Above: An immature nematode photographed at 300x. Nematodes are an important biological control agent, multiply in the body susceptible insects and carry a bacteria that cause physical damage and rapid death.

Left: Millions of microscopic, immature nematodes hatching from eggs laid inside a caterpillar. The nematodes are searching for additional insects to invade and quickly destroy (photos courtesy of Dr. Briggs).

BIO CONTROLS FOR THE GREEN INDUSTRY

Biologicals gain more acceptance as safe and effective alternatives to chemical pesticides.

by John D. Briggs, Ph.D., Ohio State University

Landscapers and horticulturists face questions from employees, the general public and clients about virtually every material they use.

Recent governmental safety investigations have provided some level of confidence in the products. But the result is increased time and costs for landscapers to explain their practices to clients.

In the past 25 years—particularly in the past decade—safe and useful alternatives to conventional pesticides have received serious attention. (Especially since government regulatory agencies have increased and refined manufacturer and applicator guidelines through federal, state and local legislation.)

Biological alternatives to conventional chemical pesticides are referred to by federal agencies as "bio-rational" agents. Manufacturers continue to center on bio-rational agents that attack and cause diseases of insects, mites and certain weeds.

Micro-organisms cause disease

The five principal groups of micro-organisms that can cause diseases of insects are bacteria, fungi, viruses, protozoa and nematodes. From these groups, bacteria, fungi and nematodes are used to market products to the landscape market (Table 1).

Milky spore products for long-term control of Japanese beetle grubs contain bacteria. These products have been under development and successfully sold under different trade names in the eastern U.S. for almost 50 years. They contain the resting spores of *Bacillus popillae* formulated as a dust for application to turf. *Bacillus popillae* spores physically damage the mid-gut and growth of the bacteria in the body cavity of beetle grubs.

For the past 30 years, another bacteria, *Bacillus thuringiensis*, has been produced and marketed by 20 different companies for managing populations of larval forms of some species of flies, beetles and moths. These products are often referred to collectively as "BT." Several manufacturers in the U.S. have registered formulations of bacteria with the EPA and USDA for landscape use (Table 1).

Mode of action for *Bacillus thuringiensis* is by a toxin produced by the bacteria which attacks the mid-gut cells and moves to the body cavity. The toxin, produced during the manufacturing process, is the active ingredient in formulations. The toxin makes the use of *Bacillus thuringiensis* unique, because the mode of action is the result of a pesticide toxin made by a bacterium.

We can now recognize three different toxins from *Bacillus thuringiensis* attacking three different kinds of insects: caterpillars (*Lepidoptera*), mosquitos (*Diptera*) and beetles (*Coleoptera*). Only the bacteria attacking caterpillars and mosquito larvae have been registered for use to date.

Important progress has been made in the production, formulation and marketing of nematodes that attack immature forms of insects in the soil and on plants. The developmental stages of insects (larvae active at night on plant parts or pupae hidden from predatory natural enemies) are primary targets.

An essential condition for nematode survival is adequate moisture in or on the material inhabited by the immature insect. Moist soil and/or moist plant parts are ideal sites for the activities of *Neoaplectana carpocapsae* nematodes. These nematodes can enter the body of an insect through any body openings, particularly the mouth and spiracle, into the respiratory system.

Nematodes are an important biological control agent because they respond to the presence of susceptible forms of insects and literally seek out their prey. *Neoaplectana* nematodes, which are marketed for use against insects, carry a bacteria that causes physical damage accompanied by rapid death. Further, the use of nematodes is attractive because they multiply in the body of the attacked insect which, in turn, increases nematodic egg production. This action results in a continuous supply of nematodes to control additional generations (if moisture conditions are suitable).

Biological herbicides

In the past five years, research activity has centered on possible biological herbicides.

For many years, we have accepted the idea of importing insects that have a specific appetite for certain weeds (a biological control). This has been accepted as a principle for control of the Klamath weed and Tansy ragwort in California and Oregon. In Australia, caterpillars are used to control cactus. In addition, experiments continue in Florida for controlling aquatic weeds by using specific viruses that infect only the weeds.

Abbott Laboratories has registered Devine as a biological herbicide in agricultural systems using a natural enemy of the weed. Although it is temporarily for use only in certain counties in Florida, we can expect a continuing line of herbicides for biological control. Eventually, these developments will provide the professional landscape horticulturist with the necessary array of bio-rational agents for both weeds and insects.

Product formulations

Bio-rational agents have been widely developed into a full range of formulations for their safe use and application with equipment used by horticulturists. Further, industry has been able to adapt a heat- and pressure-sensitive living product (the living bacteria and their toxins), to formulation procedures, and has maintained the activity of a bio-rational agent which could otherwise be harmed when exposed to procedures commonly used for formulating conventional chemical insecticides.

The production method for bacterial insecticides (for example, *Bacillus*

Everything you always wanted to know about bio-rational agents, but were afraid to ask

What they are: Bio-rational agents are biological alternatives to conventional chemical pesticides. They are micro-organisms that attack and cause diseases of insects, mites and certain weeds. Of five principal groups of micro-organisms, bacteria, fungi and nematodes are used in products marketed for landscapers.

Milky spore disease bacteria invade grubs of Japanese beetles.

How they work: Milky spore products are a good example of how biological control of insects take place. Milky spore products contain the resting spores of the bacteria *Bacillus popillae*. These spores physically damage the mid-gut growth of the bacteria in the body cavity of beetle grubs, thereby destroying them.

Such products have been on the shelves for about 50 years. Newer formulations are available for control of flies, beetles and moths. Bacteria that attack caterpillars and mosquito are also available, and important progress has been made on nematodes that attack immature forms of insects in the soil and on plants.

