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# Note

# Torpedograss control via submersed applications of systemic and contact herbicides in mesocosms

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## INTRODUCTION

Torpedograss (*Panicum repens* L.) is an invasive plant that is found in terrestrial and aquatic settings (Sutton 1996, Smith et al. 2004, Toth 2007). In aquatic systems, torpedograss impedes boat access and drainage flow in waterbodies (Smith et al. 1993, 2004). In the southeastern United States, torpedograss is a major problem in riparian areas and along drainage canals. Torpedograss is capable of aggressive range expansion in shallow water bodies when left unmanaged, and if left uncontrolled, plants can shade out native submersed, floating, and emergent plant species that provide beneficial habitat for native fauna (Hanlon and Brady 2005, Toth 2007), thereby causing ecological problems such as lowered dissolved oxygen in the water column and lower biodiversity (Hanlon and Langeland 2000).

The native range of torpedograss is uncertain; the literature suggests that this species may be native to the Americas (Guglieri et al. 2004, Liu et al. 2006), the Mediterranean region, and Africa (Waterhouse 1994), or Australia (Hoyer et al. 1996). In 1896, the earliest known specimen in the United States was collected near Mobile, AL (Tarver 1979); since that time, torpedograss has spread throughout the southeastern United States from North Carolina to Texas. Additionally, range expansion has occurred with introductions into California and Hawaii (U.S. Department of Agriculture Natural Resources Conservation Service 2018). Torpedograss can reproduce sexually through seed production (Moreira 1978) and asexually through fragmentation; however, populations in the United States have only been documented to reproduce vegetatively (Wilcut et al. 1988).

Multiple herbicides have been shown to control torpedograss in terrestrial settings (Brecke et al. 2001, Enloe et al. 2018, Hossain et al. 2001, Langeland et al. 1998, Prince et al. 2019, Williams et al. 2003, Stephenson et al. 2006), but many of these herbicides are not available for use in aquatic areas. Foliar applications of the herbicides imazapyr (acetolactate synthase [ALS] inhibition) and glyphosate (5-enolpyruvl shikimate-3-phosphate [EPSP] synthase inhibition) are typically used to control torpedograss in aquatic environments; however, these are nonselective systemic herbicides capable of damaging or killing nontarget terrestrial and emergent species (Hanlon and Langeland 2000; Shilling et al. 1990; Smith et al. 1993, 1999). Furthermore, glyphosate and imazapyr are not active as in-water treatments at label rates (Patten 2003); therefore, it may be possible that submersed torpedograss shoots could survive foliar applications of these herbicides (Prince et al. 2019). Additionally, repeated use of the same herbicides or mode of action on a particular plant population can increase the chances of that population becoming resistant to those herbicides (Arias et al. 2005, Michel et al. 2004, Puri et al. 2006). Therefore, it is beneficial to rotate herbicides with different modes of action to decrease the chance of herbicide resistance.

Previous research examined herbicide uptake through torpedograss roots in a terrestrial setting (Williams et al. 2003), but to date, no studies have evaluated root or submersed tissue (shoots and leaves) uptake of submersed herbicide in an aquatic system. Submersed herbicide applications would need to focus on products that are active in the water column and readily absorbed through roots and/or submersed tissues. Systemic herbicides would be preferable, as they may provide long-term control of torpedograss in a manner similar to foliar applications of glyphosate or imazapyr. Submersed applications of systemic herbicides have been shown to be very effective at controlling other submersed species like hydrilla (*Hydrilla verticillata* (L. f.) Royle), flowering rush (*Butomus umbellatus* L.), and Eurasian watermilfoil (*Myriophyllum spicatum* L.; Madsen et al. 2016a, Netherland et al. 1993). However, not all aquatic sites can maintain the concentration exposure time (CET) requirements necessary to control aquatic plants, so it would be beneficial to evaluate contact herbicides that are capable of controlling torpedograss in areas of high water exchange. Because contact herbicides do not readily translocate throughout the plant, multiple

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TABLE 1. HERBICIDE TREATMENTS, TRANSLOCATION ABILITY, USE RATE, EXPOSURE PERIOD, AND NUMBER OF APPLICATIONS FOR THIS STUDY.

| Herbicide | Translocation | Rate (ppm) | Exposure Period | Number of Applications |
|---|---|---|---|---|
| Reference | – | – | – | – |
| Penoxsulam | Systemic | 0.025 | Static | 1 |
| Bispyribac-sodium | Systemic | 0.045 | Static | 1 |
| Triclopyr | Systemic | 1.5 | Static | 1 |
| Topramezone | Systemic | 0.05 | Static | 1 |
| Diquat | Contact[1] | 0.37 | 24 h | 2 |
| Endothall | Contact | 3.0 | 24 h | 2 |
| Flumioxazin | Contact | 0.4 | 24 h | 2 |
| Carfentrazone-ethyl | Contact | 0.2 | 24 h | 2 |

[1]Contact herbicide applications were made 4 wk apart.

herbicide applications per growing season to control torpedograss would likely be required, which has been the requirement for controlling other problematic perennial species (i.e., hydrilla, flowering rush, and Eurasian watermilfoil) in aquatic systems (Madsen et al. 2016b, Netherland et al. 1993). Therefore, the objective of this study was to examine submersed applications of systemic and contact herbicides for long-term control of torpedograss.

