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Overview and Future Direction of Biological Control Technology

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ABSTRACT

The Corps of Engineers (CE) biological control technology area had its beginnings in 1959 when the CE and the U. S. Department of Agriculture began a cooperative research effort. Since then, numerous insects and pathogens have been studied as potential agents for the management of target plant populations. Researchers have traveled to the countries of origin of six target plants (*Eichhornia crassipes* Mart. (Solms), *Alternanthera philoxeroides* (Mart.) Griseb., *Myriophyllum spicatum* L., *Pistia stratiotes* L., *Hydrilla verticillata* (L. F.) Royle, and *Melaleuca quinquenervia* (Cav.) S. T. Blake) to search for host specific agents. As a result, 13 insect biocontrol agents have been released as management tools for five of these targets. On average these projects have developed one agent every 2.9 years. The CE also has conducted pathogen biological control research using endemic pathogens. More recently the CE has begun classical biocontrol studies using exotic pathogens as potential agents of aquatic plants. Research in the near future will be directed at the management of submersed aquatic vegetation. The past successes will be used to assist in directing the program, however, new emphasis will be placed on the development of more effective evaluation procedures to document impact of the biological control agents.

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INTRODUCTION

Exotic aquatic plants have caused significant problems in the United States since the late 1800's (Sanders et al. 1985). Water hyacinth (*Eichhornia crassipes* Mart. (Solms)), an aggressive floating plant native to South America, was introduced into the United States in 1884 and fifteen years later, was identified by the U.S. Congress as hampering the operation of navigable waterways in Florida and Louisiana (Cofrancesco 1996). Over time other aquatic plants, such as alligator weed, water lettuce, Eurasian watermilfoil, hydrilla, and melaleuca developed into problems in waterways of the United States.

Beginning in the early 1900's, three management technologies have been employed to regulate populations of noxious aquatic plants. Mechanical control methods were the first technology employed and included everything from the manual removal of plants to the development of specialized machines (Gopal 1987). The next management technology developed was chemical control which first used inorganic compounds, then progressed in the 1940's to organic compounds, such as 2, 4-D (Bose 1945, Gopal 1987) and, now employs improved products for plant management. The most recent technology developed was biological control which started in 1959 with cooperative research projects between the U.S. Army Corps of Engineers (CE) and the United States Department of Agriculture-Agriculture

Research Service (USDA-ARS). Projects were designed to located host specific phytophagous insects to manage noxious plant populations (Center et al. 1990).

Biological control technology uses two approaches to manage noxious plants. The first is the inundative or augmentative approach which utilizes endemic organisms at higher than normal population densities to inflict significant damage on target plant populations. Often this approach has been used with weakly pathogenic organisms where the releases of elevated quantities of the agents produce a decline in the target plant population. The other approach, classical biological control, uses host specific arthropods, nematodes, or plant pathogens from the target plants native range to suppress the populations of the introduced noxious plant (Harley and Forno 1992).

This paper will give an overview of the CE biological control technology for aquatic plants. It will examine the research conducted on both insect and pathogen biological control agents, identify the adjustment made in response to the 1996 funding reductions, and outline the future direction of this technology area.

OVERVIEW AND CURRENT RESEARCH

Since early 1900's the CE developed management tools for chemical, mechanical, and biological control technology to regulate problem aquatic plants. Although chemicals and equipment for the chemical and mechanical technology areas typically were provided by outside companies, the CE conducted research to evaluate the effectiveness of these new chemicals or equipment. Using this research the companies eventually profited from the sales of their herbicides or removal equipment. This cooperation with industry allowed CE research dollars for chemical and mechanical technologies to be directed on evaluating tools and not be used in tool development. Biological control technology research differs from other technology areas in that the discovery, development, and distribution of potential agents are funded totally by participating agencies. Private companies found it difficult to profit from the development and release of biocontrol agents when they could not control agent spread and distribution. This situation required that the CE in conjunction with the USDA-ARS provide all the funding and personnel for discovery, development, and distribution of the biological control agents identified. These extra steps often required increased research cost and time for development of new agents.

