Deep changes taking root in U.S. agriculture

Rising costs of fuel and of fertilizer, pesticides, and herbicides are forcing farmers to weed out inefficient practices; increasing support for plant research is expected to bear fruit in the future

With the growing season now well under way, American farmers are beset with traditional farm concerns over rain, weeds, and insects. But added to these again are the concerns of the past few years with rising costs of energy and chemicals. And these newer concerns are affecting the way farmers are going about their work.

It's a comfortable and oft-quoted statement that one American farmer can feed 50 people all by himself. The statement is true enough—on the surface. The system is incredibly robust. To Americans it seems only natural that the nation's chief dietary problem is not malnutrition, as it is in much of the rest of the world, but obesity. So bountiful is the soil of the Midwest that people actually are using edible grain—in its fermented form, ethanol—as auto fuel.

On the global scene, some 65% of the grain that is exported in the world is exported from the U.S. When the harvest is bad in the Ukraine, as it often has been of late, even the Kremlin must look to the grain elevators of Duluth—a fact made vivid by President Jimmy Carter's 1980 embargo on the sale of grain to the Soviet Union, and by the recent controversy over the Reagan Administration's lifting of that ban. Agriculture has long since entered the realm of geopolitics.

On the other hand, that fabulously productive American farmer is utterly dependent on petroleum and petrochemicals to supply him with diesel fuel, fertilizer, pesticides, and herbicides. Given the U.S.'s dependence on imported oil, and the vagaries of the Organization of Petroleum Exporting Countries and mideastern politics, there is cause to wonder how long the system can continue as it has.

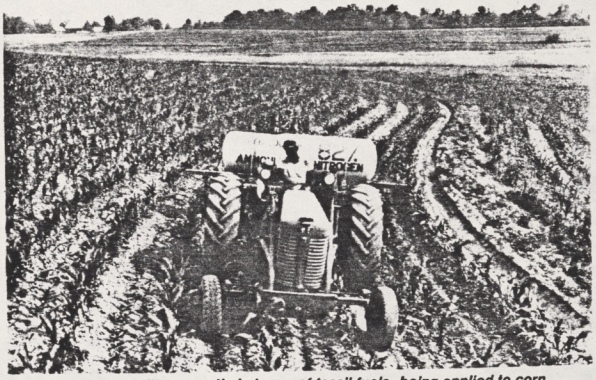
This article was prepared by former C&EN West Coast bureau head M. Mitchell Waldrop, now with *Science*, Washington, D.C.

Agricultural practices in the U.S. in fact are undergoing slow but profound changes, changes that will have equally profound effects on how and how much agricultural chemicals will be used in the coming decades. Heavy demand for grain exports, environmental concern over pesticides and herbicides, increased use of biomass energy, new crops created by genetic engineering and advanced breeding techniques all will continue to play a part. But for the present, nothing is having so great an impact as the individual farmer's efforts to cope with the rising costs of energy and petrochemicals.

Last year CRC Press published its "Handbook of Energy Utilization in Agriculture," edited by Cornell University entomologist David Pimentel. "Currently, the high yields with relatively small inputs of manpower are associated with mechanized agriculture and are due essentially to ample supplies of inexpensive fossil energy," he writes in the introduction. "The often quoted statistic that one U.S. farmer feeds about 50 people [is] an oversimplification of the facts, because the farmer himself depends upon large inputs from petrochemicals, machinery industries, and commercial services. A more realistic statement is that about one person in five in the nation's work force is involved in supplying food in the American system."

About 17% of the nation's fossil energy goes for production (including shipping), processing, and for preparation of food, with about one third allocated to each activity, Pimentel continues. For comparison, automobiles burn about 25%.

On the production end, by far the largest fossil energy inputs are for fuel and nitrogen fertilizer. The numbers vary greatly between locations in the country and even more from crop to crop. (Alfalfa, for example, is a legume that fixes nitrogen on its own and doesn't need fertilizer.) Fairly typical, however, are the handbook's estimates for corn grown in southern Minnesota. The fossil energy input is about 6.5 million to more than 7 million Btu per acre; the energy content of the final product is just under 61 million Btu per acre. Liquid fuel and



Nitrogen fertilizer, costly in terms of fossil fuels, being applied to corn

The term "integrated pest management" wasn't coined until the early 1970's. The basic concepts, however, can be traced to University of California entomologist Charles W. Woodworth, who was advocating an ecologically based pest management approach as long ago as 1896. The Berkeley campus has remained a stronghold of such thinking ever since; when chemical pesticides swept the market in the 1940's and 1950's, the agriculture school there was one of the few in the country to keep up the study of biological controls.

