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NOTES

Combinations of diquat and carfentrazone-ethyl for control of floating aquatic plants

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INTRODUCTION

Water hyacinth (*Eichhornia crassipes* Mart. Solms) is a common problem in waterways throughout the southern United States where it impedes the recreational use of rivers and lakes (fishing, swimming and boat traffic) and the generation of hydroelectric power. Water hyacinth increases the potential for flooding, reduces phytoplankton production, and alters ecosystem properties (Toft et al. 2003). Common duckweed (*Lemna minor* L.) infestations often reduce the use and aesthetics of small water bodies, may impact native submersed plant growth, and may be responsible for oxygen depletion in the water column (Hillman 1961, Parr et al. 2002). Nuisance populations of these plant species are often associated with influxes of nutrients; and in recent years, the amount of nutrients finding their way into waterbodies is increasing (Vitousek et al. 1997, Bedford et al. 1999). The influx of nutrients often results in increased growth rates, greater plant densities, and a source for new infestations. As environmental conditions for plant growth become more favorable, coupled with the ease at which floating species can disperse, new management recommendations need to be developed that result in rapid effective control.

The use of contact herbicides such as diquat (6,7-dihydrodipyrido (1,2-a:2',1'-c) pyrazinedium dibromide) have been effective for control of both water hyacinth and common duckweed (Langeland et al. 2002, Wersal and Madsen 2009). Diquat typically offers rapid results, although high applications rates are often used making the treatment of large areas cost prohibitive. Therefore, the use of low dose combinations of herbicides may offer an effective alternative than maximum rates of one product alone. Herbicide combinations have been used extensively in terrestrial situations, evident by the multitude of commercially available herbicide mixes; however, this approach is much less utilized and understudied in aquatic plant management.

Previous work has demonstrated that combinations of carfentrazone-ethyl (a,2-dichloro-5-[4-(difluoromethyl)-4,5-dihydro-3-methyl-5-oxo-1*H*-1,2,4-triazol-1-yl]-4-fluorobenzenepropanoic acid, ethyl ester) and 2,4-D results in faster Eurasian watermilfoil (*Myriophyllum spicatum* L.) and parrotfeather (*Myriophyllum aquaticum* Vell. Verdc.) control than 2,4-D alone (Gray et al. 2007). The combination of endothall (dipotassium salt of 7-oxabicyclo [2,2,1] heptane-2,3-dicarboxylic acid) and 2,4-D or triclopyr (triethylamine (TEA) salt of [(3,5,6-trichloro-2-pyridinyl) oxy]acetic acid) reduces the exposure time needed for Eurasian watermilfoil control as opposed to applying 2,4-D or triclopyr alone (Madsen et al. 2010). However, combinations of diquat and penoxsulam (2-(2,2-difluoroethoxy)-*N*-(5,8 dimethoxy [1,2,4] triazolo [1,5-*c*] pyrimidin-2-yl)-6 (trifluoromethyl) benzenesulfonamide) resulted in an antagonistic response between the herbicides when applied to water hyacinth and resulted in reduced efficacy than when applying penoxsulam alone (Wersal and Madsen 2010).

The antagonistic response is likely due to the rapid cell destruction by diquat that limits the translocation and efficacy of the slower acting enzyme inhibiting herbicides. Therefore, we evaluated the efficacy of low rates of diquat alone and in combination with low rates of another fast acting contact herbicide, carfentrazone-ethyl. The objective of this study was to determine if combinations of low rates of diquat and carfentrazone-ethly would enhance control of water hyacinth and common duckweed.

MATERIALS AND METHODS

The study was conducted once, in mesocosms, at the R. R. Foil Plant Science Research Center, Mississippi State University, from July through August 2008. Water hyacinth and common duckweed were planted into mesocosms from greenhouse stock held at Mississippi State University. Water hyacinth was placed into forty-five 378 L mesocosms to cover the water surface; and common duckweed was placed into forty-five 151 L mesocosms in a similar fashion. Plants were allowed to acclimate to growing conditions for approximately 2 weeks. Mesocosms were amended with 30 mg L^{-1} of Miracle Gro®[1] fertilizer (24-8-16) weekly to maintain growth (Wersal and Madsen 2009).

