Control Options for Acetolactate Synthase-Resistant Smallflower Umbrella Sedge in Arkansas Rice

J.K. Norsworthy, D.S. Riar, R.C. Scott, and T.L. Barber

ABSTRACT

Smallflower umbrella sedge is an increasingly problematic weed in direct-seeded rice in Arkansas. Recently, a sample collected from an Arkansas rice field was confirmed resistant to halosulfuron (Permit). Studies were conducted to determine the effectiveness of various acetolactate synthase (ALS)-inhibiting herbicides on control of the resistant biotype relative to a susceptible biotype and to evaluate alternative herbicide mechanisms of action for control of the resistant biotype. Control of the resistant biotype was <49% with a labeled rate of bispyribac-sodium (Regiment), halosulfuron, imazamox (Beyond), and penoxsulam (Grasp); whereas control of the susceptible biotype was >90% with these herbicides. Control of both biotypes was >96% with bentazon (Basagran) and propanil (Riceshot), but quinclorac (Facet), thiobencarb (Bolero), and 2,4-D (Weedar) were ineffective. Considering propanil-resistant smallflower umbrella sedge has been confirmed in California, it would be prudent to tank-mix bentazon and propanil to minimize further risk of resistance evolving to these herbicides in Arkansas rice.

INTRODUCTION

Sedges, mainly yellow nutsedge and rice flatsedge, are common in Arkansas rice fields but are not among the most problematic weeds (Norsworthy et al., 2013) most likely because acetolactate synthase (ALS)-inhibiting herbicides and propanil are often effective (Scott et al., 2013). To a lesser extent, smallflower umbrella sedge is present in Arkansas rice fields, and until recently, it has not been a weed of concern. In 2010, halosulfuron (Permit) failed to control smallflower umbrella sedge in an Arkansas rice field, and the population was later confirmed resistant to halosulfuron in a greenhouse
screening conducted the same year. This is not the first case of a smallflower umbrella sedge biotype evolving resistance to ALS-inhibiting herbicides. Actually, ALS-resistant smallflower umbrella sedge populations have been confirmed in other rice-growing regions of the world (Osuna et al., 2002; Graham et al., 1996; Kuk et al., 2004). In California, smallflower umbrella sedge is a common weed of rice having widespread resistance to ALS-inhibiting herbicides and most recently confirmed resistance to propanil (Pedroso et al., 2013).

Bensulfuron (Londax), halosulfuron, and orthosulfamuron (Strada) are sulfonylurea herbicides (ALS inhibitors) applied to rice as part of a broadleaf and sedge weed control program. Over-reliance on ALS-inhibiting herbicides for sedge control has led to evolution of resistance within sedges other than smallflower umbrella sedge, including rice flatsedge and yellow nutseed. For rice flatsedge, the level of resistance to halosulfuron was more than 480-fold (Norsworthy, unpublished data). Initial evaluations on smallflower umbrella sedge also indicate a high level of resistance to halosulfuron in this closely related species. In regards to herbicide options for control, bentazon, propanil, and 2,4-D are recommended for ALS-resistant rice flatsedge, but the effectiveness of these and other herbicides on halosulfuron-resistant smallflower umbrella sedge is not known (Scott et al., 2013).

Experiments were conducted to assess the effectiveness of ALS-inhibiting herbicides from several herbicide families on resistant as well as susceptible smallflower umbrella sedge biotypes and to evaluate currently labeled alternative herbicide mechanisms of action for control of both biotypes.

**PROCEDURES**

Seeds of the halosulfuron-resistant smallflower umbrella sedge biotype were collected from a production field in southeast Arkansas that had been in continuous rice for at least 10 years. Seeds of a confirmed ALS-susceptible smallflower umbrella sedge biotype were obtained from California. Seeds of both biotypes were sown in the greenhouse in separate trays and emerged seedlings at the 3- to 4-lf stage were treated with halosulfuron at 0.75 oz ai/acre to ensure that all resistant plants would survive and all susceptible plants would be controlled by the herbicide.

Four halosulfuron-resistant and -susceptible smallflower umbrella sedge plants each at 1- to 2-lf stage were transplanted into separate 6-inch diameter pots. At the 3- to 4-lf stage, resistant and susceptible plants were treated with one of five ALS-inhibiting herbicides, which included halosulfuron at 0.75 oz ai/acre, bispyribac-sodium (Regimen) at 0.5 oz ai/acre, imazamox (Beyond) at 0.5 oz ai/acre, imazethapyr (Newpath) at 1.0 oz ai/acre, and penoxsulam (Grasp) at 0.7 oz ai/acre. Halosulfuron, imazamox, and imazethapyr treatments contained nonionic surfactant (Induce) at 0.25% v/v; whereas bispyribac-sodium was applied with a nonionic spray adjuvant and deposition aid (Dyne-A-Pak) at 2.5% v/v and penoxsulam contained crop oil concentrate (Agri-Dex) at 1% v/v. All treatments were applied using a compressed air spray chamber having a boom fitted with two flat fan 800067 nozzles calibrated to deliver 20 gal/acre at 40 psi.
A similar setup was used to evaluate the effectiveness of alternative herbicide mechanisms of action for control of smallflower umbrella sedge biotypes. The herbicides tested in this experiment included bentazon (Basagran) at 0.75 lb ai/acre, propanil (Riceshot) at 4.0 lb ai/acre, quinclorac (Facet) at 0.5 lb ai/acre, thiobencarb (Bolero) at 4.0 lb ai/acre, and 2,4-D (Weedar) at 0.95 lb ae/acre.

