Summary 1

CONTEXT AND SCOPE

Pest management in the United States is changing. Increasingly, the emphasis is on reducing the reliance on conventional pesticides.[1] Several factors make such change almost inevitable. Increased rigor of pesticide screening, economic forces within the pesticide industry, and continuing widespread public concern about the harmful effects of pesticides are contributing to reductions in the number of available pesticides and their allowed uses. At the same time, pest control needs are rising because of the increasing occurrence of pesticide resistance and newly emerging pest threats. The growing disparity between the available pesticides and the number of pests requiring control will generate needs for more and a greater variety of pest control tools and techniques.

This problem's significance has not been lost on national policymakers. Both Congress and the executive branch have responded in recent years with initiatives related to providing pest management tools and expanding the implementation of integrated pest management (IPM).[2] It is in this context that Congress has asked the Office of Technology Assessment (OTA) to examine the current and potential future role of biologically based technologies for pest control (BBTs). These technologies are grounded in an understanding of pest biology and have a relatively low probability of harmful effects on human health or the environment.[3]

The assessment covers the following five technologies:

- *Biological Control*—Suppression of pest populations by *natural enemies* (predators, parasites, competitors, diseases). Humans can exploit biological control by permanently establishing new natural enemies in a region (*classical biological control*), by repeatedly releasing natural enemies to temporarily boost their abundance (*augmentative biological con-*

[1] Conventional pesticides are chemical compounds in wide use that kill pests quickly. These chemicals currently pervade all aspects of pest management in the United States and support annual sales exceeding $8.4 billion.

[2] The term integrated pest management or IPM refers generally to pest management practices that seek to integrate all available tools for pest control—biological, chemical, cultural, and otherwise. See box 2-1 for more detailed discussion of IPM concepts and origins.

[3] Biologically based technologies are not, however, risk free. See text that follows and chapter 4 of the report for more detailed treatment of the potential risk issues.

trol), and by engaging in practices that enhance the survival and impacts of natural enemies, e.g., reducing pesticide use (*conservation of natural enemies*).

- *Microbial Pesticides*—Relatively stable formulations of microorganisms[4] that suppress pests by producing poisons, causing diseases, preventing establishment of other microorganisms, or other mechanisms. Microbial pesticides are designed for large-scale production and application. The most common one in use today is Bt, formulated from the bacterium *Bacillus thuringiensis.*
- *Pest Behavior-Modifying Chemicals*—Exploitation of the chemical cues used by living organisms to evoke specific behaviors from other organisms. Pheromones, chemicals that communicate information between members of a single species, currently are used to disrupt pest mating or to attract pests to pesticides.
- *Genetic Manipulation of Pest Populations*—Release into the pest population of individuals genetically altered to carry genes that interfere with the pest's reproduction or impact. The method in significant use today is release of sterile males in order to reduce pest reproduction.
- *Plant Immunization*—Enhancement of plant resistance to pests by means other than breeding or genetic engineering. Scientists can enhance disease resistance in some plants by exposing them to certain microbes or chemicals. Research is also under way to transfer certain predator- and disease-deterring fungi into plants.

These technologies represent an important segment of the alternatives to conventional pesticides. Federal expenditures on BBT research and implementation exceed $200 million annually. BBTs are a major part of the U.S. Department of Agriculture's (USDA) emphasis in pest control. BBTs also comprise a significant part of the "reduced-risk pesticides," "biopesticides," and "biorational pesticides" that are receiving a good deal of attention from the U.S. Environmental Protection Agency (EPA) and state agencies.[5,6]