## MATERIALS AND METHODS

This study was conducted at the Aquatic Plant Research Facility at Mississippi State University's R. R. Foil Plant Research Center. Torpedograss was grown in 378-L (100 gal) outdoor mesocosms that were filled to a constant volume of 278 L (16-in. depth). Enough plant material was established so that plant harvests could be carried out at 8 and 52 wk after treatment (WAT; short and long-term harvests, respectively). Two 40-cm (16 in.) shoots of torpedograss were planted in 3.78-L (1.1-gal) pots that were filled with sand and amended with a slow-release fertilizer[1] (2.0 g $L^{-1}$ sediment) and placed in mesocosms. Six pots of torpedograss were established per mesocosm and plants were allowed 1 mo to establish prior to herbicide treatments with greater than half of the plant biomass under water. Pots were evenly spaced in each mesocosm.

There were eight herbicide application rates plus a nontreated reference (for a total of nine treatments), with each treatment being replicated four times (Table 1). The systemic and contact herbicides triclopyr,[2] penoxsulam,[3] topramezone,[4] bispyribac-sodium,[5] diquat,[6] flumioxazin,[7] carfentrazone-ethyl,[8] and endothall[9] were applied subsurface to torpedograss. These herbicides were selected for evaluation because, to our knowledge, they have never been evaluated for control of torpedograss. Herbicide rates evaluated here fell within target rate ranges allowed by herbicide labels and are similar to use rates used to control other nuisance aquatic vegetation. There were a total of 38 mesocosms, including 2 that were established with plants for a pretreatment harvest to establish baseline plant growth. The pretreatment harvest consisted of harvesting all pots (12 pots total) in two mesocosms and separating root and rhizome from shoot and leaf tissues and placing them in labeled paper bags. Bags were placed in a forced-air oven for 5 d at 70 C to dry plant material. After drying, the samples were weighed. After the pretreatment harvest, plants in treatment mesocosms were exposed to herbicide treatments.

Systemic herbicides were applied via submersed injection and remained in the mesocosms as static exposures for the duration of the experiment. Liquid concentrates of the systemic herbicides penoxsulam, triclopyr, and topramezone were injected under the water surface using a pipette. The systemic herbicide bispyribac-sodium (a soluble powder) was first mixed with 10 ml of water and then injected under the water surface with a pipette. Liquid contact herbicide concentrates were also applied as submersed injections using a pipette, and the plants were exposed to the herbicides for 1 d, then treated water was drained and mesocosms refilled with herbicide-free water. At 4 WAT, tanks receiving contact herbicides were retreated in the same manner.

The first posttreatment harvest was conducted 8 WAT, which consisted of randomly placing three 0.1-$m^2$ (13 by 13 in.) PVC frames on the surface of a mesocosm and harvesting all plant material within each frame to the bottom of the tank. Harvested material was separated and processed in the same manner as the pretreatment specimens. At 52 WAT, a second posttreatment harvest was conducted in the same manner as the 8-WAT harvest to determine long-term effects of submersed herbicide applications on torpedograss.

A one-way analysis of variance (ANOVA) was used to test for statistical differences in treatment means (Analytical Software 2009). Any differences detected in means were further separated using a Fisher's least significant difference test at $P < 0.05$ (Analytical Software 2009).

## RESULTS AND DISCUSSION

At 8 WAT with static systemic and repeat contact herbicide treatments, torpedograss shoot and leaf (SL) biomass were reduced 57% by triclopyr, 47% by diquat, 98% by flumioxazin, and 49% by carentrazone-ethyl, whereas penoxsulam, topramezone, endothall, and bispyribac-sodium had no effect (Figure 1). By 52 WAT, torpedograss SL tissues were still reduced by flumioxazin (97%) and carfentrazone-ethyl (57%), but were no longer reduced by triclopyr or diquat (Figure 1). Plants treated with diquat showed recovery, and had greater SL biomass than reference plants, by 52 WAT (Figure 1). Flumioxazin was the only treatment to reduce torpedograss SL tissues below pretreatment levels at 8 and 52 WAT (Figure 1). By 52 WAT,

