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Endothall Species Selectivity Evaluation: Northern Latitude Aquatic Plant Community

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ABSTRACT

Species selectivity of the aquatic herbicide dipotassium salt of endothall (Aquathol® K) was evaluated on plant species typically found in northern latitude aquatic plant communities. Submersed species included Eurasian watermilfoil (*Myriophyllum spicatum* L.), curlyleaf pondweed (*Potamogeton crispus* L.), Illinois pondweed (*Potamogeton illinoensis* Morong.), sago pondweed (*Potamogeton pectinatus* L.), coontail (*Ceratophyllum demersum* L.), elodea (*Elodea canadensis* Michx.) and wildcelery (*Vallisneria americana* L.). Emergent and floating-leaf plant species evaluated were cattail (*Typha latifolia* L.), smartweed (*Polygonum hydropiperoides* Michx.), pickerelweed (*Pontederia cordata* L.) and spatterdock (*Nuphar advena* Aiton). The submersed species evaluations were conducted in 7000 L mesocosm tanks, and treatment rates included 0, 0.5 1.0, 2.0, and 4.0 mg/L active ingredient (ai) endothall (dipotassium salt of endothall). The exposure period consisted of a 24-h flow through half-life for 7 d. The cattail and smartweed evaluation was conducted in 860 L mesocosm tanks, and the spatterdock and pickerelweed evaluations were conducted in 1600 L mesocosm tanks. Treatment rates for the emergent and floating-leafed plant evaluations included 0, 0.5, 2.0 and 4.0 mg/L ai endothall, and the exposure period consisted of removing and replacing half the water from each tank, after each 24 h period for a duration of 120 h. Biomass samples were collected at 3 and 8 weeks after treatment (WAT). Endothall effectively controlled Eurasian watermilfoil and curlyleaf pondweed at all of the application rates, and no significant regrowth was observed at 8 WAT. Sago pondweed, wildcelery, and Illinois pondweed biomass were also significantly reduced following the endothall application, but regrowth was observed at 8 WAT. Coontail and elodea showed no effects from endothall application at the 0.5, 1.0, and 2.0 mg/L application rates, but coontail was controlled at 4.0 mg/L rate. Spatterdock, pickerelweed, cattail, and smartweed were not injured at any of the endothall application rates.

Key words: Aquathol® K, aquatic herbicide selectivity, native aquatic plants, *Myriophyllum spicatum, Potamogeton crispus, Potamogeton illinoensis, Potamogeton pectinatus, Ceratophyllum demersum, Elodea Canadensis, Vallisneria Americana, Typha latifolia, Polygonum hydropiperoides, Pontederia cordata, Nuphar advena.*

INTRODUCTION

The need to control excessive aquatic plant growth and invasive exotic weeds is well documented, yet many resource and aquatic managers recognize the benefits provided by native aquatic vegetation. Some exotic weeds such as Eurasian watermilfoil and curlyleaf pondweed form dense, undesirable surface canopies that adversely affect navigation, recreation, and water quality. Dense vegetation canopies can significantly reduce dissolved oxygen, increase water temperature, and limit light penetration for native plants (Bowes et al. 1979, Honnell et al. 1993). Removal of the canopy forming exotic plants can significantly increase native plant density and diversity (Getsinger et al. 1997) and improve boat navigation and recreation. This restoration of aquatic ecosystems has led to an interest in the species selective potential of several aquatic herbicides (Netherland et al. 1997, Sprecher et al. 1998).

Dipotassium salt of endothall (7-oxabicyclo(2.2.1)heptane-2,3-dicarboxylic acid) applied as the liquid formulation Aquathol® K, is described as a contact-type, membrane-active herbicide (Ashton and Crafts 1981), but other studies have shown slow initial uptake by submersed weeds (Haller and Sutton 1973, Reinert and Rogers 1986, Van and Conant 1988). In other studies, endothall has been shown to inhibit oxygen consumption (Macdonald et al. 1993). Endothall is generally recognized as a broad-spectrum product and is listed as effective against a wide range of aquatic plants including both Monocotyledons and Dicotyledons (Westerdahl and Getsinger 1988, Madsen 1997). Endothall has been widely used to control hydrilla (*Hydrilla verticillata* (L.F.) Royle), Eurasian watermilfoil and curlyleaf pondweed (Blackburn et al. 1971, Corbus 1982). Anecdotal evidence from field applicators indicates that efficacy of endothall varies greatly with species and application rate and therefore has the potential to be used for selective aquatic plant control based on use rates and the tolerance/sensitivity of target and non-target species. A previous selectivity study conducted on species representative of a southern latitude plant community showed plant response to endothall varied greatly with species and concentration (Skogerboe and Getsinger 2001). Results further showed that hydrilla could be selectively controlled with little or no long term damage to many but not all native plant species. Concentration exposure time

