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Note

Endothall (dimethylalkylamine) concentration exposure time evaluation against two populations of *Elodea canadensis*

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INTRODUCTION

The submersed aquatic plant elodea (*Elodea canadensis* Michaux) is considered to be native or non-problematic in many parts of the U.S. (Washington State Department of Ecology 2013, University of Florida 2013); however, this plant has become problematic in irrigation canals of the Western U.S. and Australia (Bowmer and Sainty 1977, Sytsma and Parker 1999) where plants impede flow and the delivery of water for agricultural, domestic and industrial uses. Limited herbicide options exist to control this species in lakes or flowing waters. Acrolein is highly efficacious against elodea in irrigation canals (Bowmer and Sainty 1977, Bowmer et al. 1979), but is toxic to humans, fish, and other aquatic organisms (Reinert and Rodgers 1987, Eisler 1994). Both the dipotassium and dimethylalkylamine formulations of endothall are highly efficacious against hydrilla [*Hydrilla verticillata* (L. f). Royle], Eurasian watermilfoil (*Myriophyllum spicatum* L.) and sago pondweed (*Stuckenia pectinata* L.) (Netherland et al. 1991, Slade et al. 2008) and both were recently registered for plant control in U.S irrigation canals and systems with flow (Gray 2010, Gray 2011). Unfortunately, the dipotassium formulation of endothall alone has little to no effect on elodea (Skogerboe and Getsinger 2002, Sprecher et al. 2002); however, the dimethylalkylamine formulation of endothall has been used effectively in Australia to control this plant (Bowmer et al. 1979). Limited data exist on the concentration and exposure time (CET) requirements of the dimethylalkylamine endothall to control U.S. elodea populations. Therefore, research was conducted to evaluate, under laboratory conditions, CET relationships between the dimethylalkylamine formulation of endothall and two elodea populations.

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MATERIALS AND METHODS

Elodea populations were field collected from Wisconsin (hereafter referred to as WI) and Montana (hereafter referred to as MT) in the summer of 2011 from Half Moon Lake, WI, and Cabinet Gorge Reservoir, MT, on 8 July and 4 August 2011, respectively. The experiment was conducted at the U.S. Army Engineer Research and Development Center (USAERDC) in Vicksburg, MS, in a controlled-environment chamber equipped with 52, 55-L glass aquaria specifically designed for growing submersed plants. Based on previous submersed aquatic plant research conducted in growth chambers at USAERDC (Netherland et al. 1991, Skogerboe et al. 2006, Mudge and Theel 2011), conditions conducive for maintaining healthy elodea growth were maintained: temperature of 20 ± 0.4 C with a light intensity of 388 ± 57 µmol m^{-2} s^{-1} and a 14-hr/10-hr (light/dark) photoperiod. Four healthy elodea apical meristems (20 cm in length) that were green and firm with three or four lateral shoots each were planted into 750-ml plastic beakers filled with 3 : 1 topsoil[1] : sand sediment. The sediment was amended with Osmocote® 19–6–12 fertilizer[2] (2 g Kg^{-1} sediment). A 1 cm layer of silica sand was added to the sediment surface to reduce sediment and nutrient re-suspension into the water column to prevent algal contamination. Four 750-ml plastic beakers (two beakers of each elodea population) were placed in each aquaria filled with growth culture solution (Smart and Barko 1985). Beakers were marked to identify plant populations during the study. Elodea from WI was allowed to grow for 10 wk and elodea from MT grew for 6 wk, which allowed both populations to be similar in size at herbicide application. Both elodea populations exhibited healthy growth and were similar in dry weight (DW) at the time of treatment. Two beakers of each elodea population from three aquaria were used to measure elodea pretreatment shoot biomass: WI (4.1 ± 0.7 g DW) and MT (4.3 ± 0.6 g DW).

