J. Aquat. Plant Manage. 51: 84–87

Efficacy of experimental and recently registered herbicides on hygrophila

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ABSTRACT

Management of hygrophila, a submersed non-native aquatic weed, is particularly challenging because few registered aquatic herbicides effectively control the species, which most commonly occurs in slow to moderately flowing canals, streams and rivers. Seven experimental or newly registered aquatic herbicides were evaluated in 10-wk static exposure studies to determine their activity on hygrophila. Only two of the four ALS-inhibiting herbicides under evaluation reduced hygrophila biomass by 90% after treatment at experimental rates; these were penoxsulam and trifloxysulfuron, with EC_{90} values (EC_{90}: the effective concentration that reduces growth by 90% compared to untreated controls) of 240 and 274 μg ai L^{-1}, respectively. The EC_{90} values for the HPPD inhibitor topramezone and the synthetic auxin mimic quinclorac were 372 and 951 μg ai L^{-1}, respectively. The EC_{90} values for all of these herbicides were several times higher than the current or likely maximum application concentrations on the labels. However, the EC_{90} value for the PPO inhibitor flumioxazin was 158 μg ai L^{-1} (95% CI 132–195 μg ai L^{-1}). The ALS products tested in these experiments—imazamox, bispyribac, penoxsulam and trifloxysulfuron—did not provide adequate (> 90%) control of hygrophila at maximum label rates, whereas the experimental herbicides topramezone and quinclorac had very slow activity and are unlikely to provide acceptable control of hygrophila under operational conditions. In contrast, flumioxazin, which was registered for aquatic use in Fall 2010 and has a maximum application concentration of 400 μg ai L^{-1}, appears to offer effective control of hygrophila at less than half the maximum label rate, at least under static conditions.

Keywords: EUP herbicide, invasive aquatic weed, Miramar weed

INTRODUCTION

Hygrophila polysperma (Roxb.) T. Anderson, native to Southern Asia, Indochina and India, was introduced into the US by the aquarium trade in the mid 1940s (Innes 1947) and was first found growing in Florida in the 1950s. By the mid to late 1970s, hygrophila populations exploded in the flood control canals of southern Florida (Vandiver 1980) and were soon found in creeks and rivers throughout peninsular Florida and into southern Georgia as well. The species has also invaded Texas (Doyle et al. 2003) and Reams (1950) suggested that hygrophila may grow as far north as Virginia.

Sutton and Dingler (2000) reported that the emergent form of hygrophila grew fastest during summer and when cultured in hydrosoils amended with supplemental nutrients. Hygrophila initially establishes through emergent growth in saturated soils along the shorelines of waterways; it expands into water through extensive rhizomatous growth and then persists in submersed form (Fast et al. 2008). The species produces seeds and is easily fragmented; fragments quickly produce roots and serve as vegetative propagules. Establishment of hygrophila is reportedly low in still or static water and the species is much more productive in flowing water, even if flow is very slow (Van Dijk et al. 1986, Fast et al. 2008). Since hygrophila typically grows in flowing water, fragmentation often results in expansion into areas downstream from the initial infestation. This fragmentation is a particularly serious problem after heavy rains, when fragments rapidly clog the protective screens of flood control pumps and must be removed by hand to ensure continued operation (Nick Schooley, Coral Springs Water Control District, personal communication).

Fast et al. (2009) evaluated the effects of several registered aquatic herbicides on the emergent growth form of hygrophila. They found that foliar applications of glyphosate, imazamox, imazapyr and triclopyr provided excellent control and suggested that ditchbank treatments should be employed to control the emergent form of hygrophila and prevent it from expanding into deeper water. They also indicated that endothall was the only aquatic herbicide tested that listed hygrophila as a weed controlled on the herbicide label. Endothall remains the primary herbicide used for hygrophila control, but high application rates are necessary and only short term control (e.g., regrowth occurs in 4 to 8 wk) is achieved (Sutton 1995, Cuda and Sutton 2000).

Although foliar herbicide evaluations were reported by Fast et al. (2009), little information is available regarding control of the submersed form of hygrophila. For example, Vandiver and Timmer (2006) reported that submersed hygrophila growing in static tanks was controlled by five treatments of endothall, diquat and auxin-type herbicides when applications were made every 2 wk from late June to late August. Sutton et al. (1994) found that a single summertime application of potassium endothall at 2.5 or 3 mg ai L^{-1} (ppm) or the amine salt of endothall at 0.2 mg ai

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Table 1. Herbicides evaluated for hygrophila control, modes of action and EC_{90} values which indicate relative susceptibility of this weed to these herbicides.

