From Research to Implementation 5

The federal government plays a large role in the research, development, and implementation of biologically based technologies for pest control (BBTs). At least 11 agencies are involved, and annual expenditures amount to over $210 million. Despite the size of these efforts, BBTs do not move smoothly from research to providing on-the-ground solutions to pest problems (see also chapter 3). This chapter explores some of the reasons for the bottleneck. It begins by describing activities of federal agencies related to BBT research and implementation and then examines how the federal government influences decisions of farmers and other users to adopt BBTs. The chapter concludes by identifying a series of issues and options for improving the flow of research findings into their practical applications.

OVERVIEW

Several federal agencies conduct or fund BBT research. Total funds allocated to BBTs by these agencies exceed $160 million annually, approximately $30 million of which comes from the state matching funds through the Cooperative State Research, Education, and Extension Service (CSREES) (table 5-1). The states also make substantial contributions directly to the State Agricultural Experiment Stations and to land grant universities.

The public sector spends approximately $90 million each year on pest control programs based on BBTs (table 5-2). Of this, about $10 million represents the biological control programs run by 28 state departments of agriculture. The precise amount that goes toward implementing BBT programs is difficult to determine because research on classical biological control sometimes results in significant suppression of a pest following release of an imported natural enemy, although no funds for implementation per se were expended.

U.S. Department of Agriculture

Four U.S. Department of Agriculture (USDA) agencies conduct BBT-related work ranging from regulation to research, implementation, and extension. Today, their activities fall under the umbrella of policies set in place by the Clinton Administration's stated goals to reduce the use of conventional pesticides and to implement integrated pest management (IPM) on 75 percent of U.S. agricultural lands by the turn of the century (box 5-1).

CHAPTER 5 FINDINGS

- The federal government dominates research on biologically based technologies for pest control (BBTs). Total federal funds for research, which exceed $130 million annually, are dispersed among 11 agencies. Despite its size, this expenditure appears to be largely uncoordinated and to lack adequate prioritization.
- Widespread agreement exists that basic research on BBTs is poorly linked to on-the-ground applications. One reason is a lack of research necessary to translate findings into practical field applications, in part because no federal research agency takes responsibility for this function.
- The U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) now has a group of scientists developing methods for applying BBTs to control widespread pest problems. The group grew out of clear needs for applied research that were not being served by the Agricultural Research Service (ARS). Its existence engenders considerable institutional conflicts within USDA, however.
- According to some estimates, noxious weeds that degrade western rangelands are spreading at rates of up to 4,000 acres per day. Federal land managers consider biological control to be one of the cornerstones to a cost-effective solution. However, they lack the resources to support appropriate research or programs, and no federal research agency has yet made a large effort in this area.
- Attempts have been made to coordinate biological control activities within and between the federal agencies in the past. But, so far, research scientists say these efforts have been unsuccessful because the coordinating committees and institutes have had inadequate institutional status, authority, and funding.
- Use of BBTs generally requires a significant level of information and knowledge, and farmers often lack clear-cut instructions or authoritative sources of advice on how to apply them. The Cooperative Extension Service is the principal government provider of direct, hands-on services to growers, but most extension agents have had little if any formal exposure to biologically based approaches.
- The Cooperative Extension Service's role in shaping pest management practices is now secondary to that of the more numerous private crop consultants, pest control advisors, and pesticide dealers and applicators in most regions of the country. Like extension agents, many private advisors are not well versed in BBTs or integrated pest management (IPM).

TABLE 5-1: Funding for Research on BBTs

	1988	1989	1990	1991	1992	1993	1994	1995	1996 (est.)
U.S. Department of Agriculture (USDA)									
Agricultural Research Service (ARS)[a]	82	80	82	87	101	98	104	104	104
Cooperative State Research, Education and Extension Service (CSREES)[b]									
Federal	6	9	9	9	9	10	12	13	14
State	24	28	31	27	28	29	29	30	30
Animal and Plant Health Inspection Service (APHIS)[c]	3	4	6	7	8	10	12	10	10
Forest Service	3	5	4	5	5	5	5	5	NA[d]
U.S. Environmental Protection Agency (EPA)	NA	NA	NA	NA	NA	1	1	1	0
U.S. Army Corps of Engineers	0.9	0.8	1.3	1.2	1.4	1.5	1.4	1.4	0
U.S. Department of Interior (DoI)	NA	NA	NA	1	1	1	1	1	1
Total public spending	118	126	133	137	153	156	165	165	>159
Inflation-adjusted spending[e]	≈109	≈112	≈112	≈113	≈124	≈125	≈130	≈129	NA

[a] According to certain former and current ARS scientists, the ARS pest control budget has been declining since 1985. Data obtained by OTA do not confirm this assertion. According to ARS, although the pest control budget has increased modestly in recent years, its purchasing power has decreased; ARS consequently has been unable to fill biological control positions vacated by retirements.

[b] Numbers cover only biological control research and do not include microbial pesticides, pheromones, sterile insects or plant immunization.

[c] APHIS/PPQ Biological Control Operational program budget only.

[d] NA = Not available.

[e] The producer price index (PPI) was used to calculate inflation-adjusted research budgets. In 1982, the base year used, the PPI was 1.00; in 1988 it was 0.926; in 1993, 0.802; and in 1995, it is estimated to be 0.78.

NOTE: Data have been rounded to nearest million, except for the Army Corps of Engineers. This chart presents the best numbers available. The agencies do not usually report their budgets in categories consistent with OTA's scope. They and OTA's contractors exercised care in compiling the numbers; each agency also reviewed and confirmed the budget estimates. Nevertheless, some errors of under- or overreporting may have occurred. An additional complexity is that it is widely acknowledged that the Current Research Information System used to track funds and full-time equivalents has technical flaws and inconsistent definitions.

SOURCES: Compiled by OTA from E.Z. Francis, Director, Toxics/Pesticides and Water Staff, Office of Research and Science Integration, U.S. Environmental Protection Agency, Washington, DC, letter to the Office of Technology Assessment, U.S. Congress, Washington, DC, June 9, 1995; D.M. Gibbons, The EOP Foundation, Inc., Washington, DC, "Biologically-Based Technologies for Pest Control: Report on the Role of the USDA in Biologically-Based Pest Control Research," unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, January 1995; W. Klassen, Tropical Research and Education Center, University of Florida, Homestead, FL, letter to the Office of Technology Assessment, U.S. Congress, Washington, DC, 1995; K. Koltes, National Biological Service, U.S. Department of the Interior, personal communication, June 1995.; D.E. Meyerdirk, Biological Control Operations, Plant Protection and Quarantine, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Riverdale, MD, fax to the Office of Technology Assessment, U.S. Congress, Washington, DC, August 3, 1995; R. Nechols and J. Obrycki, Kansas State University and Iowa State University, "OTA Preliminary Assessment of Biological Control: Current Research," unpublished report for the Office of Technology Assessment, U.S. Congress, Washington, DC, January 1994; S.J. Rockey, National Research Initiative Competitive Grants Program, Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, Washington, DC, fax to the Office of Technology Assessment, Washington, DC, August 10, 1995.

TABLE 5-2: Funding of BBT-Based Pest Control Programs

Agency	Fiscal year 1994 dollars (millions)
Animal and Plant Health Inspection Service[a]	69.7
Forest Service	11.0
States	9.4
Bureau of Land Management	0.3

[a] Includes all APHIS pest control programs having a major focus on BBTs.

NOTE: Table does not include technology transfer functions through ARS and CSREES or classical biological control research programs in which researchers introduce a biological control agent.

SOURCES: D.M. Gibbons, The EOP Foundation, Inc., Washington, DC, "Report on the Role of the USDA in Biologically-Based Pest Control Research," unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, January 1995; W.W. Metterhouse, Cream Ridge, NJ, "The States' Roles in Biologically-Based Technologies for Pest Control," unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, November 1994; D. Meyerdirk, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Riverdale, MD, fax to the Office of Technology Assessment, U.S. Congress, Washington, DC, August 3, 1995.

BOX 5-1: USDA's Integrated Pest Management Initiative

On September 21, 1993, at a joint congressional hearing, the U.S. Department of Agriculture (USDA), the U.S. Environmental Protection Agency (EPA), and the Food and Drug Administration called for a national commitment to develop and implement Integrated Pest Management (IPM) on 75 percent of U.S. crop acreage by the year 2000. The USDA announced an Integrated Pest Management Initiative in December of the following year. Its goals include involving farmers and practitioners in the development of IPM programs, increasing the use of IPM systems, and developing active partnerships between the public and private sectors. To achieve these goals, the Administration budget for fiscal year 1996 recommended a significant increase in funding for the IPM initiative's principal programs. The budget requests for 1996 include $7 million for a regional competitive grants program; $9.5 million for ARS's areawide pest management program; and $5 million to be passed through the Cooperative State Research Education and Extension Service to the Cooperative Extension Service and State Agricultural Experiment Stations to meet priorities identified on a regional and local level. As of August 1995, the Congress had appropriated no increase to the Extension Service and only $360,000 to be used for regional programs.[a]

The Clinton Administration's commitment to IPM is the third attempt to create a national IPM program since the term *IPM* first came into use in the 1960s. Both the Nixon and the Carter administrations funded multiagency research, training, and implementation programs. These programs inspired broad interest at the state level but were unable to provide a similar sustained effort at the national level. Funding for IPM programs was redirected after the 1980 election.

The design and direction of the Clinton Administration's IPM Initiative is based on years of thoughtful planning and analysis at local, regional, and national levels. In June 1992, USDA and EPA jointly sponsored the National IPM Forum which brought together participants from all sectors involved in agriculture—including 13 federal agencies—to examine constraints and obstacles to the adoption of IPM. The following year, with partial funding from EPA, several regional workshops of growers were convened in order to follow up on the national forum. In 1994, the Experiment Station Committee on Organization and Policy and USDA jointly funded the Second National IPM Symposium.

(continued)

BOX 5-1: USDA's Integrated Pest Management Initiative (Cont'd.)

Early in 1994, under the auspices of the Deputy Secretary of Agriculture, the planning for USDA's IPM initiative began. It was decided that USDA would approach IPM at state and regional levels to identify and address the needs of growers. Essential to accomplishing this task are IPM teams composed of producers, land-grant universities, crop advisers and consultants, and private industry. In 1995, 23 teams involving 42 states were convened to identify important research and education needs and to establish guidelines for evaluating the efficacy of USDA IPM programs. Equally important, the proposed competitive grants program for funding IPM research would award grants (up to $500,000 per year for five years) to similar multidisciplinary teams to ensure that the work addresses real-world concerns of growers and that the results feed directly into field use.

The USDA's IPM initiative addresses a number of the criticisms raised in this chapter. It could encourage organization and cooperation among the federal government, states, growers, and researchers, and improve the connection between IPM research and its implementation. Ultimately, the impact of the USDA IPM initiative on pest management will depend on sustained commitments from USDA, the Administration, and the Congress. Whether support will be forthcoming from Congress is as yet uncertain.

[a] This reflects wording of the agricultural appropriations bill for fiscal year 1996 from the House of Representatives; as of August 1995 the Senate had not put together its agricultural appropriations bill.

SOURCES: J.R. Cate, and M.K. Hinkle, *Integrated Pest Management: The Path of a Paradigm*, National Audubon Society, (Alexandria, VA: Weadon Printing, Inc., July 1994); L. Elworth, Special Assistant for Pesticide Policy, Office of the Assistant Secretary for Science and Education, U.S. Department of Agriculture, personal communication, May 5, 1995; B. Jacobsen, U.S. Department of Agriculture, Washington, D.C., fax to OTA, August 17, 1995; U.S. Department of Agriculture, Cooperative State Research, Education and Extension Service, "Request for Proposal, National Integrated Pest Management Implementation Program, Fiscal Year 1995," special projects guidelines, unpublished white paper, 1995; U.S. Department of Agriculture, Office of Communications, "USDA's Integrated Pest Management," (IPM Initiative, Release No. 0942.94, December 14, 1994).

Agricultural Research Service

An estimated $104 million of the Agricultural Research Service's (ARS) annual budget goes toward research on BBTs, supporting the efforts of around 1,166 FTEs[1] (table 5-1) (114). Approximately 300 BBT-related projects were under way in 1993 (247). ARS represents the single largest concentration of BBT research in the United States. In some BBT research disciplines, the majority of U.S. scientists work for ARS; for example, seven of the 11 U.S. specialists in biological control of postharvest plant diseases[2] work for ARS (161).

ARS counts among its past accomplishments complete economic control of 11 insect pests and three weeds by classical biological control (58). The agency also played a key role in the screwworm (*Cochliomyia hominivorax*) program that eradicated this pest from the United States. Ongoing BBT research includes projects such as biological control of the rangeland weed yellow starthistle (*Centaurea solstitialis*), and suppression of diamondback moth (*Plutella xylostella*) in cabbage using a combination of pheromones, parasitic wasps, and *Bacillus thuringiensis* (Bt) (20,88,430).

ARS researchers working on BBTs are distributed throughout the agency's 129 laboratories across the country, with biological control activities occurring at 49 locations (349). The agency also has four laboratories abroad (Montpellier, France; Buenos Aires, Argentina; Tuxtla-Gutier-

[1] Full-time equivalent employees. Any given FTE in the count may represent an overall summation of part-time efforts by a number of employees.

