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Endothall Concentration Exposure Time Evaluation Against Eurasian Watermilfoil at a Lower Water Temperature

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PURPOSE: This technical note describes the results of a laboratory investigation that evaluated the concentration-exposure time (CET) relationship for endothall and Eurasian watermilfoil (*Myriophyllum spicatum* L.) (EWM) at a low water temperature (18 °C). Most of the CET research conducted on EWM has been done when water temperatures are >21 °C. The level of EWM control during early season applications when water temperatures are cooler than 21°C is unknown.

BACKGROUND: The submersed aquatic weed EWM is a nuisance in water conveyance systems throughout the United States. Federally registered aquatic herbicides and experimental use permit (EUP) herbicides are currently being evaluated in laboratory and field trials for use in western irrigation canals for control of nuisance aquatic weeds including EWM.[1] Agriculture in the Western United States is dependent upon timely delivery of irrigation water via canals and other conveyances, and aquatic weeds directly impact the movement of water in these delivery systems (Parochetti et al. 2008). Currently, there are a limited number of registered and EUP herbicides available for weed control in irrigation canals. This study was conducted because of the direct connection with production agriculture and the limited weed control herbicides currently available. Contact herbicides are being considered for use in water conveyance systems since they are fast-acting products that would fit the short herbicide contact time conditions of flowing water canals. Both formulations of endothall (7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid), dipotassium and dimethylalkylamine salts, have recently received registration for use in irrigation canals (Anonymous 2010a; 2010b) and will provide an alternative to acrolein (2-propenal) and xylene (1,2-, 1,3-, and 1,4-dimethyl benzene), which are restricted from use for weed control in irrigation canals in some states.

The dipotassium salt of endothall is highly efficacious on EWM (Getsinger and Netherland 1997; Netherland et al. 1991). The CET relationships developed by Netherland et al. (1991) indicated EWM can be effectively controlled (>85 percent) at high concentrations (5 mg acid equivalent (ae) L^{-1}) and relatively short exposure periods (12-hr exposure time). Eurasian watermilfoil can also be controlled at low concentrations (0.5 mg ae L^{-1}) with longer exposure periods (48 to 72 hr). Previous growth chamber research demonstrated that weeds commonly found in irrigation canals such as sago pondweed (*Stuckenia pectinata* L.) required a similar CET relationship when using endothall (dipotassium salt) (Slade et al. 2008).

[1] Personal communication. 2010. J. D. Vassios, Graduate Research Assistant, Colorado State University, Fort Collins, CO 80523.

Early season herbicide applications may provide better weed control since plants have not reached the water surface and formed a canopy. Water temperatures in western irrigation canals typically range from 15 to 20°C during herbicide applications.[1] The objective of this experiment was to evaluate the CET relationships for endothall and Eurasian watermilfoil at a water temperature that is typical in irrigation canals in early spring.

MATERIALS AND METHODS: The study was conducted in aquaria (55-L) within an indoor environmental growth chamber at the U.S. Army Engineer Research and Development Center (ERDC) in Vicksburg, MS. All aquaria were filled with a nutrient solution (Smart and Barko1985) and individual overflow drains maintained a constant volume (48 L). Eurasian watermilfoil was collected from research ponds at the Lewisville Aquatic Ecosystem Research Facility (LAERF) in Lewisville, Texas. Four healthy apical stem segments (15 cm) were planted per cup (750 mL) and four cups were planted per aquarium. Brown's Lake sediment (Vicksburg, MS) was amended with NH_4Cl (200 mg L^{-1}) and Osmocote fertilizer 19-6-12 (2.1 g L^{-1}).

Plants were acclimated for 26 days prior to herbicide treatment. Endothall was applied as the dipotassium salt formulation at concentrations of 1, 2, and 4 mg ae L^{-1} with exposure times of 3, 6, 12, and 24 hr. Each concentration was pipetted from a concentrated stock solution into the water column of each aquarium. Following each exposure time, aquaria were drained and filled three times to remove endothall residues. All treatments were assigned to aquaria randomly and were replicated four times. At the time of treatment, mean EWM shoot and root biomass were 0.58 g and 0.17 g per cup, respectively. Water quality conditions (temperature 17.92° C ± 0.31, conductivity 0.27 ± 0.01 mS cm^{-1}, pH 8.98 ± 0.29, and light 392.59 ± 87.22 µmol m^{-2} sec^{-1}) did not differ ($P > 0.05$) between aquaria.

Shoot and root material were harvested 0 (pre-treatment), 4, and 8 weeks after treatment (WAT), dried (70 °C for 72 hr), and weighed to obtain dry weight biomass (g D.W.). Pre-treatment biomass was collected from cups in extra aquaria and two cups per treated or untreated control aquaria were averaged per harvest at 4 and 8 WAT. All data were analyzed using the analysis of variance (ANOVA) technique (SAS version 9.1 (SAS Institute, Inc. 2003)). Treatment differences were detected at an alpha (α) of 0.05 and a Student-Newman-Keuls (SNK) procedure was used for pairwise comparisons. Normality assumptions were assessed for all response variables. Root biomass did not meet normality assumptions and thus was transformed using a base-10 log + 0.01 transformation. Root biomass means were back-transformed for graphical depictions.