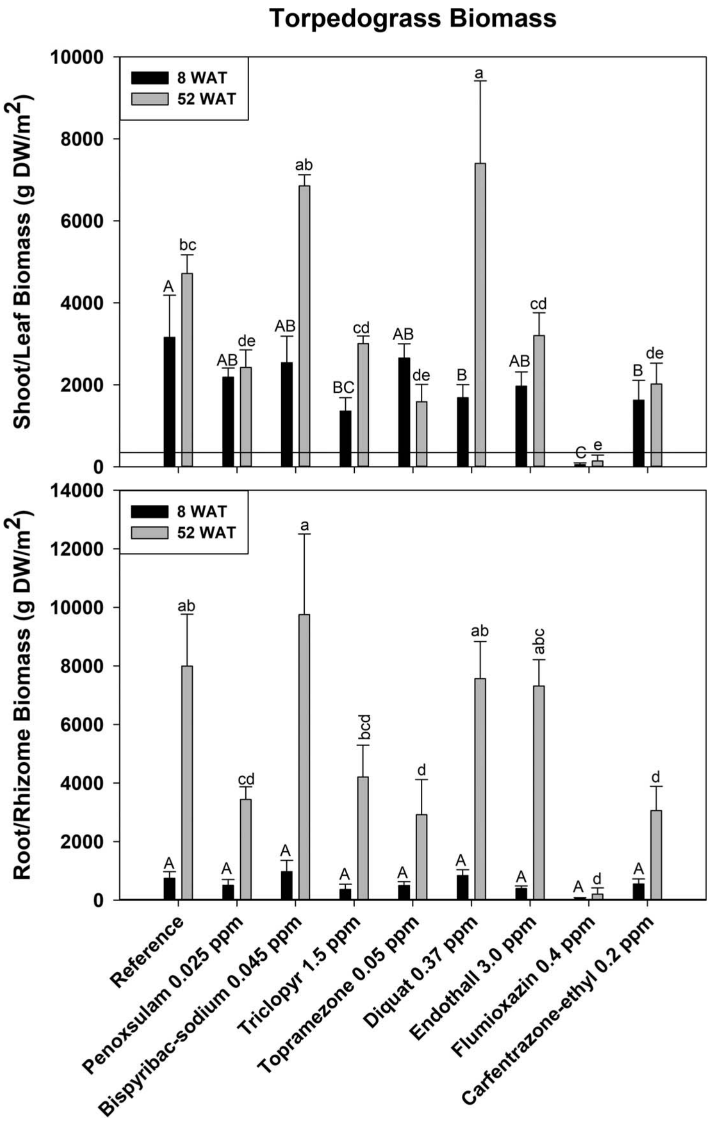

Figure 1. Torpedograss shoot/leaf (top) and root/rhizome (bottom) biomass at 8 and 52 wk after treatment (WAT). The solid lines represent pretreatment biomass; the root and rhizome pretreatment line is almost touching the x-axis. Error bars are one standard error of the mean ($P = 0.05$ significance level). Bars within sample dates sharing the same letter are not significantly different from one another; 8- and 52-WAT samples harvested using 0.1-m$^2$ PVC frames and analyzed separately.

penoxsulam and topramezone had reduced torpedograss SL tissues by 49% and 66%, respectively (Figure 1). Penoxsulam- and topramezone-treated plants typically require weeks to months to show symptomology, and it is likely that the 8 WAT harvest was conducted prior to the onset of major reductions in plant biomass.

Torpedograss root and rhizome (RR) tissues were not reduced by any herbicide 8 WAT (Figure 1). However, by 52 WAT, penoxsulam reduced these tissues by 57%, topramezone by 64%, flumioxazin by 97%, and carfentrazone-ethyl by 62% (Figure 1). At 52 WAT, triclopyr, diquat, endothall, and bispyribac-sodium failed to reduce torpedograss RR tissues (Figure 1). No herbicide reduced torpedograss RR tissues below pretreatment levels.

These results suggest that submersed applications of triclopyr (synthetic auxin), diquat (photosystem [PS] I electron diversion), flumioxazin (protoporphyrinogen oxidase [PPO] inhibitor), and carfentrazone-ethyl (PPO inhibitor) may deliver some degree of in-season reduction of torpedograss SL tissues. Flumioxazin may also be useful for burn-down applications to reduce nuisance torpedograss vegetation prior to implementing other control strategies. These data demonstrate that repeat applications of flumioxazin and carfentrazone-ethyl and static applications of penoxsulam (ALS inhibition) and topramezone (4-hydroxyphenyl-pyruvate dioxygenase [4-HPPD] or carotenoid inhibition) may reduce torpedograss SL and RR tissues for up to 52 wk. It should be noted that many factors, including plant growth stage at time of herbicide application, herbicide half-life in water (Shaner 2014), and/or climatic conditions (i.e., cold temperatures), can enhance or detract from the efficacy of herbicide applications among years as these factors can weaken plants from year to year. Similarly, herbicide application frequency, application rate, CET, plant density, and seasonal changes in epilimnion and hypolimnion water volume can affect control efficacy on target plants by affecting the amount of herbicide needed and the movement of herbicide through the water column (Getsinger et al. 2002).