How biological herbicides work: The concept behind biological herbicides is basically the same. In Florida, researchers are looking at specific viruses that infect only aquatic weeds, and Abbott Laboratories has registered a biological herbicide for use in certain counties. Landscapers can expect to add bio-rational agents to their weed-control arsenal in the near future.

How bacterial insecticides are formulated: Bacterial insecticides, such as those for caterpillars and mosquito larvae, include a final fluid suspension of bacteria. Dried products, like wettable powders, require a re-suspension of the stable powder in water. Dry, granular formulations are also available, eliminating the need to use spray equipment.

—Dr. John Briggs□

Example of Formulations and Pesticidal Activities of Biorational Pesticides Produced and Marketed for Gardens and Landscapes.

MANUFACTURER/TRADE NAME	FORMULATION	CONTENT
Biologic Co. Chambersburg, Pennsylvania		
Insecticidal Nematodes for Caterpillars (Lepidoptera), Beetle Grubs (Coleoptera)		
SCANMASK	Granular and Liquid	7 Million Active Units per pint (granular) One Billion Active Units per gallon (Liquid)
Fairfax Laboratories Clinton Corners, New York		
Insecticidal Bacteria for Beetle Grubs (Coleoptera)		
DOOM	Dust	100 Million Spores per gm
Abbott Laboratories North Chicago, Illinois		
Herbicidal Fungus		
DEVINE		6.7×10^5 Live Chlamydospores per ml (3.2×10^5 per pint)
Insecticidal Bacteria for Caterpillars (Lepidoptera)		
DIPEL ES	Emulsifiable Suspension	17,600 International Units of Activity per mg (63 Billion International Units per gallon)
DIPEL 2X	Wettable Powder	32,000 International Units of Activity per mg (14.52 Billion International Units per pound)
DIPEL 4L	Emulsifiable Suspension	8,800 International Units of Activity per mg (32 Billion International Units per gallon)
DIPEL 6L	Emulsifiable Suspension	13,200 International Units of Activity per mg (48 Billion International Units per gallon)
DIPEL 6AF	Aqueous Flowable	10,750 International Units of Activity per mg (48 Billion International Units per gallon)
DIPEL 8L	Emulsifiable Suspension	17,600 International Units of Activity per mg (64 Billion International Units per gallon)
DIPEL 8AF	Aqueous Flowable	14,500 Internation Units of Activity per mg (64 Billion International Units per gallon)
DIPEL 10G	Granular	1600 International Units of Activity per mg (0.726 Billion International Units per pound)
Insecticidal Bacteria for Mosquito Larvae (Diptera)		
VECTOBAC-AS	Aqueous Suspension	600 International Toxic Units (ITU) per mg (2.19 Billion ITU per gallon)
VECTOBAC-12AS	Aqueous Suspension	1200 International Toxic Units (ITU) per mg (4.84 Billion ITU per gallon)
VECTOBAC-G	Granules	200 International Toxic Units (ITU) per mg (0.091 Billion ITU per pound)

SOURCE: The author
NOTE: This is a partial listing of biorational pesticides available.
Endorsement of the products mentioned is not intended, nor is criticism of products excluded.

thuringiensis for caterpillars and mosquito larvae), includes a final fluid suspension of bacteria. The fluid suspension contains living bacterial cells and their toxin products. Aqueous flowable and emulsifiable suspensions of the bio-rational agents reduce and avoid clumping of the bacteria and their microscopic toxin particulates.

Dried products like wettable powders require a re-suspension of the stable powder in water. The production material must be dried at a temperature that will not reduce the effectiveness of the bacterial agents or their products but assure successful suspension in water.

Producers and formulators also provide dry granular formulations that preserve the product's insecticidal qualities. Applying granular and wettable powder formulations as dry materials to soil and turf allows the professional landscaper to penetrate larval habitats without using spray equipment. For example, a combination of wettable powder or granular formulations with fertilizer can be used with granular application equipment on sod.

As with chemical pesticides, a number of factors influence the decision to select an emulsifiable or flowable formulation (which differs only in concentration of the active agent). These factors are the equipment's large or low-volume spraying capacity, the nature and volume of spray mixture additives, and the recommended concentration of active ingredients needed to be in contact with the target insect.

Some professional horticulturists may need to serve the interests of clients who have ornamental water ponds as part of the landscape. In that case, using any one of several formulations of larvacidal bacteria for mosquitos is an important addition to the service.

Using biologicals

Aqueous suspensions and diatomaceous granules provide a suspension of larvacidal bacteria in the site. Sand granules (as carriers) deposit the bacterial insecticide in the bottom of the mosquito larval habitat.

Mosquito larvae that feed primarily at the surface encounter the bacterial insecticide in a suspension or as a floating formulation. Larvae which have a bottom-feeding behavior contact the bio-rational agent with the sand formulation which sinks and is not initially in suspension.

Granular formulations of bio-rational agents, depending on the physical qualities of the inert material, can release over an extended period of time. The granule's low solubility and the active ingredients' slow release extend the agent's residual period. This is true in ponds, in soil, in leaf axles or into the root/stem interfaces of plants.

Landscape professionals cannot expect to meet every client expectation for control of insects, mites and weeds using biological agents. However, major opportunities are now available to integrate bio-rational agents with chemical agents. That, in turn, provides the landscaper with a chance to retain the initiative for safety and effectiveness in professional programs.

In addition to their benefits to the applicator and consumer, bio-rational agents allow a high probability for the survival of beneficial organisms in the landscape ecosystem. This can reduce debate on the impact of conventional horticultural practices on honey bees, earthworms, ladybugs, green-lace wings, parasitic wasps and birds.

Next month, I will explore specifically the dreams and the realities in the quest to genetically engineer bio-rational agents. **LM**

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