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Notes

Evaluation of six herbicides for control of swamp smartweed [*Persicaria hydropiperoides* (Michx.) Small] under flooded and moist soil conditions

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INTRODUCTION

Swamp smartweed [*Persicaria hydropiperoides* (Michx.) Small] is a native perennial dicot that is found throughout the United States (McDonald 1980). Typically, swamp smartweed is found in ditches, marshes, and along the shores of lakes, ponds, and streams (Tarver et al. 1986). Swamp smartweed reproduces sexually by seed and asexually by rhizomes and fragmentation (Godfrey and Wooten 1981). Swamp smartweed is adapted to anoxic conditions, and can withstand a wide range of aquatic pH from 4.5 to 8.0 (Carter and Grace 1990).

The problems associated with uncontrolled aquatic plants are widely recognized. Unmanaged aquatic plants can form dense canopies that increase water temperature, diminish dissolved oxygen, and reduce sunlight needed for photosynthesis. Dense populations of swamp smartweed can hinder water flow through irrigation and navigation canals (Tarver et al. 1986), as well as impede recreational activities in and around shoreline areas. This plant can form nuisance growth in aquatic habitats because of its ability to regenerate quickly and colonize susceptible areas (Tarver et al. 1986). This rapid growth rate, combined with swamp smartweed's ability to withstand anoxia and wide ranges of pH, can result in monotypic populations and reductions in biodiversity. Given the generalist growth habits of this species, it has become problematic in many small ponds and wildlife management areas across Mississippi.

Triclopyr, 2-4-D, diquat, glyphosate, imazapyr, and imazamox are herbicides currently being used for controlling a variety of emergent aquatic plant species. Triclopyr and 2,4-D are selective systemic herbicides that mimic the endogenous auxin, indole-3-acetic acid, and affect cell wall integrity (Senseman 2007). Diquat is a nonselective contact herbicide used to control grasses and broadleaves in agricultural systems as well as in noncroplands (Senseman 2007). Glyphosate is a nonselective foliar-applied herbicide (Senseman 2007) used to control emergent and floating aquatic plants such as common reed [*Phragmites australis* (Cav.) Trin. ex Steud.] and waterhyacinth [*Eichhornia crassipes* (Mart.) Solms] (Lopez 2993, Derr 2008). Imazapyr and imazamox are systemic herbicides that inhibit branch chain amino acid production (Shaner and Mallipudi 1991, Senseman 2007).

To date, no research has been conducted to evaluate these herbicides for control of swamp smartweed in a pond or moist soil wetland. Therefore, the objective of this study was evaluate the sensitivity of swamp smartweed to 2,4-D, diquat, glyphosate, imazamox, imazapyr, and triclopyr in two different habitats: a flooded pond and dewatered moist soil wildlife management area.

MATERIALS AND METHODS

Two herbicide-efficacy studies were conducted near Starkville, MS on populations of swamp smartweed. Study one was conducted in a 0.1-ha pond with an average depth of 2.8 m for 5 wk beginning in June 2005 and ending in July 2005. Study two was conducted in an 8.1-ha moist-soil wetland for 6 wk beginning in April 2007 and ending in May 2007. These studies were conducted as part of a broader habitat management study in Mississippi.

Pond study

In an initial study, the control of swamp smartweed was evaluated using two rates of glyphosate[1] (2.1 and 4.2 kg ae ha^{-1}), imazapyr[2] (0.2 and 0.5 kg ai ha^{-1}), and triclopyr[3] (3.4 and 6.7 kg ae ha^{-1}), and an untreated reference. Herbicide rates were based on 50 and 100% of the maximum-labeled rate. Treatments were assigned using a randomized complete block design with three replications per treatment. Treatment plots were 1 m by 1 m and spaced 3 m apart

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Table 1. Percent control of swamp smartweed biomass from a pond for 5 wk after treatment.

Treatment	Rate	Weeks after Treatment (WAT)[1]				
		1	2	3	4	5
Untreated control	0	0 a	0 a	0 a	0 a	0 a
Glyphosate	2.1 kg ae ha^{-1}	62 cde	67 b	72 b	92 c	92 b
	4.2 kg ae ha^{-1}	97 e	98 b	97 b	97 c	97 b
Imazapyr	0.28 kg ai ha^{-1}	93 e	97 b	97 b	98 c	98 b
	0.56 kg ai ha^{-1}	58 de	65 b	72 b	93 c	93 b
Triclopyr	3.4 kg ae ha^{-1}	30 a	27 a	20 a	27 b	23 a
	6.7 kg ae ha^{-1}	76 cde	78 b	73 b	73 c	70 b

[1]Means with different letters within a column are significantly different at the $P = 0.05$ level based on ANOVA (Fisher's Protected LSD).

within each block. Blocks were separated by 30 m to minimize drift and contamination of treatments plots. Herbicides evaluated in this study were applied to actively growing plants. A nonionic surfactant[4] was added at 0.25% v/v to each spray solution. The herbicides were applied using a low-volume, 7.5-L backpack sprayer calibrated to deliver 247 L ha^{-1}. The pond site was a 5-ha pond that was fringed with swamp smartweed growing in 0.3 to 0.6 m of water at the time of treatment. Treatment plots were selected from sites along the fringe, and were 3 m by 3 m.