CURRENT USE AND FUTURE POTENTIAL OF BBTS

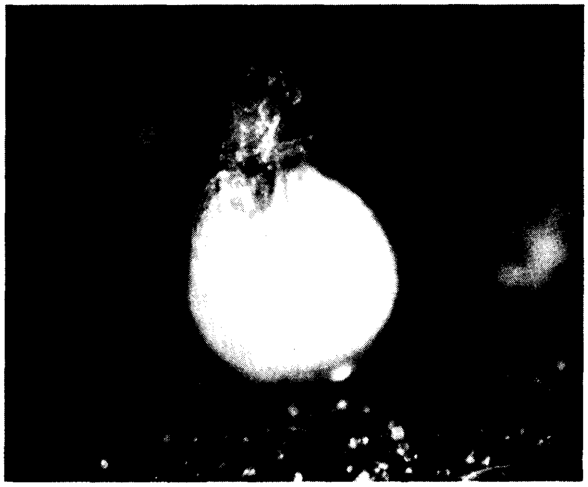
Even though conventional pesticides dominate U.S. pest management practices, BBTs have penetrated most major applications and joined the mainstream. For example, at least 28 state departments of agriculture operate their own biological control programs. The USDA Animal and Plant Health Inspection Service (APHIS) as a matter of policy promotes biological control where possible in its programs. For control of gypsy moth, a major forest defoliator found in more than 11 states, the U.S. Forest Service relies primarily on a combination of microbial pesticides and natural enemies. Numerous farmers adjust pesticide selection or spray schedules in order to minimize harmful impacts on pests' natural enemies. Several major food processing companies, such as the Campbell Soup and Gerber Companies, have set low tolerances for residues of conventional pesticides in their products and are promoting "biointensive" IPM among farmers who supply their produce.[7] And a growing array of microbial pesticides is now available

[4] Organisms too small to be seen by the naked eye, e.g., viruses, bacteria, fungi, protozoans, and certain nematodes (worm-like animals).

[5] "Reduced-risk," "biopesticide," and "biorational pesticide" have all been used with differing meanings, depending on the source, to encompass various combinations of microbial pesticides, botanical pesticides, chemicals that modify pest behavior or growth, augmentative releases of natural enemies, and conventional pesticides that have new chemistries. OTA will not use these terms because of their ambiguous meanings.

[6] Microbial pesticides and pheromone-based products made up 45 percent of all new pesticide active ingredients registered by EPA in 1994.

[7] "Biointensive" IPM refers to an IPM system that minimizes pesticide inputs and that uses BBTs for pest control in addition to other crop management practices.



Tiny Trichogramma *wasps, about the size of the head of a pin, are one of the most widely sold natural enemies for control of agricultural pests. The wasp shown here is laying its egg in the larger egg of a corn earworm* (Helicoverpa zea).

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to homeowners for control of landscape and household pests.

Current use of BBTs in the United States is patchy, however. The major share of BBT usage targets insect pests of arable agriculture, forestry, and aquatic environments. Use is growing for insect control in urban and suburban settings as new microbial and pheromone bait products become available for turf and household pests. In arable agriculture, BBTs have virtually no role at present for weed control; in contrast, classical biological control has been used to suppress a number of weeds of rangelands, pastures, and waterways. Few BBTs are yet available for control of plant pathogens, although a number of microbial products have been introduced in the past year for seed treatments and other applications.

Adoption of BBTs has occurred most frequently where conventional pesticides are: 1) unavailable because of pest resistance or small market size; 2) unacceptable, such as in environmentally sensitive habitats or where human contact is high; or 3) economically infeasible because the costs of pesticide use are high relative to the economic value of the resource, such as in rangeland management. In these situations the chief advantages of BBTs become significant assets—namely that they reduce reliance on conventional pesticides, are relatively benign in terms of impacts on human health and the environment, and, in the case of classical biological control, provide lasting, widespread, and low-cost suppression of individual pests.

Adoption is less common where effective and acceptable conventional pesticides exist and where numerous pests require simultaneous control. This is largely because BBTs do not usually compare favorably when measured against the performance standards set by conventional pesticides. Most have a narrower target range, act more slowly, provide a less efficient level of pest suppression, and, if sold commercially, have shorter field persistence and briefer shelf life. A biologically based method usually must be integrated with other control methods in order to provide an overall package of pest suppression. Reliance on BBTs thus requires a knowledgeable user and greater planning.

The limited availability of BBTs also contributes to their uneven adoption. At present, considerably more effort is focused on BBT research than on adaptation of the research findings to field use. BBTs are presently unavailable for many pest problems due to a lack of the necessary research on applications, development, or production and delivery technologies. Even when available, certain BBTs remain inaccessible to many end-users who lack sufficient training or appropriate sources of information.

ISSUES AND OPTIONS

Today's national policies on pest management and pesticide use reduction depend on the development of alternatives to conventional pesticides. Some underlying assumptions about the capacity of the public and private sectors to support expansion of BBT use may be overly optimistic. The federal government potentially exerts a significant influence on BBT adoption through its extensive and diverse roles in research, development, implementation, and regulation. Adjustment of federal policies and programs in several areas could greatly enhance the effectiveness of efforts to safely bring BBTs into wider use.