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(CET) relationships developed for Eurasian watermilfoil and hydrilla (Netherland et al. 1991) showed that even though hydrilla and Eurasian watermilfoil are both controlled by endothall, their sensitivity to the herbicide is very different. The CET relationship showed that hydrilla may require as much as twice the application rate or twice the exposure time to achieve the same control as on Eurasian watermilfoil. Concentration exposure time relationships need to be quantified on native plant species relative to target exotic species such as Eurasian watermilfoil and curlyleaf pondweed. Endothall application rates can then be selected to achieve effective control of target species, and minimize damage to, or enhance growth of non target species through reduced competition.

The objective of this study was to evaluate the tolerance/sensitivity of selected aquatic plants to dipotassium salt of endothall when applied over a range of concentrations generally recommended for field use. The plants evaluated represented a mixture of species that may occur in northern latitude aquatic ecosystems (Borman et al. 1997, Crow and Hellquist 2000a, b) dominated by the submersed exotic plants Eurasian watermilfoil and curlyleaf pondweed. A companion study, to evaluate endothall species selectivity on a southern latitude aquatic plant community (e.g., one dominated by the submersed exotic plant hydrilla) was conducted in the summer of 1997 (Skogerboe and Getsinger 2001).

MATERIAL AND METHODS

This study was conducted at a large outdoor mesocosm system at the United States Army Engineer Research and Development Center (USAERDC), Lewisville Aquatic Ecosystem Research Facility (LAERF), Lewisville, TX. Plant species were assigned to four independent test groups: a) submersed plants I; b) submersed plants II; c) emergent and floating–leafed plants; d) emergent plants.

Evaluations were conducted for submersed plants I and II, in 7000 L fiberglass, mesocosm tanks (water depth = 100 cm). Inflow valves were set to maintain a constant flow-through of water, which would provide a 24-h half-life for endothall dissipation. The stated half-life refers to dissipation resulting from water movement, and does not account for loses of endothall due to degradation. The dissipation rate was selected based on previous CET results (Netherland et al. 1991) and represent a medium length exposure time for endothall. Sediment used for growth media was collected from a dried pond located at the LAERF, and was characterized as silty clay. Healthy plant tissues of each species were planted between 11 and 13 March, 1998 in 8 L plastic containers filled with sediment amended with 10 g ammonium sulfate (21-0-0 and one "Woodace" nutrient briquette (14-3-3). Apical tips (3) of the submersed plants were planted except for sago pondweed and wildcelery, where 3 tubers were planted. Eleven containers per species and four species per tank (submersed plants I) were placed in each of 15 tanks, with plants grouped by species and separated into a quarter of each tank. The species in submersed plants I included Eurasian watermilfoil, curlyleaf pondweed, Illinois pondweed, and sago pondweed. An additional three species (submersed plants II) were planted and placed in 15 additional tanks. These plants included coontail, elodea, and wildcelery. Plants were allowed a 5-week pre-treatment growth period. On 13 May, 1998, endothall was applied as the dipotassium salt (Aquathol® K) at rates of 0, 0.5, 1, 2, and 4 mg/L ai, and each rate was replicated in three tanks. In addition, three tanks from submersed plants I and three tanks from submersed plants II received no endothall application and were used as untreated references. Plant biomass samples were collected at 3 and 8 weeks after treatment (WAT) by harvesting four pots per species from each tank at each evaluation period. The remaining containers provided backup for failed plantings. Failed plantings were identified and recorded prior to herbicide application. Shoot tissue samples were dried to a constant weight at 65 C for 96 h prior to determining biomass.

