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NOTES

The susceptibility of duckweed (*Lemna minor* L.) to fluridone and penoxsulam

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INTRODUCTION

Duckweed (*Lemna minor* L.) is a free floating aquatic perennial plant that can cause significant nuisance problems in small water bodies throughout the southeastern United States. Duckweed infestations can cause reductions in dissolved oxygen and biodiversity, impede navigation, and reduce the aesthetics of infested water bodies (Lewis and Bender 1961, Kilgore and Hoover 2001, Parr et al. 2002). Previous studies have evaluated diquat (6,7-dihydrodipyrido [1,2-a',1'c] pyrazinedium dibromide) as the primary herbicide for the control of duckweed; however, the herbicide has to come in contact with each frond, so results are dependent on a thorough application (Blackburn and Weldon 1965, Langeland et al. 2002, Wersal and Madsen 2009). Such applications are often difficult to accomplish in ponds or lakes; therefore, new management recommendations need to be developed for other herbicides to promote herbicide stewardship and reduce the likelihood of herbicide resistance developing in plants.

Fluridone (1-methyl-3-phenyl-5-[3-trifluromethyl)phenyl]-4-(1*H*)-pyridinone) is a systemic herbicide labeled for aquatic use. Fluridone is a carotenoid biosynthesis inhibitor that enhances the degradation of chlorophyll by inhibiting phytoene desaturase, which results in an accumulation of phytoene and subsequently causes degradation of chlorophyll and the "bleaching" effect seen in treated plants (Bartles and Watson 1978, Senseman 2007). Fluridone has been evaluated on a number of invasive plant species including curlyleaf pondweed (*Potamogeton crispus* L.), Eurasian watermilfoil (*Myriophyllum spicatum* L.), hydrilla (*Hydrilla verticillata* Royle) and sago pondweed (*Stuckenia pectinata* [L.] Böerner; Spencer et al. 1989, Netherland et al. 1993, Fox et al. 1994, Getsinger et al. 2002, Madsen et al. 2002). Duckweed has shown sensitivity to fluridone at concentrations of 0.25 to 4.0 mg L^{-1}, with these concentrations providing 100% control for up to 6 weeks after treatment (WAT; McCowen et al. 1979). Kay (1991) reported that watermeal (*Wolffia columbiana* Karst.), a member of the Lemnaceae family and relative to duckweed, was controlled using early fall applications of fluridone at 1.68 and 1.12 kg ai ha^{-1}.

Penxosulam (2-(2,2-difluroethoxy)-*N*-(5,8-dimethoxy[1,2,4] triazolo[1,5-*c*]pyrimidin-2-yl)-6-(trifluoromethyl) benzenesulfonamide) is another systemic herbicide, registered for aquatic use in 2009. Penoxsulam is an acetolactase synthase (ALS) inhibitor, affecting branched chain amino acid synthesis in susceptible plants (Senseman 2007). Penoxsulam is efficacious as a subsurface application for control of waterhyacinth (*Eichhornia crassipes* [Mart.] Solms) and giant salvinia (*Salvinia molesta* Mitchell) at concentrations of 2, 5, 10, and 20 µg L^{-1} (Richardson and Gardner 2007). Shearer and Nelson (2009) showed a significant reduction of hydrilla biomass when exposed to 10 ppb concentration of penoxsulam under static exposure from 35 to 90 days after treatment.

To date, minimal research has been published on the efficacy of fluridone on duckweed, and none published regarding penoxsulam efficacy on duckweed. Therefore, the objectives of this study were to evaluate the susceptibility of duckweed to a range of fluridone and penoxsulam concentrations.