RESULTS AND DISCUSSION: At 18 °C, endothall treatments including 4.0 mg ae L^{-1}/6 hr, 2.0 mg ae L^{-1}/12 hr, 4.0 mg ae L^{-1}/12 hr, and all 24-hr exposures (1.0, 2.0, and 4.0 mg ae L^{-1}) significantly reduced EWM shoot biomass 77 to 98 percent 4 WAT compared to the untreated control (Figure 1). In addition, these endothall treatments reduced shoot biomass to below pre-treatment level 4 WAT. Eurasian watermilfoil necrosis was visible as early as 3 days after treatment (DAT) for all plants treated with endothall regardless of concentration and/or exposure time, which is comparable to previous research by Netherland et al. (1991). Shoot regrowth was visibly evident in most treatments 1 WAT, predominantly at lower concentration and exposure combinations. At

[1] Personal communication. 2009. C. J. Gray, Aquatics Specialist, United Phosphorus, Inc., Peyton, CO 80831.

4 WAT, root biomass was reduced 65 to 80 percent with the 4.0 mg ae L^{-1}/6 hr, 4.0 mg ae L^{-1}/12 hr, and all 24-hr exposure endothall treatments (Figure 2).

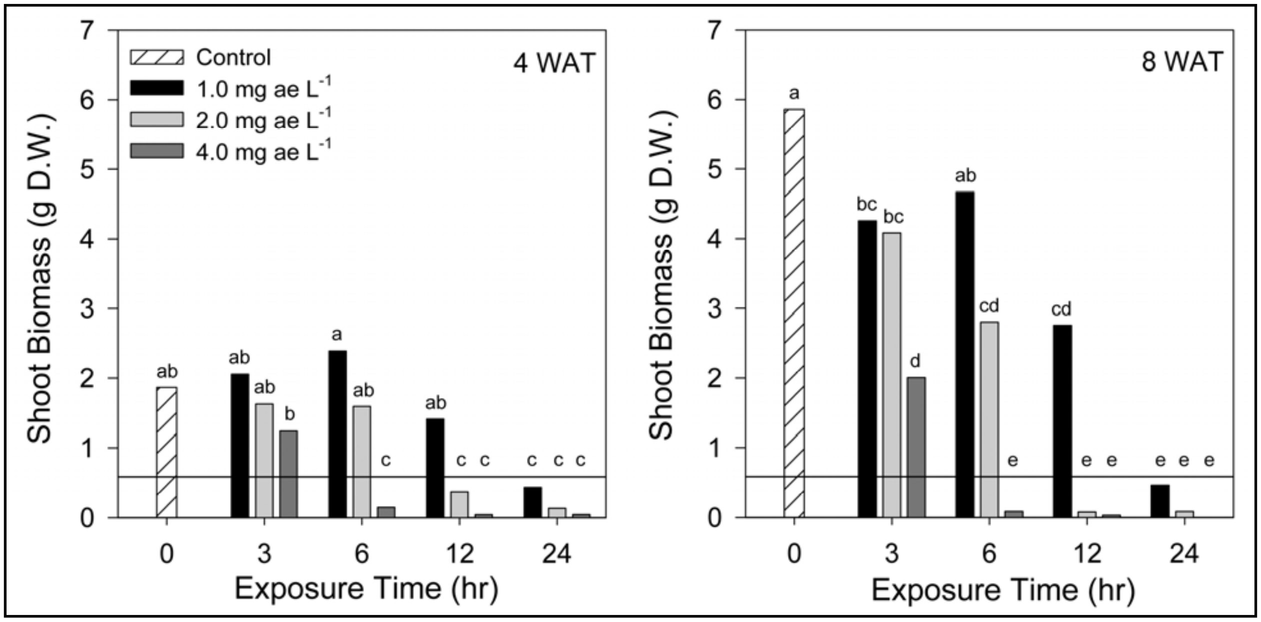

Figure 1. Endothall concentration-exposure time relationships for Eurasian watermilfoil shoot dry weight biomass (g D.W.) 4 and 8 weeks after treatment (WAT) at 18 °C. Means with a different letter within time periods differ significantly ($P < 0.05$); horizontal line represents pretreatment biomass.