The dimethylalkylamine salt formulation of endothall[3] was applied as a subsurface treatment to healthy, actively growing elodea at concentrations of 0.5, 1.0, 2.0, and 3.0 mg acid equivalent (a.e.) L^{-1} with exposure times of 6, 8, and 12 hr. At the termination of assigned exposure times, aquaria were drained and filled with nutrient amended water to

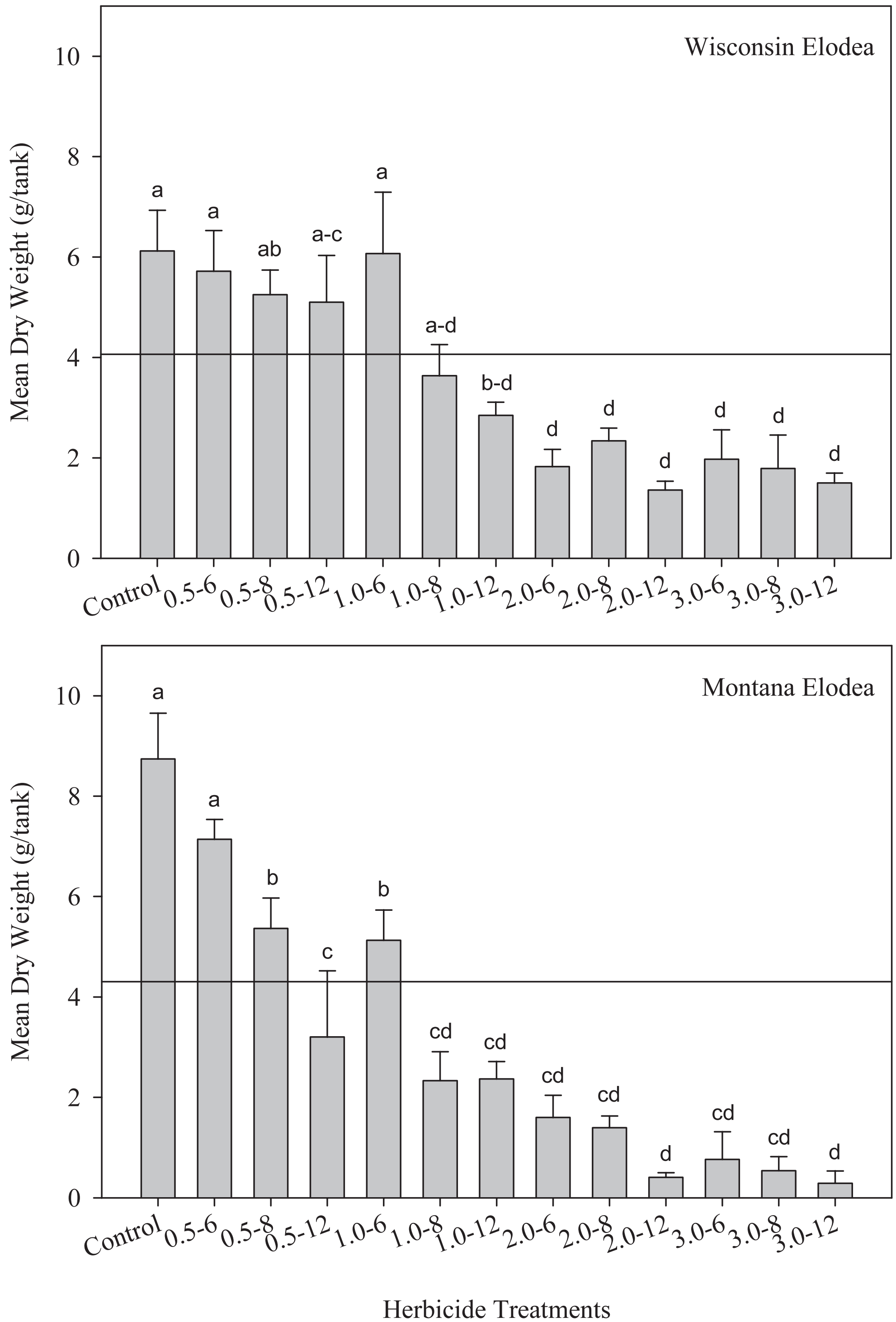

Figure 1. Effect of the dimethylalkylamine formulation of endothall at various concentration exposure times on Wisconsin and Montana populations of *Elodea canadensis* 6 wk after treatment. Horizontal lines represent pretreatment biomass. Endothall treatments are expressed as concentration (mg a.e. L^{-1})-exposure time (hr). Treatments within each graph (population) with the same letter are not significant according to Student-Newman-Keuls Method (SNK) at $P \leq 0.05$; $n = 3$.

remove herbicide residue. Non-treated reference aquaria were also used to compare plant growth in the absence of herbicide. Each treatment was replicated three times in a completely randomized design. All viable biomass attached to the main plant from both beakers of each elodea population were harvested 6 wk after treatment (WAT), placed in a forced-air drying oven at 70 C for 1 wk, weighed and analyzed for shoot dry weight biomass. Unattached plants were not collected at harvest since it was unknown which population the material belonged to. The experiment was conducted once and not repeated. A two-way ANOVA determined a treatment by population interaction; therefore, WI and MT elodea population data were not pooled. Biomass data were analyzed using ANOVA and means were separated using Student-Newman-Keuls Method (SNK) at $P \leq 0.05$.