MATERIALS AND METHODS

Two studies were conducted at the R.R. Foil Plant Science Research Center, Mississippi State University, Starkville, Mississippi. Both studies contained 3 concentrations of fluridone and penoxsulam as well as an untreated reference. Treatments were completely randomized with 4 replicates per treatment. Duckweed was collected locally from a small pond near Mississippi State University. Approximately 1.0 kg of duckweed was planted in 56 tanks, 378 L each (135 × 79 × 64 cm), to cover the water surface. Plants were allowed to acclimate for 2 weeks prior to herbicide treatments. Water was amended weekly with fertilizer[1] (15-30-15) at a rate of 30 mg L^{-1} per week to maintain plant growth (Wersal and Madsen 2009). An inert light attenuating dye[2] was used to reduce algae growth in the tanks. Study 1 was conducted for 12 weeks beginning in May 2008 and repeated at the same time in 2009. Herbicide treatments evaluated in study 1 included fluridone[3] and penoxsulam[4] applied as subsurface treatments at concentrations of 5, 10, and 15 µg ai L^{-1} (hereafter, ppb). Study 2 was conducted for 12 weeks beginning in August 2008 and repeated at the same time in 2009. Herbicide concentrations used in study 2 included fluridone and pe-

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noxsulam applied as subsurface treatments to achieve target concentrations of 25, 50, and 75 ppb.

Two weeks after planting, a concentrated aqueous solution was added to each tank to achieve the target concentrations for both studies. Subsurface applications were made to 276 L of water under static exposure. At 12 WAT, 2 biomass samples were taken from each tank using a PVC sampling device (0.002 m^2; Cheshier et al. 2008, Wersal and Madsen 2009). Biomass samples were dried at 70 C for a minimum of 48 h, weighed, and converted to g DW m^{-2} based on the area of the sampling device. Biomass data from both studies were analyzed using a mixed procedures model in SAS to examine the effects of year and concentration (Littell et al. 2006). There was no year effect for studies 1 and 2 ($p = 0.62$ and $p = 0.10$, respectively); therefore, biomass data were pooled across years. If a significant treatment effect was observed, differences were then separated by the least squares means method (Littell et al. 2006.) All analyses were conducted at $p = 0.05$ level of significance.

RESULTS AND DISCUSSION

In study 1, duckweed biomass in tanks treated with fluridone at 5 and 10 ppb were not significantly different from the untreated reference plants 12 WAT (Figure 1A). However, the 15 ppb rate of fluridone reduced duckweed biomass 40% when compared to the untreated reference plants during the same time period. Duckweed exposed to penoxsulam at 5, 10, and 15 ppb had biomass values significantly different from the untreated reference 12 WAT and resulted in 33, 62, and 63% reduction in duckweed biomass, respectively.

In study 2, subsurface applications of fluridone at 25, 50, and 75 ppb resulted in 100% duckweed control 12 WAT (Figure 1B). Penoxsulam at 25, 50, and 75 ppb reduced duckweed biomass 90, 51, and 71% respectively 12 WAT; however, viable duckweed was still present in all penoxsulam treated tanks.

Reduced fluridone efficacy at the lower concentrations may be due to increased degradation rates. Fluridone is primarily degraded through photolysis (Saunders and Mosier 1983), and when exposed to full sunlight has a half-life of 15 to 36 h (Mossler et al. 1989). Following fluridone application, the creation of openings in the duckweed mat could have increased the amount of light penetration into the water column and contributed to the reduced efficacy with the 5, 10, and 15 ppb treatments. Microbial degradation is the primary dissipation pathway for penoxsulam (Jabusch and Tjeerdema 2006a, Senseman 2007); however, photolysis can also play a role in the degradation of penoxsulam and may have aided in reduced efficacy as well (Jabusch and Tjeerdema 2006b). For both fluridone and penoxsulam, the 5, 10, and 15 ppb concentrations may be too low to effectively eliminate duckweed under field conditions, even though each significantly reduced duckweed biomass in this study.

A previous field demonstration showed that an initial treatment of 50 ppb of fluridone followed by a 40 ppb bump one month later was highly effective at reducing duckweed biomass at the lake scale (Cheshier et al. 2008). Penoxsulam at higher rates were more effective at reducing duckweed biomass; however, there was still viable duckweed 12 WAT.

