ADDRESSING THE NEED FOR HERBICIDES FOR AQUATIC WEEDS IN IRRIGATION WATER IN THE US

James Parochetti, Marija Arsenovic, Kurt Getsinger, Donald Stubbs, and William Haller consider the problems associated with weed control in irrigation waters in the USA

Key Words: herbicide, pesticide registration, aquatic weeds, invasive weeds, irrigation canals

Introduction

Aquatic weeds, particularly non-native invasive species, are serious threats to the natural and production-based ecosystems in the United States (US). They have become a major National problem, as key waterways (such as rivers, reservoirs, canals) are interconnected, traversing political boundaries throughout the country, and providing convenient avenues for movement of aquatic weeds. The proliferation and continued spread of these weeds restricts water movement in flood control and irrigation canals, increases sedimentation rates in reservoirs, reduces biodiversity, threatens endangered species (plants and animals), degrades water quality, increases mosquito breeding habitat, and causes major economic losses to agriculture, recreation, fisheries, electric power generation, and property values.

Invasive weeds in lakes, rivers and reservoirs are causing significant economic losses to fisheries and recreational water use. In addition, these weeds require annual expenditures of over $150 million of public funds for mechanical and chemical management. Despite public programs for containment and prevention of the spread of aquatic weeds, the exotic submersed species, hydrilla (*Hydrilla verticillata*), has spread from Florida to Maine on the east coast, across the Gulf Coast States, and to California and Washington on the west coast. The US Department of Agriculture (USDA)-Animal and Plant Health Inspection Service (APHIS) listed the noxious aquatic weed, giant salvinia (*Salvinia molesta)*, which was first found in South Carolina in 1994, and has now spread to natural areas in California, Arizona, Texas, Louisiana, Alabama and Florida.

In addition, agriculture in the Western US is dependent upon timely delivery of irrigation water via reservoirs, canals and other conveyances, and aquatic weeds directly impact the movement of water in these delivery systems. Many of the most problematic invasive weeds that infest surface water bodies and wetlands are spreading into the western region of the US irrigation systems, which could negatively impact over 225,400 miles of canals and drains in 17 Western US states. Invasive weeds, primarily of foreign origin, significantly reduce biodiversity, threaten survival of endangered species, and change the structure and ecological function of publicly owned parks, conservation lands and wetlands throughout the US. Old world climbing fern (*Lygodium* spp) and purple loosestrife (*Lythrum salicornia*) are southern and northern examples of the effects of these invasive weeds in natural areas. *Lygodium* (first reported in Florida in 1958) has spread to the ecologically unique tree islands throughout the Everglades, effectively destroying the over story that had provided shade for endangered ferns and destroying nesting habitat for wetland birds. The continued spread of *Lygodium* impedes the multi-billion dollar efforts of the Federal government to restore the natural functions of the Everglades. In the past century, purple loosestrife, an ornamental plant in the US since the 1700s, has gradually spread into northern wetlands from Maine to Washington State, outcompeting desirable native species such as wild rice, bullrush, cattails and other waterfowl food and habitat sources. Other riparian invasive weeds such as giant reed (*Arundo donax*) and perennial pepperweed (*Lepidium latifolium*) increasingly threaten flood control projects and native species habitat in western states.

Although the activities described in this paper are focused on herbicides as the primary tool of control, other methods of control, as demonstrated in integrated pest management (IPM) approaches are acknowledged as primary control strategies. One example of this is The Area-wide Management Evaluation of *Melaleuca quinquenervia* – 'TAME melaleuca' – which is a program recently established as a collaborative multi-agency project under the USDA Agricultural Research Service's Area-wide Pest Management Initiative (http/citt.ufl.edu/portfolio/tame/index.htm)).

The goal of the *Melaleuca* program is to demonstrate the effectiveness of an IPM approach for controlling *Melaleuca* in the US and other areas of the world where this is a problem weed. Demonstration sites are designed to display the combined effectiveness of multiple control tactics that IPM offers. Land managers and property owners will have an opportunity to adapt from these sites and apply control practices that best meet their own *Melaleuca* problems. This Area-wide Management Evaluation seeks to develop a sustainable and integrated *Melaleuca* control program through partnerships with public agencies and private land managers for the long-term control of the invasive species.