[2] Such diseases cause decomposition or rot on fruits, vegetables, and other commodities after they have been harvested.

rez, Mexico; and Panama) that conduct foreign exploration for classical biological control agents, as well as worksites in Australia, Italy, and Greece (320). No other federal or state agency possesses this capability for foreign exploration; although some state agencies, universities, and private organizations conduct foreign exploration, and other federal agencies (the Animal and Plant Health Inspection Service, the Forest Service, and the U.S. Fish and Wildlife Service) sometimes contract with international organizations to help identify potential biological control agents. Nevertheless, ARS's effort underlies numerous high-priority U.S. efforts in classical biological control (188,246,416).

ARS's pest research focuses on certain categories of pests more than others. Projects addressing insect pests account for approximately 75 percent of its BBT research (247). The remaining 25 percent is divided among plant pathogens (11 percent), nematodes (2 percent), and weeds (12 percent) (247).

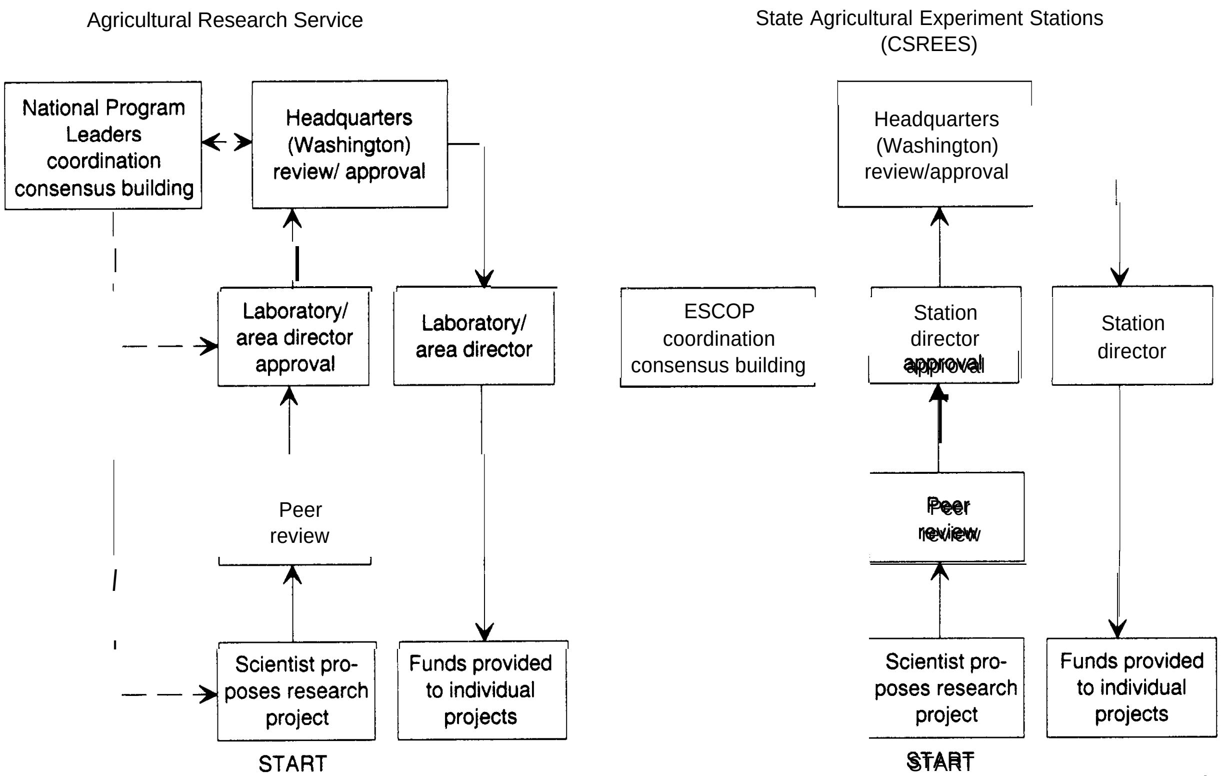
Federal land managers believe that rangeland weeds are important pests and that BBTs could play an integral role in controlling them (388). ARS's approximately $6 million weed-related work takes place primarily at the Rangeland Weeds Laboratory at Bozeman, Montana (280). The laboratory is relatively small, with a staff of four ARS scientists. The Forest Service has also assigned a scientist to the laboratory and provides $300,000 annually to fund the researcher's work. The Clinton Administration's budget proposal for fiscal year 1996 would end funding for ARS's other long-standing California-based program for biological control of weeds, although its past successes in weed control have been highly valued by state officials and others (26). Despite the relatively small allocation of resources by the agency, federal land managers give ARS scientists high marks for their collaborative efforts to address rangeland weeds. For example, ARS recently compiled a comprehensive summary of findings on weed natural enemies for use by federal, state, county and other rangeland managers (348).

The major criticisms of ARS are that, despite the agency's accomplishments, it has difficulty responding in a timely fashion to externally identified research goals and priorities, and too much of its BBT research does not find its way into applications on the ground. A number of factors may contribute to these problems. In general, ARS does not seem to have found a satisfactory way to set research goals and at the same time enable creativity and productivity among its scientific staff in accomplishing these goals. A surprisingly large number of former and current ARS staff reported their concerns about the agency's internal management to OTA during the course of this assessment.

The process by which ARS allocates funds to research, on paper, seems to provide a clear mechanism for focusing efforts on national research goals through involvement of the National Program Staff (figure 5-1). The scientist in the role of a National Program Leader is supposed to provide national leadership for a specific topic area. At least three National Program Leaders deal with BBTs. However, in practice, because the National Program Leaders lack funding authority, their influence on the overall research agenda—based on consultation and consensus building among ARS scientists located in laboratories across the country—is largely voluntary and sometimes ineffectual. Congress has with some regularity set de facto research goals by targeting appropriations for work on certain key pests, and ARS solicits related research proposals from staff scientists. According to agency critics, the quality of research can suffer when such political pressures run high (200).

Even when clearly identified goals emerge, the agency's structure imparts an inflexibility that can make it difficult to reallocate resources and staff to newly identified priorities. Existing resources are usually tied up in ongoing projects, reflecting the long periods of time required for certain types of research. However, this also leaves little funding for new initiatives. In addition, ARS managers say scrutiny by members of Congress can strongly deter attempts to move

FIGURE 5-1: General Schematic of the Decision Processes by which the Agricultural Research Service and State Agricultural Experiment Stations Award Research Funds



SOURCE: Office of Technology Assessment, 1995,

NOTE: Dashed line represents influences of the National Program Leaders (NPL) or the Experiment Station Committee on Organization and Policy (ESCOP).

projects from one congressional district to another even when warranted by changing pest problems (349). Experience with the silverleaf whitefly, *Bemisia argentifolii,* (formerly known as the sweetpotato whitefly strain B, *Bemisia tabaci)* demonstrates ARS's limitations in responding rapidly to emerging pests (box 5-2) (200). The agency was unable to mobilize a significant research effort until after the five-year USDA program was put into effect. By that time, the pest had risen to the top of the political agenda and funds were directed to the Animal and Plant Health Inspection Service (APHIS) for its control.

Perhaps in part because of such delays, ARS's research does not always match the needs of operations agencies involved in pest management. For many years APHIS, the agency with principal responsibility for control of agricultural pests, annually submitted a prioritized list of research needs to ARS (364). APHIS representatives say the agency was unable to identify tangible results that supported their operational responsibilities (364) and consequently in 1992 moved to less formal methods for communicating their needs (428). According to ARS, however, virtually all of APHIS's ongoing biological control programs are based on research accomplished by ARS; the role of APHIS's methods development staff (discussed later) has been to scale-up the findings from ARS research (320). The differing views suggest that, although ARS research does support APHIS operations, it requires significant adaptation to be put into practical use. The differing views also seem

BOX 5-2: Case Studies of USDA Pest Control Programs Involving Biologically Based Technologies

Eradication of the screwworm

The screwworm (*Cochliomyia hominovorax,* the larval stage of the screwworm fly) is a parasite that consumes the live flesh of cattle, hogs, horses, mules, sheep, goats, dogs, other domestic and wild animals, and humans. During the first half of the century, this pest caused significant damage in the southern United States. For example, between 1932 and 1934, 1.3 million livestock animals were infested by the parasite, and over 200,000 animals died in the Gulf states.

In 1951 USDA began a program to eradicate the screwworm from the United States by releasing sterile male screwworm flies into wild populations. Poor management of the production and distribution of the flies and misunderstandings of the pest's behavior and ecology led to setbacks in the Southwest between 1972 and 1976. Program scientists identified the main causes of the problems, and, by 1982, the screwworm became the only pest to be eliminated from the United States.

The screwworm program began prior to the separation of APHIS and Agricultural Research Service into two distinct agencies. After the separation, these two agencies worked together on the program until the mid-1980s. APHIS continues the program today in Mexico and Central America.

The scientists involved in the program attribute its success to several factors, including USDA's long-term commitment and sustained funding. Staff for the eradication program devote 100 percent of their time to it; in contrast, other USDA scientists work on several projects at once. Other contributing factors include regulations to control the movement of infested cattle, and cooperation among veterinarians, farmers, and federal officials. The eradication program in Mexico has been less successful partly because of the continued movement of contaminated cattle.

The boll weevil eradication program

Since 1892 the boll weevil (*Anthonomus grandis*) has caused considerable damage to the U.S. cotton industry. Aggregate losses amounted to $12 billion as of 1990. Losses per year in the mid-1970s were estimated at $200 million to $300 million. In the 1960s ARS began a program to eradicate the boll weevil from the southeastern United States. The main objectives were to reduce economic damage from the pest, to reduce the use of pesticides, and to conserve the natural enemies of the other pests in cotton fields such as the beet armyworm (*Spodoptera exigua*), fall armyworm (*S. frugiperda*), and bollworm, also called the corn earworm and the tomato fruitworm (*Helicoverpa zea*). To date, the boll weevil eradication program has succeeded in eight of the cotton belt states, while four others are engaged in on-going programs. Farmers have gained $12 for every dollar they have spent on this program. Because of decreased pesticide sprayings against the boll weevil, the beet armyworm and fall armyworm are now controlled by their natural enemies in many cotton fields.

Success of this program has been attributed to the strong coordination among federal agencies, state governments, and farmers. APHIS coordinates the overall program with the Boll Weevil Eradication Foundation, organized by the farmers who provide a majority of the funding. Farmers usually supply over 70 percent of the program funds, while the remainder comes from USDA (mainly APHIS) and the state governments. Although areawide spraying of pesticides is the main control method, a pheromone trap for monitoring boll weevil abundance, developed by ARS, is an essential component of the program. After the areawide sprayings, traps allow fieldworkers to detect and take action against each new infestation before the pest becomes abundant and spreads to uninfested fields.

(continued)

BOX 5-2: Case Studies of USDA Pest Control Programs
Involving Biologically Based Technologies (Cont'd.)

Russian wheat aphid

The Russian wheat aphid (*Diuraphis noxia*) first appeared in the United States in 1986 and has since spread to 15 states and caused more than $850 million in losses to wheat farmers. In 1988, scientists from APHIS, the Agricultural Research Service, and CSREES began research to identify classical biological control agents for the Russian wheat aphid.

APHIS has received a majority of the congressional line-item funds for the control of this pest—between $1 million and $2.5 million annually from 1990 to 1995. The agency's biological control program has not yet succeeded in establishing any natural enemies that provide adequate control. Scientists criticize APHIS for putting too much emphasis on the introduction of potential biological control agents while neglecting to carry out effective followup studies tracking the agents' impacts. Little is known about the effects, good or bad, of the introduced species on the Russian wheat aphid, on other introduced natural enemies, or on native species and ecosystems. Of the 24 species and over 100 geographic strains released, only four of the imported parasites are suspected of having become established in the wheatfields, and their effectiveness against the Russian wheat aphid remains unknown. Field workers and scientists are unable to correctly identify the released parasites because of their close resemblance to native strains and to other parasites released by ARS for control of different aphid pests. Some aphid predators (which are mainly lady beetles) released by APHIS prior to the Russian wheat aphid program have also become established, although their effectiveness against the pest is uncertain.

Scientists involved in the program feel it is too early to judge its success because establishing an effective biological control agent can take years. Others argue, however, that the program has been rushed because of APHIS's responsibility to suppress pest outbreaks. The result has been the release of numerous natural enemies without correct identification of their taxonomy or adequate knowledge of their ecological effects. Biological control programs lacking such information are less likely to succeed. For this reason, biological control is not often the best route for quick suppression of a pest, unless adequate knowledge is available at the project's inception about the ecology of both the pest and its natural enemies.

The silverleaf whitefly

The silverleaf whitefly (*Bemisia argentifolii*)—initially identified as strain B of the sweet potato whitefly (*Bemisia tabaci*)—first appeared in Florida in 1986. It attacks at least 600 different crops, including melon, cotton, tomato, lettuce, and many ornamental plants. The spread of the silverleaf whitefly across the country caused extensive crop losses estimated at $200 million to $500 million between 1991 and 1992. The Imperial Valley of California has been one of the hardest hit areas; from 1991 through 1994, an estimated 9,000 local jobs disappeared and crop losses exceeded $300 million due to the pest.

The initial response of scientists and federal agencies to the silverleaf whitefly was uncoordinated and lacking in focus. Scientists who began studying the problem were working in isolation, and thus their work was unlikely to yield rapid solutions. Despite warnings in the late 1980s by its own scientists, ARS began to mobilize a significant response to the pest only when damage skyrocketed during the 1991 outbreak in the Southwest. And according to numerous critics, APHIS and ARS had difficulty cooperating during early phases of the outbreak. USDA officials attribute the early inaction to the lack of an official mechanism for USDA agencies to jointly address new pest problems.

(continued)

BOX 5-2: Case Studies of USDA Pest Control Programs Involving Biologically Based Technologies (Cont'd.)

