State University showed that soybean farmers credit the model with increasing yields up to 29 percent and increasing irrigation efficiency fourfold.

"These types of numbers are the bottom line for models," Reddy says, "but they don't tell the full story. Perhaps equally important to farmers is how models help them examine their crops in a more timely manner and in ways they had not previously considered. And they enable researchers to study the effects of environmental conditions in ways considered impossible before. The more we learn, the more the possibilities for model applications appear limitless."—By **Don Comis,** ARS.

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To validate the corn model, plant physiologists V.R. Reddy and Dennis Gitz collect field data on corn growth and development.