Rice Tolerance to Postemergence Applications of Penoxsulam

Jason A. Bond, Timothy W. Walker, Nathan W. Buehring, and Eric P. Webster

INTRODUCTION

Penoxsulam (Grasp™) is a postemergence herbicide developed by Dow Agrosciences, LLC, which received registration in 2005 for weed control in southern U.S. rice (Lassiter et al. 2006). It is a triazolopyrimidine sulfonamide herbicide and acts by inhibiting the acetolactate synthase enzyme (ALS) (E.C. 4.1.3.18) in susceptible species. Use rates range from 0.031 to 0.044 pound of active ingredient per acre, and applications can be made preflood or post-flood in drill-seeded rice. Penoxsulam provides control of Echinochloa spp. (Lassiter et al. 2006), annual sedges (Cyperus spp.) (Walton et al. 2005), and numerous broadleaf weeds, including alligatorweed [Alternanthera philoxeroides (Mart.) Griseb.] (Lassiter et al. 2006; Willingham et al. 2006), ducksalad [Heteranthera limosa (Sw.) Willd.] (Lassiter et al. 2006), eclipta (Eclipta prostrata L.) (Lassiter et al. 2006), hemp sesbania [Sesbania exaltata (Raf.) Rydb. ex A.W. Hill] (Lassiter et al. 2006; Williams and Bums 2006), northern jointvetch [Aeschynomene virginica (L.) B.S.P.] (Walton et al. 2005), Polygonum spp. (Lassiter et al. 2006), spreading dayflower (Commelina diffusa Burm. f.) (Walton et al. 2005), and Texasweed [Caperonia palustris (L.) St. Hil.] (Strahan 2004; Williams and Burns 2006).

Inhibitors of ALS can reduce transport of photosynthetic from source leaves to roots, resulting in root growth inhibition (Devine 1989; Devine et al. 1990; Shaner 1991). Bispyribac-sodium (Regiment™) is an ALS-inhibitor with similar activity to penoxsulam, and rice injury has been reported after applications of bispyribac-sodium at 0.018, 0.027, and 0.036 pound of active ingredient per acre. Zhang and Webster (2002) observed reductions in shoot and root growth of the medium-grain ‘Bengal’ at 2 and 3 weeks after bispyribac-sodium application. Rice injury also has been reported after application of penoxsulam. Ellis et al. (2005) reported 41–58% reduction in root mass on the long-grain cultivar ‘Wells’ after 0.031- and 0.063-pound applications of penoxsulam.

Rice cultivar and/or growth stage at application may influence rice tolerance to herbicides. Previous research has indicated medium-grain rice cultivars are injured more by herbicides than long-grain cultivars (Lanclos et al. 1999; Zhang and Webster 2002; Zhang et al. 2005). Tolerance of rice to bispyribac-sodium was both cultivar- and growth stage-dependent (Zhang and Webster 2002). The medium-grain cultivar Bengal was less tolerant to bispyribac-sodium compared with the long-grain cultivar ‘Cocodrie.’ Shoot and root growth of Bengal was inhibited more when
bispyribac-sodium was applied to one- and two-leaf rice compared with two- to three-leaf rice. Zhang et al. (2005) observed that the long-grain cultivars Cocodrie, ‘Cypress,’ Wells, ‘CL161,’ and ‘CL141’ were tolerant to 0.018- and 0.036-pound applications of bispyribac-sodium made to two- to three-leaf rice or four- to five-leaf rice. However, medium-grain cultivars ‘Earl’ and Bengal varied in tolerance to bispyribac-sodium applications. Ellis et al. (2005) reported reductions in root mass that ranged from 28–77%

The objectives of this research were to evaluate the response of 10 commercial rice cultivars to penoxsulam applications and to compare the rice response to preflood applications of penoxsulam and bispyribac-sodium.

Study 1. A study to determine rice cultivar tolerance to early postemergence applications of penoxsulam was conducted in 2005 and 2006 at the Louisiana State University AgCenter Rice Research Station near Crowley, Louisiana, and at an on-farm site near Bonita, Louisiana. Soil at Crowley was a Crowley silt loam soil (fine montmorillonitic, thermic Typic Albaqualf) with a pH of 6.6 and 1.6% organic matter. Soil at Bonita was a Perry clay (very-fine, smectitic, thermic Chromic Epiaquerts) with a pH of 6.3 and 3.4% organic matter.