Actions by grower organizations and commodity groups played a significant role in improving the focus of efforts to control the silverleaf whitefly. These groups lobbied for congressional action, resulting in direct appropriations in fiscal year 1993 of $2.6 million to APHIS for the development of a biological control program. The Office of the Secretary of Agriculture stepped in to provide guidance in development of a cooperative USDA program; in 1992 the five-year action plan was put in place to coordinate the efforts of ARS, APHIS, CSREES. The grower and commodity groups also supplied direct funding to local extension scientists, which supported the essential research for developing local and regional control methods.

To date, the most effective measures for controlling the silverleaf whitefly are cultural practices, chemical insecticides, and a microbial pesticide based on the fungus *Beauvaria bassiana*. APHIS's biological control program has not yet yielded a successful natural enemy. As in the case of the Russian wheat aphid, the agency has been criticized by outside scientists for releasing multiple biological control agents with too little forethought or post-release monitoring.

SOURCES: S.L. Birdsall and D. Ritter, Imperial Valley Agricultural Commissioner and Whitefly Program Coordinator, respectively, unpublished data on the economic impact of the silverleaf whitefly in Imperial Valley, Imperial Valley, CA, 1994; H. Browning, State Agricultural Experiment Station, University of Florida, Gainsville, FL, personal communcation, August, 1995; W. Dickerson, Plant Pest Administrator, North Carolina Department of Agriculture, Raleigh, NC, personal communication, July, 1995, and August 1995; T. Engle, Budget and Accounting Office, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Riverdale, MD, fax to the Office of Technology Assessment, U.S. Congress, Washington, DC, August 21, 1995; M.J.R. Hall and W.N. Beesley, "The New World screwworm fly in North Africa," *Pesticide Outlook* 1(2):34-37, 1990; P. Karieva, Department of Zoology, Univeristy of Washington, Seattle, WA, fax to the Office of Technology Assessment, U.S. Congress, Washington, DC, August, 1995; E.S. Krafsur, Department of Entomology, Iowa State University, Ames, IA, personal communication, July, 1995; W. Lambert, extension entomologist, Univeristy of Georgia, personal communication, August, 1995; N. Leppla, Assisstant Director, National Biological Control Institute, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Riverdale, MD, personal communication, August, 1995; R.L. Metcalf and R.A. Metcalf, *Destructive and Useful Insects: Their Habits and Control 5th Ed.* (New York, NY: Mcgraw-Hill Inc., 1993); S.K. Narang, National Program Staff, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, MD, fax to Offfice of Technology Assessment, U.S. Congress, Washington, DC, August 17, 1995; J.R. Nechols, Department of Entomology, Kansas State Univerisity, Manhattan,KS, personal communication, July 24, 1995, August 21, 1995; D. Prokrym, Project Leader, Russian Wheat Aphid Biological Control Project, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Niles, MI, personal communication, August 10, 1995, letter to the Office of Technology Assessment, U.S. Congress, Washington, DC, August 11, 1995; D. Stanley, "Whitefly Causes Bleak Times for Growers," *Agricultural Research* 16(2), January, 1991; N. Toscano, Department of Entomology, Univeristy of California-Riverside, Riverside, CA, personal communication, August, 1995; U.S. Department of Agriculture, Animal and Plant Health Inspection Service, "Biological Control of the Russian Wheat Aphid," APHIS Pub. No. 1507 (Washington DC: December 1993); U.S. Department of Agriculture, Animal, and Plant Health Inspection Service, Plant Protection and Quarantine, National Biological Control Laboratory, *Russian Wheat Aphid Biological Control Project—FY 1993 Project Report,* prepared by D.R. Prokrym, J.R. Gould, D.J. Nelson, L.A. Wood and C.J. Copeland (Niles, MI: 1993); U.S. Department of Agriculture, Economic Research Service, *Economic Returns to Boll Weevil Eradication,* prepared by G.A. Carlson, G. Sappie and M. Hammig, AER Pub. No. 621 (Washington, DC: September 1989); R. Van Driesche, et al. Department of Entomology, Univeristy of Massachusetts, Amherst, MA, "Report on Biological Control of Invertebrate Pests of Forestry and Agriculture," unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, December 1994.

characteristic of the lack of good communication and cooperation between ARS and APHIS. According to outside observers, even ARS research results that might be relevant to APHIS's programs do not consistently filter through to APHIS because of poor communication between the agencies (114,176).

The working environment for individual scientists within the agency may also affect the ease with which ARS's research on BBTs moves into practical applications. Agency scientists complain that the funding environment is highly competitive, and that funds get siphoned off at several levels, leaving only a minimum amount for actually conducting the research. Some low-profile areas central to the development of BBTs, such as taxonomy and systematics, receive relatively little support (58). According to some ARS scientists, the necessary work to take research on BBTs "out of the laboratory and into the field" is discouraged. Instead, performance is judged by the number of scholarly publications—a criterion usually applied to academic scientists whose work is supposedly less mission oriented.

One mechanism for converting research results into practical applications is the Cooperative Research and Development Agreements (CRADAs) through which outside institutions help to fund federal research and obtain licensing rights to research discoveries in return. ARS has supported numerous collaborative research projects with private industry (320). As of July 1994, ARS had a total of 16 ongoing agreements related to BBTs. However, only five of these involved private sector companies or organizations; the rest were agreements with other federal agencies, states, foreign governments, or universities (300). ARS recently began to develop another new program for transferring technologies to the private sector that might provide additional opportunities for companies to help fund ARS research; the program is expected to start in fiscal year 1996 (417A) (see options in chapter 6 for additional discussion of cooperative agreements with the private sector).

ARS scientists working on classical biological control express specific dissatisfaction with the organizational structure of the agency and how it affects their ability to do timely work. They point to the 1972 restructuring of the agency as a major blow because it destroyed the previous tight coordination of related research within the agency (58). ARS had a National Program Leader for Biological Control until 1992 when the program was changed to Pest Management. Coincident with a switch in senior management, the emphasis changed back to Biological Control in 1995 (349). Whether this action will help provide the focus and coordination ARS scientists desire in the area of biological control is uncertain.

Overall, ARS as a research institution has great capabilities in the area of BBTs. Improving the flow of research findings into the field to solve real-world pest problems poses a number of challenges, however.

Animal and Plant Health Inspection Service

The Animal and Plant Health Inspection Service (APHIS) has significant responsibilities for protecting American agriculture from pests under the Plant Pest Act, the Federal Noxious Weed Act, and the Plant Quarantine Act.[3] Its functions related to the regulation of natural enemies are discussed in further detail in chapter 4. This section focuses on APHIS's pest control responsibilities.

APHIS's pest control programs incorporate a number of BBTs (table 5-3). The agency has placed special emphasis on biological control. In 1992 the APHIS Administrator issued an agencywide policy directive (the APHIS Biological Control Philosophy) stating:

> APHIS believes that modern biological control, appropriately applied and monitored, is an environmentally safe and desirable form of long-term management of pest species. APHIS believes that biological control is preferable when applicable; however, we also recognize that biological control has limited application to emergency eradication programs. Where possible, biological control should replace chemical control as the base strategy for integrated pest management (222).

In 1994, the North American Plant Protection Organization[4] adopted a similar philosophy based on APHIS's model (197). University and state scientists outside the federal government,

[3] Federal Plant Pest Act (1957), as amended (7 U.S.C. 147a *et seq*.), the Federal Noxious Weed Act (7 U.S.C. 2801 *et seq.* (1974)) and the Plant Quarantine Act (7 U.S.C. 151 *et seq.* (1967)).

[4] The North American Plant Protection Organization is part of the International Plant Protection Group that is comprised of representatives from Canada, Mexico, and the United States.

TABLE 5-3: Technologies Used in Pest Management Programs of the Animal and Plant Health Inspection Service (USDA)

Pest	Biological control	Sex pheromone trap	Sterile insect technique	Other
Insects				
Apple ermine moth (*Yponomeuta malinella*)		X		P
Boll weevil (*Anthonomus grandis*)	X	X		P, C, F
Brown citrus aphid (*Toxoptera citricida*)	X			
Cereal leaf beetle (*Oulema melanopus*)	X			
Cherry ermine moth		X		P
Euonymus scale (*Unapis euonymi*)	X			
Fruit fly detection		X		P, F, M
Grasshopper/MC	X, MD			P
Gypsy moth (*Lymantria dispar*)	X, MD	X	MD	P
Imported fire ant (*Solenopsis invicta*, *S. richteri*)	MD			P
Japanese beetle (*Popillia japonica*)	X	X		P
Medfly (*Ceratitis capitata*)	MD	X	X	P, F, M, C, E
Mexfly (*Anastrepha ludens*)	MD		X	P, F, C, E
Pine shoot beetle (*Tomicus piniperda*)	X			P, MT, C, E
Pink bollworm (*Pectinophora gossypiella*)	X	X	X	P,C, E
Russian wheat aphid (*Diuraphis noxia*)	X			
Sweet potato whitefly (*Bemisia tabaci*)	X			
Weeds				
Common crupina (*Crupina vulgaris*)	X			
Diffuse and spotted knapweed (*Centaurea diffusa*, *C. maculosa*)	X			
Leafy spurge (*Euphorbia esula*)	X			C
Purple loosestrife (*Lythrum salicaria*)	X			
Catclaw mimosa (*Mimosa pigra*)				P
Onionweed (*Asphodelus fistulosus*)				P
Goatsrue (*Galega officinalis*)				P
Hydrilla (*Hydrilla verticillata*)	X			P
Little bell morning glory (*Ipomoea triloba*)				P
Liverseed grass (*Urochloa panicoides*)				P
Mediterranean saltwort (*Salsola vermiculata*)				P
Branched broomrape (*Orbanche ramosa*)				P
Small broomrape (*Orbance minor*)				P

(continued)

TABLE 5-3: Technologies Used in Pest Management Programs of the Animal and Plant Health Inspection Service (USDA) (Cont'd.)

Witchweed (*Striga* spp.)	CS
Plant pathogens	
Black stem rust (*Puccinia graminis*)	C, RV
Chrysanthemum white rust (*Puccinia horiana*)	P, RV
Golden nematode (*Globodera rostochiensis*)	C, RV

TABLE KEY:
X = Used
C = Cultural control
CS = Chemical stimulant
E = Environmental (hot or cold air treatment)
F = Food bait trap
MD = Methods under development
MT = Mechanical Trap (traps of a particular shape , size, or color)
P = Pesticide
RV = Resistant varieties
Sterile Insect = Use of sterile insects

SOURCE: U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Biological Control Operations, unpublished 1994 data provided by D. E. Meyerdirk, Senior Staff Officer, April 1995.

however, are somewhat skeptical about the extent to which APHIS adheres to the policy (338A).

Although APHIS has identified 10 criteria for selecting target pests for biological control, the agency says that advice from the National Plant Board[5] and political considerations often emerge as the most significant factors (365). APHIS currently funds 14 pest control programs based on biological control at a total annual cost of approximately $11 million (230). Half of this money is committed in designated budget lines to only two pests. The agency has long complained that such a precise designation of funds for specific pests decreases its ability to respond to newly emerging pest threats. However, the designation also ensures that the money goes to the specific pest problem and is not diffused among several programs. Biological control programs often affect several states and, consequently, involve significant allocations of funds. The APHIS program for leafy spurge (*Euphorbia esula*), for example, covers 17 western states and cost $1.8 million in fiscal year 1994 (356).

One measure of the agency's commitment to biological control was the creation of the National Biological Control Institute in 1990 in response to a perceived need to increase the prominence of and coordinate biological control within APHIS, between APHIS and the other USDA agencies, and between APHIS and organizations outside the government. The institute's mission is "to promote, facilitate and provide leadership for biological control" (363).

APHIS created the National Biological Control Institute the same year the USDA established the Interagency Biological Control Coordinating Committee ("IBC^3") by a memorandum signed jointly by the administrators from ARS, the Cooperative State Research Service,[6] and APHIS. Two other USDA agencies, the Forest Service and the Extension Service, also partici-

[5] The National Plant Board is composed of federal agriculture officials and individuals from state departments of agriculture.

[6] The Cooperative State Research Service (CSRS) has since been merged with the Extension Service to become the Cooperative State Research, Education, and Extension Service (CSREES). CSREES is discussed later in this chapter.

pated. The committee's purpose—"to provide leadership in biological control within USDA and in proposing uniform departmental policies in such matters" (119)—was similar to that of the National Biological Control Institute. Unlike the institute, however, the committee never had any direct funding. In 1993, the committee attempted to make biological control a top USDA priority by proposing a National Biological Control Program to enhance biological control research, education, and implementation efforts in the federal government. That program called for an increase of $53 million over three years. Both the Cooperative State Research Service and APHIS received small allocations of funds in 1994 associated with the proposed program, but the proposal was never fully acted upon (75,324). As of 1995, the Interagency Biological Control Coordinating Committee had lapsed into inactivity.

Reviews of APHIS's National Biological Control Institute's impacts are mixed. The institute is effective at outreach beyond the beltway and is highly respected by scientists in state government, universities, and other institutions. Over the past four years, the institute has awarded approximately $1.5 million in grants for implementation projects, educational and informational materials, postdoctoral fellowships, meetings and workshops, publications and the development of databases (363). However, the institute's highly regarded staff and expertise are not always paid attention to within APHIS. For example, efforts by the National Biological Control Institute to involve stakeholders in the development of biological control regulations were not incorporated into the broader proposed rule that APHIS issued for nonindigenous species (see chapter 4). That rule was later withdrawn because of negative public comment. APHIS is now starting a new rulemaking process in which the agency again will seek out extensive public input (353). Moreover, the institute has not been incorporated into the working group representing various agencies in the USDA IPM Initiative. This oversight is unfortunate because it perpetuates the historical separation of biological control and IPM pest control disciplines (see chapters 2 and 3 for discussions of the relationship between biological control and IPM).

