FOLIAR WASHOFF POTENTIAL AND SURFACE RUNOFF LOSS OF TRIFLOXYSULFURON IN COTTON

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Introduction

Trifloxysulfuron (N-[(4,6-dimethoxy-2-pyrimidinyl) carbamoyl]-3-(2,2,2-trifluoroethoxy)-pyridin-2-sulfonamide sodium salt) is a sulfonylurea herbicide (SU) developed for post-emergence weed control in cotton (*Gossypium hirsutum*), sugarcane (*Saccharum officinarium*), and turfgrass (Holloway et al. 2000; Hudetz et al. 2000). It has an ionizable functional group with a pKa of 4.81. At neutral pH the octanol-water partition coefficient (K_{ow}) for trifloxysulfuron is 0.37, and its water solubility is 5016 mg L^{-1} (Vencill 2002). Consequently, trifloxysulfuron will be predominately in the anionic form at near-neutral soil pH and should partition primarily into the aqueous phase of the soil solution. However, sorption data for trifloxysulfuron have not been published.

The potential for off-site transport of SUs has been documented. In a large scale monitoring study conducted in the Midwestern United States, 212 water samples were collected from 75 surface-water sites and 25 ground water sites (Battaglin et al. 2000). At least one of the 16 targeted SUs was detected in 83% of the stream samples, 86% of the reservoir samples, and 24% of the ground water samples. In a natural rainfall study, fractional losses of sulfosulfuron were 0.5% when applied post-emergence to winter wheat at 19.8 g a.i. ha^{-1} (Brown et al. 2004). In a simulated rainfall study, fractional losses of chlorimuron-ethyl and nicosulfuron applied post-emergence at 14 g a.i. ha^{-1} to soybean and corn, respectively, did not exceed 2.2% (Afyuni et al. 1997). Fractional losses of sulfometuron-methyl applied at 0.4 kg ha^{-1} as either a dispersible granule or an emulsifiable concentrate to a mixed stand of common bermudagrass/bahiagrass and bare plots did not exceed 2.0% for any treatment (Wauchope et al. 1990). Currently there is no published data for the sorption, foliar washoff, or surface runoff potential of trifloxysulfuron in cotton production systems. These data are required for modeling and risk assessment.

Objective

The objective of this study was to determine sorption/desorption coefficients for trifloxysulfuron; quantify the potential for foliar washoff of trifloxysulfuron when applied to cotton at the 5-leaf stage; and determine the average edge-of-field concentration, total mass loss, and fractional loss of trifloxysulfuron applied to cotton at the 5-leaf stage and to bare soil.

Materials and Methods

Sorption-desorption. Sorption of trifloxysulfuron to Dundee silt loam was determined by the batch equilibration method at 24±2 C using a mixture of ^{14}C-labeled (pyridinyl-2-^{14}C) and technical-grade material. The solution to soil ratio was 3:1, and the initial solution concentrations were 0.005, 0.01, 0.05, 0.1, 0.5, and 1.0 mg L^{-1}. Each treatment was replicated four times. Desorption isotherms were obtained from the sorption samples in equilibrium with the largest initial solution concentration, 1.0 mg L^{-1}. Desorption steps were repeated three times for a total of four 24-hr desorption periods. Radioactivity was determined by liquid scintillation spectroscopy (LSS).

Foliar washoff. Cotton seed was planted in 11.0-cm diameter plastic pots containing a 1:1 v/v ratio of sand and Bosket sandy loam. Upon emergence, plants were thinned to one per pot, watered daily, and maintained in a greenhouse at approximately 35/25 C with a 14-h photoperiod. A 5-µL volume of technical grade [pyrridinyl-2-^{14}C] trifloxysulfuron dissolved in HPLC-grade water:HPLC-grade acetonitrile (60:40 v/v; 0.25% nonionic surfactant) was placed on the adaxial surface of the third youngest leaf of cotton as 15 droplets. Plants were harvested at 4, 24, 48, and 72 h after treatment. Plants and roots were divided into treated leaf, foliage above and below the treated leaf, and roots. To remove non-absorbed herbicide, the treated leaf including the petiole was rinsed by gently shaking for 15 s with 15 mL distilled water adjusted to pH 5.7. Two 1-mL aliquots of the leaf rinse were added to 15 mL scintillation fluid, and radioactivity was quantified by LSS. Plant sections were wrapped in tissue paper, placed in glass scintillation vials and oven dried at 40 C for 48 h. Oven-dried plant samples were combusted with a biological sample oxidizer, and sample radioactivity was quantified by LSS. The amount of ^{14}C present in leaf washes and plant sections was considered to be total ^{14}C recovered. The sum of the radioactivity present in all plant parts was considered to be absorbed and was expressed as the percentage of the total ^{14}C recovered.

