Strawberry Growers Test Methyl Bromide Alternatives

Sweet, juicy strawberries are one of America's favorite fruits. We each eat about 4 pounds of the plump, bright-red berries every year. Fat-free and low in calories, strawberries are loaded with vitamin C. They also furnish folate—a B vitamin—plus potassium and fiber. What's more, strawberries provide ellagic acid, a compound that fights cancer.

To raise perfect berries, most growers rely on a fumigant, methyl bromide. Berry farmers inject methyl bromide gas—along with a companion chemical, chloropicrin—into the soil a few weeks before planting. The chemicals zap soil-dwelling fungi and bacteria that can cause plant diseases. And they quell weeds that would otherwise compete with young berry plants for water, sunlight, space, and nutrients.

Wide Range of Tactics Probed

America's strawberry farmers will be among the hardest hit as the nation phases out production and use of methyl bromide. The phaseout stems from evidence that methyl bromide is an ozone depleter, that is, a substance that destroys the protective ozone layer of Earth's atmosphere. The impending loss of methyl bromide has sent growers and researchers scrambling to find safe, effective, economical, and easy-to-use alternatives.

Agricultural Research Service scientists in California—where 80 percent of the nation's fresh-market strawberries are grown—are investigating a range of new tactics for producing high-quality harvests. The researchers anticipate that growers will likely end up using an assortment of biological control and chemical options—instead of relying on a few magic-bullet chemicals like methyl bromide paired with chloropicrin.

Scientists from ARS labs in Fresno, Salinas, and Davis, California, are measuring how various compounds affect berry harvests. Their tests include not only today's leading commercial strawberry varieties, but also more traditional cultivars—ones that dominated berry fields decades ago. Some experiments scrutinize the impact of the promising chemicals on beneficial and harmful soil microbes. Others explore the effects of adding helpful microbes to fields to boost growth and provide protection from disease organisms.

In this array of projects, researchers have teamed up with university scientists and with specialists from industries that produce biological control or chemical products. Thanks to the grower-funded California Strawberry Commission, farmers from major berry-producing regions of the state have willingly set aside portions of their fields for the researchers to use and have hosted tours of those sites so neighboring farmers can also benefit from what's being learned there.

Applying Chemicals Through Drip Irrigation Systems

Most growers send irrigation water to their strawberry plants though slender polyethylene tubes known as drip tapes. Each of the raised beds in which strawberries grow has one or two of these tapes, buried an inch or more beneath the soil surface.

These same drip tapes could be used to carry fumigants. Soil scientist Husein A. Ajwa and agricultural engineer Thomas J. Trout at Fresno have probably explored more variations of that idea than any other recent scientific team. They have looked at more than half a

SCOTT BAUER (K9186-2)

Plant pathologist Carolee Bull (left) and technicians Joel Stryker (center) and Adria Bordas discuss the effectiveness of biological weed and disease control at a research site on grower Rod Koda's ranch.

SCOTT BAUER (K9180-1)