To support its implementation programs, APHIS has a methods development staff which conducts applied research on how to get BBT methods into the field to solve widespread pest problems. About $5 million is expended annually on biological control research, and $10 million overall on all BBTs (230).[7] APHIS created the Methods Development because ARS and other research agencies were not adequately addressing APHIS's pest control development needs, especially the scale-up necessary to apply methods more broadly. The existence of the methods development staff within APHIS is a source of some tension with the USDA research agencies, however. In 1991, when the Secretary of Agriculture initiated the silverleaf whitefly program, critics argued that APHIS should not have received funding for implementing a control program until more basic research by other agencies and scientists had demonstrated that technologies were available to control the pest (78). The criticism perhaps reflects an inherent overlap between research and implementation programs in classical biological control. The desired endpoint of both is the establishment of a natural enemy that provides widespread, lasting, and effective suppression of a pest; in national pest control programs the respective roles of research by ARS and implementation by APHIS in achieving this goal have not yet been well delineated.

A related concern is whether APHIS can operate objectively in regulating its own biological control programs (82). Critics point to what they claim are fast-paced and sloppy attempts to put biological control in place when a new pest rises to the top of the political agenda. Because of a

[7] In addition to Methods Development, APHIS's Animal Damage Control Division spends about $1.3 million annually developing BBTs for vertebrates, specifically immunocontraceptives and genetically engineered vaccines for coyotes (225)

Federal programs based on the release of sterile insects have eliminated the screwworm (Cochliomyia hominivorax) *from the United States.*

Agricultural Research Service, USDA

lack of communication, these efforts sometimes interfere with those of scientists in ARS or the State Agricultural Experiment Stations, eroding their relationships with APHIS (246). Experience with the Russian wheat aphid *(Diuraphis noxia)* and silverleaf whitefly tend to support this view (box 5-2). Regulatory, research, and implementation functions related to biological control all coexist in the same organizational unit of APHIS called Plant Protection and Quarantine. This situation creates significant potential for internal pressuring of regulators to expedite permitting of new biological control introductions, especially when there is great political urgency to find solutions to existing pest problems.

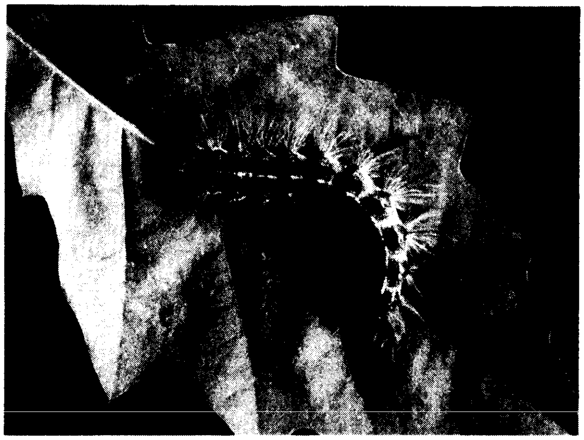
APHIS has statutory authority to conduct pest control programs and to regulate biological control introductions. The agency also has a legitimate role in developing methods to apply BBTs in the field, because these needs are not currently met by any other agency. Better insulation of each of these functions from one another, however, would perhaps ensure the best performance of all three. The current trend within APHIS may run in the reverse direction, however. The agency recently downgraded its operational biological control program (including the laboratories) and placed it under authority of the methods development staff. State agriculture departments hoping to increase the level of coordination of biological control activities worry that APHIS's action will result in a loss of identity, effectiveness, and funds for biological control operations (229).

Forest Service

The Forest Service manages the 191.5 million acre National Forest System (roughly 8 percent of the U.S. land area and 29 percent of all federally administered lands). The system encompasses 156 national forests, 19 national grasslands, and 98 other units (334). In addition, under the Cooperative Forestry Assistance Act, the Forest Service controls insect pests and diseases on other forested areas in the country (public and private, some through various cost-share arrangements).[8] To fulfill these responsibilities, the agency has units for pest management research, Forest Insect and Disease Research (FIDR), and for pest suppression, Forest Health Protection (FHP).

FIDR received $24 million in fiscal year 1994 for pest management research, of which approximately $4.5 million was used to fund work on BBTs (114,324). The latter amount was divided between biological control (approximately $3.1 million) and behavioral chemicals ($1.4 million) (114). Among funded projects in fiscal year 1995 are two new biological control studies for rangeland weeds ($300,000) and hemlock woody adelgid *(Adelges tsugae) ($150,000),* with foreign exploration for natural enemies being conducted out of the ARS laboratory in Europe (320,324). The Forest Service established a quarantine facility in Ansonia, Connecticut, in 1992 to facilitate and accelerate the agency's research and development of biological control (58). Research on BBTs is likely to increase as a result of the agency's 1993 strategic plan, "Healthy Forests for America's Future," which emphasizes eco-

8 Cooperative Forestry Assistance Act of 1978, as amended (7 U.S.C A. 2651-2654; 16 U.S.C.A. 564 *et seq.")*



National programs to suppress the gypsy moth (Lymantria dispar) *are based largely on Bt and the gypsy mothNPV virus.*

system management and calls for increases in the research, development, and use of biological control, microbial pesticides, and pheromones (381A).

FHP conducts a wide array of pest control programs. Those programs targeting insect pests rely to a significant extent on BBTs. In fiscal year 1994, BBTs were used for over half of the almost 14,000 acres of National Forests treated for insect pests (383). The diverse methods involved include pheromones and microbial pesticides based on Bt, fungi, viruses, and nematodes (383). The largest pest management effort targets the European gypsy moth *(Lymantria dispar),* relying primarily on Bt, gypsy moth NPV virus, and pheromones to monitor distribution. In 1995 the Forest Service plans to use Bt to control the gypsy moth on 505,603 acres and the NPV virus on 2,263 acres of federal and cooperative lands. Total cost of the gypsy moth program in fiscal year 1994 was $11 million, of which $8.3 million went to Bt applications.

Conventional pesticides remain FHP's method of choice for other pest categories, however. In fiscal year 1994 more than 54,000 acres of National Forests were treated for plant pathogens with chemical fungicides and fumigants, and almost 38,000 acres were treated for weeds with chemical herbicides (383). Use of natural enemies against weeds that same year occurred on 6,400 acres (383).

According to Forest Service insiders, the research unit, FIDR, has not always been able to provide the solutions required by the agency's operations unit, FHP. Part of the problem is that the research timetable does not always match the needed expediency for pest control because some techniques may require significant, and time-consuming, basic research before they can be put into practice (a problem similar to that experienced by ARS). Moreover, although FHP and FIDR conduct joint programs, the researchers at FIDR rarely communicate with the land managers, leading to the criticism that FIDR is not connected to the field. Like APHIS, FHP has begun conducting research on field applications because FIDR cannot fulfill all of its needs. Researchers worry, however, that the quality of biological control work will decline as the number of people involved increases. Some of these problems may dissipate somewhat as the Forest Service moves increasingly toward trying to manage forests to prevent pest problems (i.e., maintaining "forest health") rather than reacting to pest outbreaks.

The Forest Service has only recently begun to address problems with rangeland weeds on federal lands. One Forest Service scientist has been assigned to the ARS Biological Control of Weeds Laboratory in Bozeman, Montana (280). The Forest Service is also a member of the Federal Interagency Committee for the Management of Noxious and Exotic Weeds that was established in 1994 to coordinate federal efforts related to the identification and management of weed problems.

Cooperative State Research, Education, and Extension Service

The Department of Agriculture Reorganization Act of 1994 combined the mission and functions of the Cooperative State Research Service with those of the Extension Service (the Federal partner in the Cooperative Extension Service) to create the Cooperative State Research, Education, and Extension Service (CSREES) (98). The goal of reorganization was to pull together the research and higher education funding of the

Cooperative State Research Service and the technology transfer and education program responsibilities of the Extension Service in order to improve the movement of research findings to application and use via education. The complete integration of the two former agencies has not yet been accomplished; most notably, their budgets remain separate. This section describes the research-related functions of CSREES. The role of CSREES in education and technology transfer will be discussed later in the chapter in the section dealing with educating and influencing users of pest control.

CSREES administers federal research funds through the the National Research Initiative (NRI) and through formula funds and special grants directed to land grant universities by way of the State Agricultural Experiment Stations. The National Research Initiative is a competitive grants program that funds more fundamental research. These characteristics separate it from other sources of agricultural research funding. The program was established in 1991 following release of the 1989 National Research Council report "Investigating Research: A Proposal to Strengthen the Agricultural, Food, and Environment System." The study concluded that fundamental research in agriculture is underfunded. Although 70 percent of funds go to the land grant universities, grants from the National Research Initiative also support research of academic scientists not associated with land grant universities and of ARS scientists (247,292). Grants totaling approximately $13 million were awarded to biological control and IPM research in fiscal year 1994 (291). Of the 31 existing National Research Initiative programs, BBT research may be funded by any of seven programs (depending on the focus), including Entomology, Nematology, Weed Science, and Plant Pathology (292,371). A separate funding program specifically for biological control began in 1994 (371). The money came from a congressional line item for regional IPM that was eliminated in the 1996 House of Representatives budget proposal; its ultimate fate was uncertain as of August 1995 (291).

Within the National Research Initiative, BBT research is identified as mission oriented, although funded projects range from more basic to more applied. The application for funding asks for information about how results will relate to development of IPM programs (371). According to Sally Rockey, division director of the National Research Initiative, this applicability to pest control programs does influence research funding decisions. CSREES can increase scientists' willingness to consider applications of their work through specific calls for more mission-oriented research in announcements of funding opportunities (292). Funding recommendations are made by a panel of researchers who rank submitted proposals following external review and then make recommendations to the Chief Scientist of the National Research Initiative. A Scientific Advisory Committee provides additional advice on programmatic issues (292).

The Land Grant Universities and the State Agricultural Experiment Stations are research institutions established within the states by the Land Grant Act (also known as the Morrill Act) and the Hatch Act,[9] respectively. The Land Grant University System was designed to provide higher education, especially to the children of farmers and industrial workers, and to apply research knowledge to the solution of society's problems through outreach and extension programs (337). The Hatch Act created a research partnership between the federal government and the states by providing funding for the State Agricultural Experiment Stations. These stations are the sites of much of the nation's agricultural research. Formula funds are provided under the act and then matched by the states. These funds, as well as other competitive grants, are funneled through CSREES. For fiscal year 1995, CSREES directed $13 million in federal funds towards biological control research through the National Research Initiative and the State Agricultural

[9] Hatch Act of 1887, as amended (7 U.S.C. 361a-361i).

Experiment Stations. States provided an additional $30 million in matching funds (114,292).

In comparison with the role of the directors of the State Agricultural Experiment Stations, CSREES has a minor role in allocating formula funds to specific research projects (figure 5-1). Scientists submit research proposals to the station directors for internal review; the directors have a good deal of discretion in their funding decisions (265). Proposals that are endorsed are submitted to the CSREES headquarters in Washington, D.C., for final approval. Each station director then designates funds from that agricultural station's budget to approved projects (265).

Directors of the State Agricultural Experiment Stations make their decisions within the context of broad strategic plans (90). Since 1986, these plans—national guidelines setting the vision and mission for the State Agricultural Experiment Stations—have been set in place every four years and periodically updated by the Experiment Station Committee on Organization and Policy.[10] The broad nature of these plans and the diffusion of funding authority regionally among station directors, however, means that the State Agricultural Experiment Station System, like ARS, lacks effective mechanisms to address national goals (316).

An additional aspect of the system of state agricultural experiment stations and land grant universities is how it reflects state trends. Senior faculty at some of the nation's universities complain that as the state priorities shift (from agricultural to urban), allocations of faculty slots and research funds at land grant universities and state agricultural experiment stations devoted to such practical matters as pest control are declining (66,307). Within the University of California system, for example, administrators recently moved to consolidate pest management programs at the Davis and Riverside campuses. They began dismantling the agriculture department at Berkeley, which included the oldest biological control program in the country.