Balancing Risks and Regulations

In looking ahead to expanded BBT use, it is important to ask what risks the technologies will bring. BBTs generally rank favorably from the perspective of public health and environmental safety. Many are relatively host specific and impact primarily the targeted pests. Unlike conventional pesticides, most BBTs lack mammalian toxicity or pathogenicity. Moreover, the development of resistance by weed and insect pests appears significantly slower for most BBTs than for conventional pesticides.

Nevertheless, BBTs are not risk free. Some may pose certain hazards to human health and the environment. Some of these potential impacts are better documented than others. Allergic reactions to fungal pathogens and to insect eggs, scales, and waste in insectaries are the best-understood human health impacts. To scientists who study the ecology of natural systems, the most significant concerns relate to the impacts of biological control and microbial pesticides on native species and the functioning of ecosystems. A lack of monitoring for such effects during past decades means some of the most likely ecological effects, such as declines in native insect populations, have probably gone unnoticed.

The significance of any risk depends on how well the regulatory structure prevents the high impacts from occurring. Past regulatory review of biological control by APHIS has been inconsistent—too lax in some cases and too burdensome in others. The EPA has done a better job in its oversight of pheromones and microbial pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act,[8] although the risks posed by upcoming microbial pesticides—some genetically engineered for enhanced target range and lethality—will pose new challenges for the agency. The Food and Drug Administration (FDA) needs to clarify its regulatory responsibilities for certain uses where BBT residues may become a component of food products.

Chapter 4 of the report presents options related to:

- improving APHIS's regulatory structure for biological control;
- strengthening innovations while retaining balance in EPA's regulation of microbial pesticides and pheromones;
- anticipating food safety issues and the expanded role of the FDA that will arise as uses of BBTs on harvested produce and in food preparation areas increase; and
- reducing the likelihood that pests will develop resistance to BBTs, specifically the microbial pesticide Bt.

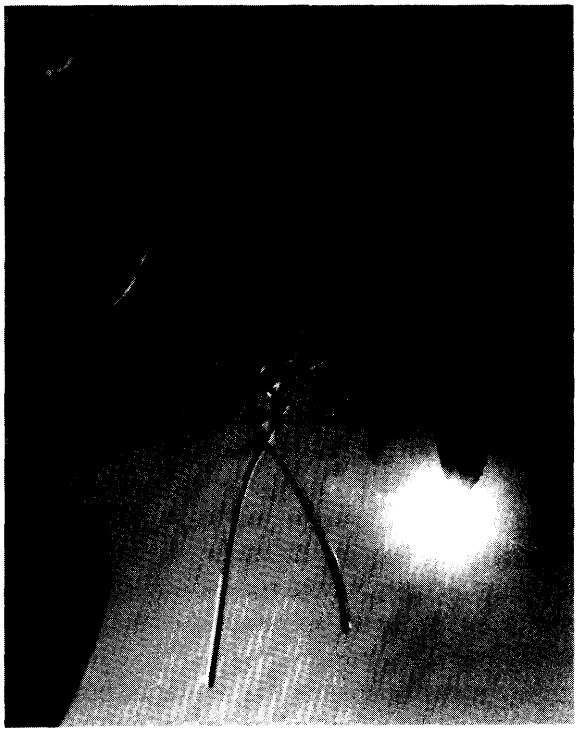
Improving the Pipeline from Research to Implementation

The federal government plays a large role in the research, development, and implementation of BBTs. At least 11 federal agencies are involved, most within the USDA. Despite the size of these efforts, BBTs do not move smoothly from research into on-the-ground solutions to pest problems.

Adjusting the Research Agenda

The gap between BBT research and its use—referred to by some long-time observers as the "valley of death"—was the single most prominent problem identified during the OTA assessment. It results, in part, from a lack of institutional coordination at several levels within and among federal departments. Ad hoc interactions among scientists working on BBTs from various government agencies and universities have generally been quite good. In contrast, problems frequently arise when cooperation between institutions is required. The results have included: a poor match between federally supported research and national priorities; abundant research that never makes it into the field; and

[8] Federal Insecticide, Fungicide, and Rodenticide Act (1947), as amended (7 U.S.C.A. 136, *et seq.*).



