Biology

Julie Ann Miller reports from Philadelphia at the symposium "Engineered Organisms in the Environment: Scientific Issues"

Lessons from biological pest control

Agriculture's extensive experience with the introduction of biological agents for pest control can offer insight for the safe and effective release of genetically engineered organisms, says David Pimentel, an entomologist at Cornell University in Ithaca, N.Y. Around the world more than 100 programs employing natural, although perhaps foreign, enemies of targeted pests are considered fully effective. On the average, it has taken the introduction of about 20 parasites or predators to find one that is successful for pest control.

Pimentel has surveyed data from 447 attempts at biological control to identify factors that increase the likelihood of success. He finds that although most potential biocontrol agents come from the native habitat of the pest, new associations — for instance, parasites of a related species from a distant location — tend to be more successful. Examples include the control of prickly pear cactus in Australia by a South American moth that naturally feeds on the tiger pear, and the control of the European rabbit in Australia by a virus introduced from the South American tropical forest rabbit.

The advantage of new associations is that no genetic balance between resistance and virulence factors has evolved between host and parasite. "Changing the genetic makeup of a parasite by genetic engineering should, by a similar principle, make the new parasite genotype a highly effective biocontrol agent," Pimentel says. "At the same time, when the genetic makeup of an organism is changed, extreme caution must be exercised before it is released to be sure that it will not be a hazard to the ecological system."

The work with biological control agents offers some guidelines as to when an organism will become established in a new location, Pimentel says. For example, if the conditions of the native habitat and release site are drastically different — say, humid versus arid — the organism probably will not become established. However, when several parasitic species are released into a habitat that has a potential host and favorable climate, at least some should become established, Pimentel says.

"Niches are never full," he says. "Community systems have tremendous flexibility to accommodate new genotypes and species." There are abundant agricultural examples of native insects extending their diet from native plants to such introduced crops as potato and sugarcane. Pimentel calculates that native insects make up 60 percent of all insect pest species associated with crops introduced into the United States.

Although Pimentel has opposed the proposed field tests of the bacterium genetically engineered to prevent frost damage in crops (SN: 3/9/85, p. 148), he says he supports the environmental release of both natural biological agents for pest control and genetically engineered organisms after they have passed an adequate set of ecological tests. "It must be recognized," Pimentel says, "that no set of protocols will ever be 100 percent effective in preventing biological catastrophe. However, with a sound basic set of ecological test-protocols, we can greatly reduce the risks of a parasite outbreak and minimize hazards of public health and the environment."

Gene travel: Plasmids around the world

Genetic engineers have taken advantage of the processes by which bacteria naturally exchange genes. One concern about the environmental release of genetically engineered bacteria is that any foreign genes that scientists have added to a microorganism might be transferred on mobile pieces of DNA, called plasmids and transposons, to other bacteria in the surroundings, with unforeseen adverse consequences. Studies of hospital patients, for example, reveal that the same plasmid or transposon, carrying a natural gene making the bacteria resistant to an antibiotic, can be found in patients across the United States and in distant nations. Some biologists suggest that the rate of bacterial gene exchange is so great that scientists must simply assume that any gene introduced into one species of bacterium will soon be found in all.

The exchange of genes is not limited to bacteria colonizing the gut of a single animal species. Stuart B. Levy of Tufts University School of Medicine in Boston and his colleagues previously demonstrated spread of plasmids from bacteria in chickens to those in people. They now add evidence that genes can also spread from bacteria colonizing the human gut to those of other animals.

The scientists recently examined bacteria in the feces of yellow baboons in a national park in Kenya. The groups of baboons that had little contact with people were about 10 percent as likely to carry bacteria resistant to antibiotics as was a group of baboons whose range included a tourist lodge, with its refuse dumps and latrines. Even though the animals were probably not exposed to any antibiotics, almost all the "lodge" baboons, but few of the free-living baboons, harbored bacteria resistant to two to four different antibiotics.

"Our findings implicate food wastes and other forms of refuse as sources of resistant nonpathogenic bacteria in the intestine," Levy and his collaborators wrote in the April Applied and Environmental Microbiology. "Moreover, these data call attention to a previously unrecognized pathway by which antibiotic-resistance plasmids may be transmitted to wild animals and subsequently spread to the natural environment."

Invasion of the ecosystem

While geneticists and ecologists are arguing about the likelihood of small genetic changes influencing the impact of an organism on its environment, Peter Vitousek of Stanford University proposes that it may be more useful in the long run to consider what happens when a totally foreign species moves into a new habitat. Genetic engineers, he says, hope eventually to make many changes in organisms — for example, to create a "supercrop" by adding to a plant species genes for nitrogen fixation, disease- and pest-resistance, higher productivity and easier harvest.

The addition or deletion of a single species can change important properties of an ecosystem, influencing the regulation of energy flow and the cycling of chemicals, Vitousek reports after considering examples of deliberate and accidental species introductions. "These can be a major nuisance, an economic problem or even cause extinctions," he says. Ecosystem upset is more likely with an introduced animal than with a plant, and domestic animals can be especially destructive.

"It is not easy to find clear examples of plant invasions altering system properties," he reports. "The invader must have access to resources not available to the natives or else must be more efficient in their use." In one identifiable case, he points to a deep-rooted, fast-transpiring tree that, when introduced into southwestern wetlands, turned them into a desert. When the U.S. Park Service eliminated the trees, the wetlands returned.

In contrast, it is not difficult to demonstrate altered ecosystems in response to animal invasions, Vitousek says. For example, feral pigs, now present in 11 states and spreading rapidly, drastically change the characteristics of ecosystems by their rooting in the soil. In the Great Smoky Mountains of North Carolina and Tennessee, he reports, regions examined that are not inhabited by pigs have no bare ground, while in comparable regions with pigs 88 percent of the ground is bare. The pigs also change the levels of calcium, phosphorus and nitrogen in the soil. "Changes in soil fertility result in changes for every species in the ecosystem," Vitousek says.