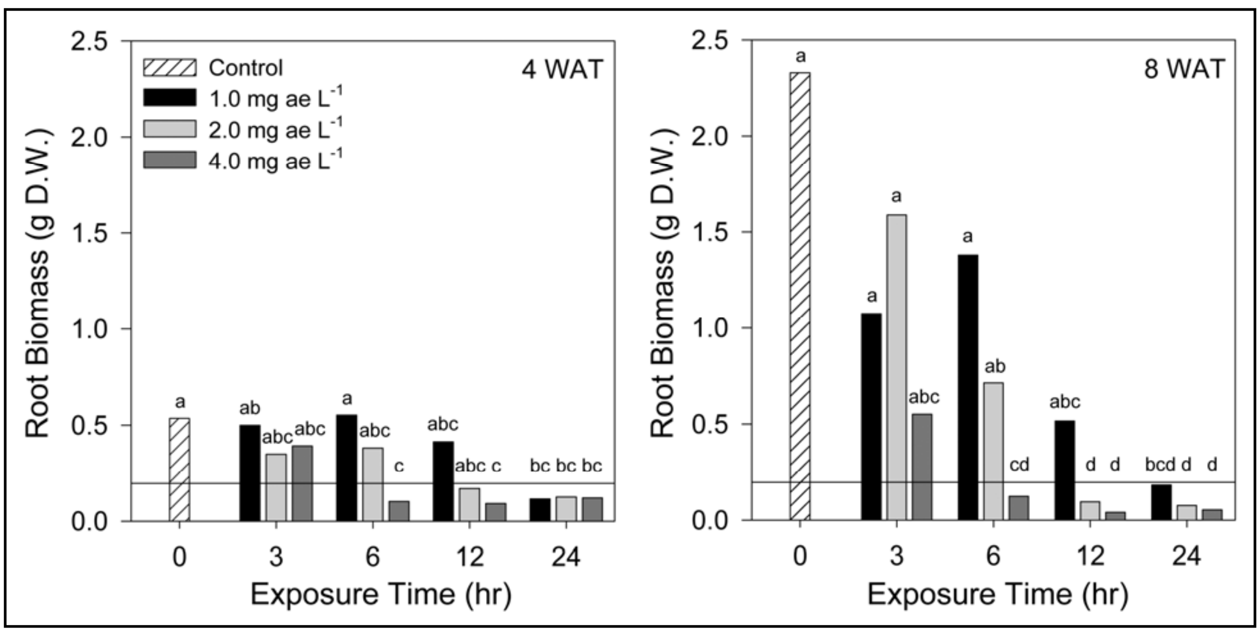

Figure 2. Endothall concentration-exposure time relationships for Eurasian watermilfoil root dry weight biomass (g D.W.) 4 and 8 weeks after treatment (WAT) at 18 °C. Means with a different letter within time periods differ significantly ($P < 0.05$); horizontal line represents pretreatment biomass.

All endothall treatments, except for the 1.0 mg ae L^{-1} 6 hr exposure, reduced EWM shoot biomass 27 to 99 percent 8 WAT (Figure 1). Half of the endothall treatments resulted in a decrease of shoot biomass to below pre-treatment level. Eurasian watermilfoil root biomass responded similarly to the shoot biomass with six of the twelve herbicide treatments providing biomass reductions to below pre-treatment level. In particular, many of the short exposure treatments regardless of endothall concentration failed to have a significant impact on EWM roots.

The CET relationships 4 WAT followed a similar pattern for both shoots and roots through the conclusion of the study (8 WAT), with lower concentration and exposure time combinations resulting in less control with more shoot regrowth than the higher concentrations and exposures. A 6- or 12-hr endothall exposure at higher concentrations as well as a 24-hr endothall exposure at all concentrations was efficacious against EWM shoots and roots 8 WAT. Results indicate endothall concentrations of 1.0, 2.0, and 4.0 mg ae L^{-1} should be maintained for a minimum of 24, 12, and 6 hr, respectively, to achieve >90 percent reduction in EWM shoot biomass 8 WAT.

The endothall concentrations (1, 2, and 4) multiplied by the required exposure time (24, 12, and 6 hr, respectively) equals a total value of 24. Any combination of concentration and exposure to equal a total value of 24 will likely achieve ≥90 percent EWM control. Conversely, previous research at 21°C indicated that endothall at concentrations of 0.5, 1.0, 3.0, and 5.0 mg ae L^{-1} should be maintained for at least 48, 36, 18, and 12 hr, respectively, to achieve >85 percent reduction in EWM biomass (Netherland et al. 1991). Results 4 WAT show greater EWM control at CET combinations of 1 mg ae L^{-1}/24 hr, 2 mg ae L^{-1}/24 hr, 4 mg ae L^{-1}/6 hr, and 4 mg ae L^{-1}/12 hr than predicted by Netherland et al. (1991), who used similar laboratory conditions but with water temperatures of 21 ± 2°C. This difference in efficacy may be due to water temperature. In the spring, EWM begins to rapidly grow at 15°C (Smith and Barko 1990), and is possibly more susceptible to endothall during this time. Therefore, future research should investigate the effects of a lower water temperature (≤15°C) on the CET relationship of endothall with regard to achieving better EWM control with lower water temperatures. Early-season (low temperature) endothall applications have been advantageous for curlyleaf pondweed (*Potamogeton crispus* L.) control (Poovey et al. 2002). Endothall (dipotassium salt) is recommended as an early season application when plants are actively growing for most effective results (Anonymous 2008), understanding the CET relationship for endothall and EWM would be beneficial for early season applications as well as in flowing systems that have cooler water temperatures such as irrigation canals.

FUTURE WORK: This research should be verified in the field to demonstrate endothall efficacy on EWM for early spring treatments. In addition, endothall should be evaluated against other weeds commonly found in irrigation canals.

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