Current situation in the US regarding aquatic weed regulatory activities

Executive Order 13112, signed by US President William J. Clinton on February 3, 1999, directs Federal agencies to use their full authority to "prevent and control invasive species to promote restoration of native species in their native

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ecosystems." This order, sought by natural resource managers and environmental groups from throughout the US, has provided increased impetus to control invasive species in natural areas of the country. The National Invasive Species Council was established to ensure that all Federal activities on invasive species management are "coordinated, complementary, cost efficient(ly), and effective", among appropriate agencies. Since few alternative aquatic weed control options are operationally or economically viable, there is a growing need for herbicides to control aquatic plants in the Nation's surface waters and in canal/drainage systems used for irrigated agriculture. However, prior to 2004, resource managers have been limited to the use of only eight herbicides that are registered for aquatic sites, and only three for irrigation canals (Table 1). Many of these herbicides have been used since the 1950s, and resistance has been documented in several important aquatic weeds for two of the registered products. Moreover, new aquatic weed species are entering the US and currently registered herbicides do not control many of them effectively.

Concurrent with the formation of an Ad Hoc Working Group to facilitate the registration of herbicides for aquatic weeds which is composed of senior weed scientists in the US federal government and cooperating Land Grant Universities, the US Environmental Protection Agency (US-EPA) started a new Registration Review process in 2004. Some of the key products for aquatic sites may be removed from the market or significantly altered during the Registration Review process currently underway. The US-EPA is also considering the potential impact of herbicides on endangered species.

This lack of herbicides is due to several factors, but primarily it is the return-on-investment issues facing potential registrants seeking to enter the aquatic use market that hamper development of research and development new products. The aquatic herbicide market is estimated at only $30-50 million (M) per year, while the irrigation canal market is estimated at only $12-15 M per year. Since it can cost $40-50 M and take 7-10 years to bring a new pesticide to market, registrants are reluctant to risk the investment for these "minor" uses; hence, only three new aquatic labels (glyphosate, fluridone, and triclopyr) were approved from 1977 to 2002 (Table 1). Since 2002, three additional herbicides (imazapyr, carfentrazone-ethyl, and penoxsulam) have received aquatic registrations, and several other products are in various phases of the registration process. There also has been little or no progress in discovering and developing registrations for "soft" herbicides and/or bioherbicides that might find important uses in the aquatic arena.

In addition, industry consolidation has lead to significant reductions in research and development budgets, especially monies to support high-cost specialty product programs, such as the development of herbicides for aquatic weed control. Furthermore, Federal support to conduct such work has been steadily declining over the past decade. For example, funding to evaluate aquatic herbicides under the US Army Corps Engineer (USACE) Aquatic Plant Control Research Program (APCRP) has been reduced by over 50% since 1996. Other Agencies, such as the USDA, the US Bureau of Reclamation (USBR), and the Tennessee Valley Authority (TVA), have either significantly downsized or eliminated their aquatic herbicide research and development efforts. Moreover, there are a limited number of university or contract researchers who are positioned, or have the resources, to conduct aquatic herbicide trials including environmental fate data necessary to register the needed herbicides.

Table 1: Currently registered (Section 3) herbicides used in aquatic sites in the US

Herbicide	Max Rate	Action	Concerns on submersed uses
Carfentrazone-ethyl	0.8 pt/A	Contact	Effective on some emergent and floating plants
Copper and Chelated Coppers	1.0 ppm	Contact/ Systemic	Not biodegradable, does not control all algal species, only widely used algaecide, Coppers may require 2-3 applications per year for submersed plant control.
Diquat	0.37 ppm	Contact	Used for submersed and floating weed control, resistant duckweed recently discovered. The only effective contact herbicide for duckweed control. May require more than 1 application per year for hydrilla and Eurasian watermilfoil control.
Endothal	5.0 ppm	Contact	Widely used alternative to fluridone against hydrilla, may require more than 1 application per year. Also effective on Eurasian watermilfoil.
2,4-D amine and ester (granular)	2.0 ppm	Systemic	Not effective on hydrilla, widely used against Eurasian watermilfoil and water hyacinth.
Triclopyr amine	2.5 ppm	Systemic	Similar to 2,4-D on Eurasian watermilfoil, not effective on hydrilla.
Fluridone	0.15 ppm	Systemic	The most widely used herbicide for submersed weed control in the US. Tolerant hydrilla and microbial enrichment and damage to non-target native species at high rates will limit its future use in Florida.
Glyphosate	6 pt/A	Systemic	Effective on most emergent and floating plants.
Imazapyr	3-4 pt/A	Systemic	Effective on most emergent and floating plants.
Penoxsulam	0.15 ppm	Systemic	Effective on hydrilla, Eurasian watermilfoil, and some floating and emergent plants