The evaluation on emergent and floating-leafed plants was conducted in twelve, 1600 L mesocosm tanks (water depth = 50 cm). The experimental design was similar to the submersed plant species test, except only two plant species were included in each tank, and water was not flowing through the tanks (see below). Plant species included spatterdock planted using rhizomes (1) and pickerelweed planted using rooted plants (2). Plant materials were rooted between 6 and 8 April 1998, and the dipotassium salt of endothall was applied at 0, 0.5, 2, and 4 mg/L ai endothall on 16 June 1998. Endothall exposure time consisted of a gradual dissipation conducted by draining ¼ of the tank at 24 h after treatment (HAT) and replacing the water with untreated water. Immediately after replacing the water an additional ¼ of the water in the tank was drained and replaced with untreated water. The entire procedure was repeated every 24 h at 48 HAT, 72 HAT, and 96 HAT. A complete 100% water exchange was then conducted at 120 HAT.

The evaluation on emergent plants, was conducted in twelve, 860 L mesocosm tanks (water depth = 50 cm). Plant species included cattail planted using rooted plants (3) and smartweed planted using stem pieces (3). The experimental design was identical to the emergent species evaluation described above, and dipotassium salt of endothall was applied at 0, 0.5, 2, and 4 mg/L ai on 7 July 1998.

Biomass data for all evaluations were subjected to analysis of variance (ANOVA) and the least significant differences (LSD) intervals ($p < 0.05$). The experimental design included 4 harvested pots each for 3 and 8 WAT nested within 3 replicated tanks per treatment. Biomass for each species was compared between treatments (0, 0.5, 1, 2, and 4 mg/L) for the 3 and 8 WAT harvests. In addition, biomass for each species was compared between time intervals (3 and 8 WAT) for each treatment. Data was transformed using the square root of biomass value in order to meet the assumptions of normality and equal variance.

RESULTS AND DISCUSSION

Eurasian watermilfoil, curlyleaf pondweed, Illinois pondweed, and sago pondweed were very sensitive to endothall (Figure 1). Biomass was less at all endothall rates compared to the untreated reference at the 3 WAT evaluation.

Eurasian watermilfoil biomass was reduced by 99% from even the lowest endothall rate of 0.5 mg/L at the 8 WAT eval-

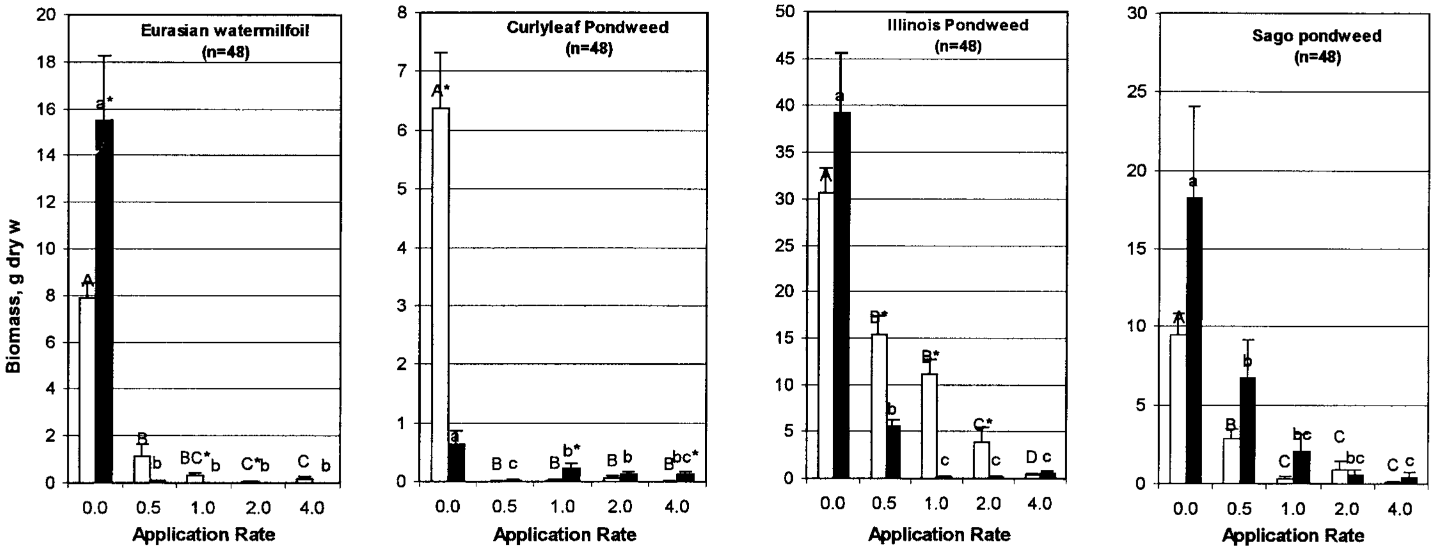

Figure 1. Submersed plant I biomass (g dry weight) at 3 (white bars) and 6 (black bars) weeks after treatment with varying concentrations of dipotassium endothall (mg/L a.i.). Capital letters indicate significant differences (P < 0.05) between treatments at 3 WAT samples, and lower case letters indicate differences between treatments at 8 WAT. Letters with asterisks (*) indicate significant differences between 3 and 6 WAT within an endothall application rate. Note differing biomass scales. Error bar represents the standard error.

