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Agricultural Research

Attacking Ag Emissions

pages 2, 4-19

Agricultural Research Service
Solving Problems for the Growing World

Sound Science, Sound Air

Helping Agriculture and Air Quality at the Same Time

The goal of the Agricultural Research Service's national program on Climate Change, Soils, and Emissions (#212) is to help make farming both more environmentally friendly and more efficient.

Often, if you accomplish one, you accomplish the other. New management strategies to solve one problem can have multiple benefits, including addressing the four components of agriculture sustainability recently identified by the National Academy of Sciences in its book "Toward Sustainable Agricultural Systems in the 21st Century":

- Satisfy food, fiber, and biofuel needs.
- Enhance environmental quality and resources.
- Maintain agriculture's economic viability.
- Improve quality of life for farmers, farm workers, and society as a whole.

If you farm more efficiently, you have less loss of nutrients, soil, and pesticides to the atmosphere and water—and less exposure of farmers, farm workers, and communities to pesticides and other air pollutants.

Many of these losses come down to nitrogen: We put nitrogen into livestock feed as a protein source, and we fertilize crops with nitrogen. But feedlot cattle lose about 85 percent of the nitrogen in livestock feed fed to them—much of this as ammonia (a gas form of nitrogen) emitted from their urine and feces. Ammonia irritates people's skin, eyes, mouth, and lungs. Ammonia in water runoff from agricultural fields also carries nitrogen to waterways, leading to algal blooms that can deplete dissolved oxygen. Livestock managers would rather have nitrogen go only to livestock growth, and farmers would prefer that nitrogen applied to crops be taken up by the crops to enhance growth.

As the story on page 4 shows, our program researches the processes governing ammonia and other emissions so that we can design management techniques to better control them.

During the process of finding ways to reduce air pollution from agriculture, we collect data that state and federal regulators need to set accurate air-quality standards and make environmental policies affecting agriculture.

The articles on page 9 and 14 discuss two other air pollutants we study: dust from cotton gin operations and soil, and ground-level ozone, which is the most damaging air pollutant to plants by far.

As the ARS representative on the U.S. Department of Agriculture Agricultural Air Quality Task Force (AAQTF), I meet regularly with representatives of all USDA agencies, with the common goal of helping agriculture reduce air pollution. The group includes representatives of the U.S. Environmental Protection Agency (EPA) and other federal agencies, state agencies, and industry groups—as well as many others, including a veterinarian and representatives of a major medical clinic that researches rural and agricultural health and safety issues.

For agricultural air-quality research, good data and computer models to use this data are especially important. Agricultural air-quality data and models are also needed for many types of production and processing systems to help with decision support.

The "Characterization of Cotton Gin Particulate Matter Emissions Project," a major 4-year project, addresses this issue for cotton gin emissions. For this project, ARS scientists are intensively sampling emissions from cotton gins strategically located throughout the Cotton Belt. They planned the project with federal and state regulators and the cotton industry.

Regulators, researchers, agricultural industries, and those involved in human health issues share a commitment to ensuring that the best scientific data is available for the challenges involved in making decisions about agricultural air quality. On farms and ranches, emissions come from many sources over large areas of land ("non-point sources"), and because farming and ranching are outdoor businesses, weather conditions and other factors also come into play.

As the story on page 18 shows, air temperature and soil moisture are two of the many factors that determine the degree to which pesticides escape to the air. Other research has shown that temperature also affects how much ammonia is emitted from cattle feedlots. Wind direction and speed, among other factors, also can determine air-quality outcomes.

The diversity of agriculture also presents challenges for data collection and modeling, with livestock, crops, and management techniques varying from one part of the country to another.

Research provides a fundamental basis for developing technologies for reducing agricultural atmospheric emissions. However, interpretation and incorporation of those discoveries into working practice is necessary for realizing that potential.

We are greatly helped in reaching farmers and ranchers through our strong ties to the USDA Natural Resources Conservation Service (NRCS), which convenes and leads AAQTF meetings. For example, we work with the NRCS Air Quality and Atmospheric Change Technology Development Team in Portland, Oregon. This team is also developing National Engineering Handbook chapters on agricultural air quality, with recommended air emission management strategies.

As agriculture evolves, ARS adjusts its research accordingly to help the agricultural community meet the challenges of increased efficiency and regulatory mandates for lower air emissions. The data and models produced by ARS also ensure that regulators are equipped with the best possible science-based information to make sound policy decisions.

Charles L. Walthall
ARS National Program Leader
Climate Change, Soils, and Air Emissions
Beltsville, Maryland

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Solving Problems for the Growing World

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In a streambed near you, E. coli may lurk.

See story on page 20.

STEPHEN AUSMUS (D2208-8)

Cover: At a study site in Beltsville, Maryland, ARS researchers measure agricultural herbicides that volatilize into the air after they are applied to the field. Soil scientist Lynn McKee (foreground) works on the pesticide air sampler while micrometeorologist John Prueger (left) adjusts the controls on the manifold and soil scientist Tim Gish downloads micrometeorological data. Story begins on page 4. Photo by Peggy Greb. (D2241-1)

Sound Science Sound Air

Sound Science
Sound Air

At ARS, the Atmosphere Is Right for Air Emissions Studies

"Air doesn't have any boundaries,"

says Agricultural Research Service (ARS) chemist Laura McConnell. "So when we study the dynamics of different components that affect air quality, we're trying to figure it out in an open system. For instance, maybe the compound we're studying comes from a local source—or maybe it's coming from a hundred miles away."

"This kind of research is a real challenge," agrees Charlie Walthall, who is the national program leader for ARS's work on air emissions. "But there is a substantial payoff for farmers and for the public. We are working to develop management practices that increase the efficiency of agricultural production and that also protect and enhance our soil, water, and air."

As part of this effort, McConnell is just one of dozens of ARS scientists conducting research in a system where controls are hard to come by. She has teamed up with ARS chemist Cathleen Hapeman, who works with McConnell at the ARS Environmental Management and Byproducts Utilization Laboratory in Beltsville, Maryland, to identify factors that affect pesticide levels in the Chesapeake Bay region "airshed." Some of these pesticides, including organochlorine insecticides and their breakdown products, are considered "legacy" pesticides because, even though farmers are no longer permitted to use them, trace levels of the chemicals can still be detected in the air, soil, and water.

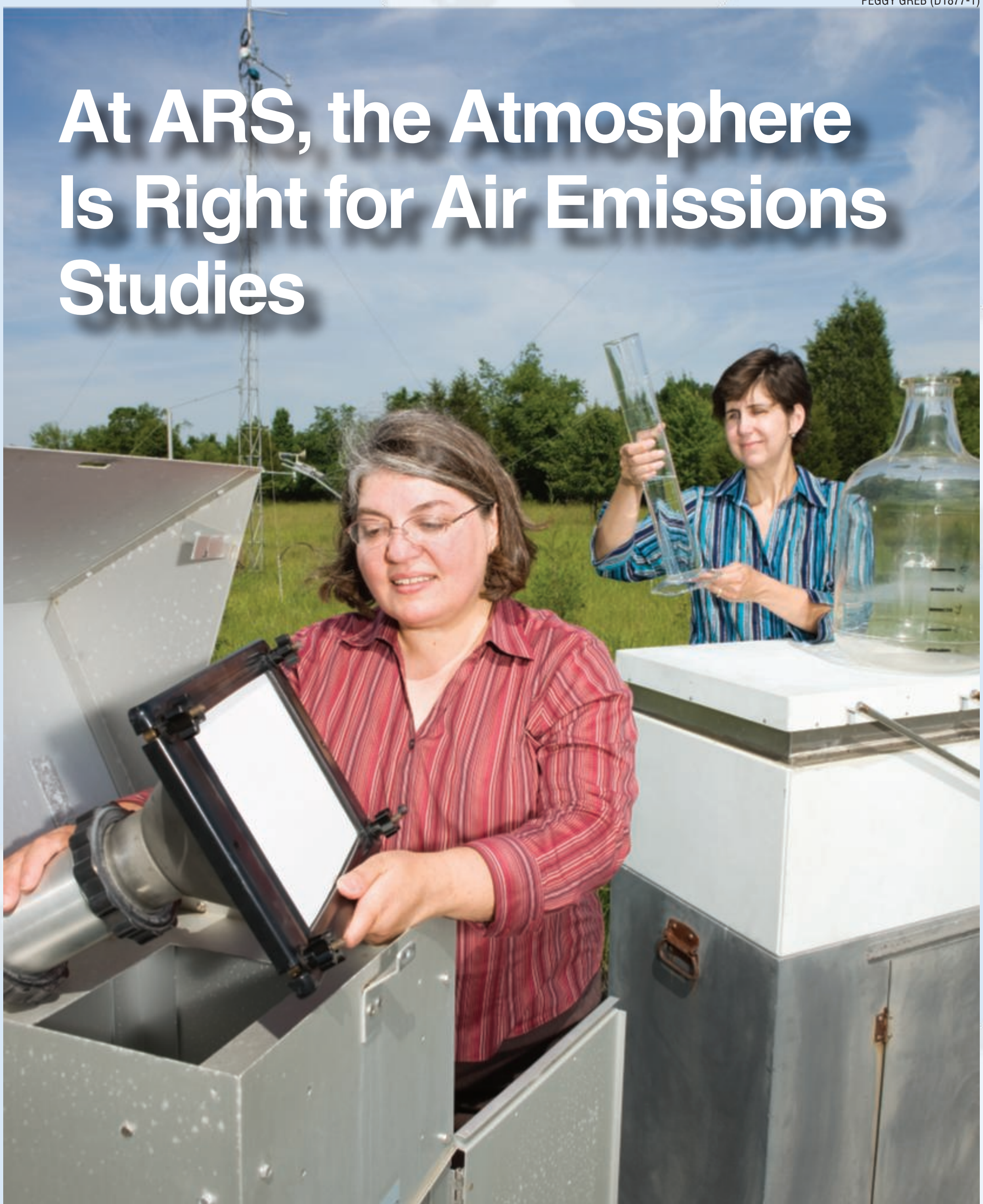
Tracking Trace Chemicals

Working with partners at the University of Maryland and the University of Delaware, the scientists established three monitoring stations in the Chesapeake Bay Watershed. One was near the Choptank River in Cambridge, Maryland. A second site was located at the University of Delaware in Lewes, and the third was set up at the Delaware National Estuarine Research Reserve in Dover.