After applying the herbicides, all pots were watered daily and once weekly with a water-soluble fertilizer. Smallflower umbrella sedge control was visually estimated 21 d after treatment (DAT) on a scale of 0 (no control) to 100 (complete plant mortality) and aboveground biomass was subsequently harvested the same day, dried, and weighed. Plant dry weight was expressed as a percent of the nontreated control.

Both experiments were conducted in a randomized complete block design. The first experiment was a two (resistant and susceptible biotypes) by five (ALS-inhibiting herbicides) factorial and the second was likewise a two (resistant and susceptible biotypes) by five (alternative non-ALS herbicides) factorial arrangement. Each experiment contained four replications (16 plants per treatment with four plants per replication), and each experiment was repeated. Percent control and dry weight data were subjected to arcsine square root transformation before analyses to improve normality. Transformed data were subjected to analysis of variance using PROC MIXED in SAS (SAS Institute, Inc., Cary, N.C.) to evaluate the effect of different herbicides on control and dry weight of halosulfuron-resistant and -susceptible smallflower umbrella sedge. Data from the repeated experiments were pooled because of nonsignificant treatment-by-experiment interactions. Means were separated using Fisher’s Protected Least Significant Difference (LSD) test \( P = 0.05 \). Additionally, resistant and susceptible biotypes were compared within a herbicide. Interpretation of results was similar with transformed and nontransformed data; thus, nontransformed means are reported.

RESULTS AND DISCUSSION

Control of the susceptible biotype with bispyribac-sodium, halosulfuron, imazamox, imazethapyr, and penoxsulam was >90% (Table 1). In contrast, control of the resistant biotype ranged from 6% to 49% for the ALS herbicides evaluated. Dry weight reduction was similar to the control estimates for both biotypes for each herbicide (data not shown).

This is the fourth weed of rice to have evolved resistance to ALS-inhibiting herbicides in Arkansas, of which the others are barnyardgrass, rice flatsedge, and yellow nutsedge (Riar et al., 2012; 2013). In regards to smallflower umbrella sedge, cross resistance to ALS-inhibiting herbicides has been reported previously for accessions from California (Osuna et al., 2002). Smallflower umbrella sedge is not a common weed of Arkansas rice; hence, whether this resistant biotype was introduced from other geographies or evolved independently as a result of repeated use of ALS herbicides is not known at this time.

Control did not differ between biotypes for any of the alternative non-ALS herbicides evaluated (Table 2). Bentazon and propanil were the only herbicides to provide effective control of both biotypes. Similar to the findings here, ALS-resistant and -sus-
ceptible smallflower umbrella sedge biotypes in Brazil were effectively controlled with bentazon (Galon et al., 2008). Propanil is recommended for a wide variety of sedges in Arkansas rice (Scott et al., 2013); however, it should be noted that propanil-resistant populations exist in California (Pedroso et al., 2013); hence, the most appropriate control tactic for smallflower umbrella sedge is likely a tank-mix of propanil plus bentazon.

SIGNIFICANCE OF FINDINGS

This research documents the existence of smallflower umbrella sedge in Arkansas having resistance to at least four herbicide chemical families, all of which are classified as ALS inhibitors. Sustaining utility of alternative herbicides that are currently effective should be of paramount importance. Most certainly, controlling resistant smallflower umbrella sedge with alternative herbicides will add to current weed management costs for producers. Based on this research, propanil and bentazon are both effective alternatives, but steps must be taken to minimize selection pressure on these two herbicides if effective control options are to be sustained.

ACKNOWLEDGMENTS

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LITERATURE CITED


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<table>
<thead>
<tr>
<th>Table 1. Control of halosulfuron-resistant and -susceptible smallflower umbrella sedge with applications of acetolactate synthase-inhibiting herbicides labeled for use in conventional or Clearfield rice at 21 days after treatment.</th>
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<tbody>
<tr>
<td><strong>Herbicide</strong></td>
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<tr>
<td>Bispyribac-sodium</td>
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<td>Halosulfuron</td>
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<td>Imazethapyr</td>
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<td>Penoxsulam</td>
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† Means for each herbicide within a row followed by the same uppercase letters and mean for each accession within a column followed by the same lowercase letters are not significantly different according to Fisher’s Protected Least Significant Difference test ($P = 0.05$).

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<th>Table 2. Control of halosulfuron-resistant and -susceptible smallflower umbrella sedge with rice herbicides at 21 days after treatment.</th>
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<tr>
<td><strong>Herbicide</strong></td>
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</tr>
<tr>
<td>Bentazon</td>
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<td>Propanil</td>
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<td>Quinclorac</td>
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<td>Thiobencarb</td>
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<td>2,4-D</td>
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† The herbicide rate for 2,4-D is reported as acid equivalents (ae) rather than active ingredient (ai).