uation, and no recovery was visible at this time. Biomass at the 3 WAT was less from the higher application rates of 2 and 4 mg/L than from the lower application rates of 0.5 and 1 mg/L, but there were no differences between the treatment rates at the 8 WAT evaluation.

Curlyleaf pondweed biomass was also reduced from all application rates compared to the untreated reference at the 8 WAT evaluation, and was reduced by 99% in the lowest application rate of 0.5 mg/L. Typically curlyleaf pondweed senesces in late spring or early summer, and this was the case in the untreated reference tanks where biomass was reduced by 90% at the 8 WAT evaluation compared to the 3 WAT evaluation. Some recovery or new growth was visibly apparent by the 8 WAT, but did not produce significant biomass.

Illinois pondweed showed a rate response to different application rates, and biomass at the 3 WAT evaluation was less from the 2 and 4 mg/L application rates than from the 0.5 and 1 mg/L application rate. No differences in biomass occurred between application rates at the 8 WAT evaluation, but visual observation indicated that new growth was occurring and Illinois pondweed would probably recover at all application rates.

Sago pondweed also showed a rate response to different application rates, and biomass at the 3 WAT evaluation was less from the 2 and 4 mg/L application rates compared to the 0.5 and 1 mg/L application rate. Biomass was greater at the 8 WAT evaluation than at the 3 WAT for the 0.5 and 1 mg/L application rates indicating that the plants were recovering from initial injury.

In contrast to the results of the four species noted above, Coontail biomass from the 0.5, and 1 mg/L endothall rates was not reduced compared to the untreated reference at both the 3 WAT and 8 WAT evaluations (Figure 2). Biomass from the 2 mg/L evaluation was not less than the untreated reference at the 3 WAT evaluation but was less at the 8 WAT evaluation. Biomass from the 4 mg/L endothall rate was less than the untreated reference and the other endothall rates at the 3 WAT and 8 WAT evaluations, and no living shoot biomass was observed.

Elodea biomass was not reduced (Figure 2) from the 0.5, 1, 2 and 4 mg/L application rates compared to the untreated references at the 3 WAT evaluations, but was reduced from the 4 mg/L endothall rate at the 8 WAT evaluation.

Wildcelery biomass was reduced from endothall rates of 1, 2 and 4 mg/L (Figure 2) compared to the untreated reference, but was not reduced from the 0.5 mg/L endothall rate at the 3 WAT evaluation. Biomass from all treatments including the untreated reference was reduced at the 8 WAT evaluation compared to the 3 WAT evaluation. Based on visual observation, plants at the 8 WAT evaluation had healthy, vigorous, green new shoots that showed signs of good recovery.

Spatterdock biomass was not affected by any application rate compared to the untreated reference at both the 3 WAT and 8 WAT evaluations (Figure 3). Pickerelweed biomass was also not affected by any application rate compared to the untreated reference at both the 3 WAT and 8 WAT evaluations (Figure 3).

Cattail biomass was not affected by any application rate compared to the untreated reference at both the 3 WAT and 8 WAT evaluations (Figure 3). Smartweed biomass was also not affected by any application rate compared to the untreated reference at both the 3 WAT and the 8 WAT evaluations (Figure 3).