Herbicide	MOA[1]	EC_{90} (μg ai L^{-1})[2]	95% Confidence Interval	r^2
Imazamox	ALS	> 1,200[3]	> 1,200[3] – > 1,200[3]	0.81
Bispyribac	ALS	> 480[3]	> 480[3] – > 480	0.82
Penoxsulam	ALS	240	173 – 391	0.93
Trifloxysulfuron	ALS	> 240[3]	161 – > 240[3]	0.75
Topramezone	HPPD	> 240[3]	232 – > 240[3]	0.84
Quinclorac	Auxin	> 400[3]	> 400[3] – > 400[3]	0.80
Flumioxazin	PPO	158	132 – 195	0.99

[1]MOA = Mode of action; ALS = acetolactate synthase inhibitor; HPPD = 4-hydroxyphenyl-pyruvate-dioxygenase (carotenoid synthesis) inhibitor; auxin = auxin mimic; PPO = protoporphyrinogen oxygenase (protox) inhibitor.
[2]EC_{90} = Effective herbicide concentration that reduces biomass by 90% compared to untreated control plants.
[3]Highest rates tested in these experiments.

L^{-1} reduced hygrophila biomass in canals for up to 4 wk after treatment, but regrowth was noted at all experimental sites within 8 to 12 wk after treatment. Potassium and amine salt combinations of endothall were applied at 4.5 and 0.2 mg ai L^{-1}, respectively, to the same canals during the following winter; and similar to the summer treatments, short term reductions in hygrophila biomass were followed by regrowth to pre-treatment levels within 3 mo after application (Sutton et al. 1995). Therefore, the objective of these studies was to evaluate the efficacy of experimental and registered aquatic herbicides on submersed hygrophila under static water conditions to provide a starting point for field evaluation of these new products, which may be useful for refining use patterns in the future.

MATERIALS AND METHODS

Hygrophila was collected from canals in South Florida and cultured in 3-m diameter plastic tanks in a shade house at the Center for Aquatic and Invasive Plants in Gainesville, FL. Five apical sprigs (approx. 10 cm long) with roots growing from several nodes were planted in solid (no drain holes) plastic pots that were 20 cm in diam and 12 cm deep. These 2-L pots were filled with 2.6 kg of clean builders' sand amended with 2.6 g of controlled release fertilizer[1]. Planted pots were placed in 95-L mesocosms (2 pots per mesocosm) in a greenhouse and water was added to achieve a depth of 2 to 3 cm over the surface of the pots. As plants grew and became established during the 3 to 4-wk period after planting, water depth was gradually increased to a final depth of 25 cm (13 cm over the top of the pots).

Single herbicide treatments representing four different modes of action were applied and mixed into the water in the mesocosms. These included the systemic ALS (acetolactate synthase) inhibitors imazamox, penoxsulam, bispyribac and trifloxysulfuron tested at concentrations ranging from 50 to 1,200, 15 to 480, 15 to 480, and 7.5 to 240 μg ai L^{-1} (ppb), respectively; the systemic HPPD [4-hydroxyphenyl-pyruvate-dioxygenase (carotenoid synthesis)] inhibitor topramezone tested at concentrations ranging from 10 to 240 μg ai L^{-1}; the systemic auxin mimic quinclorac tested at concentrations ranging from 50 to 400 μg ai L^{-1}; and the contact PPO [protoporphyrinogen oxygenase (protox)] inhibitor flumioxazin tested at concentrations ranging from 50 to 1,200 ai μg L^{-1}. Each treatment rate, along with an untreated control, was replicated 3 times; each mesocosm (containing two pots) was considered a replicate and treatments were arranged in the greenhouse in a completely randomized design.

Unchlorinated well water was added as needed to maintain mesocosm water depths at 25 cm throughout the 10-wk exposure period after these one-time applications. All live, green plant tissue above the soil level was harvested after 10 wk of exposure, then dried for 5 to 7 d at 70 C and weighed. Dry biomass data from each herbicide were subjected to analysis of variance and non-linear regression using SAS 9.3[2] to determine EC_{90} values and 95% confidence intervals. The EC_{90} value is the effective herbicide concentration predicted by the analysis that would reduce dry biomass by 90% compared to untreated control plants.