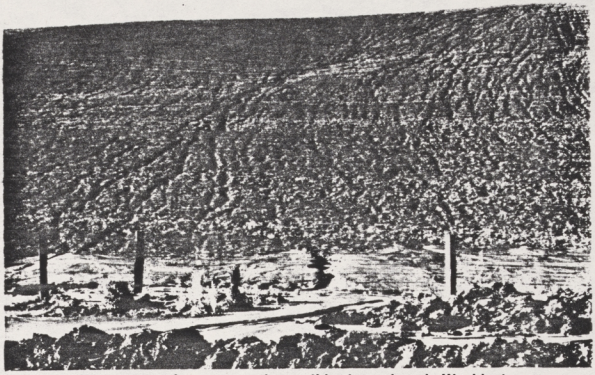
In its modern form, integrated pest management is a melding of both approaches. A consulting service, for example, might carefully monitor a field to keep track of pests and their natural enemies, and then spray only when the pests threaten to get out of hand. The consultant might recommend intercropping—alternating rows of different crops on the same plot—to slow down the spread of any one type of pest. A change in the time of planting might avoid the most destructive phase of an insect's life cycle. The solution might even be as simple as cleaning up old shells and other debris from an almond orchard to take away winter cover for the navel orangeworm.

The consulting service usually is provided at a fixed fee per acre, says Norgaard. For crops like cotton that come in big, uniform fields, the fee might run $4.00 to $5.00 per acre; for higher-value crops in smaller fields, $25 to $30 per acre. But that's still a savings, he points out, because pesticides cost up to $100 per acre—and a professional consultant can decrease pesticide use roughly 50%.

So why isn't everybody using the technique? "Three dissertations later we still don't know," Norgaard laughs. He and his students have found that integrated pest management users tend to be a little older, a little more experienced, to have stayed in a crop longer, and to be more adverse to risk—all contrary to expectations. "Perhaps it's because the consultant is providing information," he says. "Information offsets risk."

Pimentel, however, lists a number of practical problems with integrated pest management.

In the first place, the technology is far more sophisticated than a straightforward application of chemicals, he says. You need to monitor each pest and its natural enemies. Then you have to know the threshold density of the pest that will cause a significant crop loss, plus the density of natural enemies that will control the pest. Next, you have to project the infestation based on past data, including climate data. Finally, you have to predict the outcome of your intervention.



Water caused severe erosion on this steep slope in Washington

Once all that is done, Pimentel continues, there's still a bit of risk involved: If you're right on the margin you could get an outbreak anyhow. So you err on the side of pesticides.

Then there are the psychological factors. "If you spray," Pimentel says, "then at least you tried, you did something, you can see the little buggers falling to the ground and squirming. With integrated pest management you have to just sit there, depending on natural enemies you can't see. It's nerve wracking. Besides, you've got $200 per acre invested in your corn already, so another $6.00 or $8.00 to treat for corn worm sounds like a pretty cheap insurance policy. And if you pay somebody $3.00 to $5.00 per acre to scout your farm, and he tells you that two thirds of it needs spraying anyway, that's not much of a savings."

Finally, says Pimentel, there's a matter of salesmanship. There are a lot more pesticide salesmen than there are extension people.

But integrated pest management is coming on nonetheless, Pimentel says. It's a prime example of the "systems management" theme now being sounded more and more often in the agriculture schools. One extension service now being offered by the University of Michigan, for example, is a farm-management software package that can be accessed by telephone hookup to the individual farmer's home computer.

Also, a good many farmers are feeling a genuine concern about the health and environmental problems of pesticide use—after all, they are the ones who have to live with these chemicals every day. And a prime advantage of integrated pest management is that by minimizing the use of pesticides it exposes a smaller percentage of the pest population and thus slows the buildup of resistance.