While the dipotassium salt of endothall, applied as Aquathol® K, is generally recognized as a broad-spectrum product, results from this study indicate that it can be used at low concentrations to selectively control exotic plant species such as Eurasian watermilfoil and curlyleaf pondweed in northern plant communities. Selectivity of endothall was evident in this study in several ways. Target plants including

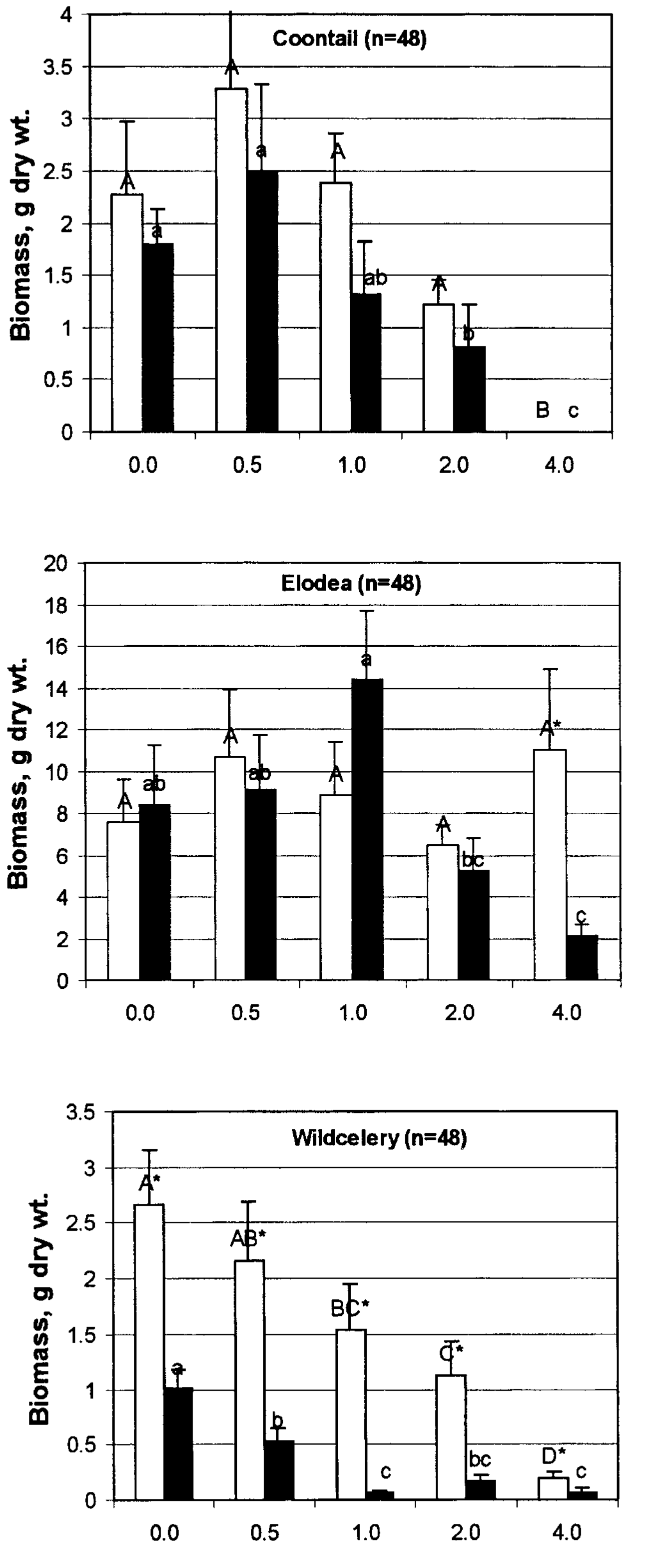

Figure 2. Submersed plant II biomass (g dry weight) at 3 (white bars) and 6 (black bars) weeks after treatment with varying concentrations of dipotassium endothall (mg/L a.i.). Capital letters indicate significant differences ($P < 0.05$) between treatments at 3 WAT samples, and lower case letters indicate differences between treatments at 8 WAT. Letters with asterisks (*) indicate significant differences between 3 and 6 WAT within an endothall application rate. Note differing biomass scales. Error bar represents the standard error.

Eurasian watermilfoil and curlyleaf pondweed were controlled by endothall at application rates of 0.5 to 1 mg/L. Other plants, including the native plants Illinois pondweed, sago pondweed, and wildcelery were initially injured or reduced by endothall but were not killed at these same rates. Depending on desired management goals, endothall could be applied at high application rates (≥2 mg/L) to control all of these species, or at lower application rates (≤1 mg/L) where native species should recover quickly, while Eurasian watermilfoil and curlyleaf pondweed would be controlled. Coontail was controlled at 2 to 4 mg/L, but no significant effects were noted at lower application rates. Many other plants were not injured or killed at any application rates of endothall evaluated in this study including elodea, spatterdock, pickerel-weed, cattail, and smartweed. In a previous study on endothall selectivity of plants found in southern plant communities, endothall did effectively control spatterdock at high rates, under a worst-case static exposure regime (Skogerboe and Getsinger 2001). In this study, however, spatterdock was exposed to varying rates of endothall using a gradual dissipation which in most cases would be more representative of lake and reservoir conditions. Under the exposure conditions used in this study, spatterdock showed no significant or visible effects from contact with endothall. These results emphasize the importance of contact time in selective control of target plant species such as Eurasian watermilfoil, curlyleaf pondweed, and hydrilla. Failure to properly anticipate or estimate exposure time could result in excessive damage to non target plant species or poor control of target plant species.