RESULTS AND DISCUSSION

The EC_{90} values for the four ALS inhibitors on hygrophila ranged from less than 250 to greater than the highest tested rate of 1,200 μg ai L^{-1} (Table 1). Penoxsulam and trifloxysulfuron had the lowest EC_{90} values (< 250 ai μg L^{-1}), whereas imazamox had the highest (> 1,200 μg ai L^{-1}). These ALS inhibiting herbicides are not likely to be used for hygrophila control because the EC_{90} values are at least 2 to 4 times higher than the maximum label rates (150, 500 and proposed 50 to 100 μg ai L^{-1} for penoxsulam, imazamox and trifloxysulfuron, respectively). Also, live plant material was still present in mesocosms after 10 wk of exposure to > 200 μg ai L^{-1} of these products (Figures A–D). This long exposure period is not likely to occur in field treatments because hygrophila in Florida typically grows in canals, creeks and other systems that incur slight to significant water flow as a result of rainfall.

The effects of the HPPD inhibitor topramezone and the auxin mimic quinclorac on hygrophila were similar to one another and to the ALS inhibiting herbicides, in that a 90% reduction in biomass did not occur at the highest experimental rates (Table 1, Figures 1E and F). Biomass of treated plants after 10 wk of exposure to the highest rates tested was about half that of the control plants for both herbicides. The ultimate use concentrations for these two experimental products are not known, but they are also unlikely to be used for hygrophila control even if approved for aquatic use because of their very slow activity on this weed, as shown in these experiments. These results were not unexpected because currently labeled products with similar modes of action (e.g., the HPPD inhibitor fluridone and the

