Soil Microbes Pose Problems for Pesticides

Microbes in some soils are undermining the efficacy of pesticides; the problem is only recently discovered and is poorly understood

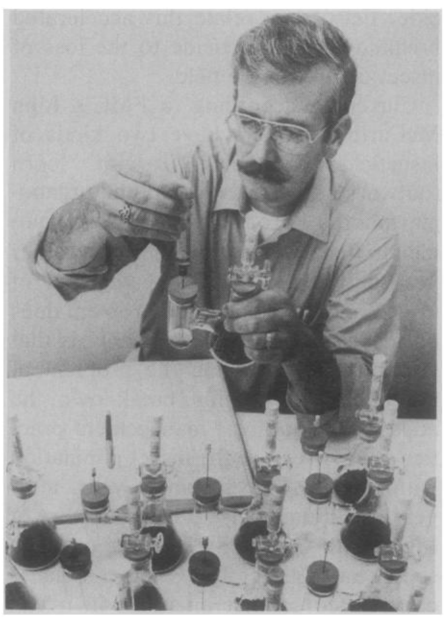
Microbes in some soils are degrading certain pesticides so rapidly that these products are losing their efficacy. Although the problem so far has mainly affected several herbicides and insecticides used in parts of the Corn Belt in the midwestern United States, it also has affected vegetable crops and managed forests. This reduced pesticide efficacy differs from the usual problem that arises when the pests themselves develop resistance to chemical treatments.

The range of opinion about the seriousness of accelerated pesticide breakdown is wide. Ecologist and entomologist Robert Metcalf of the University of Illinois calls it "a very alarming phenomenon. Resistance develops ever faster; there is shorter and shorter productivity of these compounds; and development of new products always gets more expensive." However, those views are disputed by some representatives of pesticide manufacturing companies. Although they do not deny that accelerated breakdown of their products sometimes occurs, they argue that the problem is seen so rarely that its consequences for agriculture are minor.

There is still no general mechanism to describe how accelerated degradation of pesticides occurs. Some scientists are speculating that, as with microbial resistance to antibiotics, the genes for pesticide breakdown may be carried on plasmids that can be traded freely among various microbes to speed adaptation to the pesticides.

Not only does this problem raise some provocative scientific questions, but it also carries the potential for causing economic losses should it go beyond what now are narrowly circumscribed boundaries. Although the pesticide degradation problem touches only a tiny fraction of the $3.25-billion pesticide market, its impact could grow as the practice of no- and low-till farming spreads, leading to ever greater use of these products. Moreover, these dollar figures say nothing about the potential economic impact of crop losses resulting from lost pesticide efficacy.

Evidence of the problem began to appear during the late 1970's. Recently, pesticide manufacturers, university and university extension service researchers, and scientists at the U.S. Department of Agriculture's research facility in Beltsville, Maryland, have begun sharing their findings to try to determine the scope of the problem.* In particular, soil microbiologist Donald D. Kaufman and his collaborators at Beltsville are taking the lead. According to Kaufman, the problem has intensified during recent years and broadened in scope. Soils can become "conditioned" to degrade pesticides ever more rapidly, especially when the same or similar treatment is used year after year, he says.



Donald D. Kaufman

"We don't know the mechanism yet."

In the worst situations observed so far, losses in pesticide efficacy have reached 1 percent or higher, according to Kaufman. "Always, when you deal with pesticides, a certain percent doesn't work," he says. But a few years ago, he was approached by several company representatives to look at products that were not working "for reasons that couldn't be explained." The problem of decreased efficacy worsened with repeated use of the products in successive years; it was seen only in some fields but not in others that were ostensibly the same.

