Soybean (Glycine max) Response to Imazosulfuron Drift from Rice (Oryza sativa)

S.S. Rana, J.K. Norsworthy, D.B. Johnson, and R.C. Scott

ABSTRACT

Imazosulfuron is a sulfonylurea herbicide recently labeled in U.S. rice. Soybean is prone to drift of herbicides from rice fields in the southern U.S. because the two crops are often grown in close proximity. Therefore, field trials were conducted at the University of Arkansas Agricultural Research and Extension Station, Fayetteville, and the Pine Tree Research Station, near Colt, Ark., to determine the effect of low rates of imazosulfuron applied at different growth stages of non-sulfonylurea-tolerant (non-STS) soybean. Imazosulfuron is labeled for use in Arkansas rice at a maximum rate of 0.3 lb ai/acre. Soybean was treated at the VC, V2, V6, and R2 growth stages with 1/256, 1/128, 1/64, 1/32, 1/16, 1/8, and 1/4 times (×) the maximum labeled rate of imazosulfuron. Soybean was injured regardless of herbicide rate or application timing. Injury to soybean plants from imazosulfuron was in the form of stunting and purple veins. At 2 weeks after treatment (WAT), imazosulfuron at the 1/256 to 1/4× rates injured soybean 26% to 73%, 44% to 73%, 32% to 65%, and 14% to 46% when applied at the VC, V2, V6, and R2 growth stages, respectively. The highest injury was caused by the highest imazosulfuron rate (1/4×). However, at 20 weeks after planting (WAP), soybean treated with 1/256 to 1/16× rates of imazosulfuron at the VC and V2 growth stages had only 0% to 8% and 8% to 27% injury, respectively. At higher rates (1/8 and 1/4×) of imazosulfuron, soybean treated at the VC growth stage recovered more from injury than did soybean treated at the V2 growth stage. Soybean treated with imazosulfuron at the V6 and R2 growth stages had better recovery from the injury at the lower two rates (1/256 and 1/128×) than at the higher rates (1/64 to 1/4×). Injury to soybean at 2 WAT resulted in higher yield loss if imazosulfuron was applied at V6 and R2 than at VC and V2. At the 1/256 to 1/4× rates, imazosulfuron reduced soybean yields by 0% to
37%, 14% to 50%, 19% to 70%, and 21% to 88% for the VC, V2, V6, and R2 growth stages, respectively. This research indicates that imazosulfuron can severely injure soybean regardless of the growth stage at which drift occurs; however, soybean injured by imazosulfuron at early growth stages (VC and V2) with lower application rates has a better chance of recovery over time compared to later growth stages (V6 and R2).

**INTRODUCTION**

Imazosulfuron is a new sulfonylurea herbicide labeled for use in rice (Godara et al., 2012; Riar and Norsworthy, 2011). Imazosulfuron acts by inhibiting acetolactate synthase (ALS) (EC 4.1.3.18) activity at very low concentrations and hinders biosynthesis of the branched-chain amino acids valine, leucine, and isoleucine, thereby resulting in rapid cessation of plant cell division and growth (Brown, 1990; Usui, 2001; Riar and Norsworthy, 2011). Imazosulfuron comes into the market with a trade name of League and is being produced by Valent Corporation (Walnut Creek, Calif.) for weed control in drill- and water-seeded rice at a maximum field use rate of 0.3 lb ai/acre. In rice, sequential applications (PRE fb POST) of imazosulfuron at 0.3 lb ai/acre provided excellent control of broadleaf weeds and sedges (Godara et al., 2012; Riar and Norsworthy, 2011).

Rice is one of the most important crops grown in Arkansas. Weed control in rice is highly dependent on use of herbicides; halosulfuron is the current standard of sulfonylurea herbicides used in rice (Nandula et al., 2009). In the southern U.S., soybean is also an important crop and is often grown in close proximity to rice. Halosulfuron, when applied to rice, is reported to injure soybean through off-target movement or drift (Nandula et al., 2009). The normal drift rates of herbicide during application can range from 0.01% to 10% of the applied rate (Al-Khatib and Peterson, 1999; Snipes et al., 1992). However, depending on the crop and the growth stage, injury from the off-target movement of herbicides to non-labeled or susceptible crops ranges from sublethal to severe.