From 2000 to 2003, the team obtained weekly air samples and rain samples for each precipitation event from the three sites. Then they tested the samples in the lab for several types of legacy pesticides, including chlordane and related chemical products such as heptachlor and breakdown products of chlordane; lindane; aldrin and dieldrin; DDT and its degradation products (DDD and DDE); and mirex.

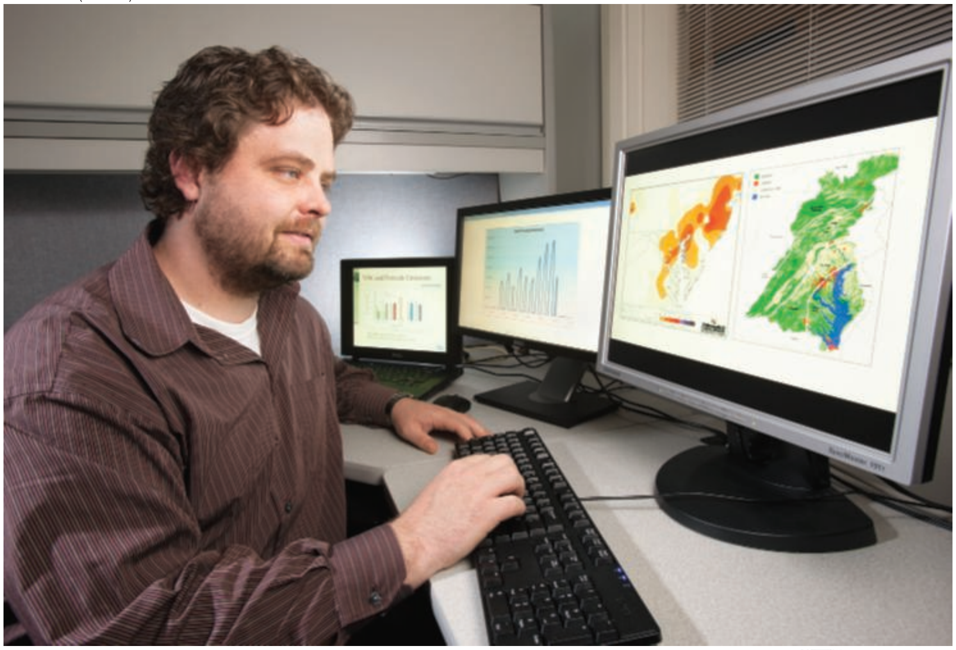
All of the pesticides were detected in at least one air sample, but they were rarely detected on particles captured from the air. Nearly all the air samples contained

PEGGY GREB (D1877-1)



Chemists Cathleen Hapeman (left) and Laura McConnell use air and rain sample collection devices to study the fate of atmospheric pollutants in the Chesapeake Bay region.

PEGGY GREB (D2239-1)



Cody Howard, an ARS environmental engineer, uses the pesticide emissions model to study and predict agricultural emissions and their effect on air quality in the Chesapeake Bay region.

lindane and chlordane products, and the pesticides with the highest mean concentrations were dieldrin and DDE.

Here, There, and Everywhere

Results also indicated that some of the legacy pesticides detected in the samples—chlordane compounds, lindane, DDE, and dieldrin—came from local and regional sources, possibly from contaminated soils. When disturbed, the generally sandy soils on the Delmarva Peninsula are more likely to release pesticides than soils with a higher organic carbon content.

But these studies also suggested that most of the lindane, heptachlor, and many of the chlordanes detected in the air samples came from sources more than 60 miles away.

Using models, McConnell and Hapeman also found that variability in air temperature and wind conditions accounted for 30 to 60 percent of the variability of compound levels. And—some good news—with the exception of dieldrin, the half-life values measured for the pesticides in the samples indicated that legacy pesticide levels were decreasing over time in the Delmarva.

“The Chesapeake Bay region is a mix of urban areas and agricultural areas,” says Hapeman. “But water quality in the bay itself is highly influenced by atmospheric chemistry, not just by runoff from urban lands and farm lands. These measurement studies and new modeling efforts with ARS environmental engineer Cody Howard are helping us understand the role that past and present agricultural practices and air quality play in restoring and maintaining water quality in the bay.”

A Pesticide’s Surprising Path

A few fields away in Beltsville, ARS soil scientist Timothy Gish and his colleagues are tackling another piece of the air quality quandary—measuring the amounts of pesticides that evaporate into the air after they’re applied to the field. ARS micrometeorologist John Prueger, who works at the National Laboratory for Agriculture and the Environment (NLAE) in Ames, Iowa, is co-leading the investigation with Gish. Other ARS scientists on the study include agronomist Craig Daughtry, hydrologist William Kustas, soil scientist Lynn McKee, and physical scientists Andrew Russ and Joseph Alfieri, who all work with Gish at the ARS Hydrology and Remote Sensing Laboratory. NLAE director Jerry Hatfield is also a project collaborator.

The scientists looked at the field dynamics of atrazine and metolachlor, two herbicides commonly used in corn production. Both herbicides are known to contaminate surface and ground water, usually through field runoff. Many experts believed the chemicals had a low volatilization rate—that is, after they were applied to the field,

In Beltsville, Maryland, soil scientist Lynn McKee and physical scientist Joseph Alfieri check the surface and subsurface soil moisture monitoring systems at the Optimizing Production Inputs for Economic and Environmental Enhancement (OPE3) study area.

PEGGY GREB (D2240-1)

they would not readily evaporate into the atmosphere—and that volatilization was not a contributing factor in local water contamination.

"A lot of research indicated that atrazine and metolachlor runoff increases during or after heavy precipitation," says Gish. "But there had never been a side-by-side comparison of pesticide lost from runoff and volatilization."

So the team set up a 10-year study at the Optimizing Production Inputs for Economic and Environmental Enhancement (OPE3) study area in Beltsville, which was established in 1998 to study major environmental and economic issues facing U.S. agriculture. It is equipped with remote-sensing gear and other instrumentation for monitoring local meteorology, soil, plants, and ground water. This allowed the team to carry out its studies on a well-characterized site where only the meteorology—and the soil water content—would vary.

"We studied the same fields with the same soil types, the same crops, the same management practice, and the same herbicide formulations" Gish says. "But we ended up with different volatilization losses from year to year."

Vanishing Into Thin Air

The team observed that when air temperatures increased, soil moisture levels had a tremendous impact on how readily atrazine and metolachlor volatilized into the air—a key factor that had not been included in previous models of pesticide volatilization. When soils were dry and air temperatures increased, there was no increase in herbicide volatilization, but volatilization increased significantly when temperatures rose and soils were wet. Most of the volatilization from wet soils occurred within the first 3 days after the herbicide was applied.

The link between soil moisture and volatilization was highlighted in 2003, when it rained at least once every week in May and June, which prevented the team from planting their experimental corn crops until July. Once the corn was in, it rained again for another 2 weeks. When the skies finally cleared, the scientists were able to apply the herbicides to the soggy fields.

"By this time, the soils were very wet. Five days after we applied the herbicides, we'd lost up to 63 percent of the metolachlor and 12 percent of the atrazine through volatilization," Gish says. "Losses were 35 to 40 percent higher in the wetter spots in the field. Generally, 4 to 5 percent losses are a big deal, so we saw a lot of compounds going off into the atmosphere."

The scientists also noted a correlation between subsoil water movement and herbicide volatilization, a dynamic they could track and document because of the extensive instrumentation at the OPE3 site. As the water rose up through the soil layers and came closer to the surface, volatilization of atrazine and metolachlor increased.

"Sometimes we've also seen volatilization occur when we haven't expected it," Prueger adds. "For instance, we've found that when the soil is dry, volatilization can increase at night because dew formation increases surface soil moisture."

Gish and colleagues plan to take their results and begin looking in more detail at volatilization processes. "Do we have the right set of data to predict pesticide loss?

PEGGY GREB (D2242-1)

Soil scientist Lynn McKee filters soil samples for pesticide analysis while technician Alex White uses a rotary evaporator to process pesticide samples.

What creates a threshold condition for volatilization? Is it moisture alone, or soil moisture with air temperature and humidity, or atmospheric stability, or what?" Gish asks. "Before I retire, I'd like to be able to develop a model for pesticide volatilization that contains all the relevant parameters."

Even though the models need refining, the results have already had a payoff. "Some farmers have become more careful about how they apply herbicides to their fields, because higher volatilization levels lower efficacy and lower yields. Besides, they live where they work, and they want to protect the local environment," says Prueger. "But we still need to improve our measurements. When we find more accurate instrumentation or techniques, we can use them to reduce our margin of error in the measurement of pesticide volatilization."

PEGGY GREB (D2243-2)

ARS soil scientist April Leytem and research leader David Bjorneberg use open-path ultraviolet-differential optical absorption spectrometry to determine ammonia concentrations at dairy operations in southern Idaho.

Calculating the Impact of Cows

Across the country in Idaho, where the number of dairy cows has increased around 88 percent in the past 12 years, another group of scientists is collecting data on greenhouse gas emissions from dairy facilities and identifying how those emissions fluctuate daily and throughout the year. Methane, carbon dioxide, and nitrous oxide can all help trap heat in the atmosphere, and the development of particulate matter from ammonia is also a concern. (See story on particulate matter, page 9.)