RESULTS AND DISCUSSION

Regardless of CET combination, the dimethylalkylamine salt of endothall injured elodea 1 to 5 d after treatment (DAT), which initially included chlorosis and necrosis followed by defoliation and stem collapse 3 to 6 WAT. The speed and severity of injury was more evident as the concentration and exposure time increased; however, no visual differences were noted between the WI and MT populations when compared at the same CET treatment and within the same aquarium. In general, as CET increased, both populations of elodea decreased in biomass in response to the dimethylalkylamine salt of endothall (Figure 1). Nevertheless, there were some differences in response for specific CETs between the populations. All 0.5 mg L^{-1} treatments, as well as the 1.0 mg L^{-1}/6-hr and 1.0 mg L^{-1}/8-hr treatments, failed to reduce WI biomass compared to the non-treated control plants 6 WAT. In contrast, all other herbicide treatments reduced WI plant biomass from 53 to 78%, which was less than pretreatment level. Only endothall applied at 0.5 mg L^{-1} for 6 hr, failed to reduce MT biomass, while all other treatments reduced biomass 39 to 97% compared to the non-treated control. None of the CET treatments provided complete elodea control, i.e. 100% reduction biomass. Plant regrowth (e.g. new meristems emerging from injured shoot tissue) for both populations were observed as follows: 1 WAT for all 0.5 mg L^{-1}, 1.0 mg/6 hr, and 1.0 mg/8 hr treatments; 2 WAT for 1.0 mg/12 hr treatment; 3 WAT for all 2.0 mg L^{-1} treatments; and 4 WAT for all 3.0 mg L^{-1} treatments (data not shown).

Based on these data, the dimethylalkylamine salt of endothall has the potential to control elodea, especially at concentrations $\geq$ 2.0 mg L^{-1}. Also, endothall was efficacious against elodea even at relatively short exposure times of 6 to 12 hr. Despite many of these treatments being highly efficacious against this noxious weed, none of the CET combinations evaluated provided complete control. Even under the most ideal CET scenarios (high concentrations and long exposures), recovery and regrowth of new apical meristems were observed by 4 WAT. Additional small-scale research should be conducted to determine if multiple or sequential applications can provide better or complete plant control. In addition, future research is needed to determine if higher concentrations (4 to 5 μg a.i. L^{-1}) at various exposure times can provide increased efficacy for longer periods of time.

Previous research by Skogerboe and Getsinger (2002) demonstrated that elodea was only controlled when the dipotassium salt of endothall was applied at 4.0 mg active ingredient (a.i.) L^{-1} for a 24 hr exposure time, which is difficult to maintain under conditions with high bulk water exchange. The dimethylalkylamine salt of endothall is generally faster in activity and more efficacious than the dipotassium salt formulation when applied at the same concentrations (MacDonald et al. 2003). Although we did not compare endothall formulations in this research, there is a strong possibility that the dimethylalkylamine salt formulation is more efficacious than the dipotassium salt. In the current research, the dimethylalkylamine salt formulation was efficacious against two populations of elodea at concentrations as low as 2 mg L^{-1} when exposed for 6 hr, whereas the Skogerboe and Getsinger (2002) mesocosm trial demonstrated a 24 hr exposure at 4 mg L^{-1} of the dipotassium salt formulation was needed to significantly reduce biomass. In addition, elodea is only listed as a species controlled on the dimethylalkylamine herbicide label (UPI 2011b) and not the dipotassium herbicide label (UPI 2011a). The results of this small scale study provided a baseline for CET relationships required to control elodea with the dimethylalkylamine salt of endothall and field evaluations and should be documented in irrigation canals of the Western U.S. to verify these findings.

SOURCES OF MATERIALS

[1]Black Kow® Topsoil, Black Gold Compost Co., P.O. Box 190 Oxford, FL 34484.

[2]Osmocote®, The Scotts Company, 14111 Scottslawn Rd., Marysville, OH 43041.

[3]Teton® Aquatic Algicide and Herbicide, United Phosphorus Inc., 630 Freedom Business Center, Suite 402, King of Prussia, PA 19406.

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