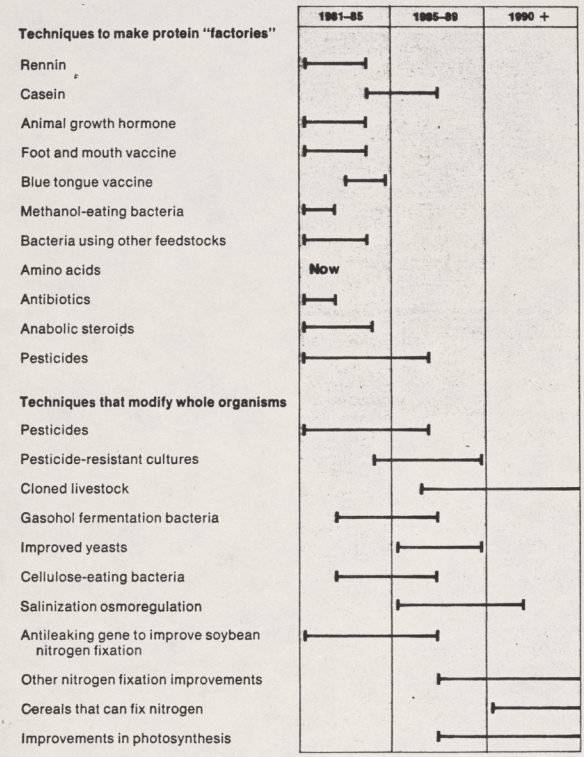
"Worldwide, there are more than 400 species of insects and mites that now have some form of resistance," Pimentel points out. "The United Nations environmental program has called this one of the four major environmental problems of the world."

In India, for example, DDT was first used for malaria control in 1950. Since people there were spraying only houses and such, he says, they exposed only a small fraction of the mosquito population. So the mosquitoes didn't build up any resistance, and the number of malaria cases plummeted. Then, the Indians started using DDT in agriculture. A large fraction of the mosquito population was exposed, the resistant strains multiplied, and the incidence of malaria increased from 100,000 cases in 1961 to 50 million in 1978.

If economic factors have promoted more efficient use of energy on the farm and a more ecologically sound use of chemicals, the same cannot be said of its impact on erosion.

"We are mining the soil," says Pimentel, "and we shouldn't be." Iowa had an average of 8 inches of topsoil when it was settled; today, 100 years later, it has 4. The U.S. as a whole now has 320 million acres routinely under

Genetic engineering techniques may soon find applications in agriculture



Note: Estimates based on available scientific information and reasonable expectations of investments.
Source: Policy Research Corp./Chicago Group Inc. study

Among the systems that Meagher thinks can be developed in the next five years are crop plants with the ability to cleave (and thus destroy) a particular herbicide. There are a number of broad-spectrum herbicides, he explains, that are degraded easily by common soil bacteria and thus present much less potential for environmental damage than the more persistent chlorinated aromatic herbicides widely used today. However, these compounds are not very selective—they kill crop plants as well as weeds. If the gene from bacteria that degrades the herbicide could be transferred to the crop plant, then it, too, would break down the herbicide, leaving only the weeds to be killed.

Key to genetic engineering changes in plants is an understanding of two steps in plant molecular biology that still are not worked out completely, Meagher says. To make any recombinant experiment work, researchers need to know exactly the DNA sequence they wish to transplant to a new organism. They must also know the appropriate "switch" for that organism—the sequence of DNA that also must be present so that the host's cell machinery will go to work on the new DNA and make proteins from it. In addition, there must be a vector, a system that can carry the foreign genetic information into a new organism without being destroyed by that organism's immune system. For animal systems and bacteria several switches and vector systems have been worked out, but for plants these systems are still being developed.

Beyond inserting a single "foreign" gene into a plant and having it function is the much more complicated task of inserting a whole collection of genes that will all work in concert to give the plant an entirely new and beneficial trait. This is the task that faces experimenters who want to make cereal plants fix their own nitrogen, for example, or improve the photosynthetic system of certain valuable, but energy inefficient, crops.

Such projects are called "blue sky" by most analyzers of the potential for genetic engineering in agriculture. They may be possible someday, but there are many hurdles of fundamental cell biology that must be gotten over before the systems will be well enough understood even to know whether such a transplant is feasible. In fact, many thoughtful researchers at USDA and elsewhere think "conventional" plant breeding experiments are just as likely as genetic engineering techniques to succeed in making this type of radical change in plant characteristics.

But neither approach is just around the corner, researchers caution. "I think it's going to be a long time until corn fixes nitrogen," Still says. "But I think it will be a short time before we can teach plants to handle drought or resist insect attack."

Genetic engineering may be useful in the near future in one type of nitrogen fixation work, however, according to the Chicago-based consulting firms Policy Research Corp. and Chicago Group. These two groups recently have completed an extensive and very bullish study of the potential for genetic engineering in agribusiness.

Genetic engineering's near-term effect on nitrogen fixation may be to make soybeans more efficient nitrogen fixers by reducing the loss of fixed nitrogen that most of these plants suffer. About 20% of soybeans grown in the U.S. contain the gene for an enzyme that prevents nitrogen gas from leaking out of the plant. Genetic engineering researchers hope to be able to transfer this "antileaking" gene to other strains of soybeans—a change that could increase the protein yield of soybeans more than 15%. The Policy Research-Chicago Group study projects this gene transfer to be possible by 1987.

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