The long-grain rice cultivars Cocodrie, ‘Cheniere,’ ‘CL131,’ ‘CL161,’ ‘Cybonnet,’ ‘Trenasse,’ and ‘XL723;’ the medium-grain cultivars Bengal and ‘Jupiter;’ and the short-grain cultivar ‘Pirogue’ were drill-seeded on April 1, 2005, and March 14, 2006, at Crowley and April 28, 2005, and May 10, 2006, at Bonita. A seeding rate of 75 pounds per acre was used each site year for all cultivars except XL723, which is a hybrid cultivar. Because of its heterosis, a seeding rate of only 30 pounds per acre is recommended (Anonymous 2006b). Rice was drill-seeded using a small-plot grain drill equipped with double-disk openers and press wheels with 7.5 inches between each row. Individual plots consisted of 12 rows measuring 20 feet in length. Plots were maintained weed-free by an application of propanil plus molinate (Arrosolo™; 3 + 3 pounds of active ingredient per acre) before flooding each site year when rice reached the one-tiller growth stage. Plots were drained approximately 2 weeks before harvest maturity was reached. Rice was harvested with a small-plot combine at a moisture content of approximately 20%.

Treatments were arranged in a randomized complete block with a factorial arrangement of 10 rice cultivars (previously described) and two penoxsulam treatments (nontreated control and penoxsulam at 0.063 pound of active ingredient per acre). The penoxsulam treatment represented twice the labeled application rate of 0.031 pound (Anonymous 2006a). Penoxsulam applications were applied to rice at the two- to three-leaf growth stage with a CO₂-pressurized backpack sprayer equipped with regular flat-fan spray nozzles (TeeJet 110015 flat-fan spray tips; Spraying Systems Co., Wheaton, Illinois) set to deliver 15 gallons per acre at 30 psi. Penoxsulam applications included the addition of crop oil concentrate (COC; Agri-Dex®) at 2.5% (v/v). Days to 50% heading were determined by calculating the time from seedling emergence until 50% of rice had visible panicles. Average mature plant height was recorded before harvest by calculating the mean plant height of five plants measured from the soil surface to the tip of the panicle in each plot. Harvest dates were August 19, 2005, and July 26, 2006, at Crowley and September 13, 2005, and September 20, 2006, at Bonita. Final rice grain yields were adjusted to 12% moisture content. Data for mature plant height, number of days to 50% heading, and rice yield were converted to a percent of the nontreated control for the respective cultivar in each replication. Percent of nontreated control data were calculated by dividing data from the treated plot by that in the nontreated plot of the same cultivar and multiplying by 100.

Data were analyzed using the Mixed Procedure (SAS 2003) with years used as random-effect parameters testing all possible interactions of location and cultivar. Years, replications (nested within years), and all possible interactions containing these effects were considered random effects; all other variables (location and cultivar) were considered fixed effects. Type III statistics were used to test all possible fixed effects or interactions between the fixed effects, and least square means at p ≤ 0.05 were used for mean separation.

Study 2. A related study to compare the rice response to applications of penoxsulam and bispyribac-sodium was conducted in 2004 and 2005 at the Mississippi State University Delta Research and Extension Center near Stoneville, Mississippi. Soil at Stoneville was a Sharkey clay (very-fine, smectitic, thermic Chromic Epiaquerts) with a pH of 8.2 and 2.1% organic matter.

The long-grain rice cultivar Cocodrie was drill-seeded on May 3, 2004, and May 4, 2005, at a seeding rate of 80 pounds per acre. The study was arranged in a randomized
Table 1. Rice cultivar response to postemergent penoxsulam application (0.063 lb ai/A) at Crowley and Bonita, Louisiana, in 2005 and 2006.1