"We've calculated some of the first on-farm emission rates for western large-scale dairies, along with emissions per cow and per unit of milk production," says ARS soil scientist April Leytem, who in 2008 was presented with the ARS Pacific West Area Early Career Research Scientist Award for her work in phosphorus cycling in the environment. "We're performing these studies on working commercial dairies, not on experimental farms."

At ARS's Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho, soil scientists April Leytem and Robert Dungan use photoacoustic field gas monitors to determine emissions of ammonia and greenhouse gases from agricultural operations.

PEGGY GREB (D2245-1)

Leytem worked on this project with several other scientists at the ARS Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho, including microbiologist Robert Dungan, agricultural engineer David Bjorneberg, and soil scientist Anita Koehn. For a year, the group monitored the emissions of ammonia, carbon dioxide, methane, and nitrous oxide from a commercial dairy in southern Idaho with 10,000 milk cows. The animals were mostly mature Holsteins that consumed a total mixed ration and produced an average of 75 pounds of milk per cow per day. The facility had 20 open-lot pens, 2 milking parlors, a hospital barn, a maternity barn, a manure solids separator, a 25-acre wastewater storage pond, and a 25-acre compost yard.

The team set out to calculate the emission rates of the four gases from three areas on the dairy facility: the open lots, the wastewater pond, and the compost yard. After they set up their instrumentation, they collected concentration data continuously for 2 to 3 days each month and recorded air temperature, barometric pressure, wind direction, and wind speed. With this data, they calculated the average daily emissions for each source area for each month.

Their results indicated that, on average, the facility—animals, equipment, buildings, and all—generated 3,582 pounds of ammonia, 33,162 pounds of methane, and 410 pounds of nitrous oxide every day. This came to daily emission rates of 0.3 pounds of ammonia, 3.1 pounds of methane, and 0.04 pounds of nitrous oxide per cow—or 0.005 pounds of ammonia, 0.04 pounds of methane, and less than 0.0006 pounds of nitrous oxide for each pound of milk produced.

The team also found that the open lots were the source of the highest levels of ammonia, carbon dioxide, and nitrous oxide emissions. These areas generated 78 percent of the facility's ammonia, 80 percent of its carbon dioxide, and 57 percent of its nitrous oxide. The lots also generated 74 percent of the facility's methane emissions during the spring.

Generally, emissions of ammonia, carbon dioxide, and nitrous oxide from the open lots were lower during the late evening and early morning, and then increased throughout the day to peak late in the day. These daily fluctuations paralleled patterns in wind speed and air temperature, both of which generally increased during the day—and also with livestock activity, which picked up as the day progressed.

Emissions of ammonia, methane, and carbon dioxide from the wastewater pond and the compost were also lower in the late evening and early morning and increased during the day. Ammonia, methane, and carbon dioxide emissions from the compost peaked during June when the compost was frequently turned and when new manure was being added to the windrows. Methane emissions from the wastewater pond were lowest in April, when seasonally cooler temperatures prevailed, but peaked during October as temperatures rose.

"These studies will help producers meet air quality standards and help regulators determine what the standards should be," says Bjorneberg.

"Dairy producers have been very supportive of this work," Leytem adds. "Now we want to start improving models that state and federal regulators can use to generate estimates for on-farm emissions from commercial dairy facilities."—By **Ann Perry,** ARS.

This research supports the USDA priority of responding to climate change and is part of Climate Change, Soils, and Emissions, an ARS national program (#212) described at www.nps.ars.usda.gov.

To reach scientists mentioned in this story, contact Ann Perry, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1628, ann.perry@ars.usda.gov. ✻

PEGGY GREB (D2244-1)

Calves at a dairy operation in southern Idaho.

On average, the facility generated 3,582 pounds of ammonia, 33,162 pounds of methane, and 410 pounds of nitrous oxide every day.

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Blowing in the Wind

STEPHEN AUSMUS (K10519-6)

An ambient PM10 high-volume sampler in a west Texas dust storm. A storm like this exposes samplers to dust particles greater than 10 micrometers, and larger dust particles increase the overall error associated with ambient air samples.

STEPHEN AUSMUS (K10513-9)

Agricultural engineers Greg Holt (left) and former ARS scientist Michael Buser, now with Oklahoma State University, Stillwater, change filters from particulate-matter samplers and collect meteorology data while sampling dust generated by a rolling cultivator (background).

Unless, perhaps, someone in our family has a dust allergy, most of us probably don't think much about dust. And if we do, we probably think about the dust on our coffee tables.

Dust, however, isn't just in our houses. It's everywhere and can affect our health. And all dust is not created equal: The smaller particles, which are more difficult to see, are potentially the most dangerous.

In 2006, the U.S. Environmental Protection Agency (EPA) lowered the limit on average PM2.5 emissions over a 24-hour period from 65 to 35 micrograms per cubic meter. Some states have set the standard much lower. This comes from a growing concern that the smallest dust particles pose the biggest health threat, because they are small enough to penetrate deeply into peoples' lungs.

"PM2.5" refers to particulate matter less than 2.5 microns in diameter—2.5 microns is about 1/30th the thickness of a human hair.

As states implement required plans to achieve federal standards—or even stricter ones—and begin to regulate various types of industries, they face the problem of a scarcity or, in some cases, a lack of data on how much PM2.5 those industries currently emit.

In the case of agricultural operations, EPA and the Agricultural Research Service are working together with the industries and the states to develop better

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MIKE BUSER (D2219-1)

Standing in a manlift basket about 30 feet off the ground, agricultural engineer Clif Boykin inserts a sampling probe into a cyclone stack at a cotton gin in California.

DEREK WHITELOCK (D2218-1)

To accurately determine the total PM10 and PM2.5 emissions from a cotton gin in west Texas, ARS biological science aids Arnold Gomez and Bud Welch directly sample exhaust from the gin's many cyclones. Samples are then brought back for processing in the ARS Air Quality Laboratory in Lubbock.

science-based information and methods to set standards.

Cotton Belt Seeks "Just the Facts" on Air Pollution

Roger Isom, executive vice president of the California Cotton Ginners and Growers Association in Fresno, says that California, Arizona, and North Carolina are among the first states to begin evaluating PM2.5 emissions from agricultural and other types of industries.

Cotton gins are one of the many agricultural operations these states are looking at. As they do with other industries, the states have to decide whether to require much more expensive PM emission controls, which could risk a business's survival. In California, the gins are already required to install enhanced cyclone pollution-control devices at all emission points. These cyclones capture cotton lint, stems and other plant parts, and soil and spin them so most of the material collects at the bottom and clean air comes out the top.

One of the options California's San Joaquin Valley Air Pollution Control District is considering—if cotton gins are designated as "significant sources of PM2.5"—is to require "baghouses" in addition to cyclones. Baghouses are facilities that house multiple air-filter bags. These are used in other industries, including foundry and steel operations and chemical manufacturing. The bags look like large tube socks that are generally 6 to 10 inches in diameter and often are 10 to 20 feet long.

$1 Million-Plus Controls May be Too Much for Cotton Gins

Agricultural engineer Mike Buser, formerly with ARS and now at Oklahoma State University at Stillwater, says that "one of the California gins we tested has 13 separate air-quality emission systems. That gin would have to have two baghouses, each holding about 500 bags. That would cost more than $1 million."

Isom shares the concerns of gin associations throughout the cotton belt—which stretches from California to North Carolina—that the lack of data could lead to an erroneous overestimation of PM2.5 emissions. So they pressed for research to find out how much gins actually emit.

Cotton gins in states like Missouri are already finding it difficult to obtain air-quality permits to operate, because the standards are based on EPA models that are more suited to industrial smokestacks. Gins' exhaust pipes are much closer to ground level, mostly 30 feet high, with the tallest ones usually no more than 65

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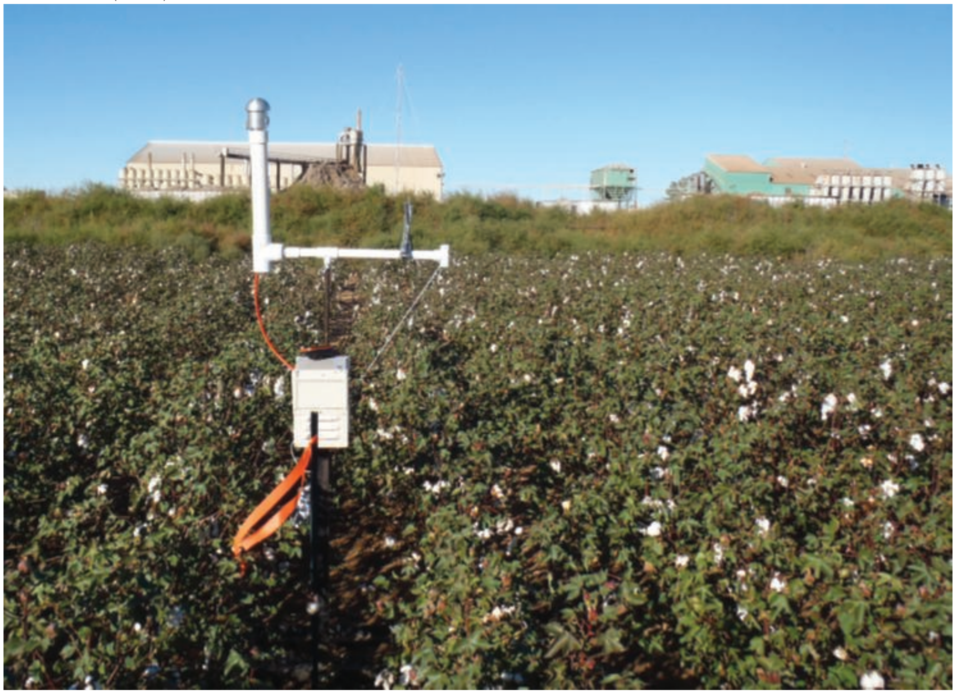
DEREK WHITELOCK (D2221-1)



ARS scientists measure the levels of PM2.5 and PM10 in the air outside a cotton gin by surrounding the gin with 126 ambient air samplers, such as this one located in a cotton field near a cotton gin in west Texas.

feet high, so their emissions tend not to travel far from the gin. These models may overestimate the distance gin dust travels by 10 times.