Glyphosate injures non-glyphosate-resistant soybean when applied from vegetative through reproductive stages; however, the vegetative growth stages of soybean had better chances to recover from the injury compared with the reproductive growth stages (Norsworthy, 2004). Therefore, soybean is considered more sensitive to glyphosate applications made later in the season because there is less time to recover from the injury. Halosulfuron at 0.004 to 0.06 lb/acre applied to 4-trifoliate (V4) soybean caused 78% to 89% injury at 28 days after treatment (DAT) (Nandula et al., 2009). At the same rates, halosulfuron applied to full bloom (R2) soybean injured soybean 70% to 75% at 28 DAT. Imazosulfuron at as little as 0.005 lb/acre (1/64×) injured non-STS soybean from cotyledonary (VC) through R2 growth stages; whereas, STS soybean was not injured (Norsworthy et al., 2010). Moreover, imazosulfuron applied at 0.15 lb/acre (1/2×) caused more than 80% injury to soybean. In the same work, soybean treated with 0.005 and 0.009 lb/acre of imazosulfuron at emergence (VE) and at the 3-trifoliate (V3) soybean growth stages recovered from the injury and resulted in no yield reduction compared with the non-treated control. Recovery of soybean plants treated at early
growth stages with lower imazosulfuron rates was because of ample time available for early-season-treated soybean to recover from the injury. For the same reason, the late-maturing soybean varieties have a better chance of recovery from imazosulfuron injury compared with the early-maturing soybean varieties (Davis et al., 2011). Injury from imazosulfuron is generally in the form of chlorosis, purple veins, and stunting that is characteristic of sulfonylurea herbicide (ALS-inhibiting herbicide) injury to soybean (Brown, 1990; Norsworthy et al., 2010). In addition, severely injured soybean fails to produce grain (Norsworthy et al., 2010).

There is little information available for the sensitivity of soybean to drift rates of imazosulfuron. Therefore, it is imperative to conduct research to understand the potential of imazosulfuron to injure soybean via off-target movement from rice.

PROCEDURES

Field trials were conducted at the University of Arkansas Agricultural Research and Extension Station, Fayetteville, and the Pine Tree Research Station, near Colt, Ark., in summer 2011. The experimental arrangement used was a factorial in a randomized complete block design with four replications; factor A was four application timings and factor B was seven imazosulfuron rates. The four application timings were the VC, 2-trifoliolate soybean (V2), 6-trifoliolate soybean (V6), and R2 growth stages. Imazosulfuron was applied at 1/256, 1/128, 1/64, 1/32, 1/16, 1/8, and 1/4 times ($\times$) its labeled rate, 0.3 lb/acre. Treatments also included a non-treated control. Data were recorded for injury at 2 WAT, late-season injury, delay in days to maturity, and yield reduction.

Data were subjected to analysis of variance in SAS JMP v.10 software (SAS Institute, Inc., Cary, N.C.). Data were presented as the percent of non-treated check for all the parameters measured, and data from the nontreated check were not included in the analysis. Data were tested for normality prior to analysis. Data were pooled over the locations with location treated as a random effect. Data were then regressed against imazosulfuron rate using Sigmaplot v. 12 (Systat Software, Inc., San Jose, Calif.) using best-fit regression model.

RESULTS AND DISCUSSION

The response of soybean to imazosulfuron was comparable among response parameters, and there were no significant location interactions for any of the response variables, except for injury at 2 WAT. Therefore, data were pooled across the locations.

Imazosulfuron injury to soybean was noticeable within a week after treatment and peaked at 2 WAT. At 2 WAT, injury symptoms, which were purple veins and stunting, were more severe at higher rates applied at early growth stages. Imazosulfuron at 2 WAT injured early growth stages, VC and V2, more than the later growth stages, V6 and R2. Imazosulfuron at the highest (1/4$x$) rate resulted in soybean injury of 73% when applied at VC and V2 growth stages, followed by V6 (65%), and R2 growth stages (46%), respectively (Fig. 1, Table 1). The sensitivity of early growth stages of soybean to imazosulfuron is attributed to higher herbicide absorbance by young and rapidly growing plants than mature plants (Devine, 1989; Wanamarta and Penner, 1989).
When observed late in the growing season, soybean injury was greatest for the V6 growth stage followed by R2, V2, and VC growth stages, where imazosulfuron at 1/4× rate caused the highest injury of 68% at the V6 growth stage followed by the R2 (59%), V2 (57%), and VC (17%) growth stages (Fig. 2, Table 1). The higher injury at V6 than at the R2 growth stage may be because of higher sensitivity of vegetative growth stages of soybean to sulfonylurea herbicides than reproductive stages (Bailey and Kapusta, 1993).

Yield loss increased with increasing rates of imazosulfuron, regardless of the application timing. The greatest yield reduction of 88% occurred for soybean treated with the 1/4× rate of imazosulfuron at the R2 growth stage (Fig. 3, Table 1). Across the application timings, the yield reduction is rather higher for the V6 growth stage followed by the R2, V2, and VC growth stages. At the 1/4× imazosulfuron rate, yield reductions of 70%, 50%, and 37% were observed for the V6, V2, and VC growth stages, respectively. The yield reduction data followed the trend of late-season injury data where maximum injury from imazosulfuron occurred at the V6 growth stages followed by the R2, V2, and VC growth stages (Figs. 2 and 3, Table 1).