New initiatives to facilitate aquatic herbicide registrations

The Interregional Research Project No. 4 (IR-4 Project) is a USDA funded program (See reference citation Holm *et al*. for more detailed information about IR-4). The IR-4 project helps the producers of specialty crop protection agents to obtain US-EPA registration for pest control materials. The IR-4 Project works with farmers, agriculture scientists and extension personnel to carry out research, and then submit the resulting data to the US-EPA in order to obtain tolerances for specific pesticide uses needed by specialty crop producers. The IR-4 Project is the principal public effort to gain US-EPA approved tolerances for safe and effective pest control products on specialty crops.

Faced with the serious threat of a growing US-wide aquatic weed problem, and with few practical solutions on the horizon, experts from the IR-4 Project, the USDA-Cooperative State Research, Education, and Extension Service (CSREES), the US-EPA Office of Pesticide Programs ((OPP), the US Army Engineer Research and Development Center (USAERDC), and the University of Florida Center for Aquatic and Invasive Plants met on 21 June 2004 in Washington, DC to discuss the potential role of the IR-4 Project to include weed control in aquatic sites and irrigation canals. This group formed, by consensus, an *Ad Hoc* Working Group for Registration of Herbicides for Aquatic Weeds to develop support for inclusion of two new categories of research to support the registration of herbicides in two areas for aquatic weed control: 1) weed control in irrigated agriculture; and 2) weed control in aquatic sites.

The Working Group was formed in 2004 as a National forum to address the needs of herbicide registration for aquatic weed management. The Working Group has representation from federal and state university scientists and involves the user community in the Working Group's meeting. The Working Group provides guidance and direction for the work to be accomplished as well as to facilitating the accomplishment of those tasks and resolution of policy issues with the members' own agency or organization. The goals of the Working Group are to have the US-EPA establish tolerances for herbicides and biological products for (1) aquatic weed management resulting in registrations addressing irrigated agriculture, (2) aquatic weeds in lakes, reservoirs and rivers, and (3) natural areas that are include wet land, arid and dry lands. This third goal is not currently being considered as a high priority, but weed control in natural areas has potential if stakeholders advocate for this initiative.

Figure 1: **Water lettuce (*Pistia stratiotes*) is one of the many aquatic weeds that can serious impede the flow of irrigation water. Herbicides used in irrigation waters must be registered so as to not impact on subsequently irrigated crops. (photo by permission from Dr. Michael Masser, Texas A&M University).**

Figure 2: **Aquatic weeds in flowing canals fragment easily and clog siphon tubes as well as pump intakes. This prevents efficient irrigation and clogged filters and pump intakes can result in costly repairs.**

Primary emphasis is on goal one, which is herbicides and biological products for aquatic weed management resulting in registration of herbicides for irrigated agriculture. The primary reason for focusing on goal one is that these uses support crop production; irrigation water, treated with herbicides, must safe to use on crops. Registration of these herbicides allows greater flexibility for growers of all crops. The objectives of the Working Group are a) to be a National forum and action group composed of interested federal and state agencies to facilitate registrations of chemicals and biological products for aquatic weed management, b) to solicit input from stakeholders to establish priorities to obtain tolerances and subsequent registrations, and c) to seek adequate funding to obtain the data necessary for clearances by US-EPA.

As a result of the Working Group's efforts, the IR-4 Project's Strategic Plan for 2005-2010 includes an initiative to support the establishment of a herbicide tolerance initiative. However, funding for this initiative must be secured from sources other than those used for traditional food and ornamental crops.

Current activities of the working group

The Working Group has a tri-chair leadership consisting of Drs. James. Parochetti, USDA-CSREES, Marija Arsenovic, IR-4 Project, Rutgers University, and Kurt Getsinger, USAERDC. The Working Group meets regularly; meetings are being held at the national Aquatic Plant Management

Figure 3: **Timely delivery of water through over 200,000 km of irrigation canals is essential to agricultural production in the 17 western states. Aquatic weeds are also problems in concrete lined canals where submersed weeds only require a small amount of sediment to take root and grow.**

Society (APMS) and the Weed Science Society of America (WSSA) meetings. Meeting attendance is approximately 30 persons per session, with representation from academia, government research and regulatory agencies, and industry. In February 2005, the Working Group made a formal presentation at the IR-4 Project's Strategic Planning conference seeking their support on behalf of the Working Group. Dr. Getsinger presented the Working Group's vision for obtaining data for registration of herbicides for irrigation canal waters. The Working Group's plan was adopted by the IR-4 Project's stakeholders, however, activities were conditional on securing new funding. The stakeholders were very clear, that existing funds for traditional food, ornament and biopesticide research objectives were not to be diverted to the new aquatic initiative.