Urban Samplers, Models Wrong for Cotton Gins?

Buser found that EPA samplers could be overestimating PM2.5 emission concentrations by 14 times. Buser was at the ARS Cotton Production and Processing Research Unit in Lubbock before transferring to Oklahoma State University in 2009. He continues his research as an integral part of the “Characterization of Cotton Gin Particulate Matter Emissions Project.”

Isom, well aware of Buser’s research, called Buser in 2007 and asked for help in getting scientific answers on PM2.5 concentrations.

So, in 2008, ARS scientists at cotton ginning labs—including Buser; Derek Whitelock, an agricultural engineer with the ARS Southwestern Cotton Ginning Research Laboratory in Mesilla Park, New Mexico; and fellow agricultural engineer Clif Boykin, at the ARS Cotton Ginning Research Unit in Stoneville, Mississippi— organized a major 4-year project to intensively sample emissions from seven cotton gins strategically located throughout the Cotton Belt. From the very start, they planned the project with federal and state regulators and the cotton industry to address the various concerns of each cotton-growing region.

“Texas, for example, wanted more information on the total amount, size, and percentages of all the particles emitted from gins, including PM10. The cotton growers’ and ginners’ organizations wanted more accurate computer models to predict emissions,” Buser says.

To accurately determine the total emissions—PM10 and PM2.5—from a cotton gin, they directly sample the exhaust from the gin’s many cyclones, using EPA methods. To do this, the scientists joined forces with a certified stack tester from California to measure the PM emissions from cotton gins.

They also measure the level of PM2.5 and PM10 in the air outside a cotton gin by surrounding each gin with 126 ambient air samplers, compared to the half-dozen samplers used in previous, less intensive, studies. There are 6 sampling points at different levels on each of 12 towers. Each tower is 33 feet tall.

Whitelock says, “More than 1,500 samples are brought back from each gin for processing,” which is done in the ARS Air Quality Laboratory at Lubbock, under the direction of research leader Greg Holt.

Intensive Air Sampling

They have already sampled one gin in New Mexico, two in Texas, two in California, and one in Missouri. In 2011, they’ll test the last gin, in North Carolina.

It will take another year, through 2012, to analyze the data from all the tests.

At a field day event in Pullman, Washington, soil scientist Ann Kennedy uses canning jars to illustrate the greater volume of larger sized clumps of soil found in direct-seed soil compared to soil tilled multiple times. These larger sized clumps will not be subject to wind erosion.

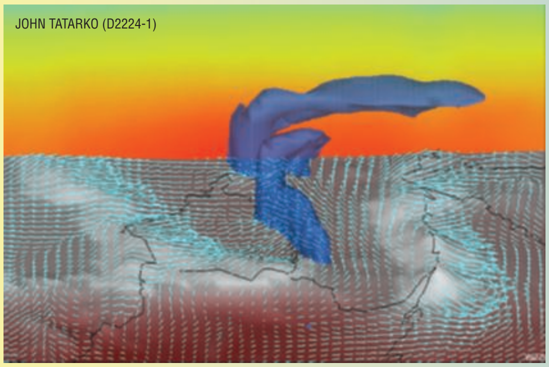
DENNIS BROWN (D2227-1)

Predicting Pathways for Windblown Dust

An Agricultural Research Service scientist and partners have combined models of wind erosion and regional climate patterns to simulate the sources and dispersion of particulate matter—such as tiny bits of soil and other substances—blowing in dust storms around Mexico City.

People who inhale particulates with a diameter of 10 micrometers or less (PM10) can develop respiratory problems, so public health officials are anxious to predict how these airborne pollutants are dispersed over time.

Soil scientist John Tatarko, who works at the ARS Engineering and Wind Erosion Research Unit in Manhattan, Kansas, collaborated with scientists at the National Autonomous University of Mexico on this research. His partners included Emmanuel Díaz, Arón Jazcilevich, Agustín García, Ernesto Caetano, and L. Gerardo Ruíz-Suárez.


JOHN TATARKO (D2224-1)

This three-dimensional simulation of an actual dust plume (shown in dark blue) over the Valley of Mexico was generated by the combined model system called "MCCM-WEPS."

The team combined two existing models to explore how wind erodes PM10 from farm fields and dry lakebeds around Mexico City, where poor air quality is an ongoing concern. The first model was the Wind Erosion Prediction System (WEPS), which was developed by ARS scientists to simulate rates of soil loss, PM10 emissions, and other data for specific erosion events.

The other model, developed at the Karlsruhe Institute of Technology in Germany, was the Multiscale Climate and Chemistry Model (MCCM). It combines information about weather conditions and other factors to produce estimates of the transport of air pollutants. The combined model system was called "MCCM-WEPS."

The researchers collected field data on four dust storms around Mexico City during the dry season. Then they compared PM10 erosion rates from these storms with MCCM-WEPS simulations of erosion rates for the same storms.

The team found that the simulated rates produced by MCCM-WEPS generally aligned with the PM10 erosion rates that had been measured from the dust storms—and accurately simulated the PM10 dispersion downwind. The model also suggested that the horizontal transport of PM10 accelerates when wind currents mix and form low-pressure systems, which prompt the upward movement of the particulates. These combined findings all indicate that wind erosion is a major cause of high PM10 concentrations in Mexico City.

Results from this research were published in 2010 in *Aeolian Research.*—**Ann Perry,** ARS.

California officials and gin associations are especially anxious for the project data on their two gins, giving them the first real numbers to work with.

Whitelock says that he, Buser, and Boykin "set up a gin advisory group and an air-quality advisory group to help us plan the project, and we always invite cotton gin associations and regulators to observe each sampling campaign."

The gin advisory group includes people from cotton gin associations; Cotton Incorporated, whose world headquarters are in Cary, North Carolina; the National Cotton Council of America in Cordova, Tennessee; and Texas A&M University at College Station. It was formed to identify prospective gins for sampling and to act as liaison between the gins and ARS.

The air-quality advisory group includes people on the gin advisory group as well as from EPA and state environmental regulatory agencies and the U.S. Department of Agriculture. This group was formed to advise on methods and equipment for sampling, quality control, and data analysis.

"Participation of these advisory groups is essential to the success of this project and for the results to be accepted by industry and regulators," Whitelock says. "This way we have their buy-in on our data-collection methods before we ever start, minimizing the chances of having our results questioned after the experiments are over," Whitelock says.

Funding for the project comes from several sources, with a long list of cooperators.

"With cotton-production costs soaring, all decisions on more costs have to be based on sound science. That is key to ensuring that the U.S. cotton industry remains strong and competitive globally," Whitelock says.

Pacific Northwest Farmers Can See Soil Blow Away

EPA's regulations on PM2.5 and PM10 affect every aspect of agriculture, not only cotton gins but also cattle feedlots and farming operations.

For the Columbia Plateau region of the Pacific Northwest, the focus is on topsoil blowing in the wind: The smaller particles occasionally contribute to poor air quality in the region.

Farmers in this wind-erosion-prone region are as anxious as any others about the prospect of farms being regulated like cotton gins and other industries, with fears of urban air-pollution samplers surrounding their farmland. But they also want their rich topsoil to stay in place, so they are eager to reduce wind erosion.

Brenton Sharratt and Ann Kennedy, at the ARS Land Management and Water Conservation Research Unit in Pullman, Washington, are identifying practices that will keep the soil from blowing away.

Sharratt, research leader of the unit, examines the physical properties, and Kennedy, a soil scientist, studies the biological properties of soils that affect wind erosion.

Sharratt measures the quantity and size of soil particles blown off fields while Kennedy analyses the soil for its lipid content from the microbes living in the soil. Each microbe community has a unique fingerprint that can be used to identify the soil. Sediment deposited far downwind of a field can potentially be traced back to where it blew from.

Although she and Sharratt focus on soils of the Columbia Plateau region in parts of Idaho, Oregon, and Washington State, Kennedy also works with ARS scientists in Colorado, Idaho, Missouri, and Texas on fingerprinting soils. The scientists exchange soil samples to study a variety of soils from different regions. Interestingly, microbial communities from dirt and gravel roads differed from adjacent agricultural soils whether in Washington or Texas.

"Apparently, the microbial communities found on roads change with time because of the lack of plants and restricted water infiltration," Kennedy says.

They collect samples from devices that trap blowing soil particles; these devices were invented by ARS scientists in Lubbock.

Sharratt is investigating how soil and crop management affects the amount of soil and PM10 eroded from fields during high winds. Tillage and crops can influence soil roughness, soil aggregation (or size of soil clods), and the quantity of crop residue on the soil surface. All these factors affect the soil's susceptibility to erosion by wind or water. He is also looking at how soil moisture and crusting can protect the soil from wind erosion.

"Maintaining roughness and nonerodible material such as crop residue on the soil surface is key to controlling wind erosion" Sharratt says. "We're looking for ways to manage soils that minimize blowing and are cost effective for the farmer."

