Rapid Development of Enhanced Atrazine Degradation in Soil Under Two Cropping Systems: Continuous Corn and Corn-Cotton Rotation

L.J. Krutz[1], R.M. Zablotowicz[1], K.N. Reddy[1], C.H. Koger[1] and M.A. Weaver[1]

[1] USDA-ARS-SWSRU, Stoneville, MS 38776

Introduction

Atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine) is an herbicide used to control annual grasses and broadleaf weeds primarily in corn (*Zea mays* L.) and grain sorghum [*Sorghum bicolor* (L.) Moench]. Historically, it has been considered relatively recalcitrant in the environment; however, in the last decade, enhanced degradation of atrazine has been reported for soils with an atrazine history (Barriuso and Houot 1996; Houot et al. 2000). Bacteria able to mineralize *s*-triazine rings have been isolated (Mandelbaum et al. 1995), and genes that encode catabolic mineralization of atrazine, *atzABC*, have been fully sequenced and characterized (de Souza et al. 1995; Boundy-Mills et al. 1997; Sadowsky et al. 1998). Moreover, homologues of the *atzABC* genes have been detected in atrazine-degrading bacteria isolated from geographically distinct regions indicating that these genes are widespread and highly conserved (de Souza et al. 1998). Consequently, the potential for enhanced atrazine degradation in soil with an atrazine history is global. Yet, no study has assessed the development of enhanced atrazine degradation in a field experiment or evaluated residual weed control in soil that exhibits accelerated atrazine degradation.

Objective

The objective of this study was to evaluate the development of enhanced atrazine degradation and to determine the potential for reduced residual weed control in two cropping systems: continuous corn receiving annual applications of atrazine and a corn-cotton rotation receiving an application of atrazine once every two years.

Materials and Methods

Field studies. Experiments were conducted from 2000 to 2005 at Stoneville, MS on a Dundee silt loam. Treatments consisted of continuous corn (CC), continuous cotton (NAH), and corn-cotton rotation (CCR). The experimental design was a randomized complete block with 4 replications. Plot size was 45.7-m by 8.2-m, and row spacing was 1.0 m. Corn plots were treated with atrazine + metolachlor at 1.8 + 1.4 kg ha^{-1}, respectively. Cotton plots were treated with fluometuron + pendimethalin at 1.7 + 1.1 kg ha^{-1}, respectively. Mineralization of ^{14}C-ring-labeled atrazine was monitored in 2000, 2001, 2002, and 2005, and data were fitted to the Gompertz growth model. Field dissipation of atrazine was evaluated in 2003 and 2005, and dissipation data were fitted to a first-order kinetics model.

Greenhouse studies. Weed efficacy experiments were conducted in October 2005 with soil collected from CC, CCR, and NAH. Thirty seeds of four weed species including prickly sida (*Sida spinosa*), redroot pigweed (*Amaranthus retroflexus*), pitted morningglory (*Ipomoea lacunosa*), and broadleaf signalgrass (*Brachiaria platyphylla*) were planted in 0.5-m by 0.24-m trays. Trays were either treated with atrazine at 1.8 kg ha^{-1} or were not treated with herbicide. Experimental units were placed in the greenhouse at 35/25C with a 12 h photoperiod. Dissipation of atrazine in trays was monitored insitu, while mineralization kinetics were evaluated in the growth chamber at 30 C.

Results

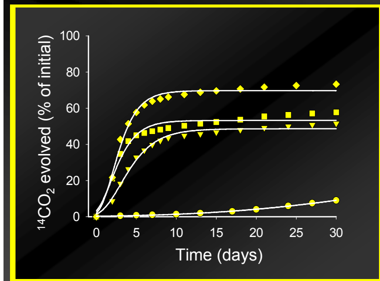

Figure 1. Mineralization kinetics of ^{14}C-ring-labeled atrazine in continuous corn fitted to the Gompertz growth model: 2000 (●), 2001 (▼), 2002 (■), and 2005 (◆). Symbols represent the mean of four replicates.

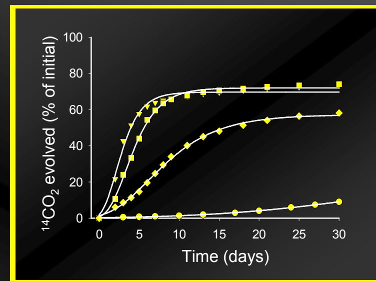

Figure 2. Mineralization kinetics of ^{14}C-ring-labeled atrazine fitted to the Gompertz growth model: 2005 continuous corn (▼), 2005 corn-cotton rotation (■), 2005 no atrazine history (◆), and 2000 baseline (●). Symbols represent the mean of four replicates.

Table 1. Shoot fresh weight of broadleaf signalgrass (BG), pitted morninglory (MG), prickly sida (PS), and redroot pigweed (PW) grown in soil collected from continuous corn (CC), corn-cotton rotation (CCR), and no-atrazine history (NAH). All plots were treated with atrazine at 1.8 kg ha^{-1}, and shoot fresh weight was determined 21 DAP. Experimental units were placed in the greenhouse at 35/25C with a 12 h photoperiod.