Surface runoff. Surface runoff of trifloxysulfuron was determined in 2.2-m long by 1.2-m wide by 0.25-m deep fiberglass trays filled with Dundee silt loam. Trifloxysulfuron was applied at 7.9 g a.i. ha + NIS (Induce) at 0.25% v/v using a compressed-air tractor mounted sprayer delivering 187 L ha^{-1} operating at 241 kPa. Herbicide was applied with 8004 flat fan nozzles at 48 cm approximately 10 min after solution preparation. Twenty-four h after herbicide application, simulated rainfall was applied at 7.5 cm h^{-1} for 20 min resulting in a nominal application of 2.5 cm of rainfall. Runoff was captured in a holding tank containing, and cumulative runoff was determine by recording the water height in the holding tank with a Campbell Scientific CR-200 electronic data logger at 60-s intervals. At the end of the 20-min simulation, composite water samples were collected in 1-L glass jars. Water samples were subjected to solid-phase extraction, and herbicide concentration was determined by HPLC.

Results

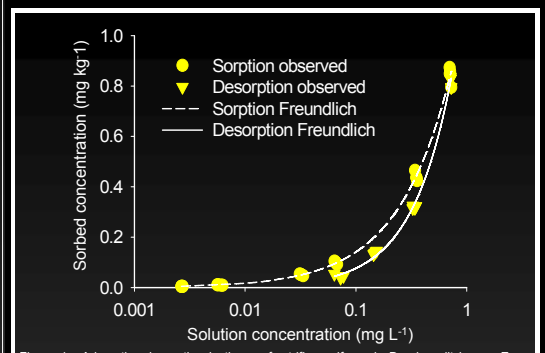

Figure 1. Adsorption-desorption isotherms for trifloxysulfuron in Dundee silt loam. Error bars indicate one standard deviation and do not appear when smaller than the symbol for the mean.

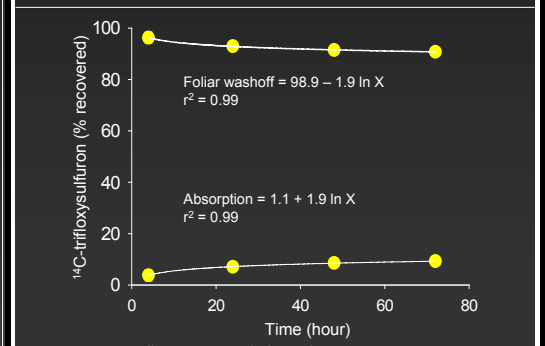

Figure 2. Foliar washoff and absorption of trifloxysulfuron. Error bars indicate one standard deviation and do not appear when smaller than the symbol for the mean.

Table 2. Measured application rates, average edge-of-field concentrations, mass loss and fraction loss of trifloxysulfuron applied to bare and cotton plots.

Parameter	Units	Bare	Cotton	T-test
Mass applied	g ha^{-1}	8.0 (1.2)	7.8 (1.8)	0.81
Concentration	µg L^{-1}	0.8 (0.1)	1.3 (0.2)	0.05
Mass Lost	g ha^{-1}	0.1 (0.05)	0.2 (0.05)	0.07
Fraction Lost	%	1.7 (0.5)	2.7 (0.5)	0.07

Table 1. Vegetation, soil, rainfall, and hydrologic characteristics of cotton and bare plots.

Parameter	Units	Bare	Cotton	T-test
Canopy cover	%	0.0 (0.0)	15.7 (1.7)	0.0001
Canopy height	cm	0.0 (0.0)	25.6 (0.5)	0.0001
Soil moisture	%	18.2 (2.5)	14.9 (1.6)	0.07
Rainfall	cm	2.3 (0.1)	2.4 (0.1)	0.06
Time to runoff	min	3.3 (1.3)	3.8 (0.5)	0.49
Runoff	cm	1.6 (0.1)	1.6 (0.1)	0.58
Runoff rate	L min^{-1}	2.7 (0.1)	2.8 (0.1)	0.30