State Agriculture Departments

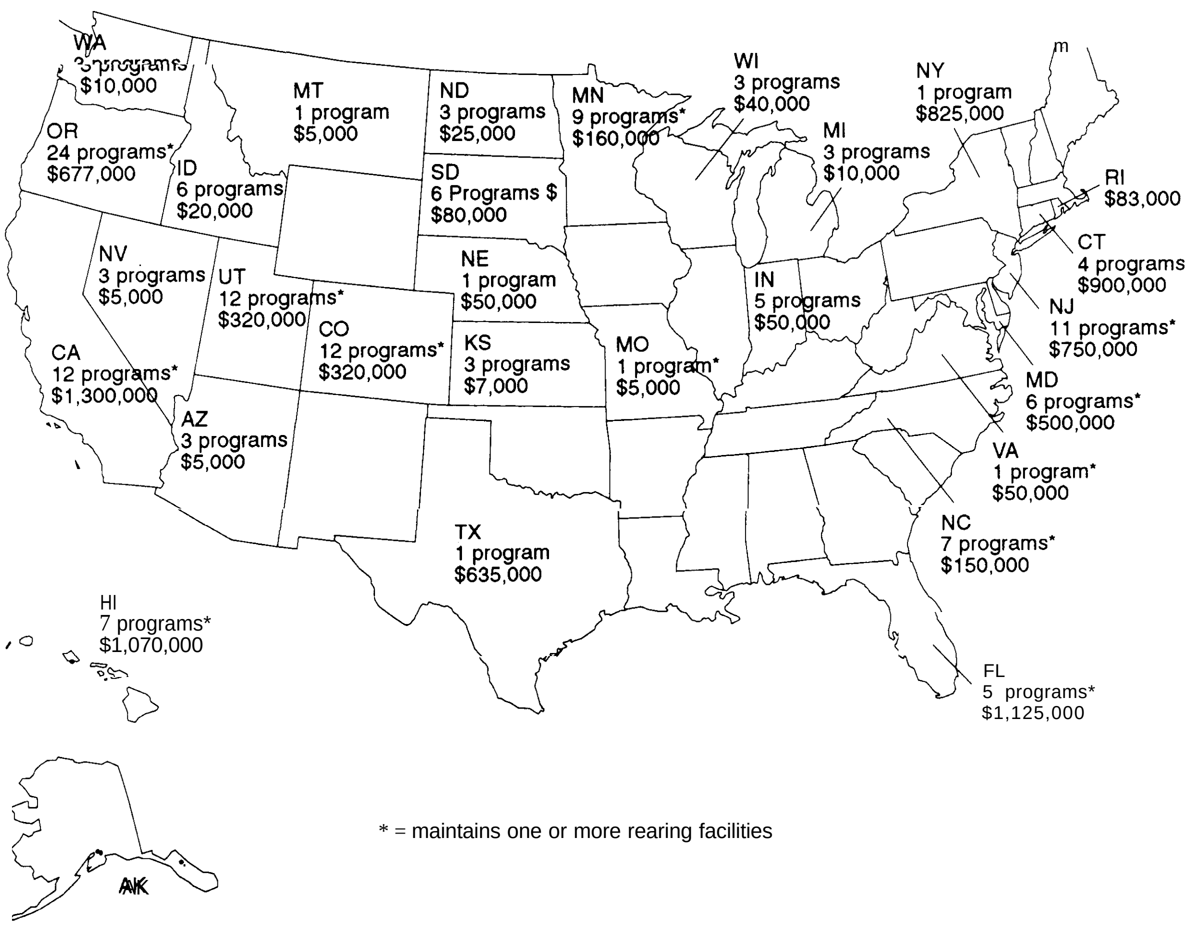
The states are involved in BBT research and implementation through several routes. They provide research matching funds for the State Agricultural Experiment Stations through CSREES and also directly fund experiment stations and land grant universities for BBT work. Precise estimates of the direct funding are unavailable, but the amounts are probably significant; state and private-sector contributions made up 86 percent of total funding for the State Agricultural Experiment Stations in 1990 (154). In addition, a number of state departments of agriculture have developed their own programs to research and implement biological control against important pests affecting their states. These state government programs are the focus of this section.

In recent years, state departments of agriculture have been increasing their use of BBTs in integrated pest management systems because of concerns about groundwater pollution, food safety, and pest resistance (228). Biological control, in particular, now plays a key role. Currently, 28 states have biological control programs, at a total annual cost of almost $10 million (figure 5-2) (228). Several states maintain insect-rearing facilities as part of these efforts, although budget constraints have caused some to close over the past four years; total state funding declined by $2 million from 1990 to 1994. California has the largest program; it is part of an overall movement within the state to reduce reliance on conventional pesticides (box 5-3).

State-funded BBT programs (most are applied classical biological control) generally work cooperatively with APHIS, the Agricultural Research Service, the Land Grant Universities, and the U.S. Fish and Wildlife Service (228). A

[10] The Experiment Station Committee on Organization and Policy is a subcommittee of a CSREES committee with representation from every State Agricultural Experiment Station.

FIGURE 5-2: Biological Control Expenditures and Programs in State Departments of Agriculture



SOURCES: Compiled by OTA from W.W. Metterhouse, Cream Ridge, NJ, "The States' Roles in Biologically-Based Technologies for Pest Control," unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, November 1994.

close relationship with APHIS results from common regulatory responsibilities and the location of APHIS operational staff within each state to assist with implementation programs. States depend on APHIS to provide educational services and deliver materials for field implementation (228). Once a released biological control agent becomes established, however, it usually becomes the state's responsibility to distribute the agent further, although sometimes APHIS continues distribution when a state cannot (320).

Since 1966 there have been a number of successful federal-state biological control programs. Of the 28 states with biological control programs, 22 have cooperative efforts with federal agencies. Successful programs include cereal leaf beetle *(Oulema melanopus),* involving USDA, ARS, APHIS, and the states of Michigan and Indiana; Colorado potato beetle *(Leptinotarsa decemlineata),* involving ARS and the state of New Jersey; and the gypsy moth programs, involving ARS, APHIS, the Forest Service and several states (228).

■ U.S. Department of the Interior

Historically, the resource management agencies of the U.S. Department of the Interior (DoI) conducted their own research to support manage-

BOX 5-3: California Takes an Active Role in Changing Pest Management Practices

California is perhaps the nation's leader in changing pest control practices and the adoption of BBTs. The state supports a diverse agricultural mix, with a significant emphasis on minor crops. Thus regulatory restrictions on pesticides and declining availability of minor use chemicals are expected to hit the state especially hard. Innovations in pest control practices have also been driven in part by its health-conscious population. California has a long history of involvement with biological control and IPM; it was the site of many of the most significant developments in the field, including the widely cited successful introduction of the vedalia beetle (*Rodolia cardinalis*) to control cottony cushion scale (*Icerya purchasi*) in citrus.

The changes occurring in California reflect an overall effort within the state to shift away from a reliance on conventional pesticides. They are not haphazard; California has actively sought to develop strategic goals and policies to accomplish them.

The California Environmental Protection Agency's program to regulate pesticides parallels that of the U.S. EPA. Its policies have an important influence on the decisions of pesticide manufacturers because of the size of California's potential pesticide market. The state now requires extensive reporting of pesticide use. It also licenses pest control advisors, who must be college-educated in an agriculture-related field, fulfill course requirements, and participate in continuing education. State regulators are currently considering a proposed requirement that pest control advisors undergo four hours of training in the use of biological control and natural enemies.

The California Department of Food and Agriculture has the largest state program for biological control. It maintains an insectary for rearing natural enemies, and programs to implement biological control, costing about $1.3 million annually. Recent projects have addressed euonymus scale (*Unapis euonymi*), grape leafhopper, and water hyacinth (*Eichhornia crassipes*).

The University of California is home to an active statewide IPM program that is perhaps the best in the country at promoting pesticide alternatives, including BBTs. Funded partly through USDA, this program sponsors hundreds of IPM research projects. It has been particularly effective at getting research results into the field: Of the 180 research projects funded between 1979 and 1988, about 43 percent resulted in pest control products or information that are now in use. A disproportionate number of the nation's experts in BBTs are on the faculty of the University of California, and many have collaborated with private consultants and growers to develop innovative approaches using BBTs.

Farmers within the state have developed their own ways of promoting pesticide alternatives. The publication *Farmer to Farmer*, written by and for farmers to share success stories in sustainable farming practices, originated in California. Regional organizations such as the Community Alliance with Family Farmers Foundation have worked with growers to develop biologically intensive farming practices such as the use of natural enemies and other BBTs in almond orchards. Not surprisingly, many of the biggest natural enemy companies are located in California.

SOURCES: C.M. Benbrook and D.J. Marquart, *Challenge and Change: A Progressive Approach to Pesticide Regulation in California*, contractor report prepared for the California Environmental Protection Agency, Department of Pesticide Regulation (Sacramento, CA: April 1993); Community Alliance with Family Farmers Foundation, "BIOS: A New Project Promoting Biological Almond Farming," Davis, CA, 1995; J.I. Grieshop and R.A. Pence, "Research Results: Statewide IPM's First 10 Years," *California Agriculture* 44(5): September-October 1990; M.L. Flint, et al., *Annual Report, University of California Statewide IPM Project* (Davis, CA: University of California, September 1993); M.L. Flint and K. Klonsky, "IPM Information Delivery to Pest Control Advisors," *California Agriculture* March-April, 1989; T.L. Jones, Special Assistant to the Director, Department of Pesticide Regulation, California Environmental Protection Agency, Sacramento, CA, personal communication, U.S. Congress, Washington, DC, July, 1995; W.W. Metterhouse, Cream Ridge, NJ, "The States' Roles in Biologically-Based Technologies For Pest Control," unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, November 1994.

ment functions. This arrangement changed with the formation of the National Biological Service, the newly consolidated research arm of the department that was established in November 1993 by an order of the Secretary of Interior.[11]

The National Biological Service inherited a somewhat mixed portfolio of BBT-related research programs. Most of these had grown out of specific concerns of federal land managers rather than any overarching program or stated goal to implement BBTs. For example, the National Biological Service is studying insects and fungi as potential controls for non-native invasive plants for the National Park Service and the Fish and Wildlife Service. Past efforts have included working with USDA and the National Park Service to evaluate bacteria for control of gypsy moth (427). Other related research projects are evaluating waterfowl and fish predation as potential controls for zebra mussel (*Dreissena* spp.), several species of flea beetle for control of leafy spurge, and several weevil species for control of purple loosestrife (*Lythrum salicaria*) (427). Expenditures by DoI on BBT research totalled around $1 million in fiscal year 1994 (181). This figure includes $85,000 to $100,000 in funds from the Bureau of Land Management "passed through" to help support the ARS weeds lab in Bozeman, Montana (290).

The Department of the Interior has only a few pest control programs using BBTs. These programs are scattered haphazardly throughout DoI within at least four resource management agencies. The Bureau of Land Management uses biological control on weeds in nearly all of the Western states. The weed targets include field bindweed (*Convolvulus arvensis*), gorse (*Ulex europaeus*), poison hemlock (*Conium maculatum*), diffuse and spotted knapweed (*Centaurea diffusa*, *C. maculosa*), yellow starthistle (*Centaurea solstitialis*), leafy spurge, and purple loosestrife. The lack of greater emphasis on BBTs within DoI is somewhat surprising, given the technologies' potentially high compatibility with management of environmentally sensitive areas. It may, in part, reflect the historical lack of emphasis on pest management among federal land management agencies (338). The result has been a growing belief among many managers that pests of natural and less managed areas—specifically nonindigenous species that kill, consume, parasitize, or compete with native species—are now significant threats to the biodiversity and continued value of these natural resources (338).

A number of DoI agencies are members of the Federal Interagency Committee for the Management of Noxious and Exotic Weeds mentioned earlier in the chapter (303,388). This group arose in response to new requirements in the 1990 Farm Bill[12] that all federal land managers develop programs for control of "undesirable plants." In addition, concern had been growing for some time among staff within the Bureau of Land Management that noxious weed problems were rapidly outstripping the Bureau's ability to manage them with conventional methods. The interagency group has representatives from four agencies in the USDA: the Forest Service, ARS, APHIS and CSREES; six agencies in DoI: the National Park Service, the Bureau of Land Management, the Fish and Wildlife Service, the National Biological Service, the Bureau of Reclamation, and the Bureau of Indian Affairs; the Department of Defense; and several other agencies. Among this group's stated goals is to increase the necessary research to discover and develop biological control agents for weed control (388).

DoI initiated several related efforts in 1995. The Secretary of the Interior designated a new task force to address noxious weeds specifically on DoI lands and issued a secretarial order requesting that DoI bureaus develop coordinated weed prevention and management strategies (290,303). The departmental manual's guidance

[11] CFR Vol.. 58, No 229 December 1, 1993, 63387.

[12] The Food, Agriculture, Conservation and Trade Act of 1990, P.L. 101-624.

on weed control was revised, and now specifies incorporation of integrated pest management, including biological control, into weed control programs. The revised guidance also established a committee to coordinate DoI weed control activities and instructed the National Biological Service to provide scientific information and research support for the DoI weed programs, including development of integrated weed management systems (303).

Army Corps of Engineers

The Army Corps of Engineers has had a research program on biological control of noxious and nuisance aquatic weeds since 1959, funded at around $1 million for the past few years. In cooperation with USDA, the Corps conducts research to identify natural enemies for weeds that impede navigation, restrict water flow, and dominate the natural system by the formation of single species stands. In the 36 years of joint research, the Corps believes that the program has been extremely successful. Scientists have released 12 biological control agents for the management of four plant species, including alligator weed (*Alternanthera philoxeroides*), water hyacinth, water lettuce (*Pistia stratiotes*), and hydrilla (*Hydrilla verticillata*). These programs cover 15 states. Corps scientists have also been involved in evaluating three potential pathogens for weed control. Aside from ARS collaborators, no one else in the federal government conducts similar work to address aquatic weeds.

Through the Department of Defense's membership in the Federal Interagency Committee for the Management of Noxious and Exotic Weeds, scientists from the Corps's aquatic weed program have recently become involved in developing systems to enhance implementation of weed control programs using BBTs and other methods (51). One project under way is the construction of a database of ongoing research on weed control. The other is development of an expert system that will eventually provide users with information on various options for controlling specific weeds, constraints on the use of these methods, and their effectiveness.

The Army Corps of Engineers program for biological control of aquatic weed, such as water hyacinth (Eichornia crassipes) *is one of two weed control programs slated for elimination in the current round of federal budget proposals.*

The Clinton Administration proposed eliminating the approximately $10 million budget for the Corps's aquatic weed program in its fiscal year 1996 budget proposal. As of August 1995, the fate of the program was as yet undecided in Congress.