In one regard, the breakdown of pesticides is a salutary feature of recent agricultural chemistry. Earlier, widely used pesticides accumulated because they resisted degradation, and eventually made their way into many higher organisms, sometimes with devastating effects. Newer pesticides are intended to circumvent this problem by being degradable, either by physical-chemical forces or by biological action. But rapid breakdown by soil microbes is an unexpected phenomenon, according to Kaufman. Some ecologists argue that the near-total ignorance about those pesticide breakdown products is worrisome. "Because you don't know how far destruction goes, you can't say that it's 'therapeutic,' " says Metcalf. No one can say whether pesticide breakdown products are deleterious to the environment. However, Kaufman speculates that such chemical intermediates, which no longer act as pesticides, might help soil microbes adapt to these chemicals.

Nonetheless, pesticide degradability is considered a desirable property by environmentalists. Hence it is ironic that, despite wide realization that degradation occurs, nobody really expected microbes in soil to thrive on these chemicals. Compared to the tons of crop residue left in the soil, Kaufman explains, there is very little of any pesticide—typically only a few pounds of chemical per acre—for microbes to come to rely on. Thus, although these pesticides are applied with the expectation that they will not persist indefinitely, there has been a parallel and somewhat inconsistent expectation that soil microbes could not possibly use these pesticides as a principal source of nutrients.

So far, two main groups of pesticides are affected by accelerated breakdown by microbes: the carbofuran insecticides, sold under the tradename Furadan by FMC, Inc., headquartered in Chicago; and the thiocarbamate herbicides, whose active ingredient is called Eptam by Stauffer Chemical Company, Westport, Connecticut. Stauffer sells two Eptam-containing products used widely by

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corn growers, Eradicane and Eradicane Extra.

Eradicane Extra was brought into the market by Stauffer largely because the product is more persistent than its predecessor, Eradicane. But in certain problem soils, Eradicane Extra "was not working by 1982 and in 1983," according to weed scientist Gordon Harvey of the agronomy department, University of Wisconsin, Madison. "If there was no herbicide 'history' in the field, we see no degradation. But if it's the second year of use, we see very rapid degradation." Richard Fawcett of the plant pathology department at Iowa State University sees much the same thing.

Several Stauffer representatives state that the newer product is not being broken down unduly rapidly, and thus is effective. "There's no question that Eradicane is capable of being degraded in some soils," says Richard F. Gold, manager of market planning in Stauffer's agricultural chemical division, adding: "The potential problem is fairly small. University people say Eradicane Extra has the same problem. We do not see that in up to 4 years of continuous testing in corn . . . I don't say it can't happen, but we haven't seen that." Fawcett says, however, that "Extra" was available "only in limited quantities last year so there was not much chance for this problem to show up yet."

The thiocarbamate herbicides are used by corn growers for controlling "problem" weeds, and thus they are by no means the most widely used of current herbicides. In Iowa, they are used on a small portion of the total corn crop, and a problem is seen perhaps in only 1 percent of those cases, Fawcett estimates. Nonetheless, accelerated breakdown is "a major concern for farmers with problem weeds because the treatment of choice has been Eradicane," he says, adding: "For a small percentage of the total acres, we're at a loss for a product." And in Wisconsin, where the problem weed wild millet is "exploding," the failure of Eradicane Extra noted by Harvey could become more serious for corn farmers. Gold says, however, "We only claim suppression, not control of millet because of its multiple flushes." But, he adds, "We have a [different] opinion from Gordon [Harvey]. I have no explanation. I am not disputing his results. We don't see the same pattern developing."

Although accelerated breakdown of thiocarbamates has been seen in some midwestern farms, Albert Benson, a department research manager at Stauffer, points out, "In certain soils in California, we can't *make* it happen." He says, "We have isolated cases where degradation occurs in individual fields," but "all you have to do is rotate the herbicide out and the crop out and get a good drying autumn. The problem has been identified with fields in continuous corn, but even when used continuously, the problem is not that great." Benson concludes: "From a theoretical standpoint, this is an interesting problem. From a practical standpoint, it's not a great problem. In what we're seeing, there's no major economic impact at all—unless it's psychological."