Ultimately, Sharratt, Kennedy, and their colleagues are looking for management practices that reduce the soil's vulnerability to wind erosion. They know that no-till—eliminating plowing or frequent tillage before planting, leaving adequate amounts of protective residue from previous crops on the surface—is very effective at reducing wind erosion and PM10 emissions from agricultural lands. But no-till is often not economically viable in the very driest parts of the Columbia Plateau. There are challenges yet to be worked out before no-till systems can be used with success throughout the region.

One tillage technique that seems promising is undercutting, which slices beneath the soil surface and gently lifts and sets down the uppermost layer of soil in place. Undercutting severs the roots of weeds without inverting the soil as a plow does.

"Undercutting has reduced soil and PM10 loss from fields during high wind events by as much as 65 percent as compared to conventional tillage practices in the drier parts of the region," Sharratt says. "This breaks open compacted layers and breaks up harmful fungi, while leaving the soil and organic matter intact, with positive effects on beneficial microbes," Kennedy says.

"We always thought that most of the carbon that makes up organic matter was lost to the atmosphere as carbon dioxide," Kennedy says. "But we have found that a lot of organic matter is actually being lost to the wind as soil blows off a farm field, as much as 10 percent of total organic matter losses. This is one more incentive, as though any were needed, for farmers to keep the soil in place. "—By **Don Comis,** ARS.

This research supports the USDA priority of responding to climate change and is part of Climate Change, Soils, and Emissions (#212), an ARS national program described at www.nps.ars.usda.gov.

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BRENTON SHARRATT (D2215-1)

One can see the dramatic amount of soil loss; over 3 inches of the potato stem including roots were exposed after a 2010 dust storm in southeastern Washington State.

Breeding Plants for a High-Ozone World

Soybean breeder and geneticist Tommy Carter inspects research plots during extreme drought stress at the North Carolina State Sandhills Research Station. Carter evaluates approximately 25 acres (5,000 plots) of soybean for drought/stress resistance annually.

Geneticist Thomas Carter has bred soybeans for the Agricultural Research Service for 30 years, but for the last couple of years, he has been trying to solve a mystery: Why do the world's most stress-resistant soybean types hail from a little village in far-northern Sweden?

Stress resistance is a rare commodity in soybean, but these Swedish varieties put up with a host of problems—drought, iron deficiency, toxic soil aluminum and salts, and even high levels of ozone.

Although Sweden is not known for its soybean production, Swedish breeders made a major breakthrough—but one that went unnoticed for decades by the soybean community and even by the breeders.

"We now know that they did something very right. The mystery is how," Carter says.

Carter, who is in the ARS Soybean and Nitrogen Research Unit at Raleigh, North Carolina, has long been interested in breeding for stress resistance. Ozone resistance has become his most recent interest, in large part because of his collaboration with ozone expert Kent Burkey, a plant physiologist in the ARS Plant Science Research Unit at Raleigh.

Their stress studies led the scientists to the treasure trove of genetic resistance in Swedish soybeans, which appear to have an even more pronounced resistance to ozone than to the other stresses. Understanding the ozone effect may be a key to unraveling the secrets of the broad stress resistance of the Swedish soybeans.

Tracing the American Soybean's Family Tree

Carter uncovered the resistance mystery after analyzing thousands of soybean types to generate the family tree of North American soybeans. From this, he found 30 ancestors, which together account for 92 percent of the genetic material in North American soybeans.

Carter screened these ancestors first for salt tolerance. He found two lines of vegetable soybeans—Fiskeby 840-7-3 and Fiskeby III, both from the Swedish village of Fiskeby—that were the most salt tolerant. Then he screened for aluminum tolerance, and again the Fiskeby plants stood out.

"Then, my colleagues and I saw the same thing with drought tolerance and ozone" and realized a pattern had emerged, Carter says.

ARS scientists in Raleigh and in Urbana, Illinois, study how increases in atmospheric greenhouse gases, particularly carbon dioxide and ozone, will affect crops, especially soybeans and wheat.

To screen the ancestors for ozone tolerance in a 2003 to 2005 study, Carter turned to Burkey for help. The two scientists combined the results of this study with breeder pedigree records and found that only a few U.S. cultivars trace their ancestry to the Fiskeby stress-tolerant types. "This indicates that there is great potential to increase tolerance to ozone and other stresses in North American soybeans by adding genes from Fiskeby," Burkey says.

He and Carter and Jim Orf, a soybean breeder/geneticist at the University of Minnesota at St. Paul, have crossed Fiskeby III with ozone-susceptible Mandarin Ottawa and developed 240 breeding lines from the offspring. With the help of funding from the United Soybean Board, in Chesterfield, Missouri, the team is mapping the genes in these lines to see which genes are connected to resistance to ozone and the other stresses.

"This approach can be applied to other soybean-producing regions such as China, Brazil, and Europe," says Burkey. "Their breeding programs, in turn, may offer us other important germplasm to explore for ozone tolerance genes."

Cell Wall the First Line of Ozone Defense

Ozone enters leaf stomata as a gas and then dissolves in the liquid layer, called the "apoplast," that surrounds plant cells. The apoplast is considered the first line of defense against pollutants, where ozone can be detoxified before it reaches the leaf cell surface and causes the damage that interferes with photosynthesis and reduces yields.

In the search for ways to improve crop ozone tolerance, Burkey and Cosima Wiese—associate professor of biology at Misericordia University in Dallas, Pennsylvania—recently began studying Fiskeby to see whether leaf apoplast antioxidants might be at least part of Fiskeby's defense against ozone. Burkey and others have found that, in certain other species, vitamin C plays a role in keeping ozone from penetrating through the cell's first line of defense. But soybean contains little vitamin C in the leaf apoplast, so they are looking for other antioxidants that may play a role.

Breeding Ozone-Tolerant Crops

ARS scientists in Urbana are taking a slightly different, but complementary, approach to the work of the Raleigh scientists. They are using SoyFACE (Soybean Free Air Concentration Enrichment) to screen soybean varieties for ozone tolerance and sensitivity. SoyFACE involves testing plants in open-air field conditions, under atmospheric conditions predicted for the year 2050. At that time, ozone concentrations are expected to be 25-50 percent higher than today's concentrations.

The work is being done by molecular biologist Lisa Ainsworth, Amy Betzelberger, a graduate research assistant in the Department of Plant Biology at the University of Illinois at Urbana-Champaign, and geneticist Randall Nelson and other ARS colleagues at Urbana.

During 2007 and 2008, the team tested 10 soybean varieties that had been released between 1952 and 2003. These were selected from initial tests of 22 cultivars and experimental lines that had been evaluated for 4 years. The scientists found that, on average, exposure to 82 parts per

AMY BURTON (D2252-1)

At the ARS Soybean and Nitrogen Research unit in Raleigh, North Carolina, Tommy Carter (right) and plant physiologist Kent Burkey examine a Fiskeby soybean ancestor being placed in greenhouse exposure chambers to assess its ozone injury response.

Ozone: Plants Don't Like It

Ozone is a greenhouse gas found in smog. It is formed mostly when sunlight "cooks" automotive and industrial pollutants that originate from combustion of carbon-based fuels.

Ozone is the most damaging air pollutant to plants.

Fitz Booker, an Agricultural Research Service plant physiologist at the Plant Science Research Unit at Raleigh, North Carolina, says, "Ozone has long been known to affect a wide range of plants, including grasses, field crops, horticultural crops, and forests. Our research and that of other scientists has shown that many crops and forages are damaged by high ozone levels, including soybeans, wheat, cotton, oats, potatoes, rice, peanuts, tomatoes, grapes, alfalfa, clover, and barley."

In fact, during the 1950s, Howard Heggestad (deceased) discovered that what were thought to be symptoms of a plant disease on tobacco leaves in the smoggy Connecticut River Valley was actually damage from ozone. In the Washington, D.C., area, he found similar damage to plants from ozone in smog. At the time, Heggestad was an ARS plant pathologist.

Globally, yield losses from ozone have been estimated at $14 to $26 billion for rice, soybean, corn, and wheat combined.—**Don Comis, ARS**.

Sound Science Sound Air

PEGGY GREB (D1550-1)

To assess oxidative stress in soybeans grown at SoyFACE under elevated ozone concentrations, ARS molecular biologist Lisa Ainsworth (back) and graduate student Kelly Gillespie use a liquid-handling robot to perform a high-throughput assay.

billion (ppb) ozone reduced soybean yields by 23 percent in 2007, and exposure to 61 ppb reduced yields by 12 percent in 2008. They found significant differences in ozone tolerance among the 10 varieties. "But we didn't see any significant improvement in ozone tolerance in soybean varieties released after the 1980s," Ainsworth says. This again shows the potential and need for breeding more ozone-tolerant varieties.

Ozone Damage Seen From Above

In a 2002 to 2006 study led by the National Aeronautics and Space Administration, NASA scientists, Ainsworth, ARS plant physiologist Fitz Booker, and university scientists investigated widespread ozone damage to soybeans in Iowa, Illinois, and Indiana using ozone surface monitors, satellite instruments, and historical yield data. Ainsworth says that satellite information is useful for investigating ozone's impacts on crop yields in areas without ground-monitoring networks, such as rural regions. "Satellite observations of farmland in other countries could provide important insight into the global extent of this problem," she adds.

In the study, the scientists found that ozone levels above 50 ppb could reduce yields by about 10 percent in the Midwest Corn Belt, costing more than $1 billion in lost crop production.

Their findings are consistent with those from their SoyFACE studies and studies in outdoor open-top chambers.

Ozone levels in most urban areas of the United States have declined with improvements in emission controls. But ozone levels are expected to rise in countries like India and China, as growing populations are able to afford more cars and build more power plants. Another concern is that ozone levels will rise in developing countries, where people can least withstand losses of staple crops such as rice and wheat.

"All this research promises to give breeders the tools they need to help farmers by providing them with more ozone-hardy crop varieties. This is great science with a solid application, the goal of all ARS research," Carter says.—By **Don Comis,** ARS.