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Rice height</th>
<th>Days to 50% heading</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-grain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheniere</td>
<td>100 a (33)</td>
<td>100 a (89)</td>
<td>103 a (8,450)</td>
</tr>
<tr>
<td>CL131</td>
<td>102 a (30)</td>
<td>100 a (87)</td>
<td>100 a (7,640)</td>
</tr>
<tr>
<td>CL161</td>
<td>101 a (36)</td>
<td>101 a (91)</td>
<td>101 a (8,040)</td>
</tr>
<tr>
<td>Cocodrie</td>
<td>101 a (33)</td>
<td>101 a (86)</td>
<td>94 a (8,410)</td>
</tr>
<tr>
<td>Cybonnet</td>
<td>99 a (33)</td>
<td>100 a (88)</td>
<td>108 a (7,610)</td>
</tr>
<tr>
<td>Trenasse</td>
<td>102 a (35)</td>
<td>101 a (82)</td>
<td>105 a (8,980)</td>
</tr>
<tr>
<td>XL723</td>
<td>98 a (42)</td>
<td>100 a (86)</td>
<td>100 a (10,330)</td>
</tr>
<tr>
<td>Medium-grain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bengal</td>
<td>100 a (33)</td>
<td>100 a (90)</td>
<td>95 a (9,290)</td>
</tr>
<tr>
<td>Jupiter</td>
<td>99 a (34)</td>
<td>99 a (91)</td>
<td>100 a (10,160)</td>
</tr>
<tr>
<td>Short-grain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pirogue</td>
<td>99 a (35)</td>
<td>99 a (90)</td>
<td>101 a (9,230)</td>
</tr>
</tbody>
</table>

Data averaged across two locations and two experiments. Data expressed as a percent of nontreated control for the respective cultivar. Numbers in parentheses represent rice height (inches), number of days to 50% heading (days), and yield (lb/A) of nontreated control for each cultivar.

Results and Discussion

Study 1. The main effects of location and cultivar and all interactions containing these variables were not significant for rice height, days to 50% heading, or grain yield. Application of twice the labeled rate of penoxsulam did not negatively impact the agronomic performance of the 10 rice cultivars in this study (Table 1).

Previous research has indicated varied results when evaluating rice cultivar tolerance to herbicides. Five long-grain rice cultivars exhibited equivalent tolerance, but two medium-grain cultivars exhibited differential tolerance to applications of bispyribac-sodium (Zhang et al. 2005). Fenoxaprop (Whip®) reduced grain yield of the medium-grain cultivar ‘Mars’ 6–20% over 2 years, but grain yields of the long-grain cultivars ‘Tebonnet’ and ‘Lemont’ were reduced only 1–17% and 1–14%, respectively, over 2 years (Griffin and Baker 1990).

Although earlier research established that medium- and short-grain cultivars may exhibit lower levels of tolerance...
to a variety of herbicides, we did not observe any differences in cultivar response to penoxsulam. Equal herbicide tolerance among long-, medium-, and/or short-grain rice cultivars has been reported for some herbicides and/or production systems (Ellis et al. 2005; Scherder et al. 2004). Fourteen commercial long- and medium-grain cultivars and four experimental cultivar lines were tolerant to clomazone at 0.3 and 0.6 pound of active ingredient per acre in a drill-seeded production system (Scherder et al. 2004). Ellis et al. (2005) reported no differences in yield for the cultivars Bengal, Cocodrie, Wells, and XL8 after 0.031- and 0.063-pound applications of penoxsulam. Despite the lack of differences in rice cultivar response to an application of penoxsulam at twice the labeled rate with respect to height, days to 50% heading, and yield, rice yields were numerically greater for some cultivars (more than 100% of the nontreated control) after application.

**Study 2.** No differences in root injury were detected among herbicide treatments, but root injury up to 76% was observed after the 0.063-pound penoxsulam application (Table 2). Rice root injury appeared as a reduction in root mass and length compared with the nontreated control. Ellis et al. (2005) reported 65% and 77% root injury 7 days after 0.031- and 0.063-pound penoxsulam treatments, respectively, when applications were made to rice in the four- to five-leaf growth stage. The penoxsulam label indicates that severe rice injury may be observed after application when soil pH is higher than 7.8 (Anonymous 2006a). The soil pH at Stoneville was 8.2, so bioavailability of penoxsulam at the high soil pH most likely impacted the root injury observed after penoxsulam application. Other herbicides are also more injurious at high soil pH levels (Hutchinson et al. 2005). The pKₐ of penoxsulam is 5.1 (Anonymous 2004), and Jabusch and Tjeerdema (2005) reported that penoxsulam is present almost entirely as the anionic species at near-neutral pH. The reductions in rice root mass observed in our study could be a product of increased penoxsulam absorption by rice roots resulting from exposure to higher concentrations over a longer time because of less soil adsorption and slower hydrolysis at high soil pH. Furthermore, we speculate that the injury observed at high soil pH may be due to a greater availability of higher proportions of the applied rate in the soil solution rather than an influence on the physiology of absorption.