	BG	MG	PS	PW
	g			
NAH	0.23	0.20	0.02	0.00
CCR	1.03	3.40	0.34	0.06
CC	1.00	2.43	0.49	0.06
LSD	NS	1.95	0.18	0.04

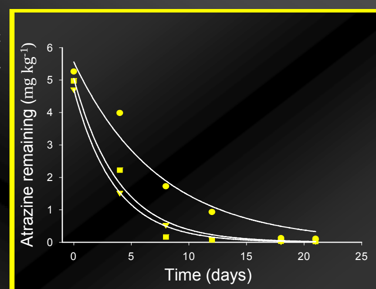

Figure 3. Greenhouse dissipation kinetics of atrazine fitted to a first-order kinetics model: continuous corn (▼), corn-cotton rotation (■), and no atrazine history (●). Symbols represent the mean of four replicates.

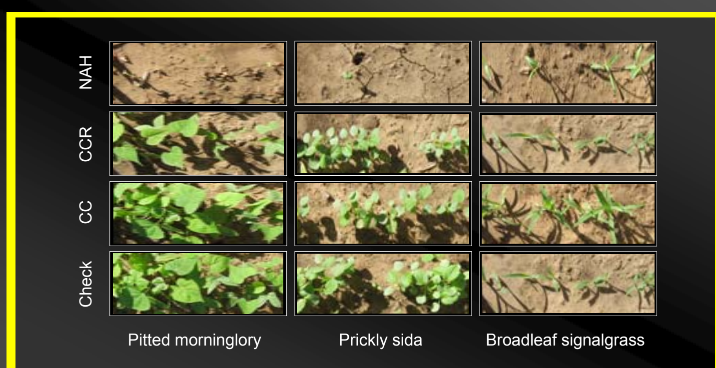

Figure 5. Visual injury of pitted morninglory, prickly sida, and broadleaf signal grass, in non-atrazine treated soil (Check), continuous corn (CC), corn-cotton rotation (CCR), and no-atrazine history soil (NAH). With the exception of the check, all plots were treated with atrazine at 1.8 kg ha^{-1}.

Conclusions

Development of Enhanced Atrazine Degradation

Prior to 2000, field plots had no exposure to atrazine, and cumulative mineralization at 30 d was 9% (Figure 1). After one year of atrazine application, cumulative mineralization increased 5-fold compared to 2000 data, and the estimated lag phase was reduced from 16 d to 3 d. These data demonstrate that the development of enhanced atrazine degradation in the Mississippi Delta can occur after one year of atrazine application.

Rotation Effects on Enhanced Atrazine Degradation

In 2005, the kinetics of atrazine mineralization in CC and CCR were similar (Figure 2). For both treatments the lag phase was < 3 d, and cumulative mineralization was > 70%. Thus, the development of enhanced atrazine degradation was not reduced in a corn-cotton rotation that received an application of atrazine once every two years.

Detecting Enhanced Atrazine Degradation Insitu

In 2003 and 2005, field dissipation of atrazine was monitored in CC and CCR plots. In 2005, plots previously established in cotton were planted in corn to monitor the field dissipation of atrazine in a no atrazine history soil (NAH). For both CC and CCR plots, the 2003 and 2005 data were pooled. Dissipation of atrazine followed first-order kinetics, and the estimated half-life increased in the order of CC (8 d) = CCR (9 d) < NAH (16 d) (Data not shown). These data confirm that enhanced degradation of atrazine can occur and be detected under field conditions. Consequently, residual weed control with this compound may be reduced in atrazine history soils.

Confirming Loss of Residual Weed Control

In the greenhouse studies, dissipation of atrazine in all soils was rapid but followed the same trend as noted in the field dissipation study: CC (2.5 d) = CCR (2.7 d) < NAH (5.2 d) (Figure 3). With the exception of broadleaf signalgrass, the shoot fresh weight of the evaluated weed species was lower in NAH soil compared to either CC or CCR (Table 1). In most cases, visual injury in CC and CCR plots was similar to the non-atrazine treated check (Figure 5.). These data demonstrate that the efficacy of atrazine is reduced when applied to soil that exhibits enhanced degradation of atrazine.

References

Barriuso, E. and S. Houot. 1996. Rapid mineralization of the *s*-triazine ring of atrazine in soils in relation to soil management. Soil. Biol. Biochem. 28:1341-1348.

Boundy-Mills, K., M.L. De Souza, R.M. Mandelbaum, L.P. Wackett, and M.J. Sadowsky. 1997. The *atzB* gene of *Pseudomonas* sp. Strain ADP encodes the second enzyme of a novel atrazine degradation pathway. Appl. Environ. Microbiol. 63:916-923.

de Souza, M.L., J. Sefernick, B. Martinez, M.J. Sadowsky, and L.P. Wackett. 1998. The atrazine catabolism genes *atzABC* are widespread and highly conserved. J. Bacteriol. 180:1951-1954.

de Souza, M.L., L.P. Wackett, K.L. Bound-Mills, R.T. Mandelbaum, and M.J. Sadowsky. 1995. Cloning, characterization, and expression of a gene region from *Pseudomonas* sp. strain ADP involved in the dechlorination of atrazine. Appl. Environ. Microbiol. 61:3373-3378.

Houot, S., E. Topp, A. Yassir, G. Soulas. 2000. Dependence of accelerated degradation of atrazine on soil pH in French and Canadian soils. Soil. Biol. Biochem. 32:615-625.

Mandelbaum, R.T., D.L. Allan, and L.P. Wackett. 1995. Isolation and characterization of a *Pseudomonas* sp. That mineralizes the *s*-triazine herbicide atrazine.

Sadowsky, M.J., Z. Tong, M.L. de Souza, L.P. Wackett. 1998. *AtzC* is a new member of the amidohydrolase protein superfamily and is homologous to other atrazine-metabolizing enzymes. J. Bacteriol. 180:152-158.