Journal of the Iowa Academy of Science: JIAS

Volume 96 | Number | Article 10

1989

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Jour. Iowa Acad. Sci. 96(2):68-70, 1989

Biological Pesticides: Biotechnology's Answer to *Silent Spring*

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In the 25 years since the publication of Rachel Carson's *Silent Spring* the public has come to realize the environmental impact of heavy use of chemical pesticides. To add insult to injury, many insects, including the disease vector, the mosquito, are now virtually resistant to standard chemical pesticides. Biotechnology is now providing a positive response to these dilemmas through the production and development of improved forms of microbial pest control agents: biological pesticides. Biological pesticides are pathogens, or predators, of insects such as bacteria, fungi, and viruses, and predatory insects or vertebrates such as mosquito fish which reduce the population of the pest. Several biological insecticides are now registered with the EPA and are used as safe alternatives to chemicals. These agents are highly specific to the insect pests which they attack and are extensively tested and shown not to be toxic to man or animals or indeed to non-target insects. Biological pesticides are excellent models for release of genetically-engineered microorganisms into the environment because literally millions of tons of certain of these biological pesticides have been released and extensive studies have been done on their persistence. The goals of genetic engineering are to decrease the costs of production by increasing yield and specific activity of biological pesticides. Through the use of genetic engineering, plants with the genes of biological pesticides incorporated into their own genomes are now in field trials. These new developments further reduce the environmental impact of the pesticide by removing it from the environment niches of insects which do not attack the specific crop.

This presentation will review the persistence of non-genetically-engineered microorganisms. The release of newly-engineered organisms into the environment will be critically discussed, considering the ethics and economic impact of genetically-engineered biological pesticides.

INDEX DESCRIPTORS: biological control, biological pesticides, biotechnology, genetic engineering

In 1964, Rachael Carson published a book called "Silent Spring" which created a concentration of enthusiasm on environmental issues and against the use of chemical pesticides. I chose as a title for my talk, "Biological Pesticides: Biotechnology's Answer to 'Silent Spring' "; because it is a little bit controversial. It is difficult to tell from this title exactly which side of the fence I stand on, whether I'm against the silent spring or in favor of it. The conclusion of the book, however, is that Rachael Carson was very much in favor of using biological control as opposed to using chemical pesticides. As a matter of fact, one of the chapters in her book, which defines alternatives to chemical pesticides, is called "The Other Road". In this book, she describes a large number of other microbial and biological control means to replace chemical pesticides in the containment of insect pests on agricultural and forest crops, and also in terms of human disease vectors such as the mosquito.

Now I would like to define what biological pest control means and what types of biological control are available. I will discuss the process of registering new biological pesticides and the currently existing regulatory mechanism which governs what kinds of agents can be used as microbial pesticides or biochemical pesticides, and I will explain the difference between those categories. I will talk about the current use of *Bacillus thuringiensis,* which is the major regulatory microbial control agent, and I will discuss the benefits that we would hope to derive from genetic manipulation of this organism and its products.

Pest control agents are subdivided into chemical pesticides and biochemical and biological derived pest control agents. This actually breaks down into the use of living organisms, for example, mosquito fish, fungi, or other types of agents that would attack insects, in the category of "biorational pesticides". Biorational pesticides include two categories: microbial pest control agents (bacteria, fungi, protozoans and viruses) and biochemical pesticide pest control agents, which are products of these microbial agents (i.e., non-living organic regulatory chemicals, if you will). In the case of the major point that I will be discussing today, the product is a protein, a biodegradable protein, which is insecticidal and very specifically insecticidal. These microbial pest control agents comprise one aspect of today's discussion. They have to do with living microorganisms that are released in abundance in order to control particular pests of forest crops or human disease vectors.

In a sampling of microbial pesticides that are registered by the EPA for use today, I want to indicate that most of these are bacilli. They include such agents as *Bacillus popillae,* which is used to control Japanese beetle, and *Bacillus thuringiensis,* which is one form of this microorganism used to control agricultural pests, usually of the Lepidoptera type (caterpillars). There now are agents that control beetles, and another type of *Bacillus thuringiensis* called variety *israelensis* is a very effective microbial pesticide against mosquitoes. It is playing a very important role in mosquito control in Africa where most chemical pesticides no longer are active against the mosquito. The mosquito is continuing as a vector of the most terrible diseases known to man, and the World Health Organization is very happily using *Bacillus thuringiensis israelensis* as practically the sole mosquito control agent in those countries. As I will discuss, a lot of these organisms are being released into the environment. The difficulty with that particular agent, *Bacillus thuringiensis israelensis,* known as Bti, is that it does not survive very long in the environment, so it is a great expense to place this agent into the environment and then find that in two days its ability to control mosquitoes is completely gone.

In a micrograph, the bacterial spores of *Bacillus thuringiensis,* produced during the fermentation process, appear as large, shiny bodies. These microorganisms can be grown through fermentation on things like corn steep, left-over corn products from other fermentation industries, or other organic matter. For example, natives could pick leaves of grass and boil them up to make a kind of hay infusion broth and grow their own microbial pesticides. A diamond-shaped crystalline protein that is produced by this bacterium is the insecticidal product. It is a protein that is edible by man, biodegradable by other microorganisms, and happens to be pathogenic to insects. Different varieties of *Bacillus thuringiensis* produce different microbial toxic agents. In a micrograph taken from a commercially produced strain of *Bacillus thuringiensis,* we can see two: the diamond-shaped crystal and a cuboidal crystal which is actually a mosquitocidal factor that is not as effective as the Bti that I mentioned before. We have in our hands a number of bacteria that produce insecticides which, as Rachael Carson recognized and we have found since that time, are ecologically safe. I'm sure that statement will be questioned, but at least we have evidence to back it up.