The Working Group's primary goal is to focus on controlling aquatic weed in water conveyance systems (irrigation canals) in the 17 Western US states. This focus was chosen because of the direct connection with production agriculture and the limited weed control herbicides currently available. Candidate products include the contact herbicides, endothal and diquat, since active ingredients have received re-registration status for general use in aquatic sites, and they are quick-acting products that would fit the short herbicide contact time conditions of flowing water canals. The IR-4 Project has been working with the registrants, the US-EPA staff and the Chemistry Scientific Advisory Panel (ChemSAC) to develop crop grouping scenarios to establish crop tolerances. Standardized draft protocols for Good Laboratory Practices (GLP) crop tolerance trials have been approved by ChemSAC. The IR-4 Project is coordinating a project to remove the water holding period for endothal.

Since 2007, the IR-4 Project has been limited in activity in the aquatic arena because new financial resources have not been appropriated. In the future, funds might come from other US Federal or state authorizations or industry. There is no intent to use existing funding sources from the IR-4 Project which currently are used for the registration of pesticides for specialty crops.

Background on the need for this Working Group was based on the facts that up to that time there had been only three new herbicides registered for use in aquatic sites over the past 25 years, yet, during this same period the spread of invasive aquatic and wetland weeds had increased dramatically, and the awareness and needs to control these weeds had never been greater. The cause for this conundrum has been driven by a number of factors. The cost of the registration process is considerable with estimates ranging from $10-40 million. Aquatic sales are estimated at only $100-150 million per year in the US, a relatively minor share of the overall pesticide market (estimated at $1-3 billion/yr). Major changes in US-EPA requirements, such as Re-registration and the Food Quality Protection Act (FQPA), have complicated and slowed the entire process. State regulatory and permitting processes, the National Pollution Discharge Elimination System (NPDES) requirements, and the public perception of pesticides have placed added complexity and burdens on registrations. Also, the patent life of a pesticide, combined with the specter of generics, may discourage development of proprietary aquatic products. The combination of these factors can result in a low return on investment for potential registrants. In addition, the critical interactions among the research community, the registrants, and the regulatory community, have been greatly diminished. All three groups have lost in-house technical expertise, have experienced downsizing due to reduced budgets and resources, and have lost the interactive communication required to secure an aquatic label.

Aquatic herbicides registered by US-EPA since 2004

Since 2004, several new Section 3 (US-wide pending approval of states) registrations have been issued for products that can be used in aquatic sites. These include: imazapyr, carfentrazone-ethyl and penoxsulam. Current

Table 2. List of resources that provide information on invasive aquatic plants and different management options available for control.

USDA Agricultural Research Service's Area-wide Pest Management Initiative – http/citt.ufl.edu/portfolio/tame/index.htm
University of Florida – Center for Aquatic and Invasive Plants http://plants.ifas.ufl.edu
Florida Department of Environmental Protection – http://www.dep.state.fl.us/lands/invaspec/index.html
US Army Engineer Research and Development Center – http://el.erdu.usace.army.mil/aqua/
Aquatic Plant Management Society – http://apms.org/
Aquatic Ecosystem Restoration Foundation – http:///www.aquatics.org

actions for new chemicals in aquatics include US-EPA Experimental Use Permits[EUP] for imazamox, quinclorac, bispyribac-sodium and flumioxazin, and a US-EPA Section 24 special local needs (SLN) permit for imazamox in Florida.