Environmental Protection Agency

The Office of Research and Development of the U.S. Environmental Protection Agency (EPA) administers a research program to provide risk assessment tools. These research activities are undertaken in part to assist the EPA's Office of Prevention, Pesticides, and Toxic Substances during pesticide registration, special review, and review of premanufacture notices submitted by industry (107). EPA's research focuses primarily on microbial pesticides. Its purpose is to assist in making sound evaluations of the risks and benefits of microbial pesticides, including those based on bacteria, fungi, and viruses, and certain genetically modified organisms (398). Funding for microbial pesticide research at three EPA laboratories totaled $684,600 for fiscal year 1995. It included cooperative field studies with universities regarding the potential fate of microbial agents and their effects on terrestrial environments, food web interactions, ecosystem functions, freshwater populations, and nontarget marine and estuarine animals (107).

Other Federal Sources of Funding

The National Science Foundation and the National Institutes of Health provide a small amount of funding for BBT research, primarily on the natural enemies of arthropods and behavior modifying chemicals (247). Between 1989 and 1993 the National Science Foundation awarded an average of $1.5 million annually for research on biological control, and a total of $388,000 for research on behavior-modifying chemicals. The agency also provided several grants for studies of the systematics of parasitic Hymenoptera (a taxonomic group that contains a number of biological control agents). In 1993, the National Institutes of Health awarded $500,000 for biological control research and close to $1 million for research on behavior modifying chemicals (247).

Funds from several small programs of USDA also are potentially available for BBT research, although researchers have been somewhat disappointed in the level of BBT work supported by these programs (247). The Small Business Innovation Grants program funded one to three biological control programs per year between 1989 and 1992. The Alternative Agriculture Research and Commercialization center, whose charge is to aid in the commercialization of agricultural products for industrial use, contributed $170,000 to develop a microbial pesticide based on Bt in 1993. That same year, USDA's Sustainable Agriculture Research and Education program funded two biological control projects.

The Interregional Research Project No. 4 ("IR-4"), funded by CSREES and ARS, carries out the necessary research to supply data required for registration of pesticides (including microbial pesticides and pheromones) for use on minor crops. Over the 10-year period following the program's expansion in 1982 to cover "biorational" products, it supported research projects on 13 microbial agents (130). BBTs represent only a minor component of the program; most funds go to research on conventional pesticides (247).

EDUCATING USERS

In addition to direct administration of research and implementation programs, federal and state agencies affect the adoption of BBTs by farmers and other users. The major institutions involved are the Cooperative Extension Service and Land Grant University system. Decisions of users to adopt BBTs also may be influenced by produce standards, and other legal and financial mechanisms. Today, private consultants play an increasingly important role in pest control decisions, sometimes far surpassing that of government programs. This section begins by exploring farmers' perspectives and then examines some of the factors that influence their adoption of BBTs.

The Farmers' Perspective

Most farmers have little or no information on the efficacy, quality, economic feasibility or other aspects of BBTs (141,270). Even farmers who use these technologies often lack clear-cut instructions on how to apply them. Many BBTs are labor-intensive and their optimal use requires a significant amount of information (59) (see chapter 3). Few farmers will embrace technologies that seem to involve many inexact procedures and unknown consequences (6,240).

Farmers also lack information on their specific pest control options (271). Growers need information on what BBTs are available and how to obtain the best results using the technologies. Such information—custom-designed for the target audience and specific to the local crop, pest, and environmental conditions—is usually unavailable (79,253). In a survey of organic farmers, about 60 percent said existing information sources failed to meet their needs (260). In many cases such information has never been developed (292). Implementation of even the most effective BBTs suffers when the base of research on their application is inadequate.

Some of the well-known advantages of BBTs (e.g., superior environmental profiles, and lower susceptibility to resistance) accrue to the broader agricultural community rather than to the individual grower. Farmers may wonder whether it is truly in their personal best interest to switch to BBTs. Of more immediate concern to most farmers are the effectiveness, cost, and demonstrated success of the product, as well its ease of application, safety, compatibility with natural enemies, and other factors (49,114,135,179,213). Unlike conventional pesticides, many BBTs cannot be applied across wide areas with the expectation of consistent results (see also chapter 3) (253).

Despite their pragmatic concerns about cost-effectiveness, many farmers would prefer to use less chemical-dependent technologies (101). They are prompted in part by consumer demand, the development of pesticide resistance, the declining array of registered pesticides, economic considerations, and the growing awareness of the effects of chemical pesticides on local groundwater supplies. Environmental and occupational health concerns play a role as well. A 1992 study of 297 fruit growers in Michigan, for example, found that less than 1 percent planned to increase pesticide use, while 61 percent said they would decrease pesticide use in the future by adopting IPM or organic techniques (231). In some cases the use of BBTs and other IPM approaches has resulted largely from economic considerations. These practices sometimes prove economically superior to conventional approaches (238), for example, when pests become uncontrollable due to resistance or when pesticide use (and therefore costs) can be reduced through IPM.

Use of some BBTs has become widespread practice in certain crops and geographic regions (see chapter 3). In Florida a majority of cabbage growers use Bt rather than conventional pesticides against diamondback moths, because they want to conserve natural enemies such as lady beetles and lacewings (213). Florida growers often use pheromones as a scouting tool, but less frequently for trapping pests given the high costs of this technique. Roughly 30 to 40 percent of Florida strawberry farmers release predatory mites to control spidermites, and many citrus growers rely on parasitic wasps to control citrus snowscale (*Unaspis citri*) (213).

In California nearly 300,000 acres of citrus with low pest abundance have been set aside as biological control zones. Growers follow crop management practices that conserve the native natural enemies, and they also augment the biological control populations when necessary. According to the California Citrus Research Board, such orchards can be highly cost-effective, relying on natural enemy populations built up over many decades (18). But they are precarious arrangements; for example, natural enemy populations that had been built up over half a century in one Corona (California) orchard were destroyed by mass-spraying of malathion against the Mediterranean fruit fly (*Ceratitis capitata*). The growers subsequently abandoned the orchard (18).

Even a number of more prominent firms are interested in diversifying their pest control technologies (see figure 3-1 in chapter 3). The Dole Company rears predatory sixspotted thrips (*Scolothrips sexmaculatus*), while the Gallo Wineries use *Trichogramma* wasps, green lacewings, and predatory mites (270). The goal of Fetzer Vineyards is to produce or buy 100 percent organically grown grapes by the year 2000 (94). Campbell Soup Company has nearly eliminated the use of synthetic insecticides on its processing tomatoes in Sinaloa, Mexico, using pheromones, *Trichogramma* wasps, and Bt (38). Campbell's IPM efforts (box 5-4) show that IPM is feasible and even profitable on a crop for which some companies consider non-conventional methods neither promising nor practical (137).

For some crops and pest control needs, however, few BBT options exist. According to one blueberry growers' marketing cooperative in Michigan, commercial buyers do not tolerate *any* evidence of pest activity—a standard that few

BOX 5-4: Campbell Soup Company

Campbell Soup Company has dramatically reduced its reliance on conventional pesticides in certain regions by adopting IPM systems that incorporate BBTs, field scouting, and disease monitoring. The company employs its own in-house IPM specialists who conduct field research and put the programs in place.

Campbell's most active IPM efforts take place in tomato farming. The company has nearly eliminated synthetic insecticide usage and has reduced fungicide application by more than 50 percent in its processed tomato operations in Sinaloa, Mexico. Growers use Bt to control armyworm; *Trichogramma* wasps to control tomato fruitworm (*Helicoverpa zea*); and synthetic sex pheromones to disrupt the mating of tomato pinworms (*Keiferia lycopersicella*). Other IPM techniques include: selecting fields and planting times to minimize risks of virus diseases that are transmitted by whitefly pests; monitoring pest and natural enemy abundance using pheromone traps and scouting; and using a computerized disease forecasting system that tracks hourly temperature and leaf-wetness to pinpoint when to spray fungicides to control late blight. Taken together, the IPM programs in Sinoloa save an estimated $400 per hectare when compared to conventional pesticides.

Campbell Soup encourages its U.S. tomato growers to use IPM, but the level of adoption trails its Mexico operations. Comparison of the company's operations in Sinaloa and California illustrates how locational differences—such as labor costs, infrastructure, and pest pressures—can affect adoption of BBTs and IPM. In Mexico, the company conducts monitoring and other IPM activities for the grower, while in California, the choice of pest control method rests with the individual farmer. The company encourages California growers to reduce pesticides and offers education programs. Campbell Soup also demonstrates BBTs and other IPM techniques in growers' fields, with the company assuming all financial risks for drops in yield during the experimental period. In Mexico, low labor costs make more labor-intensive techniques cost effective, such as those involving pheromone dispensers, natural enemies, and scouting. Also, the absence of native natural enemies in Sinaloa makes augmentative releases essential; in northern California the native natural enemies partially protect tomatoes against fruitworm and other regional pests.

Campbell Soup Company relies heavily on land grant universities and extension in developing its IPM programs and educating California growers. The company actively seeks out researchers whose work is relevant and provides small grants to direct their attention to particular issues.

SOURCES: H.A. Bolkan, "Campbell Soup Company Integrated Pest Management," *IPM Monitor,* Summer, 1994; Campbell Soup Company, Integrated Pest Management Research and Implementation, "Economic Profitability and Environmentally Compatible Alternatives," *Products and Progress Report* 1994–1995; R.K. Curtis, Campbell Soup Company, Sacramento CA, letter to Eduardo Martinez Curiel, Consul of Mexico, February 1, 1994; R.K. Curtis, Campbell Soup Company, Sacramento, CA, personal communication, Summer 1995; P. Marrone, President, Novo Nordisk Entotech, Davis, CA, personal communication 1995.

BBTs can attain (see also chapter 3) (331). Consequently, the only suitable BBT presently available is Bt for use against cranberry fruitworm (*Acrobasis vaccinii*) and leaf rollers. Growers would like more BBT options, particularly for major pests such as blueberry maggot (*Rhagoletis mendax*), Japanese beetles (*Popillia japonica*), and the many diseases affecting blueberries (331).

Technology Transfer to End Users

The Government's Role Through Extension

The principal governmental provider of direct, hands-on assistance to growers is the Cooperative Extension Service. The system is made up of federal personnel at the USDA Cooperative State Research, Education, and Extension Service (CSREES), as well as state and county-level agents. These components are often loosely coordinated through the land grant colleges. Extension is represented in nearly all of the nation's 3,150 counties (342). However, private pest control consultants seeking assistance in solving difficult pest problems frequently bypass county agents in favor of the more technically educated state specialists (412). Each state runs its extension program differently. In Vermont, for example, all extension is closely tied to the state university, while in New York State each county runs its own program, even though all are officially under the umbrella of the Cornell Cooperative Extension (121).

Although extension programs historically played a key role in farmers' pest control decisions, today this role is minimal in most states (114). In general, the Cooperative Extension Service is financially strapped and the workforce spread thin among multiple responsibilities, ranging from programs aimed at preventing pregnancy and drug use, to nutrition education for low-income families. Despite the recent retirement of many "old guard" extension agents, who entered the land grant colleges after World War II and were trained in conventional pest control, the more recently educated and, in some cases, IPM-oriented agents may have only limited opportunity to bring nonchemical practices to the field (98,166).

Most extension agents have had little if any formal exposure to biologically based approaches (207). The relationship between the Agricultural Research Service and Cooperative Extension is a distant one (114), and many of the extension-affiliated land grant colleges offer at most minimal training in BBT use.

Moreover, in many parts of the country, the limited amount of research on applications of BBTs provides little locally generated and regionally relevant information (97,207). Consequently extension specialists often do not have many "field-ready" BBT options. They also lack the resources to do the applied research needed for implementation. Many extension personnel feel caught in the middle between a clientele who asks for pesticide alternatives and a research pipeline that fails to deliver effective, ready-to-use technologies (180).

This inadequacy helps explain the lack of detail found in most of the educational materials produced by the 27 states that support biological control as part of their IPM programs (97). A small, informal survey of randomly selected states in the Northeast, North Central, South and West found tremendous variation among the states in their extension publications' educational value to growers regarding BBTs (247). Of the 13 states sampled, New York consistently topped the ratings; it was the only one having extension manuals devoted solely either to natural enemies or to pheromones (247). Another small survey that evaluated extension publications from the North Central states concluded that the coverage is usually too perfunctory to provide the skills necessary to adopt biological control (207).

In fiscal year 1995, CSREES received approximately $14 million in appropriations for extension work in IPM research and implementation. It is uncertain whether increases in this area proposed under the USDA IPM Initiative for fiscal year 1996 will occur (see box 5-1). In contrast, at least in certain regions of the country, extension scientists expect increased responsibilities in this area; according to a 1994 survey of 38 extension entomologists in North Central states, most spend slightly more than 10 percent of their time on classical biological control programs, but they expect this percentage to triple over the next decade. Most of the agents also reported an increase in questions from growers about biological control and pesticide reduction (207).

Private Pest Control Advisors

In most regions, the Cooperative Extension Service now plays a role that is secondary or intermediary to that of the private information sources such as pesticide dealers, pest control advisors, crop consultants, and pesticide applicators (253). Extension agents may develop demonstration projects and training activities for growers and commercial crop consultants, and sometimes they validate private sector recommendations or investigate unusual pest outbreaks. But most growers rely far more on private sector advisors than on government agricultural experts (253). The lack of funding for extension activities at universities has strengthened the private pest management business (270). Often the Extension agents are far outnumbered by private advisors (291). Large farm operations, which can spread the cost of obtaining information over more units of production, depend particularly heavily on private consultants and can afford to hire the very best (see box 5-4) (141).