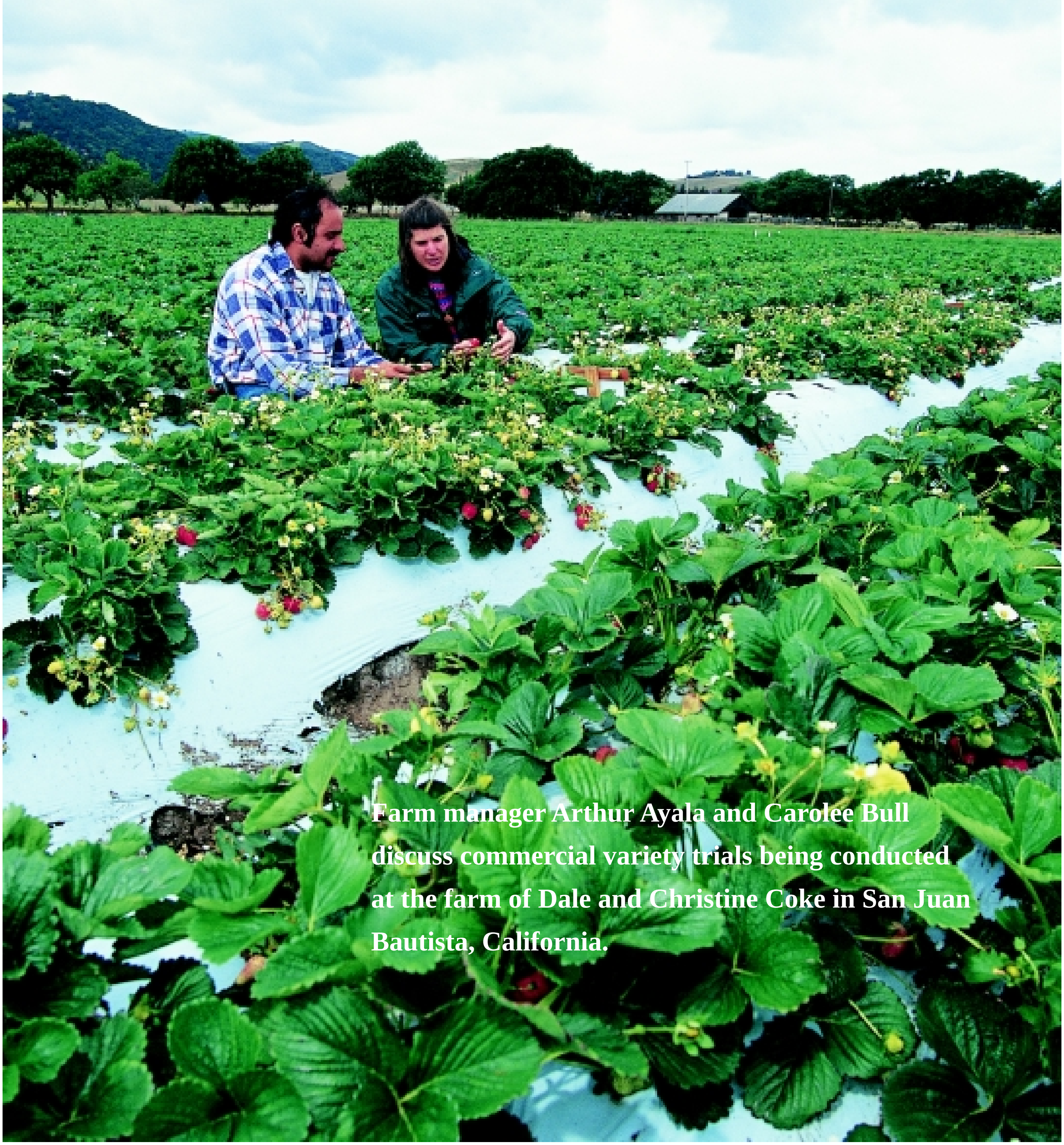
To gauge the effectiveness of crop rotation strategies and methyl bromide alternatives, technician Cameron Blackford counts colonies of the root pathogen *Pythium ultimum* that survived the soil treatments.

BRIAN PRECHTEL (K9194-1)

The healthy looking strawberry plant was grown in soil treated with methyl bromide alternatives. The other is from untreated and unfumigated soil and is infested with Verticillium wilt.

BRIAN PRECHTEL (K9189-1)

SCOTT BAUER (K9186-1)



Farm manager Arthur Ayala and Carolee Bull discuss commercial variety trials being conducted at the farm of Dale and Christine Coke in San Juan Bautista, California.

Ranchers in California set aside portions of their farms for collaborative studies on methyl bromide alternatives for strawberries. Carolee Bull (right) and Adria Bordas evaluate biologically based methods for weed and disease control at Rod Koda's ranch.

SCOTT BAUER (K9179-1)

dozen chemicals—used alone or in combination with other compounds. In some tests, they tried different concentrations of the chemicals and applied them at different rates, as well. In other experiments, they scrutinized emulsifiers that make the compounds soluble in irrigation water.