Moist soil wetland study

After the pond study, additional herbicides were selected to examine treating swamp smartweed in a wetland under drawdown (e.g., moist soil). The moist-soil wetland study contained two rates of 2,4-D[5] (2.1 and 4.2 kg ae ha^{-1}), diquat[6] (2.2 and 4.5 kg ai ha^{-1}), glyphosate (2.1 and 4.2 kg ae ha^{-1}), imazamox[7] (0.6 and 1.1 kg ai ha^{-1}), imazapyr (0.2 and 0.5 kg ai ha^{-1}), and triclopyr (3.4 and 6.7 kg ae ha^{-1}), and an untreated reference. Herbicide rates were based on 50 and 100% of the maximum-labeled rate. Treatments were assigned using a randomized complete block design with four replications. Treatment plots were 1 m by 1 m and spaced 3 m apart within each block. Blocks were separated by 50 m to minimize drift and contamination of treatments plots. Herbicides evaluated in this study were applied to actively growing plants. The aforementioned nonionic surfactant was added at 0.25% v/v to each spray solution. The herbicides were applied using a low-volume, 7.5-L backpack sprayer calibrated to 247 L ha^{-1}.

A low-volume application was used to minimize the effects of drift during the application. Faircloth et al. (2004) and Kogan and Zúñiga (2001) found that low volume spray systems had no effect on the efficacy of glyphosate and could be used in place of high volume systems. In addition, efficacy of herbicides from the imidazolinone family also showed no decreased herbicide efficacy from a low volume spray system (Ramsdale and Messersmith 2001, Patten 2003).

The moist-soil site was a seasonally inundated wetland used for fall and winter waterfowl habitat. During the summer, it was drained to allow wetland plants such as swamp smartweed to sprout and to provide food and cover to waterfowl in the fall. Plots of 3 m by 3 m were placed randomly throughout the wetland in stands of swamp smartweed. At the time of treatment, no standing water was present, but the soil was saturated.

Data analysis

Each plot was rated on a scale of 0 to 100% control using 10% increments. Percent control estimates were made weekly for 5 and 6 wk following application to the pond and moist-soil wetland studies, respectively. Acceptable control was defined as greater than or equal to 90% control. Percent control ratings in both studies were analyzed separately using ANOVA and a post-hoc comparison of means tests using a Fisher's Protected LSD ($P = 0.05$). There was no effect of block in either study ($P > 0.05$).

RESULTS AND DISCUSSION

Pond study

Imazapyr at 0.28 kg ai ha^{-1} and glyphosate at 4.2 kg ae ha^{-1} provided acceptable swamp smartweed control (> 90%) throughout the 5-wk pond study, beginning at 1 wk after treatment (WAT), whereas the imazapyr at 0.56 kg ai ha^{-1} and glyphosate at 2.1 kg ae ha^{-1} treatments required 4 wk to achieve 90% control (Table 1). Swamp smartweed control was statistically different from the reference when plants were treated with the 6.7 kg ha^{-1} rate of triclopyr, but neither rate of triclopyr provided greater than 90% control. Similar results were found in another Polygonaceae species, hybrid knotweed [*Fallopia* × *bohemica* (Chrtek & Chrtková) J.P. Bailey], with all rates of imazapyr and glyphosate showing effective control (Metzger and Patten 2006). Swamp smartweed control with triclopyr was poor (20 to 30%) at 3.4 kg ha^{-1} and better but still not acceptable (70 to 78%) at the 6.7 kg ha^{-1} rate.

Moist soil wetland study

Both the 2.1 and 4.2 kg ae ha^{-1} rates of 2,4-D effectively controlled swamp smartweed by 2 WAT (91% and 95%, respectively) and were maintained throughout the duration of the study (Table 2). The 4.2 kg ae ha^{-1} rate of glyphosate achieved acceptable control (≥ 90%) by 3 WAT, whereas 2.1 kg ae ha^{-1} achieved acceptable control by 4 WAT. Imazamox and imazapyr at both rates effectively controlled swamp smartweed by 4 WAT (90, 93, 95, and 94%, respectively). Triclopyr at 6.7 kg ae ha^{-1} reached 90% control 1 WAT and maintained effective control through the entire study, whereas the 3.4 kg ae ha^{-1} rate did not achieve ≥ 90%

Table 2. Percent control of swamp smartweed biomass from a moist soil wetland for 6 wk after treatment.