Insects

The use of insects as biological control agents for plants in the U.S. dates back to the 1902 release of *Aerenicopsis championi* Bates on Lantana in Hawaii. This was followed by additional releases of insect biological control agents for klamath weed, musk thistle, and other exotic plants (Julien 1992). In 1959, alligator weed (*Alternanthera philoxeroides* (Mart.) Griseb.), a native of South America, was the first aquatic plant targeted for classical biological control research. A USDA laboratory was established in Argentina as part of the cooperative effort of the USDA and CE to identify host specific phytophagous insects to manage alligator weed (Coulson 1977). During the initial surveys more than 40 insects were found feeding on alligatorweed (Coulson 1977). As testing progressed, the number of potential agents was reduced to five insects and in the end three agents were approved for release in the United States beginning in 1964 alligatorweed flea beetle (*Agasicles hygrophila* Selman & Vogt), alligatorweed thrips (*Amynothrips andersoni* O'Neill), and the alligatorweed stem borer (*Vogtia malloi* Pastrana); (Cofrancesco 1988, Vogt et al. 1992).

Over the last 38 years, the CE and USDA have joined forces to conduct research on six exotic plants (alligatorweed, water hyacinth, water lettuce, hydrilla, Eurasian watermilfoil, and melaleuca) and have released 13 biological control agents. These achievements have required research to be conducted on six continents; development of three overseas research facilities in Argentina, Australia, and China; and utilization of numerous facilities in other regions of the world. Table 1 gives an outline of agent introduction over the years. On average, an agent has been released every 2.9 years. Examination of release dates indicates there is always a significant lag time between identification of a new target plant and introduction of the first biocontrol agent. Projects also can have lag times develop when research operations are reduced or moved. Overseas research is the cornerstone of a successful classical biological control program. If researchers stop putting agents into the evaluation pipeline, then we stop having new agents available to manage the target population. The research leader must balance agent input into the pipeline with other facets of a biological control program, such as host specificity testing, agent release, and field establishment, to ensure a balanced overall program.

With the 1996 reduction in funding for the Aquatic Plant Control Research Program (APCRP) adjustment in insect biological control work units occurred. Four work units dealing with insect biocontrol agents were consolidated into one work unit. Although research efforts and funding priorities were structured so that critical facets of the research operation were maintained, a 50% reduction in funding occurred in the areas of release, establishment, and distribution of agents and an 80% funding reduction occurred in overseas research.

The primary focus of the consolidated insect biological control work unit was establishment and distribution of hydrilla biocontrol agents. Apparently, some agents approved for release on hydrilla will have little if any management value in the U.S. The tuber feeding weevil appears to be effective only in areas where hydrilla is dewatered, and tubers are exposed in the mud flats. *Hydrellia balciunas* Bock, an ephydrid fly from Australia, has been released at a number of locations in three states, however, the establishment of field populations has been difficult (Grodowitz et al. 1993). Efforts to widely establish the stem bore weevil (*Bagous hydrillae* O'Brien) have continued, however, only limited field populations of the agent have been documented (Grodowitz et al. 1994). Under laboratory and greenhouse conditions, the population of *Hydrellia balciunas* and *Bagous hydrillae* develop rapidly. The reason for difficulties in establishing field populations of these agents should be investigated.

Hydrellia pakistanae Deonier has been the most successful of the biocontrol agents released for hydrilla. It is widely dis-

TABLE 1. INFORMATION IS PRESENTED FOR EACH TARGET PLANT. THE TABLE IDENTIFIES THE YEAR THAT THE PROJECT STARTED ALONG WITH THE YEAR THE INSECT SPECIES WERE FIRST RELEASED IN THE UNITED STATES. THE NUMBERS INDICATE THE NUMBER OF INSECT SPECIES RELEASED DURING A SPECIFIC TIME PERIOD.