This research supports the USDA priority of responding to climate change and is part of Climate Change, Soils, and Emissions (#212) and Plant Genetic Resources, Genomics, and Genetic Improvement (#301), two ARS national programs described at www.nps.ars.usda.gov.

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ARS scientists Carl Bernacchi (left), Don Ort (center), and Lisa Ainsworth in a plot of soybeans treated with elevated carbon dioxide at the SoyFACE Global Change Research Facility at the University of Illinois Research Farm in Urbana.

PHOTO BY INSTITUTE FOR GENOMIC BIOLOGY/UNIVERSITY OF ILLINOIS (D1546-2)

PEGGY GREB (D1548-1)

Ozone Erodes CO_2 Benefits for Plants

Plant physiologist Fitzgerald Booker prepares to place an optical scanner into a tube positioned in the soil to photograph soybean roots. The photos will show changes in root growth caused by elevated carbon dioxide and ozone, pumped into the open-top field chambers.

Experiments by Agricultural Research Service scientists at Raleigh, North Carolina, and Urbana, Illinois—and their university colleagues—have shown that future higher levels of ozone may cancel out some of the benefits to crops expected from higher carbon dioxide (CO_2) levels.

For one thing, crops wouldn't achieve the 30-percent increase in photosynthesis—and resulting higher yields—expected as CO_2 levels continue to rise.

The scientists have also found that ozone can thwart expected high CO_2 benefits by lowering crop quality. It can also help invasive weeds outcompete forage and other crops.

"We are beginning to look at interactions between ozone and diseases such as stripe rust and stem rust of wheat," says David Marshall, research leader of the Plant Science Research Unit at Raleigh, and an expert on wheat rusts.—**By Don Comis,** ARS.

ARS National Research Program for Air Quality

To the public, air quality and agriculture may not seem that connected. There are, however, critical interactions between farming and the atmosphere—from dust storms to emissions from agrochemicals and animals to carbon dioxide impact on yield. In some cases, we are just beginning to scientifically understand these interactions and how they can be managed.

The impacts of agriculture on the atmosphere must be mitigated, especially when there is a risk to soil, water, and air quality or to human and animal health. For the farmer, emissions from agrochemicals, especially nitrogen, also constitute an economic loss. Limiting economic losses as well as environmental impacts requires new technologies and information to manage and ultimately reduce emissions.

The Agricultural Research Service research program for air quality is focused on developing such understanding and technologies through many projects, which fall under national programs including Climate Change, Soils, and Emissions (#212), Agricultural and Industrial Byproducts (#214), and Food Animal Production (#101).

Research priorities are set through input from customers and stakeholders, including other federal agencies such as the USDA Natural Resources Conservation Service, the U.S. Environmental Protection Agency, the Agricultural Air Quality Task Force Federal Advisory Committee, and the agricultural air-quality science community.

ARS seeks to understand, predict, and manage emissions from plant and animal operations and postharvest processing systems. There is a notable lack of emissions data from production and processing facilities. Existing data is often limited to short time periods and small areas, which in turn limits our ability to asses the effects on local and regional ecosystems and regional air quality. Whole-farm emissions assessments are virtually absent. Consequently, policymakers are hard-pressed to develop regulations based on science.

ARS is working to develop the ability to characterize emissions of soil particulates, volatile organic chemicals, pesticides, nitrogen, and greenhouse gases, and to identify their sources. Process-simulation models that can run on easily collected data are being developed and will provide the foundations for decision-support tools.

Air quality also affects crop growth and yield, so ARS researchers are working to understand how to increase the resilience of agriculture to atmospheric changes such as increasing ozone and carbon dioxide.

ARS air-quality researchers have formed an Air Quality Researchers Working group to better coordinate research across programmatic and scientific disciplines. Collectively, these scientists are addressing the need for standardized measurements, building a database, and planning joint research activities to leverage financial and expertise resources. This effort includes creating mobile instrumentation facilities, such as those used for measuring particulate-matter emissions, and a lightweight lidar system suitable for detecting and measuring emissions over entire farms.

Part of this working group is focused on emissions of greenhouse gases from animal systems, thus merging the strengths of air-quality research science with the successful GRACEnet project. GRACEnet is a nationwide research program to identify agricultural practices that will reduce agricultural greenhouse gas emissions and enhance soil carbon sequestration and provide a sound scientific basis for carbon credit trading programs.

Agriculture must continually increase production in an environmentally friendly way to meet increasing global need for food and other products from renewable resources. Research is the most promising way to achieve these goals.

Sound Science Sound Air

Helping Growers Adapt to Changing Rules on Fumigants

DAN CHELLEMI (D2246-1)

In a fumigated, tarped field in Tifton, Georgia, (left to right) horticulturist Jerry Johnson, plant pathologist Randy Driggers, and technicians Taylor Ivy and Nick Rotindo collect soil and air samples for analysis of chemical fumigants. Samples were collected to evaluate the impact of good agricultural practices on the soil fate and atmospheric emission of chemical fumigants.

For decades, methyl bromide has been an extremely important tool for vegetable, strawberry, deciduous fruit, nursery, and ornamental growers in their efforts to combat soil-dwelling nematodes, diseases, and weeds. But the fumigant is being phased out because of its harmful effects on the Earth's protective stratospheric ozone layer, and alternative fumigants are presenting new challenges for growers and regulatory officials who want to keep the air clean.

The Agricultural Research Service has been conducting research to find the best alternatives to the fumigant since the mid-1990s, and because of the issue's critical importance, the agency initiated a special areawide pest-management project 5 years ago that made several additional research efforts possible. As part of that 5-year effort, ARS researchers in Florida and California are helping to minimize release of the alternative fumigants into the atmosphere with studies focused on fumigant emission rates and the effectiveness of tarps used as barriers to cover fumigated soil. The work also is designed to assist the U.S. Environmental Protection Agency (EPA) and other regulators charged with developing new fumigant requirements to better protect people who use them or live near treated fields.

Under requirements being imposed by EPA, growers who use fumigants will need to establish buffer areas around treated fields to protect neighbors from excessive exposure and develop detailed management plans that include either fumigant monitoring or notifying neighbors of fumigant applications. Experience in California suggests that many growers and pesticide applicators have been able to adapt to these types of fumigant requirements within about a year. But many smaller operations, particularly those near suburbs, may be unable to meet the proposed standards because of their proximity to homes, institutions, and public rights-of way. These include some California strawberry growers and south Florida growers of tomatoes, peppers, and cucumbers, says Dan Chellemi, an ARS plant pathologist at the U.S. Horticultural Research Laboratory in Fort Pierce, Florida.

The vertical air-monitoring station located in the center of a fumigated field at a Duette, Florida, site is designed to continuously collect air samples at several heights. Fumigant-collection tubes were exchanged and air-sampling pumps calibrated every 6-12 hours for 10 consecutive days to ascertain fumigant flux rates from soil.

DAN CHELLEMI (D2247-1)

The financial implications could be significant. In Florida, for instance, tomatoes were a $622 million crop in 2008, and bell peppers were valued at $267 million.

Field studies conducted by Chellemi, Husein A. Ajwa, a former ARS scientist now with the University of California-Davis, and colleagues, showed that implementation of recently developed application equipment and methods reduced emissions to levels far below those found in previous studies. "We found that the differences were quite significant," Chellemi says.

Chellemi and colleagues applied several alternative fumigants under commercial application conditions at three sites near Duette, Florida, and three sites near Tifton, Georgia. The fumigants included chloropicrin, metam sodium, metam potassium, dimethyldisulfide, and 1,3-dichloropropene (sold as Telone). The fumigants were injected into the soil using shanks and low-disturbance coulters mounted on tractors, application methods that are becoming standard practice. The soil was then immediately covered with plastic tarps designed to prevent the fumigant from escaping.

The researchers used different types of plastic tarps, selected sites that included different soil types, and recorded the temperatures and moisture levels of the soil at times when the fumigants were applied. They also set up weather stations to monitor wind speeds and air sampling stations to track emission levels.

They found that emission rates could be drastically affected by the quality of the soil and the type of covering used. Coverings include tarps made with polyethylene or metal and VIF's (virtually impermeable films), which have layers of nylon or other materials imbedded in them. The researchers found that in dry soils with low organic matter content, VIFs worked best at keeping emissions low, while in areas with moisture above field capacity, a more permeable metalized film was equally as effective at reducing emissions. Their studies confirmed that good agricultural practices are critical factors in determining how much fumigant is released into the atmosphere. The EPA has used the results, published in the journal *Atmospheric Environment,* along with results from other recent research, to develop the fumigant standards currently being considered.

At an experimental site near Bakersfield, California, a tractor injects fumigants 46 centimeters deep into the soil while technician Qiaoping Zhang walks along the field and places boundary markers to identify the area of treated soil. Gas samples will be taken to determine fumigant emission rates in the field.

SCOTT YATES (D2248-2)

Testing Film Quality

ARS researcher Sharon Papiernik and her colleagues used specially designed chambers to test the permeability of dozens of films used in field trials to come up with a "resistance factor" that measures each film's ability to serve as a fumigant barrier. Papiernik sandwiched each film between two chambers, injected fumigants into one chamber, and measured both the fumigant that passed through the film into the second (receiving) chamber and fumigant that remained in the source chamber. Because each fumigant had a different chemistry, each behaved differently with each tarp.

The researchers tested 200 film-chemical combinations, including those used in large-scale field trials from the areawide pest management project, and came up with a resistance factor that can be used to determine emission rates for each film and fumigant under a wide range of growing conditions and weather patterns. Papiernik is research leader of the North Central Agricultural Research Laboratory in Brookings, South Dakota.