Pheromone dispensers are widely used in California peach orchards to suppress the oriental fruit moth (Grapholita molesta) *by disrupting the pest mating.*

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national programs to control emerging pest threats that are beset by delays in the development of appropriate management tools.

The diffuse decision-making structures within the USDA research agencies (the Agricultural Research Service and Cooperative State Research, Education, and Extension Service) often fail to effectively focus research onto nationally identified needs. For example, although herbicides make up the single largest category (57 percent) of pesticide use in the United States today, only 15 percent of federal BBT research is directed toward control of weeds. The scattered portfolio of BBT research rarely addresses all of the research components necessary to enable the practical uses of a given BBT. No agency has consistently taken responsibility for conducting or funding the essential research to translate the work of scientists on BBTs into practicable applications for farmers and other users.

Educating and Influencing Users

Few farmers will readily embrace technologies that involve unfamiliar procedures and uncertain consequences. Many BBTs require a significant level of information to use properly, and farmers often lack clear-cut instructions or authoritative sources of advice on how to apply them.

The Cooperative Extension Service is the principal governmental provider of direct, hands-on services to growers and historically played a key role in farmers' pest control decisions. In most states, however, extension plays only a minimal role in educating farmers about BBTs; most extension agents have had little if any formal exposure to biologically based approaches. Moreover, the Cooperative Extension Service's role in shaping pest management practices is now secondary to that of the far more numerous private consultants in most regions (crop advisors, pest control advisors, and pesticide dealers and applicators). However, like extension agents, many private advisors are not well versed in BBTs or 1PM. Many are associated with conventional pesticide manufacturers or suppliers and are thus inclined to recommend chemically based technologies. According to representatives of major pesticide companies that also produce BBTs, even their own sales representatives do not adequately promote Bt or other biologically based products.

A number of other factors are thought to indirectly influence the pest control decisions of some users, although most lack adequate documentation. Produce standards set by USDA and our international trading partners, for example, sometimes require minimal pest damage, and may provide strong incentives for more frequent pesticide application. Certain production contracts and other arrangements with food processing companies may direct growers to use specific pest management practices.

Chapter 5 of the report presents specific options designed to address the shortcomings of the federal research system and the indirect influences of the federal government on the pest control decisions of farmers, These options include:

- better coordinating the USDA research agenda with national pest management needs identified by EPA and the land management agencies;
- modifying mechanisms of funding BBT research to better ensure the research makes it into field applications;
- providing an institutional structure for coordinating biological control activities at a national level in order to increase the potential for success and decrease the risks;
- addressing currently unmet research needs related to weeds and monitoring of BBT impacts and effectiveness;
- maintaining the necessary levels of technical expertise in IPM and taxonomy; and
- improving the flow of BBT information to users.

Commercial Considerations

Certain BBTs lend themselves to commercial production—specifically, natural enemies for augmentative release, microbial pesticides, and pheromone-based traps and mating disrupters. Almost all of the biologically based products sold to date have been for control of insect pests. Over the near term, BBTs are thus unlikely to capture a significant proportion of the conventional pesticide market, only about 29 percent of which is aimed at insect control.

Nevertheless, BBTs represent one of the fastest growing sectors of the pesticide industry. Biologically based products now comprise around 2 percent of the U.S. pest control market and 1 percent of the international market (approximately $120 million and $214 million in annual sales, respectively). The companies involved are diverse, ranging from small owner-operated companies to large multinational corporations. Almost all of the major agrochemical companies, such as Ciba-Geigy, have invested to some degree in BBTs, mostly microbial pesticides, although this involvement is somewhat tentative.

In general, these are financially troubled times for many of the companies specializing in the development or marketing of BBT products. Numerous small companies operate at a low profit margin, are vulnerable to unstable markets, and have difficulty investing in product discovery or formulation and production technologies. An important obstacle to wider use is that BBTs do not move easily through the extensive entrenched infrastructure currently in place for the research, development, and marketing of conventional pesticides.

According to a workshop of private sector experts convened by OTA, in the absence of any change to federal policies and programs, BBTs are likely to experience slow gains and will remain restricted primarily to high-value crops (e.g., fruits and vegetables) and other niche areas. Due to economic factors within the agrochemical industry, future conventional pesticides will tend to be broad-spectrum chemicals that fit poorly into IPM.