Treatment	Rate	Weeks after Treatment (WAT)[1]					
		1	2	3	4	5	6
Untreated control	0	0 a	0 a	0 a	0 a	0 a	0 a
2,4-D	2.1 kg ae ha^{-1}	84 bc	91 bcd	91 bc	93 bc	90 bc	96 b
	4.2 kg ae ha^{-1}	93 b	95 b	95 b	95 b	96 b	96 b
Diquat	2.2 kg ai ha^{-1}	68 cde	53 g	28 d	34 d	6 a	6 a
	4.5 kg ai ha^{-1}	80 bcd	60 fg	28 d	17 a	10 a	10 a
Glyphosate	2.1 kg ae ha^{-1}	58 e	74 ef	88 bc	94 b	94 b	95 b
	4.2 kg ae ha^{-1}	64 de	86 bcd	93 bc	98 b	98 b	98 b
Imazamox	0.6 kg ai ha^{-1}	63 e	78 de	88 bc	90 bc	93 b	93 b
	1.1 kg ai ha^{-1}	65 de	79 bcde	90 bc	93 b	95 b	95 b
Imazapyr	0.28 kg ai ha^{-1}	64 de	84 bcde	91 bc	95 b	99 b	100 b
	0.56 kg ai ha^{-1}	65 de	74 c	75 cb	94 b	99 b	100 b
Triclopyr	3.4 kg ae ha^{-1}	89 bc	89 bc	93 bc	93 b	89 b	89 bc
	6.7 kg ae ha^{-1}	90 b	93 b	94 b	95 b	96 b	96 b

[1]Means with different letters within a column are significantly different at the $P = 0.05$ level based on ANOVA (Fisher's Protected LSD).

control until 3 WAT. Diquat did not effectively control swamp smartweed at either rate and was not different from the untreated reference by 5 WAT.

Both rates of triclopyr achieved effective control of swamp smartweed in the moist soil wetland study, but poor control in the pond study. These differences could be attributable to the flooded conditions in the pond. Swamp smartweed in the pond that was largely emergent was effectively controlled, but plants that were largely submersed were not controlled, possibly because they did not absorb a lethal dose of triclopyr. Poor control of submersed swamp smartweed by triclopyr might be due to a combination of rapid degradation by photolysis in water (Johnson et al. 1995) and a sublethal concentration of triclopyr within the water column. The half-life of triclopyr under daytime, summer conditions can range from 1 to 12 h, which is plausible for a decrease in herbicide efficacy and uptake (McCall and Gravit 1986, Johnson et al. 1995). Conversely, plants treated in the moist-soil wetland were completely exposed to the herbicide. Further research is needed to investigate herbicide uptake and translocation in flooded and moist-soil habitats; many species of aquatic plants can be found in both types of habitats, and these species might respond differently, depending upon environmental conditions.

In another Polygonaceae species, hybrid knotweed, all rates of imazapyr, glyphosate, and triclopyr were found to provide effective control of emergent plants (Metzger and Patten 2006). However, management protocols for similar species, such as Japanese knotweed [*Fallopia japonica* (Houtt.) Dcne. var. *japonica*], have also shown reduced efficacy with triclopyr when compared to imazapyr or glyphosate (Gover et al. 2005). Based on the results of the current study, we recommend either glyphosate or imazapyr for swamp smartweed control in flooded pond situations, and 2,4-D, triclopyr, glyphosate, imazapyr, and imazamox in moist-soil habitats, although cost and habitat use will ultimately influence herbicide selection. Although glyphosate, imazamox, and imazapyr required 3 to 4 wk to become fully effective, by 5 WAT, they provided more than 90% control. In the moist-soil study, 90% control was achieved within the first week or two after treatment. Diquat was ineffective at controlling swamp smartweed in moist soil habitats.

Although imazapyr was effective at controlling swamp smartweed, it is nonselective and negatively impacts more desirable species. In the southeastern United States, moist-soil wetlands provide important wintering habitat for migrating waterfowl (Fredrickson and Taylor 1982, Reinecke et al. 1989). These seasonally flooded wetlands are dominated by grasses and sedges (Fredrickson and Taylor 1982), and the use of auxin-mimicking herbicides such as 2,4-D and triclopyr can be used to select graminoid species over broadleaf species. Future work should assess herbicide combinations and application timing that could potentially maximize control and reduce application costs.

SOURCES OF MATERIALS

[1]Rodeo®, Dow AgroSciences LLC, 9330 Zionsville Road, Indianapolis, Indiana 46268.

[2]Habitat®, SePRO Corporation, 11550 North Meridian Street, Suite 600, Carmel, Indiana 46302.

[3]Renovate 3®, SePRO Corporation, 11550 North Meridian Street, Suite 600, Carmel, Indiana 46302.

[4]Dyne-Amic®, Helena Chemical Company, Collierville, Tennessee.

[5]DMA 4 IVM, Dow Agrosciences LLC, 9330 Zionsville Road, Indianapolis, Indiana 46268.

[6]Reward®, Syngenta Crop Protection, Inc., 410 South Swing Rd., Greensboro, North Carolina 27419.

[7]Clearcast®, SePRO Corporation, 11550 North Meridian Street, Suite 600, Carmel, Indiana 46302.

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