Most private advisors have been educated with an orientation toward conventional pesticides. Most are not well versed in biologically based methods—around 5 percent, according to some natural enemy companies (269). The extent to which advisors use BBTs varies tremendously; some are eager to embrace these technologies but do not have adequate information or find that few biological approaches suit their pest control needs. Some advisors lack confidence in the BBT options and do not want to harm their reputations by recommending a technology that they themselves question (282).

Moreover, most private pest control advisors are affiliated with the chemical industry. There are also about 3,500 "independent" consultants who do not work for chemical suppliers (340). In California, for example, about 200 (less than 10 percent) of the pest control advisors who are active in agriculture are considered independent; the rest work for chemical companies, distributorships and applicators (141). In a few states, such as California, Arizona and Florida, some of the pest control advisors specialize in BBTs (435). Independent consultants charge growers a fee, averaging from $3.75 per acre for wheat to $17.40 per acre for vegetables (340), whereas those affiliated with pesticide companies offer free advice as an incentive for product purchases.

Independent consultants may be more inclined than industry-affiliated advisors to recommend nonchemical technologies. A study of pest control advisors in California found that those not involved in the sale or application of pesticides were much more likely to seek help from the extension personnel than from pesticide company representatives or other information sources (102). A 1994 nationwide survey of the farmers under contract with independent consultants found that 20 percent of the vegetable growers were releasing beneficial insects and 39 percent were using pheromones (340)—rates of use substantially higher than the national averages (e.g., ref. 377).

Few states have licensing requirements for private pest control advisors (309). Many advisors are, however, certified by professional societies such as the American Society of Agronomy and the National Alliance of Independent Crop Consultants (7,16,166). The societies have developed certification standards to eliminate the need for government intervention. These standards vary among states. No state government requires pest control advisors be trained specifically in BBTs (5), although such training has been proposed in California (see box 5-3). Likewise EPA has no certification requirements for private pest control advisors and offers no guidance to the states in this area (431).

EPA does annually pass through about $2 million to CSREES for development of model curricula for training pesticide applicators (370). These curricula suggest including a section on IPM, although very little specificity is included regarding what techniques might be covered. The curriculum, with modifications related to state laws, is used by the Cooperative Extension Service in all states to annually train over 500,000 private, commercial, and urban pesticide applicators (370). Under the Federal Insecticide, Fungicide and Rodenticide Act, however, EPA is barred from requiring IPM training for licensing of pesticide applicators. Pesticide applicators unfamiliar with BBTs might pose an obstacle to growers interested in experimenting with these technologies.

Other Factors Affecting the User's Choice

A number of institutional factors and marketplace forces may also affect farmers' pest control decisions. The precise influence of most has not been rigorously documented. For example, the market for foods grown with reduced or no pesticide use, and the prices consumers are willing to pay for these foods, may affect whether and how great a cost farmers are willing to incur in switching to pesticide alternatives. Bankers who are unfamiliar with IPM or BBTs and who perceive the methods as presenting a higher risk of crop failure may be unwilling to approve agricultural loans to farmers who use these methods (435). Some growers worry that use of IPM and BBTs may be impeded by the new Worker Protection Standards recently issued by EPA that increase the amount of time after pesticide application during which agricultural workers are barred from reentering fields. The required delay will prevent growers and crop consultants from reentering fields shortly after spraying to scout for remaining or fresh pest populations; some growers argue the lack of immediate monitoring will force them back to calendar spray schedules (31).

Perhaps the most commonly discussed influence is cosmetic standards. Federal, state, and private grading standards for specific attributes such as the shape, color, and surface defects of fruits or vegetables may also drive certain pest control decisions. USDA grades for fresh fruits and vegetables, commonly specified in business contracts, are required under some federal marketing orders establishing minimum standards, as well as for produce sold to the federal government and for certain commodities imported and exported (380). Most retailers buy only produce of the highest USDA grades to ensure adequate appearance (297). In addition, some states have standards for certain crops, and many firms, such as Sunkist, have private standards for fresh produce. The failure to meet particular grading standards can lead to downgrading or to loss of access to the fresh market altogether, and consequently a substantial loss of income (298).

Produce standards in many fruit, vegetable and nut crops are also affected strongly by export markets. For example, about 40 percent of California citrus is destined for Asian and European consumers. Cosmetic standards for these markets are far higher than those in the United States, making use of conventional pesticides almost unavoidable for produce intended for export (18).

The extent to which growers use conventional pesticides to meet cosmetic standards remains controversial, however (189,298,380). Some studies suggest that a grading system which emphasizes external appearance may leave growers and packers little choice but to apply large amounts of conventional pesticides. Some surveys of apple and citrus growers report, for example, that for a majority of growers at least half of their pesticide usage is to attain a suitable cosmetic appearance (298). Although citrus is a crop that lends itself well to BBTs (18), in parts of California no BBT can fully control the thrip and red scale pests responsible for cosmetic blemishes. Fruit going to the processed market sometimes has been treated with the same amount of conventional pesticide as that going to the fresh market by growers hopeful that most of their fruit crop will be accepted in the fresh market (92,298).

Production arrangements vary in the extent to which they direct the grower to use particular pest management approaches; most only require that the final product meets certain standards, although some are quite specific (21,83). In general, processors are more likely than fresh commodity buyers to specify the desired pest control method in a grower agreement or contract (213). However, the degree of producer control can vary greatly, even within a particular crop for a particular use. The variation reflects differences among growers and firms in management skills, access to credit, and risk preferences (435). For example, three California firms handle more than 75 percent of US fresh carrot production. Their production arrangements with growers range from some that give virtually complete control over pest control, to others that cover only the purchase of output.

FROM RESEARCH TO IMPLEMENTATION

Chapter 5 has shown that the federal government supports sizable efforts on the research and implementation of BBTs, funded annually around $210 million. Despite these efforts, applications of BBTs in the field are relatively few (chapter 3). And a significant gap lies between the research on BBTs and its use—a gap referred to by some long-time observers as the "valley of death." The problem characterizes BBTs in other countries as well (e.g., box 5-5). Here OTA identifies some of the major reasons for this chasm and suggests options that might help provide solutions.

Coordination Is Needed to Enhance Delivery to the Field

A lack of necessary coordination between research and implementation was the most prominent problem identified by every workshop and advisory panel convened during the OTA assessment, and by dozens of scientists and representatives of federal agencies. The issue is not simple;

BOX 5-5: Connection between Research and Implementation in Australia

U.S. scientists often point to Australia as a potential model for the United States to emulate in the regulation of biological control. It is unclear, however, whether differences between the U.S. and Australian regulatory systems have had a significant impact on the relative adoption and success rates of biological control or other BBTs. Although Australia is thought to be several steps ahead of the United States, both its research and its implementation efforts appear to confront many of the same obstacles plaguing U.S. programs—most notably, low rates of success, adoption, and commercialization. Despite regulatory developments, discontent about the screening and approval process for introductions remains prevalent.

The Australian government has instituted several national policy initiatives that have removed some of the regulatory obstacles that American scientists and natural enemy companies claim inhibit the success of biological control in the United States. The result, however, has not been greater use or commercialization of BBTs. A series of complete and partial successes have kept BBTs in the public eye and in demand, but private-sector involvement remains minimal. Research results are not getting into the community for widespread use, and the Australian government has been ambivalent in its attempts to improve the situation.

In 1989 the Australian government spent only a small percentage of its pest control research budget on BBT research and implementation—$20 million, an amount equivalent to approximately 2 percent of the funds spent on chemical research. Although there is widespread acceptance of the need to encourage BBTs, there is little in the way of explicit directives, and resources are still limited. The government does not give any subsidies to encourage BBT use, and support for redistribution of biological control agents and implementation projects and resources is still inadequate. The only potential government incentive for growers to adopt BBTs is the increasing restriction on conventional chemical pesticides. This incentive may eventually become strong, but it has not yet had much impact on growers.

The Australian government has several policies that help link research to implementation. One of the conditions of government funding is that recognition be given to the importance of long-term research and research for public benefit. Consequently, Australian scientists often integrate the implementation phase with the initial research. Both the central government and the state governments encourage research agencies to promote their work on BBTs more publicly. Nevertheless, farmers and researchers alike realize that the results are not getting out to the field.

SOURCE: J.M. Cullen, and T.E. Bellas, Division of Entomology, CSIRO, Canberra, Australia, "Australian Laws, Policies, and Programs Related to Biologically Based Technologies for Pest Control," unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, March 1995.

this need for coordination occurs on several levels. In general, ad hoc interactions among scientists from various government agencies and universities working on BBTs have been quite good. Problems arise, however, when institutional coordination is necessary.

Interdepartmental Coordination

In the 1990 Farm Bill, Congress directed EPA to coordinate with USDA in identifying pressing national needs where shortages in pest control methods are likely to occur through the loss of conventional pesticides. The most obvious causes of such shortages are the lack of reregistration of chemicals for minor use crops and pesticide resistance (see chapter 2). USDA was instructed to address these priorities through its research and extension programs.[13] In 1994, the Secretary of Agriculture and the Administrator of EPA signed a memorandum of understanding belatedly agreeing to collaborate in exchanging necessary information on upcoming pesticide losses (403).

OTA has not been able to identify any clear mechanism by which such priorities are consistently identified and acted upon in the development of the portfolio of USDA-funded research on BBTs. The first step would be to improve the information exchange between USDA and EPA.

OPTION *Congress could, through its oversight functions, encourage USDA and EPA to act on their recent memorandum of understanding.*

OPTION *Congress could specify and provide direct appropriations (perhaps as a proportion of the funds requested for the USDA IPM Initiative) for USDA and EPA to collaborate in developing and maintaining a database on upcoming pest control needs (resulting from pesticide loss and resistance) and available alternatives for filling these needs. Careful consideration would need to be given to the appropriate institutional site for this function; the database would require sustained support. It should be constructed to ensure universal accessibility and also so that it can provide guidance for the funding decisions of research agencies.*

In December 1994, Argonne Laboratories, under contract with the Cooperative State Research, Education, and Extension Service began developing the software for a database that would incorporate state information on the use of various pest control methods and EPA data on pesticide reregistration (289). CSREES hopes the database will one day include information on pesticide resistance and USDA research, and that it will eventually be supported by states and users. Should Congress decide to designate this database as the national repository of information on pending pest control needs, some early adjustment might be needed to make sure it fulfills the criteria just discussed. For example, CSREES should consult with the Agricultural Research Service and other agencies to ensure that the database is constructed so that it can inform their decisionmaking regarding research priorities.

Providing for Follow-Through in the Research

The Agricultural Research Service (ARS) and the State Agricultural Experiment Stations fund most of the research on BBTs. In both cases, the science usually is generated “bottom up.” National goal-setting mechanisms lack funding authority and therefore have little direct influence over the research agenda. The decision processes of ARS and the State Agricultural Experiment Stations have the advantage of keying research to regionally identified problems. Where they fall down, however, is in their ability to address externally identified strategic needs. This is particularly a problem for work on BBTs. A vast array of pest management questions deserve scientific investigation. The diffuse mechanisms for generating research projects and the limited funds available cannot help but result in a research portfolio that is dispersed and lacks coordination.

One consequence of the scatter is that some of the research components necessary to enable the practical uses of BBTs are not addressed. The application of any given BBT against a specific pest problem results from research ranging from

[13] Under the Conservation and Research Titles of the 1990 Farm Bill.

fundamental aspects of the pest problem to details of how the BBT is applied. The latter has consistently been underemphasized. OTA fully acknowledges the value of more fundamental research and is not addressing whether the current allocation here is appropriate. But it is clear that not enough attention has been given to the essential research to take BBTs out of the hands of scientists and into those of farmers and other users. Historically, no research agency has identified this function as its responsibility. Extension scientists might have been logical candidates but have not assumed this role (84).

Another consequence of the funding processes of the ARS and the State Agricultural Experiment Stations is that the agencies have difficulty responding to externally generated research needs, such as those identified by operations agencies. Despite clear-cut institutional responsibilities, ARS has not always delivered solutions that are field-ready to APHIS; as a result, APHIS has developed its own research capabilities for adapting BBTs originally identified by ARS and others for larger-scale field use. Similarly, the needs of the land management agencies for BBTs to use in weed control have been met only by a small scale effort at ARS, even though weed-infested lands are extensive and represent a significant national problem. In part, this reflects the fact that agencies within the Department of the Interior (DoI)—the Bureau of Land Management in particular—lack pass-through funds that they could allocate to ARS for the related work. Future needs of the DoI agencies may be particularly acute because their research agency, the National Biological Service, lacks support in the current Congress and has been targeted for downsizing, elimination, or merger.

The difficulty that USDA's major research agencies have in responding to externally identified priorities does not bode well for how the agencies will deal with impending pesticide losses through reregistration or pesticide resistance, even if this information is made readily available through better coordinated efforts with EPA. This has special significance for BBTs because these technologies are most likely to be adopted where conventional pesticides disappear (see chapters 3 and 6).

Experience has shown that research flows more expeditiously into applications of BBTs when directed funds circumvent the normal, highly structured, institutional processes. OTA's options attempt to build on this experience.