Congress could alter this scenario, however, by adjusting the many influences the federal government presently exerts on the BBT industry.

Options set out in chapter 6 of the report address:

- fashioning public-private partnerships in research;
- supporting development of voluntary product standards and the registration of BBTs; and
- enhancing market opportunities for BBTs.

RETHINKING PUBLIC AND PRIVATE SECTOR RESPONSIBILITIES

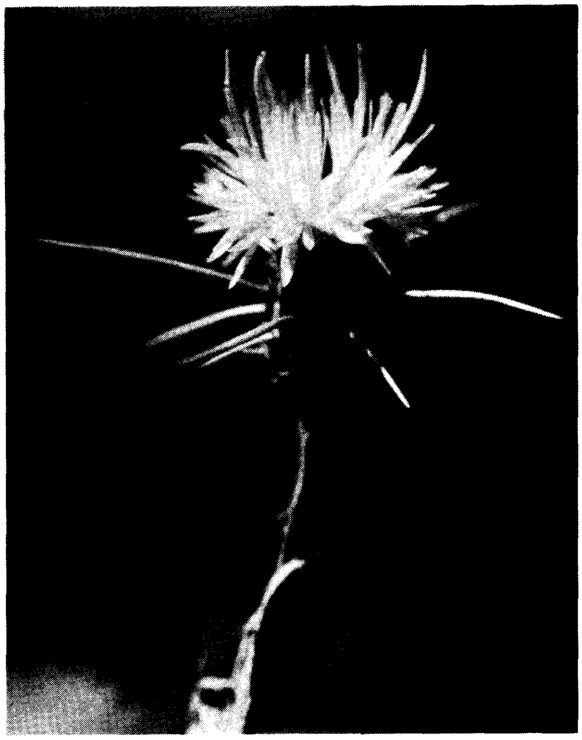
As Congress looks ahead to the future of pest management in the United States, two things are clear. First, the status quo cannot continue. Future approaches to pest management will require a greater diversity of tools and techniques. Over the near term, conventional pesticides will continue to play a key role, but the chemicals will need to be used more strategically in order to enhance natural control of pests and minimize the potential for pest resistance and other harmful impacts.

Second, adjustment of today's dominant paradigm based primarily on conventional pesticides will not come easily. Alternative technologies do not exist for certain pest problems. Many of those that do exist require a change in the way farmers and other users think about pest control and its goals and methods.

In the past, the federal government has shouldered a significant part of the research and development of BBTs. The investment is appropriate because the costs of *not* planning for the future will fall on the public at large; for example, in reduced agricultural productivity or degradation of native ecosystems because certain pests are uncontrollable, or in health and environmental impacts because more harmful pesticides are kept on the market. Moreover, the private sector cannot or is unlikely to become involved in certain key areas because no marketable product is involved (e.g., classical biological control and conservation of natural enemies).

Consideration of the current division of public and private responsibilities suggests some reapportioning is warranted, however. Most new biologically based products will address control of insect pests, with several other new products coming on line for plant pathogens. Weeds have been largely ignored by both the private and public sectors. Increased public investment might ensure that technical successes in weed control remain available to farmers, even if the profit margin is too low to sustain commercial interest.[9] Conversely, private sector innovations in the rearing of natural enemies would be more likely to occur if markets for these products were expanded and stabilized; for example, by contracting out production of natural enemies and sterile insects for the federal government's pest control programs.

The effectiveness of federal efforts to bring BBTs into widespread use could be improved. Better mechanisms are needed to ensure that the federal government's annual investment of more than $135 million into BBT research delivers solutions to national priorities. And certain goals and approaches of Cooperative Extension merit adjustment to ensure the greatest impact of the system's limited resources.



Many land managers expect biological control to be an important part of the solution to widespread pests on low-value lands—such as this yellow starthistle (Centaurea solstitialis), a noxious weed that is now spreading across western rangelands.

J. Asher, Bureau of Land Management

Scientists have been warning for years that meeting the nation's future needs in pest management will require new tools and techniques. While BBTs won't fulfill all of these needs, they could play a significant role. Safely bringing biologically based tools into the hands of farmers and other users will require certain changes in the operation of various federal agencies. The report that follows focuses on the underlying technical and institutional issues and identifies potential solutions.

[9] A good example is Collego, a very effective microbial pesticide for weed control that became a commercial failure because it could not sustain a large enough market,