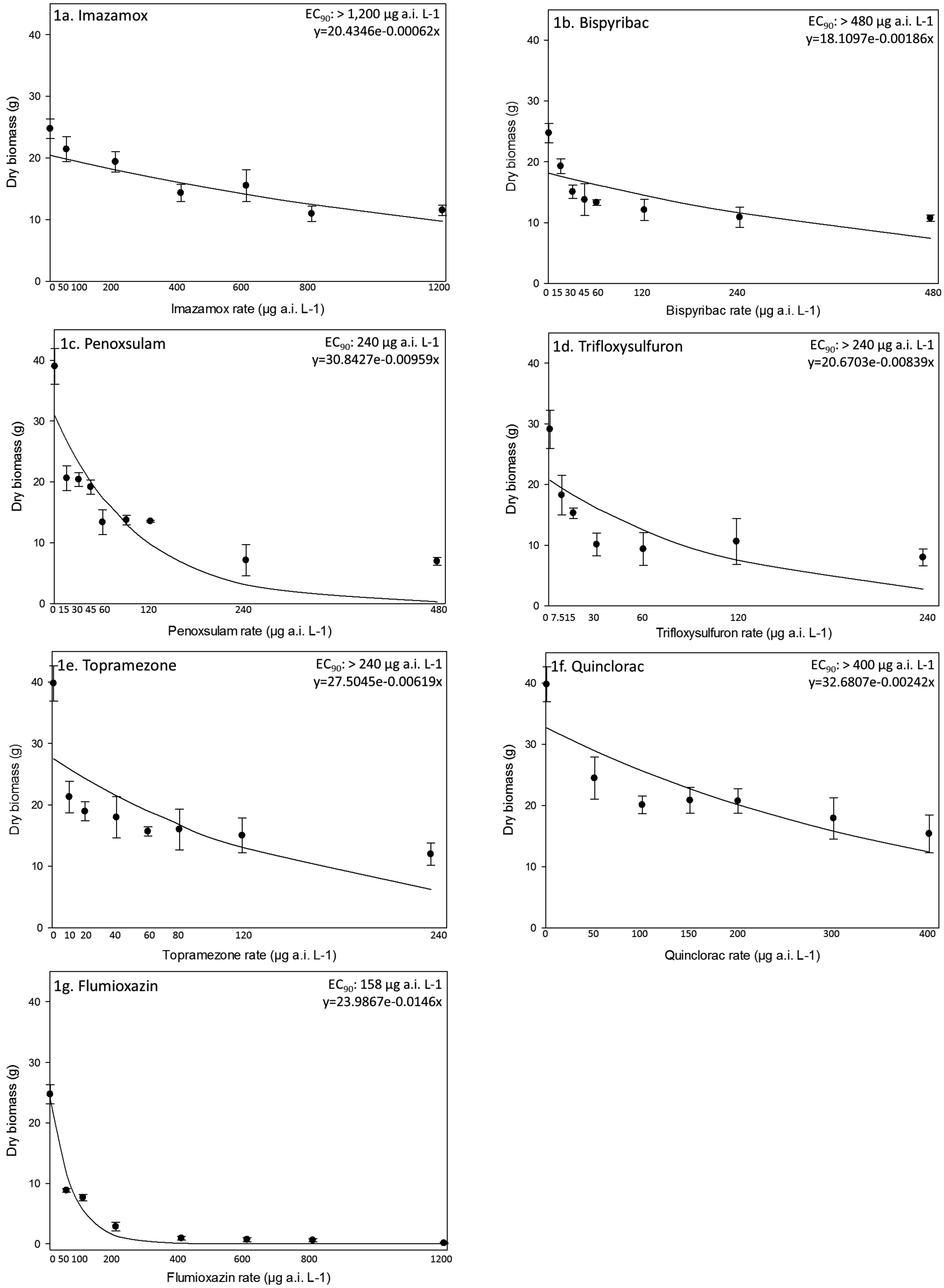

Figure 1. Effect of a single herbicide application on dry biomass of hygrophila 10 wk after treatment. EC_{90}: effective concentration that reduces biomass by 90% compared to untreated control. (A): imazamox. (B): bispyribac. (C): penoxsulam. (D): trifloxysulfuron. (E): topramezone. (F): quinclorac. (G): flumioxazin.

auxin mimics 2,4-D and triclopyr) do not provide effective control of hygrophila (Sutton 1995, Cuda and Sutton 2000).

In contrast to the results described above, the PPO inhibitor flumioxazin was effective at much lower concentrations (Table 1, Figure 1G). The EC_{90} for flumioxazin was 158 μg ai L^{-1}, with a 95% confidence interval of 132 to 195 μg ai L^{-1}. This may be because the auxin mimic and the ALS and HPPD inhibitors described above are slow-acting systemic herbicides that may have required longer exposure times than those studied in these experiments, whereas flumioxazin is a contact herbicide that is rapidly absorbed into plant tissue. Other studies investigating contact : exposure times have shown that flumioxazin requires a 5.5 h contact time to effectively control hygrophila when applied at a concentration of 200 μg ai L^{-1} (Haller, Gettys and Uchida, unpub. data). The rapid absorption and activity of flumioxazin, combined with its relatively short half-life in water (hours to a few days) (Katagi 2003, Senseman 2007), makes this product a very viable candidate for hygrophila control. The federally approved (EPA) Section 3 aquatic label for flumioxazin allows applications in quiescent or minimally flowing water at concentrations of up to 400 ai μg L^{-1} (Valent 2011), a rate that is greater than twice that needed to reduce biomass by 90% compared to control plants in these experiments. Also, flumioxazin, being a PPO inhibitor, can be alternated with the only other products that have activity on hygrophila (endothall or endothall-diquat combinations) to provide two modes of action for resistance management.

The survival of live hygrophila tissue following 10 wk of static exposure to the ALS, HPPD and auxin herbicides was not unexpected. Live tissue is usually present in small amounts in 95-L mesocosms following similar exposures to these herbicides, and is common even when fluridone is applied to fluridone-susceptible hydrilla (W. T. Haller, personal observation). The unacceptably high (e.g., above maximum label rate) EC_{90} values for the ALS, HPPD and auxin herbicides tested in these experiments preclude the use of these products for hygrophila control, particularly where dry seasons are short and even minimal flow is encountered. In contrast, these studies are the first to reveal that flumioxazin has high activity on hygrophila at rates below the maximum label rate. These results suggest that flumioxazin may provide an effective means to control an aquatic weed for which there are few other management tools. However, additional studies are needed to verify the efficacy of flumioxazin on hygrophila under field conditions and where flowing water is present.

SOURCES OF MATERIALS

[1]Osmocote Plus 15–9–12; The Scotts Co. LLC, Marysville, OH.

[2]SAS Institute Inc., Cary, NC.

ACKNOWLEDGEMENTS

This research was supported by funds from the Environmental Protection Agency as part of the Osceola County Demonstration Project on Hydrilla and Hygrophila in the Upper Kissimmee Chain of Lakes, FL (EPA Grant ID: X796433105). We thank Jay Ferrell and Brent Sellers for their reviews of this manuscript. Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product and does not imply its approval to the exclusion of other products or vendors that also may be suitable.

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