Dipotassium endothall can be used to selectively control exotic weeds such as Eurasian watermilfoil and curlyleaf pondweed through careful selection of application rates and a thorough knowledge of the hydrodynamics at the treatment site which controls herbicide exposure time or dissipation half life. Selective control should have the added benefit of preventing or slowing re-infestation by Eurasian watermilfoil or curlyleaf pondweed. Native plants that are not noticeably affected by endothall or those that recover quickly will be better able to compete for space, nutrients, and light, and should therefore help to prevent re-infestation of the invasive weeds. In addition, endothall is a non-persistent compound that degrades quickly and would therefore be unlikely to severely damage vegetation for any great distance away from the target treatment zone. Endothall may therefore also be considered as spatially selective.

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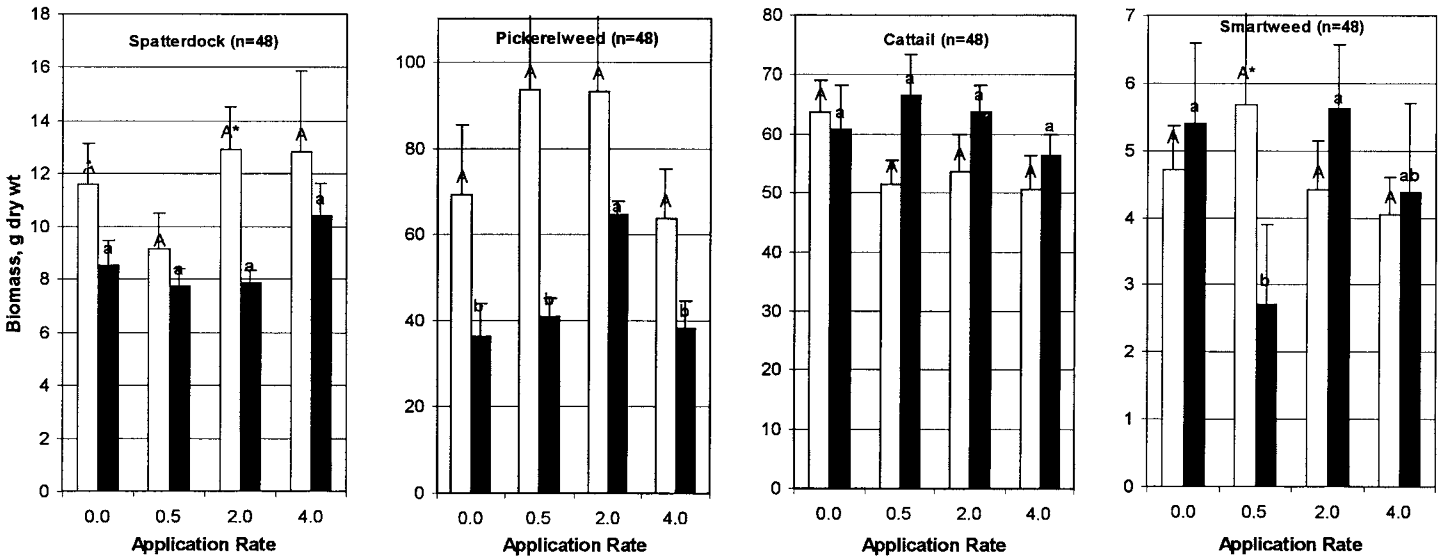

Figure 3. Emergent and floating-leafed plant biomass (g dry weight) at 3 (white bars) and 8 (black bars) weeks after treatment with varying concentrations of dipotassium endothall (mg/L a.i.). Capital letters indicate significant differences ($P < 0.05$) between treatments at 3 WAT samples, and lower case letters indicate differences between treatments at 6 WAT. Letters with asterisks (*) indicate significant differences between 3 and 6 WAT within an endothall application rate. Note differing biomass scales. Error bar represents the standard error.

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