Years	ALLIGATORWEED (started 1960)	WATERHYACINTH (started 1960)	WATERLETTUCE (started 1982)	HYDRILLA (started 1980)	MELALEUCA (started 1987)	TOTAL Species Released
1960-61						
1962-63						
1964-65	1					1
1966-67	1					1
1968-69						
1970-71	1					1
1972-73		1				1
1974-75		1				1
1976-77		1				1
1978-79						
1980-81						
1982-83						
1984-85						
1986-87			1	2		3
1988-89				1		1
1990-91			1	1		1
1992-93						
1994-95						
1996-97					1	1
Total	3	3	2	4	1	13

tributed in Florida and has been released in four other states. In pond studies conducted at the Tennessee Valley Authority (TVA) facility, this agent proved it could overwinter in this northern range (Grodowitz et al. 1995). In addition, the TVA study showed that when large fly populations developed, the plants declined (Grodowitz et al. 1995). Once a sufficient density of individuals develops at field sites, studies will be undertaken to evaluate agent impact and compare with the TVA pond study.

Overseas and quarantine research efforts have been reduced significantly due to the funding reductions instituted in 1996. However, even under these reduced levels researchers have identified a number of agents associated with hydrilla in Thailand (Ted Center, USDA-ARS, personal communication). These initial survey efforts found two new weevil species and an undescribed ephyrid fly feeding extensively on hydrilla. Research efforts in China and India prior to funding reductions identified new potential agents for both Eurasian watermilfoil and hydrilla (Bennett 1993, Bennett 1994). Some of these agents are being maintained in quarantine until funding allows the completion of their host specificity testing. Along with these overseas efforts, Habeck (1996) completed work on the three Australian moths that feed on hydrilla. All of the moths produce damage of various degrees to hydrilla but none appear to possess the host specificity level necessary for release in the U.S.

Pathogens

Pathogen agent development for biological control of noxious plants has followed a decidedly different pattern from that of insect agents. When the CE entered into pathogen biological control research in the 1960's, the only available approach was using endemic pathogens in an inundative strategy. Initiation of classical pathogen biological control research was not an option because a plant pathogen quarantine facility did not exist in the U.S. until 1971 (Melching et al. 1983). In addition, it was extremely difficult to obtain approval for exotic pathogen releases. Between 1971 and the present, only *Puccinia chondrillina* Bubak and Syl., introduced in 1976 for management of skeleton weed (*Chondrilla juncea* L.) in the western U.S. (Supkoff et al. 1988, Julien 1992), have been approved for release in the U.S. Because of these factors, the CE has focused its pathogen biocontrol research on endemic pathogens for management of noxious aquatic plants.

The inundative approach was used with endemic fungal species *Cercospora rodmanii* Conway on *Eichhornia crassipes* (Freeman et al. 1981, Theriot et al. 1981) in the 1970's and a Massachusetts strain of *Mycoleptodiscus terrestris* (Gerg.) Ostazeski on *Myriophyllum spicatum* L. in the late 1980's (Gunner 1983, Gunner et al. 1991). This strategy applied the pathogen at rates that would overwhelm plant defense mechanisms resulting in a disease epidemic and reduction in biomass similar to that achieved with the use of herbicides. Formulation technology during this period was a new field; incorporation and preservation of living biological organisms into inert biocarriers was still in its infancy. In addition, formulation development was directed toward the needs of terrestrial plant pest problems ignoring the special needs of formulations for use in an aquatic environment. Neither formulations of the fungal pathogens proved effective in field tests because the formulations were inadequate. Further development was then halted.

Research continued using endemic pathogens for biological control of hydrilla even after the 1996 funding reductions. The Texas strain of *Mycoleptodiscus terrestris* has shown great promise as a biological control agent for hydrilla in laboratory, greenhouse, and field trials. To be marketable as a biological control agent, the fungus must be formulated, perform well in an aquatic system, have a shelf life, and be applied easily using conventional equipment. Progress has been slow but recent developments in encapsulation technology have demonstrated that viability of living organisms can be retained in a dry formulated product. Recent work with the newly formed company Trans America Product Technology (TAPT) has been extremely encouraging. Incorporating the fungus into a patent pending biocarrier, Biocar 405, has resulted in a formulation which in initial testing has proved efficacious, operational in an aquatic environment, and viable on the shelf for up to three months.