Following the acclimation period, foliar applications of diquat as Reward®[2] and carfentrazone-ethyl as Stingray®[3] were applied alone and in combination at ratios of 15:1, 7.4:1, 3.7:1, and 1.85:1 (diquat:carfentrazone-ethyl). An untreated reference was included for statistical comparisons to treated plants. A 0.25% v:v non-ionic surfactant (Cygnet Plus®[4]) was added to the spray solution and applied at 468 L ha^{-1} (50 gal

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acre^{-1}) using a CO_2 pressurized single-nozzle spray apparatus. Each treatment was replicated in three mesocosms. At 4 WAT, one biomass sample was harvested in all water hyacinth mesocosms using a 0.10 m^2 quadrat and two samples harvested in all common duckweed mesocosms using a 0.002 m^2 sampling device (Wersal and Madsen 2009). Dead above ground water hyacinth leaves and petioles were removed, although all root biomass was included in all samples. All common duckweed fronds were included in the harvesting and subsequent analysis. Plants were washed dried at 70 C for 72 h and weighed to determine biomass.

Statistical analyses

A general linear model was used in SAS® to determine differences in biomass and herbicide treatments within plant species. If a significant difference was detected, treatment means were separated using the Fisher's Protected LSD test. All analyses were conducted at a $p < 0.05$ level of significance.

RESULTS AND DISCUSSION

Water hyacinth

Water hyacinth treated with the combination of diquat and carfentrazone-ethyl at 280 and 152 g ai ha^{-1} resulted in a 99% reduction in biomass 4 WAT; although control was similar to diquat applied at 560 g ai ha^{-1}, carfentrazone-ethyl applied at 76 and 152 g ai ha^{-1}, diquat+carfentrazone-ethyl at 140+76 g ai ha^{-1}, and all other combinations containing 280 g ai ha^{-1} of diquat (Figure 1). Diquat applied alone at 560 g ai ha^{-1} resulted in an 88% reduction in water hyacinth biomass with respect to untreated reference plants. Carfentrazone-ethyl applied at 152 g ai ha^{-1} resulted in 89% biomass reduction 4 WAT. Diquat applied at 4600 g ai ha^{-1} resulted in greater than 95% control of water hyacinth 14 days after treatment (DAT; Langeland et al. 2002). Data from this study suggest that comparable water hyacinth control can be achieved using reduced rates of diquat and carfentrazone-ethyl out to 4 WAT. Additionally, the combination of herbicides did not offer increased efficacy when compared to diquat applied at 560 g ai ha^{-1} or carfentazone-ethyl applied at 76 and 152 g ai ha^{-1}.

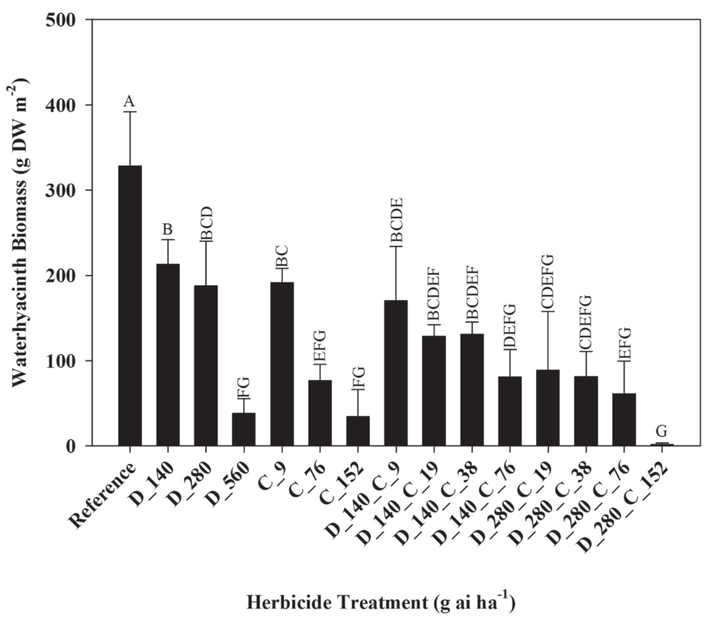

Figure 1. Mean biomass (±1 SE) of water hyacinth 4 weeks after treatment with low rates of diquat and carfentrazone-ethyl alone and in combination. Bars sharing the same letter are not significantly different according to a Fisher's Protected LSD analysis at a $p < 0.05$. On the x-axis, a D indicates a treatment of diquat and a C indicates a treatment of carfentrazone-ethyl, with the number that follows signifying the rate of the active ingredient in g ai ha^{-1}.