Aided by a sophisticated, field-ready version of an instrument known as a gas chromatograph, they have probed different kinds of soils to track the compounds, learning how far down—and how far across the raised beds—these materials move and whether the spread is uniform. By tracking how long it takes the chemicals to deteriorate, they've determined when it is safe to re-enter fields to plant the beds.

Ajwa says that applying fumigants through drip irrigation systems may reduce worker exposure and decrease the amount of chemicals needed to treat fields. Among the best performing of the compounds that he and Trout have examined is InLine, a combination of about 60 percent 1,3-dichloropropene and up to 35 percent chloropicrin.

The manufacturer, Dow Agro-Sciences LLC, is pursuing registration of this material for use in strawberry fields. InLine is the water-soluble formulation of Telone C35, a parent compound that is already approved for use on strawberry fields. But it requires a buffer zone and has a maximum-use-per-township limit, meaning that not every grower on every farm could use as much as would be needed.

At some sites, marketable yields of InLine-treated plots were from 95 to 110 percent of those from plots treated with methyl bromide, Ajwa reports. Plots that he treated with another option—chloropicrin alone, at a lower rate—provided a yield about 94 to 100 percent that of the methyl bromide sites.

Ajwa also found that reduced rates of InLine, or of chloropicrin, can also produce yields equivalent to methyl bromide if either alternative chemical is

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used in tandem with metam sodium—another fumigant. Metam sodium would be applied 1 week later through the same irrigation system.

"Or a compound known as methyl iodide can be applied with chloropicrin, using drip irrigation," Ajwa adds. "We got about the same yields from this combination as from methyl bromide." That test was likely the first to apply methyl iodide in a drip irrigation system.

"We've also seen very promising results with a chemical called propargyl bromide," says Ajwa. "It gave yields that were up to 110 percent of those from the methyl bromide plots."

BRIAN PRECHTEL (K9193-1)

Soil scientist Husein Ajwa (right) and postdoctoral research associate Shad Nelson inspect strawberries from a test plot near Watsonville, California.

This year Ajwa plans to find out how much of the drip-applied fumigants escape into the air. Those figures may be particularly valuable if the manufacturers of candidate compounds, such as methyl iodide or propargyl bromide, seek U.S. Environmental Protection Agency and State of California approvals for this use of their products.

Harnessing Helpful Microbes

When fields are fumigated, good and bad microbes alike may be wiped out. But what if beneficial microbes were routinely added back to the soil? Plant pathologist Cynthia Eayre at Fresno is investigating rhizobacteria, which live on or around plant roots in the soil zone called the rhizosphere. In particular, she's looking at plant-growth-promoting rhizobacteria.

Eayre has screened more than 130 strains of these friendly bacteria to pinpoint those which might boost the vigor and yield of young berry plants. She's working with plants growing in nonfumigated soil and those growing in beds fumigated with methyl iodide or chloropicrin, for instance.

How do these microbes help plants?

"We think they use nutrients that might otherwise be taken up by harmful bacteria," says Eayre, "Or the rhizobacteria might colonize sites on strawberry roots, edging out pathogenic bacteria.

"The rhizobacteria can also release hormones that encourage root growth and can produce compounds that inhibit the harmful bacteria. In some other crops, they can enhance disease resistance, but we don't know exactly how they do that."

From her screening of these microbes, Eayre has found about a half-dozen worth further scrutiny. Among them is a strain from EcoScience Corp., in Longwood, Florida. In one test, yields from plants that she inoculated with the EcoScience formulation and then planted in chloropicrin-fumigated soil were equal to those from methyl bromide plots. Ideally, instead of hand-dipping the plantlets into the inoculum—as Eayre had to do—tomorrow's planting stock could be quickly and easily treated by adding a freeze-dried version of the microbial product into drip irrigation systems.

Foiling *Phytophthora*—a Formidable Fungal Foe

One of the worst soilborne enemies of strawberry plants is a fungus called *Phytophthora*.