Gauging the extent of the problem of degradation of insecticides by microbes is more difficult than judging herbicides. Both Kaufman and entomologist Allan Felsot at the University of Illinois, Champaign-Urbana, however, have evidence that carbofurans, such as FMC's Furadan, are degraded rapidly in some "conditioned" soils, that is, soils receiving repeated treatment of the same pesticide. Felsot can relate this accelerated breakdown of insecticide to the loss of insect control in the field.

Currently, according to FMC's John McCarthy, farmers have two kinds of insecticides to deal with corn rootworms, the carbofurans and organophosphorus products. FMC recommends that growers switch every other year between these two categories of insecticides. "If done, the problem does not develop," he says. Not only is that important for avoiding the problem of accelerated carbofuran breakdown, he adds, "it's good pest management practice not to pressure the insect population with the same substance year after year." Entomologist Jon Tollefson of Iowa State University sees the problem somewhat differently. Once a field is conditioned so that microbes in it can rapidly break down the carbofurans, "it takes several years before they get back to usefulness—we don't know how many," he says.

However, no one is saying that the problem of accelerated breakdown of carbofurans is particularly frequent or widespread. The problem is still fairly rare, but it nonetheless can cause headaches to anyone in the pesticide business. "The kicker is," says Felsot, "we need a product that works consistently. Farmers talk to each other, and a product loses its credibility." Thus, the difficulties in estimating the extent of the problem, and coping with it sensibly, can be compounded when the farmers' dimming view of a product's efficacy distorts the market for it.

Perhaps the most worrisome, but so far the least documented possibility is that substantially different pesticides, applied sometimes for altogether different purposes, will enhance the degradation of one another. "We can actually create problems for some insecticides by treating soils with certain herbicides," Kaufman says. "The microbes haven't read the book; they just degrade [the chemicals]." Here again, there's little consistency between one situation and the next. Kaufman's collaborator Yaacov Katan facetiously explains that some soils are "intelligent," meaning the microbes there quickly adapt to the pesticides, whereas other soils are "stupid." Kaufman also argues that chemically similar substructures in the different classes of compounds, including pesticides but also fungicides and fertilizers, could inadvertently conspire to trigger the same adaptation by soil microbes. Thus, for example, a urea group (found in fertilizers and herbicides) resembles the methylcarbamate group (found in insecticides) and also resembles a thiocarbamate (herbicides). Because soils can be treated with such a wide variety of chemicals, there is no easy way of saying what their combined effects might be.

Kaufman claims that two major families of products—the insecticides and herbicides—can exert crossover effects on soil microbes. That is, the use of one product, say an insecticide, may predispose soil microbes not only to destroy it but also other products including herbicides. This finding, which comes from controlled lab and field studies, has not been fully confirmed. "There may be a slight interaction, but we've found no interaction in the thiocarbamate [products]," says Stauffer's Benson. "I think Kaufman is backing off a bit. We think he's wrong; let's put it that way," another company spokesman says. Officials from both Stauffer and FMC say that the phenomenon has not been seen empirically in farm use, but also say that it hasn't been looked for systematically.

Thus Kaufman's idea that soil microbes have a special aptitude for prematurely destroying pesticides from different chemical classes is not a subject that gets high marks from many industry representatives, although several university researchers say they have preliminary findings that may be consistent with Kaufman's idea. Those who disagree with Kaufman say that although he may be able to coax microbes to adapt to diverse chemicals under laboratory conditions, such behavior is unlikely to occur in field conditions. Recently, however, according to Kaufman, treatment of vegetable plots in Maryland with diphenamide herbicides apparently has predisposed microbes in those fields to degrade carbofuran insecticides.

Curiously, a reverse phenomenon is sometimes seen. Instead of one pesticide predisposing soil microbes to degrade another chemical, one treatment may protect or extend the efficacy of another product. In New Zealand, according to Harvey, some farmers have been switching between Eradicane and herbicides containing the active ingredient alachlor in alternate years, and this seems to prevent Eradicane failures. Kaufman and his collaborators have seen similar protective effects by alachlor in the lab, and this protection extends to other compounds. "This looks like a benefit," Kaufman says, "but we don't know the mechanism yet."