Pathogen biological control efforts continue to research the use of endemic pathogens but an important dimension has been added through the initiation of foreign exploration to find agents that can be used in a more classical approach. Overseas surveys for pathogens of aquatic plants began in 1994 in Europe through a contract with the International Institute of Biological Control (IIBC) and in China as a cooperative research effort with the USDA. Between 1994 and 1996, IIBC researchers surveyed 200 sites in 12 countries in western Europe for pathogens of Eurasian watermilfoil, and collected 290 isolates (Harvey and Evans 1997). During 1994 and 1995, more than 200 isolates were obtained from hydrilla and Eurasian watermilfoil tissue in China and preserved in long term storage at the National Cancer Institute, Ft. Detrick, Frederick, MD (Shearer 1997). Screening of the isolates for potential pathogens is being conducted at the USDA-ARS Foreign Disease Weed Science Research Facility.

Recent events in the permitting process in the United States have made the release of exotic pathogens more realistic. Within the last few years, the USDA has been reevaluating the criteria for release of exotic pathogens. Under the new federal and state guidelines pathogen releases should become more frequent.

FUTURE DIRECTION

Biological control research efforts must build on past success and move forward to predict the long term impacts of agents that have been released. We need to maintain a technology area that is responsive to the needs of our customers and visionary enough to identify potential problems before they are excessive. We must educate our customers on how to effectively use the biocontrol resources they have available either alone or in conjunction with an integrated management program. By educating and interacting with our customers, we can become aware of problems as they develop and be in a better situation to adjust our research efforts to meet their needs. Our future research emphasis will be placed on developing agents for submersed aquatic macrophytes and post evaluation of agents already released.

Pathogen biological control research will be conducted on both endemic and exotic pathogens. Research on endemic pathogens will focus on the formulation of *Mycoleptodiscus terrestris* (Mt) for use on hydrilla. Classical biocontrol research of pathogens will continue to survey and develop host specific exotic organisms for submersed vegetation. Overseas research efforts to find pathogens of hydrilla and Eurasian watermilfoil have covered only a small portion of the range of these plant species (to date, western Europe and a few areas of north and central China). Areas within the native range of hydrilla and Eurasian watermilfoil that have not been surveyed for pathogens include eastern Europe, most of Asia, Australia, and Africa. In the past year, contacts have been made with cooperators in eastern Europe, Russia, and southeast Asia who have indicated they would assist with survey efforts in those regions. Russian scientists in St. Petersburg have collected some pathogens of Eurasian watermilfoil and are willing to cooperate in their evaluation as well as in additional exploration. Availability of overseas cooperators combined with more realistic guidelines for release of exotic pathogens make research in this area a timely, feasible, and worthwhile effort.

The release and establishment portion of the insect biological control research program will change its direction. Instead of attempting to obtain broadest possible distribution of the agents, we will attempt to make mass releases of *Hydrellia pakistanae* on large lakes to develop the same kind of situation that was observed in the TVA study. We also will begin to institute laboratory studies directed at determining why particular agents have difficulty in establishing field populations and try to better understand how each agent is impacting their target plant.

Along with the above studies, research will be conducted to develop more effective evaluation procedures to document impact from biological control operations. These evaluation procedures will be used to document the historical impact of biocontrol agents and evaluate introduction of the new agents. A review of the impacts of insect biological control has been long overdue. This information can be presented to our sponsors, to assist in their education of how to employ the biocontrol resources that are available.

Overseas insect studies will address areas of the world that have not been explored and focus on developing agents for hydrilla and Eurasian watermilfoil. Many of these overseas efforts will be conducted in conjunction with pathogen research wherever possible. The wealth of the agents identified in Thailand from a relatively short trip indicates that a number of potential insect agents still exist. Special efforts will be made to expedite the introduction of these new agents, particularly the weevils which usually have a limited host range, a key requirement for a biocontrol agent.

Research also will be directed to determine the feasibility of using endemic insects as biological control agents of Eurasian watermilfoil. The CE funded much of the laboratory and field research that has been conducted on the native weevil *Euhrychiopsis lecontei* Dietz (Creed and Sheldon 1993). The results of these studies along with studies that have been conducted by researchers in Minnesota make this approach worth investigating for Eurasian watermilfoil management.

The Biological Control Research Technology Area for the CE will attempt to balance all research efforts identified to ensure a comprehensive program that meets the needs of our sponsors. Although priorities will be established once the funding for the program has been identified, management of submersed aquatic vegetation will be the primary focus of the technology area in the future.

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