Rice grain yield was 6–9% higher after the 0.063-pound penoxsulam application compared with the nontreated control and the 0.031-pound penoxsulam or 0.025-pound bispyribac-sodium applications (Table 2). According to Ellis et al. (2005), although Cocodrie root injury was 77% after a 0.063-pound penoxsulam application, rice grain yield was not negatively impacted. An explanation in our study for the increased grain yield after application of penoxsulam at twice the labeled rate was not apparent. Obviously, rice recovered from the injury to roots observed after the herbicide application. However, overcoming the observed reductions in root mass would seemingly require the plant to reallocate resources into roots, thereby depriving the aboveground plant sections of photosynthates needed for growth and ultimately yield. At some point between root injury evaluation and harvest, rice was able to recover from the injury and actually produce higher grain yields. Rice may have responded to the stress caused by the root injury by producing more tillers, which could influence final grain yield, or by producing more adventitious roots, which could influence the efficiency of nutrient uptake from the soil. Previous research has indicated variable results with the use of ALS-inhibiting herbicides. In an imazaquin (Scepter®) carryover study in Arkansas, rice yield decreased after imazaquin applied preplant incorporated and preemergence to soybean [Glycine max (L.) Merr] at 0.13 pound of active ingredient per acre compared with the higher rate of 0.26 pound (Helms et al. 1989). Webster and Shaw (1996) reported similar results with soybean following pyrithiobac (Staple®) applied to cotton (Gossypium hirsutum L.).

![Table 2. Root injury and rice yield at Stoneville, Mississippi, in 2004 and 2005 after postemergence herbicide applications.](image)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate</th>
<th>Root injury</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penoxsulam</td>
<td>0.031</td>
<td>71 a</td>
<td>8,510 b</td>
</tr>
<tr>
<td>Penoxsulam</td>
<td>0.063</td>
<td>76 a</td>
<td>9,250 a</td>
</tr>
<tr>
<td>Bispyribac-sodium</td>
<td>0.025</td>
<td>65 a</td>
<td>8,610 b</td>
</tr>
<tr>
<td>Nontreated control</td>
<td>—</td>
<td>—</td>
<td>8,700 b</td>
</tr>
</tbody>
</table>

1Means followed by same letter in a column are not significantly different at p ≤ 0.05.
2Rice roots from nontreated control were used as comparison for visually estimating root injury in treated plots.
Other researchers reported that differences in herbicide tolerance among rice cultivars were more easily distinguished when twice the registered rate of the herbicide was used for screening tolerance (Zhang and Webster 2002; Zhang et al. 2004). Our cultivar tolerance study utilized penoxsulam at 0.063 pound of active ingredient per acre, twice the labeled application rate. Therefore, our data indicate that commercial rice cultivars currently grown in the southern U.S. rice belt exhibit tolerance to postemergence applications of penoxsulam based on rice height, number of days to 50% heading, and grain yield. Substantial reductions in root mass may occur after penoxsulam application, particularly when soil pH is high. This reduction in root mass could complicate management of the rice crop by delaying flood establishment or compounding difficulties associated with rice water weevil (Lissorhoptrus oryzophilus Kuschel) infestations. However, in our study, rice grain yield was greater when the higher use rate was applied and injury was severe. The yield increases that occurred are not easily explained and warrant further investigation into the response of the rice plant to root injury observed after application of penoxsulam.

ACKNOWLEDGMENTS

We thank the Mississippi Rice Promotion Board, the Louisiana Rice Research Board, and Dow AgroSciences Corporation for their funding of this research. We thank station personnel at the Louisiana State University AgCenter Rice Research Station and the Mississippi State University Delta Research and Extension Center for their assistance.

LITERATURE CITED


Helms, R.S., T.N. Tripp, R.J. Smith, Jr., F.L. Baldwin, and M. HACKWORTH. 1989. Rice (Oryza sativa) response to imazquin residues in a soybean (Glycine max) and rice rotation. Weed Technol. 3:513-517.


Webster, E.P., and D.R. Shaw. 1996. Carryover potential of pyrithiobac to rotational crops on a Mississippi black belt region clay soil. Weed Technol. 10:140-144.


Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the Mississippi Agricultural and Forestry Experiment Station and does not imply its approval to the exclusion of other products that also may be suitable.

Discrimination based upon race, color, religion, sex, national origin, age, disability, or veteran’s status is a violation of federal and state law and MSU policy and will not be tolerated. Discrimination based upon sexual orientation or group affiliation is a violation of MSU policy and will not be tolerated.