Most industry officials argue that the phenomenon of rapid pesticide breakdown is more likely to remain a curiosity than to become an epidemic and that traditional pest management practices, such as crop and pesticide rotation, will alleviate most difficulties. Despite that optimism, however, the people affected by accelerated pesticide breakdown admit they'll be watching its incidence closely.—**Jeffrey L. Fox**

First Trimester Prenatal Diagnosis

A new method of prenatal diagnosis may largely replace amniocentesis

A new technique for obtaining fetal cells for prenatal diagnosis, now being tested in the United States and Europe, may largely replace amniocentesis within the next few years, clinical researchers predict. Known as chorionic villus biopsy, the experimental method permits prenatal testing during the first 3 months of pregnancy and yields results on chromosomal and biochemical disorders within days—or even hours. Amniocentesis, by contrast, cannot be performed before the sixteenth week of gestation and test results are not available for about 2 weeks.

Preliminary evidence indicates that chorionic villus biopsy is safe but the question needs further study. According to Sumner Yaffee, director of the Center for Research on Mothers and Children at the National Institute of Child Health and Human Development (NICHD), the government is aware of the need to "ascertain the safety as well as the efficacy" of the procedure. A small task force will be convened this fall to determine what needs to be done, he reports. One good possibility is that NICHD will sponsor a clinical trial or a national registry to evaluate and track developments.

The chorionic villi, which are the source of fetal cells in this procedure, are hairlike projections of the membrane that surrounds the embryo early in pregnancy. After about 10 weeks, the villi begin to disappear as part of the chorion thickens to become the placenta and the rest becomes a thin membrane. Chorionic villus biopsies, therefore, must be done between 8 and 10 weeks of pregnancy.

The new procedure is not difficult to learn, according to Maurice Mahoney of Yale University School of Medicine. "It is not a highly difficult procedure. This is a test that a lot of doctors will be able to learn and to do well."

A physician, guided by ultrasound, inserts a thin catheter into the pregnant woman's cervix and, using suction, removes a small plug of tissue from the end of one or more villi. This tissue constitutes rapidly dividing fetal cells that can immediately be analyzed for chromosomal and biochemical defects. With amniocentesis, the fetal cells are so dilute in the amniotic fluid that they must be grown for 2 weeks in tissue culture before there are enough of them for analysis.

Source of fetal cells

Chorionic villi from an 8- to 10- week-old embryo can be analyzed for biochemical and chromosomal abnormalities.

Although chorionic villus biopsies are only now exciting U.S. and European investigators, the idea behind this technique is not new. In the late 1960's, Swedish and Danish researchers demonstrated that they could get tissue from chorionic villi for prenatal diagnosis, but they did not pursue the methodology because amniocentesis was developed at about the same time and quickly became the procedure of choice.

Then, in 1975, Chinese scientists reported that they were using the technique to determine fetal sex. Since they did not have tissue culture facilities, they could not look for chromosomal aberrations or biochemical abnormalities. According to a World Health Organization (WHO) report, the Chinese abandoned their attempts to do chorionic villus biopsies because women were using the information to abort female embryos and because they could not obtain medically useful information without doing tissue cultures. The Soviets also made a brief foray into chorionic villus biopsies, reporting the results of 13 pregnancies in 1975. Like the Chinese, the WHO reports, they only used the method to determine sex.

But those scientists in the United States and Europe who knew of the Chinese and Russian results tended not to believe them, according to Joseph Schulman of George Washington University Medical School. The technique began to catch on when a group of British researchers, headed by J. M. Old and D. J. Weatherall from John Radcliffe Hospital in Oxford and R. H. T. Ward of University College in London and, inde-