OPTION *Congress could direct the Agricultural Research Service to allocate a proportion of its BBT funds to a targeted competitive grants program within the agency. These funds would be available for collaborative research projects that provide the follow through into field applications. Evaluation of the needs of farmers or other users at the inception of the research and of ways in which the BBT would meet this need would be essential to ensure real-world applicability. The size of this effort would need to be balanced against its potential effects on the agency's capability to conduct longer-term studies.*

OPTION *Proposed research funding for fiscal year 1996 provided through CSREES under the USDA IPM Initiative has taken this approach to ensure "buy in" by researchers, farmers, and others involved in all phases of the development and implementation of IPM programs (see box 5-1). Congress could fund this research initiative. Its potential influence on BBT research is unclear, however, because the role of BBTs in the IPM Initiative has not been explicitly stated. Hence, funding of the research component of the IPM Initiative would affect BBTs only if Congress instructed USDA to identify the role of BBTs or to allocate a proportion of the program for IPM research that incorporates biologically based approaches (i.e., biointensive IPM).*

OPTION *Congress could increase the accountability of the Agricultural Research Service to the operations and land management agencies by designating funds within these agencies for pass-through to ARS for meeting their operational needs. Because new funding is unlikely in the current fiscal climate, these funds would have to be derived from the current budgets of these agencies.*

OPTION *Alternatively, Congress could allocate to the operations and land management agencies "redeemable credits" toward research that targets* *their needs by the USDA research agencies. These credits would obligate the research agencies to conduct a specified amount of research to meet the needs of the operations and land management agencies, but no exchange of funds would occur (i.e., funds would remain in the research agencies). The research agencies would have to be informed, during their appropriations processes, of their obligations, and some tracking mechanism might be necessary to assure accountability for conducting the work and producing results according to the agreed priorities.*

OPTION *Congress could improve the match between ongoing research and the needs of farmers by requiring research agencies to seek input from farmers and other users into funding decisions. For example, representatives of user groups, commodity groups, etc., could sit on funding panels or make recommendations to the Deputy Administrator of the National Program Staff of the Agricultural Research Service.*

OPTION *Congress could create a competitive grants program specifically targeted toward BBTs that are well researched but not yet in practical use. The goal would be to invest in bringing research discoveries that currently lie unused into the field, particularly those of high technical merit but likely to yield profits too low to be of commercial interest. Such funds might be administered through CSREES, perhaps as a part of its extension functions. Although new money would be required to set up the program, it would be very cost-effective, because only technologies on the verge of application would be funded. The same type of targeted funding mechanism currently underlies the Cooperative Research and Development Agreements under which private-sector companies invest in government research (see also chapter 6 for further options related to CRADAs). However, those agreements primarily address research that is amenable to commercial development.*

Coordination of Biological Control

Coordination of biological control research poses separate but related problems. Researchers point to dwindling resources and institutional obstacles as significant reasons why current rates of success in classical biological control are low (58) (see chapter 3). At the same time, the numbers of people and organizations conducting biological control are growing ever larger. Numerous small companies also rear and sell natural enemies (see chapter 6). In the past, scientists at the Agricultural Research Service and universities conducted most biological control introductions. Today, federal, state, and county government agencies responsible for pest control carry out their own programs, often in the rush of addressing a new, high-cost pest, such as the Russian wheat aphid.

Research scientists worry that the quality of biological control work will suffer as it becomes increasingly dispersed. The consequences might include increased introduction of ineffective agents, greater potential for introduced agents to interfere with one another, and a further lack of adequate monitoring to evaluate effectiveness and nontarget impacts. Moreover, poor coordination of biological control programs among government agencies can result in replication of effort; conversely, the agencies sometimes end up working at cross purposes (see box 5-2).

Better coordination of biological control work would increase the potential for success and reduce the costs and risks (82). Biological control is worth supporting because of the high potential payoffs when it succeeds. By coordination, researchers usually mean disseminating information about ongoing work, enabling collaborative efforts, making research findings readily available, and maintaining good databases of biological control introductions and their results. Good databases are essential to develop biological control into a more predictive science (see chapter 3). In addition, good research in biological control requires support over a period of years, far longer than is the norm in most funding cycles. What biological control workers seek is a centralized administration that would coordinate the various sequential and interdependent activities required for a biological control program, including assistance with satisfying regulatory requirements. Such coordination could incorporate private sector involvement in the production and dissemination of natural enemies (see chapter 6 options). It might also deal with use of biological control in non-agricultural habitats, such as in wilderness preserves and aquatic ecosystems. The coordinating mechanism might range from an organization that simply coordinates information and needs to a single entity responsible for all aspects of biological control research and implementation.

The harshest critics say that the necessary coordination is virtually nonexistent today (58). In fact, two USDA entities, the National Biological Control Institute (in APHIS) and the Interagency Biological Control Coordinating Committee (IBC^3) were designed for this function. Neither fulfills it perfectly—the institute because it is located within an operations agency and lacks funds and authority; the committee because it has largely ceased to function.

Representatives of the Agricultural Research Service suggest that their agency, through its National Program Staff, should be the coordinating site (320). However, ARS has not shouldered this responsibility under its existing structure, and this option would suffer the same (real or perceived) problem as the National Biological Control Institute—it would place responsibilities for coordination within a single agency having its own vested interests.

OPTION *Congress could select either the National Biological Control Institute, the Interagency Biological Control Coordinating Committee, or a new unit (perhaps incorporating both organizations) as the institutional site for national coordination of biological control. Selection of the National Biological Control Institute would require its elevation to a higher level within USDA, because its current position makes it accountable to the priorities of one agency (APHIS). Selection of the Interagency Biological Control Coordinating Committee would require revitalizing the now inactive committee. Specific coordinating responsibilities and appropriations would need to be assigned to whatever organization is selected.*

OPTION *Alternatively, Congress could create a centralized agency responsible for all federal activities related to biological control. This option seems only remotely feasible today, because biological control programs are dispersed throughout at least eight agencies, in many cases related directly to their pest control responsibilities.*

OPTION *Congress could strengthen and stabilize the new biological control program within the National Research Initiative, and also make provisions so that CSREES could fund some projects of long duration rather than the five-year grants the agency says are mandated by current law. Note that the National Research Initiative program on biological control has not received strong support from the current Congress and might be eliminated in fiscal year 1996.*

OPTION *Should Congress choose to fund the USDA IPM Initiative, it could stipulate that the designated organization for coordinating biological control be a participant. Even without designating a coordinating organization, Congress could require that the National Biological Control Institute be involved in the initiative to help integrate biological control and IPM programs (see also chapter 3 for discussion of problems related to a lack of coordination between biological control and IPM).*

OPTION *Congress could direct USDA to maintain a consistent and comprehensive database on biological control introductions. Several different institutional sites might be possible. Previous attempts at developing such a database in the Agricultural Research Service suffered from erratic support. The history of poor documentation and recordkeeping by the APHIS regulatory unit that permits biological control introductions (see chapter 4) makes it seem an equally problematic site at this time; although whatever data are developed by APHIS via the permitting process should be incorporated into the biological control database. Other possibilities include the National Agricultural Library or the National Germplasm Program. Development of a biological control database could occur even if no coordinating structure for biological control is designated.*

Addressing Currently Unmet Research Needs

Although this report does not seek generally to address details of what specific BBT research should be conducted,[14] gaps in two areas have

[14] In part this is because the upcoming report from the National Research Council should do a thorough analysis of this topic.

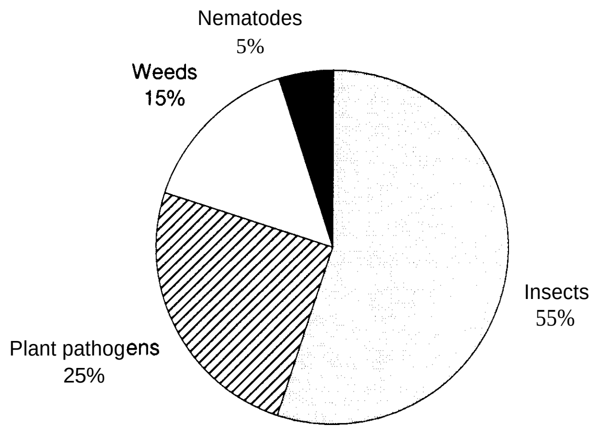
become particularly obvious during the course of the assessment. First, examination of the proportion of federal funds going to research on various categories of pests shows an obvious slant towards insect pests (figure 5-3), Weeds receive a disproportionately small allocation, even though herbicides represent the single greatest category of pesticide use in the United States, accounting for approximately 59 percent of pesticides used in agriculture and 57 percent of overall pesticide use[15] (399). The emphasis on insects may be a historical artifact of when BBT research developed, because the widespread use of herbicides is a relatively recent practice in U.S. agriculture. Nevertheless, it means that a significant category of pests currently receives relatively little attention. In the absence of any action, this pattern is likely to continue; the executive branch's budget proposal for fiscal year 1996 eliminated funding for the ARS biological control of weeds project in California and the Army Corps of Engineers program for biological control of aquatic weeds.

A second major gap is the followup and monitoring of BBTs, especially biological control. Very little of this type of work is conducted in the United States. According to biological control workers, such research will be essential to develop better predictive capabilities and therefore streamline biological control projects (see chapter 3). The lack of followup has another important consequence. It makes evaluation of the potential nontarget impacts of BBTs exceptionally difficult to assess, resulting in a regulatory system based more on assumptions about safety rather than on documentation to that effect (see chapter 4).

OPTION: *Congress could direct the Agricultural Research Service and the Cooperative State Research, Education, and Extension Service to allocate a greater proportion of their research funding toward control of weeds,*

OPTION: *Congress could direct all federal agencies that conduct or fund biological control programs to initiate or fund monitoring projects, especially for higher risk categories (see chapter 4 for discussion of risk categories). One way this might be accomplished is to give higher priority to research projects that include a monitoring component.*

FIGURE 5-3: Distribution of Federal BBT Research According to Pest Type (1994)



SOURCES: D.M. Gibbons, The EOP Foundation, Inc., Washington, DC, Report on the Role of the USDA in Biologically-Based Pest Control Research, " unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, January 1995; J.R. Nechols and J.J. Obrycki, Kansas State University and Iowa State University, "OTA Preliminary Assessment of Biological Control Current Research, " unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, January 1994,

NOTE. EPA, APHIS, and states are not included because research and development could not be identified by pest type

Maintaining the Necessary Level of Technical Expertise

At a nationwide scale, technical expertise is lacking in certain key areas for the development and implementation of BBTs. For example, two significant obstacles to increased use of BBTs are the lack of adequate incorporation into 1PM programs (see chapter 3) and the paucity of related information about BBTs available to users. Part of the problem lies with the lack of staff adequately trained in BBTs and 1PM within the Cooperative Extension System.

15 Percentages calculated according to weight of active ingredient.

A second area where adequate expertise is disappearing is the field of taxonomy and systematics. The number of qualified taxonomists is shrinking; yet the discovery and development of new biological control agents, because of their specific nature, relies on accurate taxonomy—the identification and classification of living organisms (142,186).[16] Funds and resources for taxonomy and biosystematics are difficult to obtain, and critics say the science is considered to have relatively low priority among ARS administrators (58). According to the natural enemy industry, only one U.S. scientist can identify various species of *Trichogramma* wasps that are among the most commonly sold natural enemies in the United States. Incorrect identifications can lead to a mismatch of biological control agents with their pest targets, or to poor control agents unintentionally being sold as natural enemies. Moreover, an accurate and knowledge-rich classification is essential to enable a more predictive approach to biological control (186).

OPTION *Congress could support education in IPM through the Land Grant University system. Various approaches might be possible, for example, funding graduate fellowships in IPM.*

OPTION *Congress could direct the Agricultural Research Service to increase resources and staff slots allocated to the Biosystematics Laboratory for work related to biological control.*

OPTION *Postdoctoral fellowships from APHIS's National Biological Control Institute have been used successfully to support U.S. taxonomic work. Congress could direct APHIS to allocate a larger share of its biological control funding for this purpose.*

Educating and Influencing Users

A significant weak link in the implementation of BBTs is getting farmers to experiment with these technologies. Many lack sufficient information to make informed decisions, and the available technical support may be strongly biased in favor of conventional approaches. Today, extension's direct role in educating farmers about pest control has been dwarfed by that of private consultants. Congress could help improve access of private consultants to information on BBTs and IPM in several ways.

OPTION *The Federal Insecticide, Fungicide, and Rodenticide Act prohibits the federal government from requiring training in IPM for certification of pesticide applicators. Congress could amend the act to rectify this situation and require that pesticide applicators be knowledgeable in the full range of pest control options, including BBTs.*

OPTION *Several different types of consultants affect pesticide use decisions. Several professional associations influence the types of information these consultants provide through training programs and certification standards. Extension has worked with at least one society, the Agronomy Society, to help integrate IPM into their certification program. Congress could encourage similar efforts through the Cooperative Extension System, perhaps by providing targeted competitive funds for projects that involve collaboration between extension personnel and professional societies to integrate BBTs and IPM into training programs or certification standards.*

Certain financial incentives are thought to sway farmers' decisions in favor of conventional pesticide-based methods, such as cosmetic standards. In addition, constraints on the availability or cost of conventional pesticides affect the array of affordable pest control options available to farmers. Several agricultural economists have suggested that markets for BBTs could be expanded by creating incentives for farmers to use these approaches or disincentives to use conventional approaches (e.g., taxing conventional pesticides).

One problem with this approach is it assumes the availability of BBTs is directly driven by market forces. However, BBT research, especially in certain areas, is primarily publicly funded at this time. OTA has found that clear

[16] Taxonomy is part of the larger field of biosystematics that examines broad aspects of the relationships among living organisms (species and higher taxonomic categories like families).

mechanisms have not existed to match this research to the needs of farmers or other users. Policy changes that increase the demand for BBTs, but neglect to improve the supply of BBTs coming through the pipeline, might be a set-up for failure. Adjusting the research agenda to better ensure that BBTs make it into the hands of farmers and other users will be an important part of policies that seek to decrease pesticide use.