"*Phytophthora* can cause severe root rot and crown rot, not only at the nurseries where strawberry plants are started, but also later in the fruiting fields where the berries are produced," says Greg T. Browne. His approaches to fending off *Phytophthora* include evaluating strawberry varieties for strong natural resistance that could be bred into new commercial cultivars.

An ARS plant pathologist at Davis, Browne is also testing fungicides to provide new and more detailed information about their effectiveness.

The screening procedure that Browne developed for ferreting out gene-based resistance to *Phytophthora* has been adapted for use in the University of California's strawberry breeding program—the state's oldest and largest. Browne's procedure involves growing *Phytophthora* colonies in a nutrient-rich mixture that's later stirred, or rototilled, into soil at experimental sites in either the nursery or berry-producing fields. Says Browne, "We think this research procedure mimics natural conditions in which the fungus grows and spreads. Some plants collapse from fungal infection early in the field tests. Those which don't are monitored for their marketable yield."

Browne's test of fungicides included two compounds already approved for use on strawberries—Ridomil Gold, which is applied to soil, and Aliette, which is applied first as a dip before planting, then as a spray after planting.

"Our preliminary tests," he says, "indicate these chemicals may be an important component of an overall strategy that uses many different weapons and tactics."

Other Pathogen Problems Probed

While powerful pathogens such as *Phytophthora* can clobber strawberry plants outright, slower-acting, stealthier microbes can't be ignored. These pathogens include "root nibblers," as Frank N. Martin refers to them.

"Collectively, they may not kill plants," he says. "But they can have dramatic effects on yields by damaging the fine roots that bring water and nutrients to plants."

In his Salinas studies, Martin—a plant pathologist—is tracking the fate of such soil-dwelling foes as *Pythium, Rhizoctonia,* and *Cylindrocarpon* species, among others. In nursery, greenhouse, and field tests, he has scrutinized more than a dozen different commercial strawberry cultivars for any signs of resistance to these microbes.

His field trials with 17 cultivars planted in soil inhabited by the root-nibblers showed that losses in marketable yield ranged from minimal up to about 80 percent, compared to plants grown on methyl-bromide-fumigated plots. "Even though some of the more tolerant cultivars are no longer grown commercially," Martin says, "it may be possible to breed that tolerance into new cultivars."

In other work, Martin and University of California colleagues Krishna Subbarao and Steven T. Koike are finding out how strawberry pathogens fare if the crop is rotated with broccoli or Brussels sprouts. Earlier work, done elsewhere, showed that these plants contain substances called glucosinolates, which decompose naturally into compounds that are thought to kill microbes.

SCOTT BAUER (K9184-1)

Plant pathologist Frank Martin examines cultures of different root pathogens that can reduce yields of strawberries grown in poorly or nonfumigated soil.

Chemical-Free Strategies Eyed

Conventional growers may learn from the experience and expertise of organic farmers, "who never relied on methyl bromide in the first place," says Carolee T. Bull, a plant pathologist with ARS at Salinas. Her work with organic producers has included testing commercial cultivars on fumigant-free farms, to get a precise picture of comparative yields. This work is likely some of the first of its kind in California.

"These varieties were developed for conventional farmlands treated with methyl bromide," explains Bull. "So of course they were tested on methyl-bromide fumigated fields. That means there wasn't a pressing need to select them for natural resistance to the pathogens that methyl bromide kills."

She's also scrutinizing beneficial microbes known as *Myxobacteria*. "We're examining organisms like *Myxobacteria flavescens, M. fulvis, and M. zanthus,*" she says, "because they may produce compounds that can weaken or kill strawberry pathogens. We may be able to use them as biological control agents by adding them to soil to increase protection."

Organic growers often produce lower yields, but they can offset those losses when their crop commands top prices. The number of organic strawberry growers in California has increased in the past several decades, with some of the state's largest and best-known growers now converting some of their acreage to organic production.—By **Marcia Wood,** ARS.

This research is part of Methyl Bromide Alternatives, an ARS National Program (#308) described on the World Wide Web at http://www.nps.ars.usda.gov.

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