Summary

This paper details the action that was initiated by a small group of senior level Federal and state university personnel with weed science responsibilities to address the critical need for additional herbicides to control aquatic weeds. The group consists of scientists, who are the authors of this paper, and represent the USDA, the USACE, the US-EPA, the IR-4 Project at Rutgers University, and the University of Florida. Each scientist brings to the group the collective support of their organizations. The group meets regularly and meeting participation has been extended to all interested persons; as an example, those attending have included pesticide registrants, state regulatory agencies, university scientists and extension specialists. The *Ad Hoc* Working Group for Registration of Herbicides for Aquatic Weeds was formed to work towards the inclusion of two new categories of research to support the registration of herbicides in two areas for aquatic weed control: 1) weed control in irrigated agriculture; and 2) weed control in aquatic sites.

The Working Group's vision was to obtain data for registration of herbicides for irrigation-canal waters. The Working Group's plan was adopted by the IR-4 project stakeholders. However, the IR-4 Project's activities were conditional on securing new funding. The IR-4 Project stakeholders were very clear, that existing funds for traditional food, ornament and biopesticide research objectives were not to be diverted to the new aquatic initiative. Initially, as a result of informal meetings of the authors, it was recommended that a cost effective and timely process for registering irrigation canal and aquatic herbicides, in coordination with government, academic and private sector partners, be initiated by the IR-4 Project.

Since 2007, the IR-4 Project has been limited in activity in the aquatic arena because new financial resources have not been appropriated. In the future, funds might come from other US federal or State authorizations or industry. There is no intent to use existing funding sources from the IR-4 Project which currently are used for the registration of pesticides for specialty crops.

Additional reading

Robert E Holm, Jerry J Baron and Dan Kunkel (2006) The IR-4 Program: Interactions with the Crop Protection Industry and with the Regulators. *Outlooks on Pest Management*. **17**(**4**): 185-8.

MD Netherland, KD Getsinger & DR Stubbs. (2005). Aquatic Plant Management: Invasive Species and Chemical Control. *Outlooks on Pest Management*. **16**(**3**): 100-4.

Permission has been granted by the Chief of Engineers to publish this information.

James. Parochetti earned a BS in Agriculture Science from the University of Illinois, an MS in Horticulture from Purdue University in 1964, and a PhD in Plant Physiology from Purdue University in 1967. Currently Dr. Parochetti is the National Program Leader for Weed Science, Cooperative State Research, Education, and Extension Service, US Department of Agriculture, Washington, DC. He is a Fellow of the Weed Science Society of America.

Marija Arsenovic earned a BS in Agriculture/Plant Protection from University of Novi Sad, Serbia in 1974, an MS in Agriculture/Plant Protection from the University of Novi Sad, Serbia in 1978, and a PhD in Agriculture/Weed Science from University of Osijek, Croatia in 1984. As Associate Professor at University of Novi Sad, Dr. Arsenovic has had responsibilities for aquatic plant management in irrigation and drainage canal systems. During the summer of 1992, as a Visiting Scientist, she was involved in aquatic weeds and herbicide research at the Center for Aquatic and Invasive Plants, University of Florida, Gainesville, FL. From 1994 to 1999, Marija was lecturer and researcher in weed science at the Department of Horticulture, Cornell University, NewYork. Since 1999 she has served as a Research Scientist in Weed Science at the IR-4 Project, Rutgers, The State University of New Jersey, responsible for coordination of herbicide registration in specialty crops.

Kurt Getsinger earned a BS in Biology from Campbell University in 1973, an MS in Biology from East Carolina University in 1976, and a PhD in Plant Physiology from Clemson University in 1982. Dr. Getsinger has been studying the biology, ecology, and management of aquatic plants since 1973. He is currently with the US Army Engineer Research and Development Center, Vicksburg, MS, and is a past president of the Aquatic Plant Management Society.

Donald Stubbs received a Liberal Arts degree with a major in biology from Knox College in 1970 and a Master of Environmental Science degree from Hood College in 1997. Donald has spent 33 years with US-EPA. He is currently the Associate Director, Registration Division, the Office of Pesticide Programs, US Environmental Protection Agency, Washington, DC.

William Haller earned a BS in Agronomy from Cornell University in 1969, an MS in Agronomy from the University of Florida in 1971, and a PhD in Agronomy from the University of Florida in 1974. Dr. Haller has been studying the biology, ecology, and management of aquatic plants, with an emphasis on invasive weeds since 1969. Currently he is the Acting Program Director and Professor, Center for Aquatic and Invasive Plants at the University of Florida, Gainesville.

Similar articles that appeared in *Outlooks on Pest Management* include – 2005 **16(3)** 100; 2005 **16(6)** 277; 2007 **18(5)** 213; 2008 **19(1)** 22