Common duckweed

The herbicide rates and combinations evaluated in this study did not result in control of common duckweed 4 WAT ($p = 0.57$), and no treatment resulted in >8% reduction in biomass (data not shown). There were early visual injury symptoms observed on plants treated with 560 g ai ha^{-1} of diquat, but these symptoms were minimal at the conclusion of the study. Previous studies have reported >95% control of common duckweed when using 4600 g ai ha^{-1} of diquat (Langeland et al. 2002, Wersal and Madsen 2009). The use of carfentrazone-ethyl alone or in combination with diqaut, at the rates tested in this study, also did not offer control of common duckweed. The closely related landoltia (*Landoltia punctata* [G. Mey.]) was reported to have an EC_{90} value of 772.7 g ai ha^{-1} and was the most tolerant of floating plants to carfentrazone-ethyl (Koschnick et al. 2004). Our results, and those previously published, suggest that higher rates of diquat and carfentrazone-ethyl are needed to control common duckweed.

Herbicide combinations have been well documented in agricultural settings to improve efficacy, reduce the costs associated with weed control, and identify antagonistic combinations (Green 1989). As additional chemistries become available for use in aquatic habitats and as plant community compositions change due to nonnative species or environmental factors, studies that assess the compatibility and efficacy of herbicide combinations will be of greater importance. In aquatic plant management this could lead to reduced costs through lower use rates, greater herbicide efficacy, meeting contact and exposure requirements, increasing management efficiency by targeting more than one plant species with a single application, and could complement herbicide stewardship programs. Future research needs to assess herbicide interactions for aquatic plant management, identify additional beneficial herbicide combinations, and effective rates for herbicide combinations.

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SOURCES OF MATERIAL

[1]Miracle-Gro® Water Soluable All Purpose Plant Food, The Scotts Company, PO Box 606 Marysville, OH 43040

[2]Reward® Landscape and Aquatic Herbicide, Syngenta Professional Products, PO Box 18300 Greensboro, NC 27419

[3]Stingray®, FMC Corporation, 1735 Market Street, Philadelphia, PA 19103.

[4]CygnetPlus®, Brewer International, PO Box 690037, Vero Beach, FL 32969.

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Evaluations of contact aquatic herbicides for controlling two populations of submersed flowering rush

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ABSTRACT

Flowering rush (*Butomus umbellatus* L.) is a rapidly spreading invasive aquatic plant in the northern United States. Introduced from Eurasia, it grows as an emergent plant along shorelines and as a submersed plant in deeper water of lakes and rivers. Because submersed flowering rush grows in fluctuating water levels, management of this plant has been inconsistent and unpredictable. Two small-scale experiments were conducted to evaluate contact herbicide efficacy on the submersed form of flowering rush from two triploid populations, one from Minnesota and one from Idaho. In the first experiment, various concentrations and exposure times of diquat, endothall, and flumioxazin were applied to Minnesota flowering rush. In the second experiment, concentration–exposure time relationships were investigated for flumioxazin against Idaho flowering rush. One treatment of endothall was used to compare flumioxazin, a newly registered compound, with an older chemistry. Results of both experiments showed that contact herbicides are effective against flowering rush. Although flumioxazin (200 µg ai L^{-1}) did not significantly reduce shoot biomass for exposure periods of 12 or 24 h, concentrations of diquat (370 µg ai L^{-1}) for exposure times of 6 and 12 h, and endothall (1500 and 3000 µg ai L^{-1}) for exposure times of 12 and 24 h reduced shoot biomass of Minnesota submersed flowering rush by >70%; however, these treatments did not significantly impact root biomass. Lateral rhizome buds, which serve as a source of annual reinfestation, were found in all treatments. Concentrations of flumioxazin (400 µg ai L^{-1}) and endothall (3000 µg ai L^{-1}) for exposure times of 24 h controlled Idaho submersed flowering rush by successfully reducing shoot and root biomass by >70%. Application strategies for complete control of triploid flowering rush shoots and roots with contact herbicides may require repeat applications and/or combinations with each other and systemic herbicides. Further evaluation of herbicides for controlling triploid as well as diploid flowering rush is warranted.

Key Words: *Butomus umbellatus*, diquat, endothall, flumioxazin, triploid.

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