The results, reported online last year in the *Journal of Environmental Quality,* showed that the VIFs were in fact significantly better barriers to fumigant diffusion than the polyethylene films, but their effectiveness varied depending on the fumigant tested. Some VIFs were less effective under higher humidity levels.

The EPA is developing this approach as the standard testing method for evaluating agricultural plastics used in soil fumigation. The results, along with those from other studies, have provided basic standards for film manufacturers and guidance for growers on which films offer the best options for reducing fumigant emissions.

Math Makes It Simple

A major goal in many fumigant studies is determining the amount of gas released from the soil during the fumigation period. But measuring and calculating emissions is no easy task. It means trying to estimate how much of a fumigant is released in an outdoor environment, where variables range from the chemistry of the fumigant to the temperature and the amount of water vapor in the air.

Such constantly shifting variables make it difficult to determine not only the amount of fumigant being released, but also its effectiveness at killing pests.

Researchers also need to determine how emissions rates are affected by a complicated list of crop-management decisions, such as the permeability of the film being used, the amount of time the film covers the fumigated soil, and the depth of the shank used to inject the treatment into the soil.

Scott Yates, research leader of the Contaminant Fate and Transport Unit at the U.S. Salinity Lab in Riverside, California, took a mathematical approach to the problem and developed a model focused on determining fumigant volatilization rates, the amount of fumigant retained in the soil, the amount released into the air, and the relationship between soil-chemical properties and emissions.

In work published in the *Journal of Environmental Quality,* Yates used the model to calculate fumigant emission rates that compared reasonably well to actual methyl bromide emissions observed in field trials where a polyethylene film was used to cover an 8-acre field. The model can be used to determine how a fumigant will be distributed throughout a field and offers a consistent method for determining emission rates under a wide variety of crop-management scenarios.—By **Dennis O'Brien,** ARS.

This research supports the USDA priority of responding to climate change and is part of Methyl Bromide Alternatives (#308) and Air Quality (#203), two ARS national programs described at www.nps.ars.usda.gov.

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Sound Science Sound Air

E. coli: Alive and Well, Probably in a Streambed Near You

Escherichia coli is a survivor. It's at home in the gut of mammals and other vertebrates, but it can also live in soil and water and in biofilms that can form on some moist surfaces.

"Even though most *E. coli* strains don't cause illness, it's an 'indicator organism'—one that water-quality managers use to measure fecal contamination," says Agricultural Research Service soil scientist Yakov Pachepsky. "When it's found in surface water, agriculture or urban runoff is usually implicated as the source. But it can also come from wildlife, leaking septic tanks, or even irrigation equipment, so we need to know more about the sources of *E. coli* in the environment."

Another spot where many strains of *E. coli* lurk is in streambed sediments. Pachepsky is conducting studies with microbiologist Daniel Shelton and other scientists at the ARS Environmental Microbial and Food Safety Laboratory in Beltsville, Maryland, to learn more about where the pathogens in streambeds come from, where they end up, and how long they can survive.

Working with University of Maryland Environmental Science and Technology professor Robert Hill and honors student Amanda Garzio-Hadzick, Pachepsky collected streambed sediments and surface water from three sites along Beaverdam Creek in Beltsville. Then they added some dairy manure slurry to the samples, which increased nonpathogenic *E. coli* levels in the sediments and water.

Lab studies indicated that the bacteria survived much longer in the sediments than in the water and that they lived longer when levels of organic carbon and fine sediment particles were higher. They also found that when organic carbon levels were higher, water temperatures were less likely to affect survival rates—and they published the first evidence that *E. coli* can overwinter in the sediment.

The ARS team also evaluated whether adding data about the deposition and release of *E. coli* in streambeds would improve computer simulations of microbial water quality. They collected 3 years of data on streamflow, weather, and *E. coli* levels in water and sediments from a Pennsylvania stream fed by several smaller tributaries. Then they used the information to calibrate the Soil and Water Assessment Tool (SWAT), a computer model developed by ARS scientists that predicts how farming practices affect water quality on a watershed scale.

The resulting simulations indicated that bacterial releases from the streambed persistently degraded water quality and that pasture runoff only contributed to *E. coli* levels in nearby streams during temporary interludes of high waterflows. The team concluded that SWAT simulations would overestimate how much pasture runoff contributes to surface water contaminated with *E. coli,* unless the model included data on *E. coli* levels in streambed sediments.

"Now we want to look more closely at why *E. coli* doesn't die in the sediment. Is it because of contributions from wildlife or from high-flow events? This is still a big unknown," says Pachepsky. He adds, "The mud is something not many people are interested in. But it could change our conception of microbial water quality."—By **Ann Perry,** ARS.

This research is part of Water Availability and Watershed Management (#211) and Food Safety (#108), two ARS national programs described at www.nps.ars.usda.gov.

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STEPHEN AUSMUS (D2208-8)

Soil scientist Andrey Guber takes water samples from Beaverdam Creek to test levels of *E. coli* released from the disturbed bottom sediments during high-flow events. Water flow was increased by discharging water from a truck (background) into the stream at a rate and volume that replicated conditions caused by heavy rain.

Yeasts Produce "Green" Surfactants

Surfactants, wetting agents that lower a liquid's surface tension, have a long list of uses—from detergents and cosmetics to paints and pesticide formulations. Annually, about 10 million tons of surfactants are produced; most of these are petroleum based and rely on limited supplies of fossil fuels.

To develop a renewable alternative, an Agricultural Research Service team in Peoria, Illinois, has begun focusing increased attention on the properties of sophorolipids, surfactant-like molecules produced by naturally occurring yeasts. In 2010, for example, microbiologist Cletus Kurtzman and colleagues at ARS's National Center for Agricultural Utilization Research in Peoria set their sights on *Starmerella,* conducting the largest survey yet of yeasts belonging to this taxonomic group.

Using phylogenetic analysis and mass-spectrometry, the team screened 19 of the 40 known *Starmerella* members for their ability to produce sophorolipids. Phylogenetics, which traces the evolutionary relationships between species or groups of organisms, was particularly useful because it enabled the team to determine which members produce sophorolipids based on shared gene sequences for the trait. Of particular interest were certain *Candida* species that were shown to be asexual members of the genus *Starmerella.*

Only a few *Candida* species had previously been shown to make the surfactants—most notably, *C. bombicola* and *C. apicola,* when fed various agricultural byproducts in lab experiments. To broaden the search, the team tapped the ARS (microbial) Culture Collection, an extensive repository maintained at the Peoria center's Bacterial Foodborne Pathogens and Mycology Research Unit (BFPMRU).

In studies there, the team cultured the *Starmerella* yeasts on a diet of glucose (a simple sugar), or oleic acid (a fatty acid in, for example, soybean oil). They then measured the microbes' sophorolipid production levels over a 24- to 168-hour period using mass-spectrometry analysis, which can identify compounds by their unique molecular weights.

As initially expected, *C. bombicola* and *C. apicola* boasted the highest sophorolipid yields. But these weren't the only ones: The team's analyses also turned up three other high-producing yeasts, including a completely new species known only as "*Candida* NRRL Y-27208," which will be the subject of further investigation.

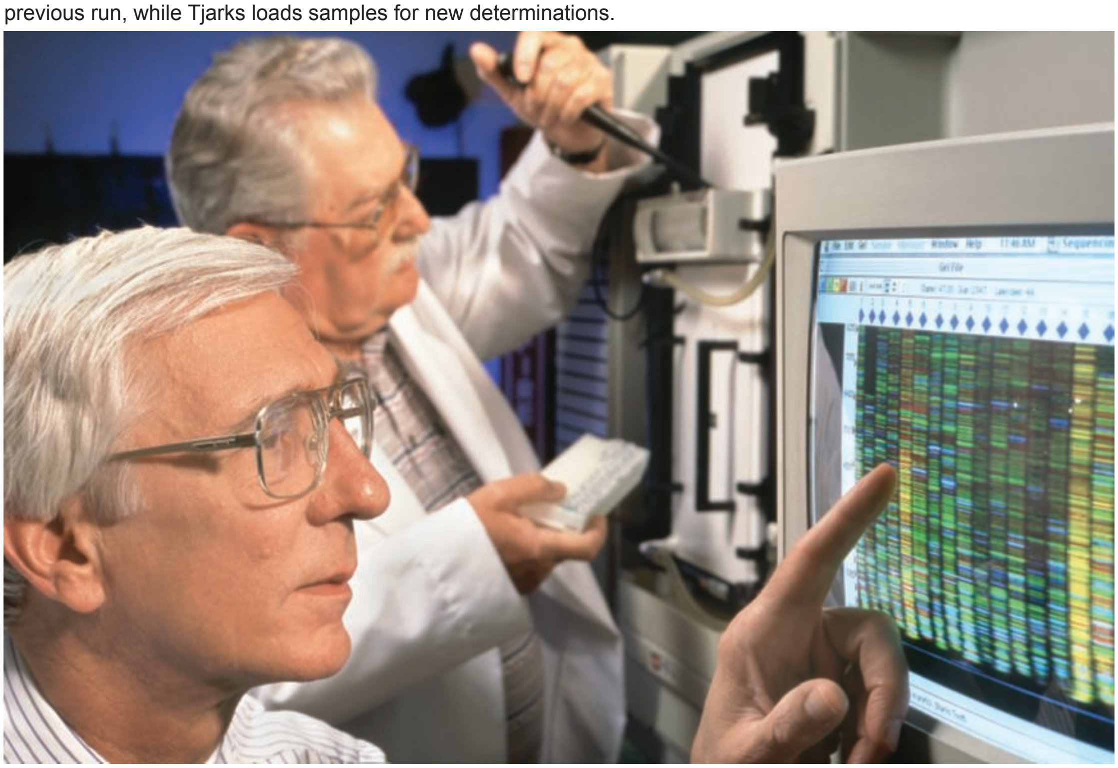
The findings add to a short list of candidate yeasts with potential for use in fermentation-based methods of mass-producing sophorolipids as green alternatives to petroleum-derived surfactants. "Yields from this study are good, and I am sure they could be enhanced markedly in scale-ups," says Kurtzman. He and colleagues in the ARS Renewable Products Technology Research Unit—chemist Neil Price, laboratory technician Karen Ray, and chemist Tsung-Min Kuo (deceased)—reported their work in *FEMS Microbiology Letters.*

The team's work also advances BFPMRU's mission of preserving, characterizing, and ensuring genetic diversity in microbial specimens submitted to the microbial culture collection, which currently numbers 95,000 strains. "This project is also an interesting example of using phylogeny to predict the occurrence of a particular biochemical property in an organism," Kurtzman adds.—By **Jan Suszkiw,** ARS.