Discussion

Sorption-desorption. Preliminary studies indicated that sorption of trifloxysulfuron to centrifuge tubes and chemical hydrolysis were negligible during the time course of the experiment. Sorption equilibrium was achieved within 4 h (data not shown). For the concentration range evaluated, the Freundlich equation adequately described the sorption and desorption of trifloxysulfuron to Dundee silt loam. Fitted Kf_{ads} and Kf_{des} values for trifloxysulfuron were 1.2 and 1.2, respectively, and both values were within the range of those reported for various SUs. Fitted values for $1/n_{ads}$ were greater than unity which is indicative of an S-type curve, and implies that the affinity of trifloxysulfuron for Dundee silt loam increases with herbicide concentration. The fitted values for $1/n_{ads}$ were slightly larger than the $1/n_{des}$ values, and the calculated hysteresis coefficient, H, was 0.76. An H value near 1 implies that desorption proceeds as quickly as sorption and that hysteresis is absent. Conversely, a value of H < 1, as in this study, indicates that the rate of desorption is slower than the rate of sorption and that hysteresis occurred. Considering the sorption data for trifloxysulfuron and its potentially high water solubility in agriculturally important soils, trifloxysulfuron will likely be mobile in the soil profile and be transported primarily in the dissolved phase of surface runoff.

Foliar washoff. The availability of ^{14}C trifloxysulfuron for foliar washoff decreased logarithmically as a function of time. Yet, after 72 h, 91% of trifloxysulfuron was available for washoff. Concurrently, absorption of trifloxysulfuron by cotton increased logarithmically from a low of 4% at 4 h to 9% at 72 h. These data indicate that a large fraction of trifloxysulfuron is available for washoff if a rainfall event occurs within 72 h of application.

Runoff losses. The average edge-of-field concentration of trifloxysulfuron was greater for cotton plots compared to bare plots. Cumulative trifloxysulfuron losses from cotton plots were 0.21 g ha^{-1} while losses from bare plots were 0.13 g ha^{-1}. These values correspond to factional losses of 2.7% for cotton plots and 1.7% for bare plots. Fractional losses of trifloxysulfuron from both treatments were in the range of those reported for other SUs including sulfosulfuron, chlorimuron ethyl, nicosulfuron, and sulfometuron-methyl (Brown et al. 2004, Afyuni et al. 1997; Wauchope et al. 1990). Greater loss of trifloxysulfuron from cotton plots was likely due to foliar washoff. Results from the foliar washoff study indicated that 91% of trifloxysulfuron applied to cotton at the 5-leaf stage was available for washoff ≤72 h after application. Once washed of cotton foliage, trifloxysulfuron would be available for sorption to soil, leaching, and/or transport in surface runoff. Sorption-desorption experiments indicated that sorption of trifloxysulfuron to Dundee silt loam was minimal, and that sorption equilibrium required approximately 4 h. Thus sorption of washed off trifloxysulfuron to soil during the 20-min rainfall simulation would be minimal, but a large fraction of the herbicide would be available for leaching and surface runoff.

Conclusions

Based on our sorption data, trifloxysulfuron can be classified as a moderately sorbed compound. It will likely be mobile in the environment and transported primarily in the dissolved phase of surface runoff.

Foliar washoff data indicate that approximately 90% of the trifloxysulfuron that is intercepted by 5-leaf cotton is available for foliar washoff if rainfall occurs within 72 h of application.

Under a worse-case-scenario, the surface runoff loss of trifloxysulfuron was minimal, < 3%.

Literature Cited

Afyuni, N.M., M.G. Wagger, and R.B. Leidy. 1997. Runoff of two sulfonylurea herbicides in relation to tillage system and rainfall intensity. J. Environ. Qual. 26:1318-1326.

Battaglin, W.A., E.T. Furlon, M.R. Burkhardt, and C.J. Peter. 2000. Occurrence of sulfonylurea, sulfonamide, and imidazolinone, and other herbicides in rivers, reservoirs, and ground water in the Midwester United States, 1998. Sci. Total Environ. 248:123-133.

Brown, C.D., I.G. Dubus, P. Fogg, M. Spirlet, and C. Gustin. 2004. Exposure to sulfosulfuron in agricultural drainage ditches: field monitoring and scenario-based modeling. Pest. Manage. Sci. 60:765-776.

Holloway, J.C., Jr., J.W. Wells, and H. Hudetz. 2000. CGA-362622 application timing, rates, and weed spectrum in cotton. Proc. Souther. Weed Sci. Soc. 53:240

Hudetz, M., W. Forey, J. Wells, and J.E. Soares. 2000. CGA 362622, a new low rate Novartis post-emergent herbicide for cotton and sugarcane. Proc. South. Weed Sci. Soc. 53:163-166.

Wauchope, R.D., R.G. Williams, and L.R. Marti. 1990. Runoff of sulfometuron-methyl and cyanazine from small plots: effects of formulation and grass cover. J. Environ. Qual. 19:119-125.