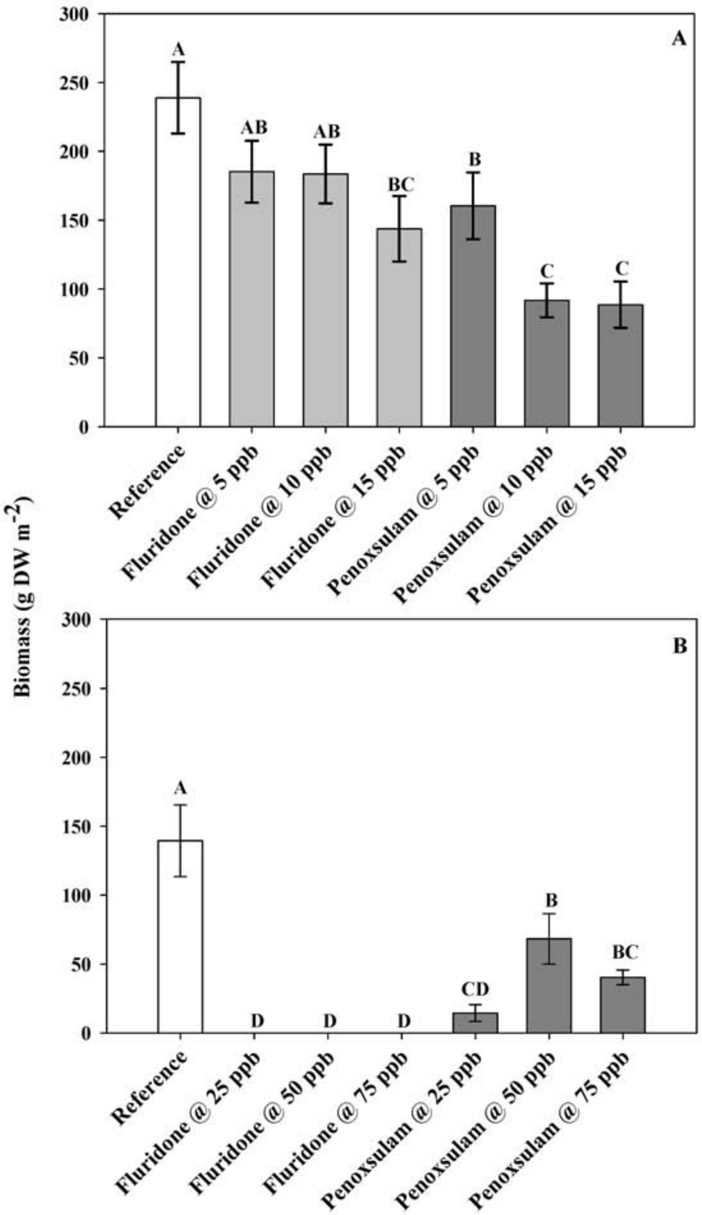

Figure 1. Mean (±1 SE) duckweed dry weight biomass (gDW m^{-2}) harvested 12 WAT treated with subsurface applications of (A) 5, 10, and 15 ppb fluridone and penoxsulam, and with (B) 25, 50, and 75 ppb fluridone and penoxsulam. Bars sharing the same letter are not significantly different at a $p = 0.05$ level of significance according to least squares means.

The 25, 50, and 75 ppb concentrations used in this study are within the label recommendations for penoxsulam; however, no more than 150 ppb can be applied per annual growth cycle (SePRO Corporation 2009). These data indicate that a concentration of 25 ppb or higher of fluridone and 25, 50, and 75 ppb concentrations of penoxsulam can effectively reduce duckweed biomass. However, higher concentrations of penoxsulam may be required for complete control of duckweed. Although penoxsulam significantly reduced duckweed biomass at 25, 50, and 75 ppb, further research should be conducted to evaluate foliar versus subsurface application methods on the efficacy of penoxsulam against duckweed.

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SOURCES OF MATERIALS

[1]Miracle-Gro® Water Soluble All Purpose Plant Food, The Scotts Company, P. O. Box 606 Marysville, OH 43040.

[2]AquaShade®, Arch Chemical, Norwalk, Connecticut.

[3]Sonar AS®, SePRO Corporation, Carmel, Indiana.

[4]Galleon SC®, SePRO Corporation, Carmel, Indiana.

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