This research is part of Plant Genetic Resources, Genomics, and Genetic Improvement, an ARS national program (#301) described at www.nps.ars.usda.gov.

To reach scientists featured in this article, contact Jan Suszkiw, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1630, jan.suszkiw@ars.usda.gov. ✻

With an automated DNA sequencer, microbiologist Cletus Kurtzman (left) and chemist Larry Tjarks can quickly obtain a detailed genetic analysis of an unidentified microbe. Here, Kurtzman inspects a yeast DNA sequence from a previous run, while Tjarks loads samples for new determinations.



KEITH WELLER (K8554-2)

Egg Quality Preserved After Exposure to Egg Crack Detection Technology

Microcracks in the shells of eggs pose a major food safety concern to consumers. Research has shown that cracked eggs are more likely to harbor bacteria, including foodborne pathogens. A new technology—called the "modified-pressure imaging system"—combines negative pressure with imaging and can accurately detect almost 100 percent of cracked eggs.

The device, developed by Agricultural Research Service scientists in Athens, Georgia, was discussed in detail in "A Better Way To Spot Eggshell Cracks," *Agricultural Research,* February 2009. It uses a negative-pressure chamber to essentially pull the eggshell outward very gently to clearly show any microcracks present in the shell.

The next step was to see whether quality suffered after eggs were subjected to the device.

Food technologist Deana Jones, research leader Kurt Lawrence, engineer Seung-Chul Yoon, and hyperspectral image specialist Gerald Heitschmidt, in the Egg Safety and Quality Research Unit, conducted a study to determine whether exposure to the modified-pressure imaging system had any effect on egg quality during storage.

"After 5 weeks of refrigerated storage, only a slight difference in the amount of water in the whole egg was noted between imaged and nonimaged eggs," says Jones. "All other quality attributes were the same for imaged and nonimaged eggs."

These other quality attributes include the egg's weight, albumen (egg white) height, shell strength, vitelline (yolk) membrane strength, and Haugh unit. A Haugh unit—considered by the egg industry as the "gold standard" of interior egg quality—is a mathematical formula that takes into account the egg's weight and the height of the albumen.

"This information lets us know that the use of the modified-pressure imaging system to detect cracked eggs does not affect egg quality, making it an important tool for enhancing the safety of shell eggs for U.S. retail sale," says Jones.—By **Sharon Durham,** ARS.

Deana Jones is in the USDA-ARS Egg Safety and Quality Research Unit, Richard B. Russell Research Center, 950 College Station Rd., Athens, GA 30605; (706) 546-3486, deana.jones@ars.usda.gov. ✻

New Primer Helps Identify More DNA Markers

DNA markers are important tools for identifying genes that control traits of interest to plant breeders, such as disease resistance or fruit quality. DNA markers are usually generated using "primers," short segments of DNA that are used by geneticists to look for genes that control specific traits. In general, geneticists use random primers in their search for DNA markers, but that process is often long and arbitrary, and it can result in researchers spending a lot of time and money to identify just one DNA marker.

To streamline the process, Agricultural Research Service geneticist Amnon Levi and plant pathologist Pat Wechter have developed a new method for identifying DNA markers. They used genomic data to search for small pieces of DNA, called "oligonucleotides," that are prevalent in watermelon genes and could be used as primers. Levi and Wechter believed that these new primers would generate a larger number of markers because they are more targeted than random primers.

Zhangjun Fei, an ARS-funded bioinformatics researcher at the Boyce Thompson Institute for Plant Research in Ithaca, New York, collaborated with Levi and Wechter and wrote a computer script to identify oligonucleotides that exist in high numbers in genes of watermelon. They named the new primers "high-frequency oligonucleotides targeting active genes," or HFO-TAG for short.

Working from the U.S. Vegetable Laboratory in Charleston, South Carolina, the scientists and fellow ARS and university colleagues tested their theory on 12 closely related watermelon cultivars. The researchers found that the HFO-TAG primers identified more DNA fragments than random primers did. Finding more fragments means researchers have a greater chance of finding DNA markers for genes that control desirable traits. And they don't have to invest as much time and money to identify the markers.

Levi and Wechter are currently using the HFO-TAG primers to look for watermelon genes that control disease or pest resistance and fruit quality. The primers will also be useful in genetic studies and genetic mapping of watermelon.

According to the scientists, this simple and straightforward method can be applied to genetic studies of other plants as well as animals. A full description of this study has been published in the *Journal of the American Society for Horticultural Science*.—By **Stephanie Yao,** formerly with ARS.

Amnon Levi and Pat Wechter are with the USDA-ARS U.S. Vegetable Laboratory, 2700 Savannah Hwy., Charleston, SC 29414; (843) 402-5326 [Levi], (843) 402-5318 [Wechter], amnon.levi@ars.usda.gov, pat.wechter@ars.usda.gov. ✻

The Agricultural Research Service has about 100 labs all over the country.

Map courtesy of Tom Patterson, U.S. National Park Service

Locations Featured in This Magazine Issue

- ARS locations included in this issue where air quality research is conducted
- Other ARS locations where air quality research is conducted
- Other ARS locations included in this issue

Pullman, WA
6 research units ■ 144 employees

Northwest Irrigation and Soils Research Laboratory, Kimberly, ID
1 research unit ■ 39 employees

San Joaquin Valley Agricultural Sciences Center, Parlier, CA
3 research units ■ 117 employees

Riverside, CA
3 research units ■ 46 employees

Las Cruces, NM
2 research units ■ 54 employees

North Central Agricultural Research Laboratory, Brookings, SD
1 research unit ■ 55 employees

Ames, IA
8 research units ■ 501 employees

Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, NE
6 research units ■ 120 employees

Lincoln, NE
2 research units ■ 81 employees

Center for Grain and Animal Health Research, Manhattan, KS
5 research units ■ 115 employees

Conservation and Production Research Laboratory, Bushland, TX
2 research units ■ 57 employees

Cropping Systems Research Laboratory, Lubbock, TX
4 research units ■ 121 employees

Poultry Production and Product Safety Research Unit, Fayetteville, AR
1 research unit ■ 13 employees

Dale Bumpers Small Farms Research Center, Booneville, AR
1 research unit ■ 24 employees

Madison, WI
5 research units ■ 140 employees

Wooster, OH
3 research units ■ 54 employees

National Center for Agricultural Utilization Research, Peoria, IL
7 research units ■ 226 employees

Urbana, IL
2 research units ■ 46 employees

Animal Waste Management Research Unit, Bowling Green, KY
1 research unit ■ 16 employees

Jamie Whitten Delta States Research Center, Stoneville, MS
7 research units ■ 277 employees

Mississippi State, MS
3 research units ■ 80 employees

Athens, GA
9 research units ■ 210 employees

Pasture Systems and Watershed Management Research Unit, University Park, PA
1 research unit ■ 40 employees

Henry A. Wallace Beltsville Agricultural Research Center, Beltsville, MD
30 research units ■ 953 employees

Raleigh, NC
4 research units ■ 100 employees

Coastal Plains Soil, Water, and Plant Research Center, Florence, SC
1 research unit ■ 36 employees

U.S. Vegetable Laboratory, Charleston, SC
1 research unit ■ 44 employees

Center for Medical, Agricultural, and Veterinary Entomology, Gainesville, FL
4 research units ■ 144 employees

U.S. Horticultural Research Laboratory, Fort Pierce, FL
3 research units ■ 133 employees

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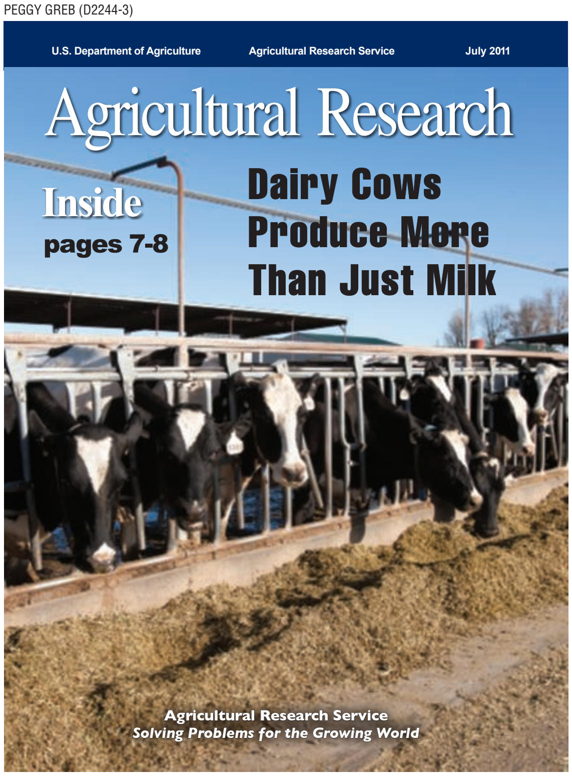

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