Herbicides move through water in two major ways: diffusion and mass flow (a.k.a. bulk water exchange). For whole-lake treatments in closed systems, diffusion is the major factor driving herbicide dispersal; herbicide residues will diffuse though the water column until a steady concentration is reached within a treated layer of water (epilimnion vs. hypolimnion; Getsinger et al. 2002, Mudge et al. 2011). For whole-lake treatments, the volume of epilimnion and hypolimnion water can change seasonally as the thermocline moves vertically through the water column (Wetzel 2001), so timing of herbicide application can affect the amount of herbicide needed to control target plants. In partial lake herbicide treatments or herbicide treatments in flowing waters, mass flow (i.e., water currents) is also a major factor. Wind and wave activity, tidal activity, and downstream flow can move herbicide-treated water off of a treatment site (Fox et al. 1993, Turner et al. 1994). For this reason, understanding the relationship between herbicide concentration and exposure time on target vegetation is needed to maximize herbicide efficacy.

Torpedograss sensitivity to synthetic auxins (Brecke et al. 2001, McCarty et al. 1993) and ALS-inhibiting herbicides has been documented multiple times (Hanlon and Langeland 2000, Langeland et al. 1998, Stephenson et al. 2006, Toth 2007, Williams et al. 2003), but never as a subsurface injection to aquatic environments. To date, this is the first work to document short-term reduction of torpedograss by diquat (PS-I); however, Hossain et al. (1997) documented control of torpedograss by other herbicides that affect light processes (PS-II photosynthesis inhibition). Similarly, this is the first documentation of torpedograss reduction by an herbicide that affects carotenoid biosynthesis (topramezone). Lastly, this work appears to be the first to document control of torpedograss in any environment using PPO inhibitors (flumioxazin and carfentrazone-ethyl). Flumioxazin has been shown to control other weedy grass species in agricultural and turf settings (Grichar and Colburn 1996, Reed 2013), and may have a use for torpedograss control in associated aquatic environments (i.e., irrigation and golf course ponds) and associated riparian areas (i.e., pond margins).

It is beneficial that multiple herbicide modes of action exhibited some level of control of torpedograss, as they may provide alternatives to the standard glyphosate and imazapyr treatments that are commonly used on torpedograss in aquatic environments. The ability to use multiple modes of action could prevent herbicide resistance from occurring in torpedograss populations. Additionally, glyphosate and imazapyr are not known to control submersed plants so a chemical alternative would be beneficial when torpedograss occurs as a submersed plant in flooded conditions or during initial growth stages under water. Studies regarding CET requirements should be conducted to determine further the role of the herbicides tested here in flowing waters or water bodies where a static exposure is not feasible. Future studies should also be conducted on naturalized populations of torpedograss to determine if the results observed in the current mesocosm trial would translate to a field setting and to determine if the herbicides used here could give selective control of torpedograss. In addition, studies would need to be conducted to evaluate lower use rates, which could allow natural resource managers to have a lower financial input for managing torpedograss populations.

## SOURCES OF MATERIALS

[1] Osmocote 19-6-12 fertilizer, Scotts-Sierra Horticultural Products Company, 14111 Scottslawn Rd., Marysville, OH 43041.

[2] Navitrol® Landscape and Aquatic Herbicide, Lonza, 1200 Bluegrass Lakes Pkwy., Alpharetta, GA 30004.

[3] Galleon* SC Aquatic Herbicide, SePRO Corporation, 11550 North Meridian Street, Suite 600, Carmel, IN 46032.

[4] Oasis® Aquatic Herbicide, SePRO Corporation, 11550 North Meridian Street, Suite 600, Carmel, IN 46032.

[5] Tradewind™ Herbicide, Valent U.S.A. Corporation, P.O. Box 8025, Walnut Creek, CA 94596.

[6] Harvester® Aquatic Herbicide (diquat dibromide), Lonza, 1200 Bluegrass Lakes Pkwy., Alpharetta, GA 30004.

[7] Clipper® SC Aquatic Herbicide, Nufarm Inc., 11901 S. Austin Ave., Alsip, IL 60803.

[8] Stingray® Aquatic Herbicide, SePRO Corporation, 11550 North Meridian Street, Suite 600, Carmel, IN 46032.

[9] Aquathol® K Aquatic Herbicide, United Phosphorus, Inc., 630 Freedom Business Center, Suite 402, King of Prussia, PA 19406.

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