**SIGNIFICANCE OF FINDINGS**

The results of this research suggested that non-STS soybean was injured from drift rates of imazosulfuron (1/256 to 1/4×) and at all the application timings (VC, V2, V6, and R2). However, soybean treated with lower imazosulfuron rates at early growth stages recovered better from imazosulfuron injury and resulted in less yield loss compared with higher imazosulfuron rates at later growth stages.

**ACKNOWLEDGMENTS**

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**LITERATURE CITED**


Table 1. Regression parameter estimates and R-square values for regression of injury at 2 WAT, late-season injury, and yield reduction with imazosulfuron rate using Gompertz-3P model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Application timing</th>
<th>Regression parameters (± SE)</th>
<th>R-square</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>a†</td>
<td>b</td>
</tr>
<tr>
<td>Injury at 2 WAT</td>
<td>VC</td>
<td>73.05 (1.91)</td>
<td>0.19 (0.03)</td>
</tr>
<tr>
<td></td>
<td>V2</td>
<td>73.08 (1.94)</td>
<td>0.17 (0.05)</td>
</tr>
<tr>
<td></td>
<td>V6</td>
<td>64.67 (1.93)</td>
<td>0.18 (0.05)</td>
</tr>
<tr>
<td></td>
<td>R2</td>
<td>45.83 (2.07)</td>
<td>0.14 (0.04)</td>
</tr>
<tr>
<td>Late-season injury</td>
<td>VC</td>
<td>17.45 (2.95)</td>
<td>0.06 (0.02)</td>
</tr>
<tr>
<td></td>
<td>V2</td>
<td>56.78 (3.46)</td>
<td>0.05 (0.01)</td>
</tr>
<tr>
<td></td>
<td>V6</td>
<td>67.47 ((1.55)</td>
<td>0.16 (0.02)</td>
</tr>
<tr>
<td></td>
<td>R2</td>
<td>59.07 (1.95)</td>
<td>0.09 (0.01)</td>
</tr>
<tr>
<td>Yield reduction</td>
<td>VC</td>
<td>36.96 (3.87)</td>
<td>0.15 (0.06)</td>
</tr>
<tr>
<td></td>
<td>V2</td>
<td>49.66 (5.69)</td>
<td>0.05 (0.03)</td>
</tr>
<tr>
<td></td>
<td>V6</td>
<td>70.30 (3.45)</td>
<td>0.17 (0.04)</td>
</tr>
<tr>
<td></td>
<td>R2</td>
<td>87.49 (5.72)</td>
<td>0.06 (0.01)</td>
</tr>
</tbody>
</table>

† Abbreviations: SE = standard error; a, asymptote of the curve; b, growth point of the curve; c, inflection point of the curve; WAT, weeks after treatment. Imazosulfuron was applied with Agri-Dex at 1% v/v.
Fig. 1. Soybean injury at 2 weeks after treatment (WAT) as affected by rate of imazosulfuron applied at VC, V2, V6, and R2 growth stages at the University of Arkansas Agricultural Research and Extension Station, Fayetteville, and the Pine Tree Research Station, near Colt, Ark., in 2011.

*Abbreviations: VC, vegetative cotyledonary; V2, vegetative 2nd trifoliate; V6, vegetative 6th trifoliate; R2, reproductive full bloom.

*The equations and regression parameters of each curve is listed in Table 1.
Fig. 2. Soybean late-season injury as affected by rate of imazosulfuron applied at VC, V2, V6 and R2 growth stages at the University of Arkansas Agricultural Research and Extension Center, Fayetteville, and the Pine Tree Research Station, near Colt, Ark., in 2011.

Abbreviations: VC, vegetative cotyledonary; V2, vegetative 2nd trifoliate; V6, vegetative 6th trifoliate; R2, reproductive full bloom.

*The equations and regression parameters of each curve is listed in Table 1.
Figure 3. Soybean grain yield reduction as affected by imazosulfuron drift at VC, V2, V6, and R2 growth stages at the University of Arkansas Agricultural Research and Extension Center, Fayetteville, and the Pine Tree Research Station, near Colt, Ark., in 2011.

Abbreviations: VC, vegetative cotyledonary; V2, vegetative 2nd trifoliate; V6, vegetative 6th trifoliate; R2, reproductive full bloom.

*The equations and regression parameters of each curve is listed in Table 1.