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SHORT COMMUNICATION

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Effect of Roundup Ultra on atrazine degradation in soil

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Abstract Tank mixing pesticides and the use of prepackaged mixtures have become common agricultural practices. However, pesticide degradation in multi-pesticide systems is rarely evaluated. The objective of this laboratory study was to determine the effect of Roundup Ultra on atrazine degradation in soil. Based on a 2-mm glyphosate-soil interaction depth, the isopropylamine salt of glyphosate was added to Aatrex-amended and non-amended soil at rates of 0, 1 (43 mg ai kg^{-1}), 2, 3, 4, and 5×. Treatments were incubated for 4, 8, 12, 16, 20, 24, 28, and 32 days. Atrazine degradation was significantly different among treatments at 8 days. In the 0× treatment (Aatrex only), 87% of the atrazine was degraded. During the same 8-day period, atrazine degradation in the 1, 2, 3, 4, and 5× treatments was 77%, 69%, 60%, 61%, and 52%, respectively. Atrazine degradation approached 97% for all treatments after 12 days and statistical differences were no longer observed. Atrazine degradation was inversely correlated with Roundup Ultra rate and microbial activity at 8 (r^2 =0.97) and 12 days (r^2 =0.92). These results indicate that Roundup Ultra stimulated microbial activity while simultaneously inhibiting atrazine degradation.

Keywords C mineralization · Degradation · Glyphosate · Atrazine · Soil microbial activity

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Introduction

Tank mixing pesticides and prepackaged mixtures have become common agricultural practices (Singh et al. 1990; Colvin 1993), yet pesticide degradation in multi-pesticide systems is rarely evaluated. Research indicates that organic amendments affect atrazine degradation but varying amendments could enhance or hinder degradation. Atrazine degradation was retarded by the addition of glucose (Abdelhafid et al. 2000a), Sudan hay (Alvey and Crowley 1995), sodium citrate (Alvey and Crowley 1995), arginine, albumin, adenine, biuret, and pyrazine (Abdelhafid et al. 2000b). The herbicide cyanazine competitively inhibited atrazine degradation in washed-cell suspensions and crude cellular extracts (Gebendinger and Radosevich 1999). Conversely, atrazine degradation was stimulated by the addition of rice hulls (Alvey and Crowley 1995) and cellulose (Yassir et al. 1998). In our earlier work, glyphosate applied to soil as Roundup Ultra either had no effect or slightly stimulated soil atrazine degradation (Haney et al. 2002). The impact of postemergence applications of glyphosate and atrazine on weed control in glyphosate-tolerant crops has been evaluated (Johnson et al. 2000). Soil atrazine degradation has not been evaluated under different Roundup Ultra application rates and was the objective of this study.

Materials and methods

The upper 2 cm of a Weswood silt loam (fine, mixed, thermic Fluventic Ustochrept) with pH 8.3 (1:2 soil:water), soil organic matter content of 10.6 g kg^{-1}, 115 g sand kg^{-1}, 452 g silt kg^{-1}, 310 g clay kg^{-1}, and 123 g $CaCO_3$ kg^{-1} soil was collected from unfertilized *Sorghum bicolor* plots located on the Texas A&M University Agricultural Research Farm near College Station, TX. Extractable soil P was in the very high category as determined by the Texas A&M University Agricultural Extension Service soil testing lab. The plot had received the same cultural practices for 16 years prior to sampling.

Atrazine, in the form of Aatrex 4L, was added to soil at a 1× rate (3.86 μg g^{-1} soil) based on 2.24 kg ai ha^{-1} and a 58-mm soil interaction depth. The isopropylamine salt of glyphosate as RoundUp Ultra (480 g ai l^{-1}) was added to soil at 0, 1 (43 μg

g^{-1}), 2 (86 μg g^{-1}), 3 (129 μg g^{-1}), 4 (172 μg g^{-1}), and 5× rates (215 μg g^{-1}). The 1× glyphosate rate was based on 0.86 kg ai ha^{-1} and a soil interaction depth of 2 mm. A control treatment with no herbicide was included.

Soil samples were dried at 40°C to ensure homogeneity of soil moisture content and passed through a 2-mm sieve. Subsamples (40 g) were subsequently re-wetted to 10% moisture to re-establish steady-state microbial activity and incubated in the dark at 30°C for 7 days prior to herbicide addition. Herbicides were added to the soil samples in 2 ml distilled water, increasing the final moisture content to 20%. Four 40-g subsamples per replicate were placed in gas-tight 1-l glass containers with a vial containing 10 ml 1 M KOH to trap evolved CO_2 and a vial of water to maintain humidity. Soils were incubated as described above and traps replaced 4, 8, 12, 16, 20, 24, 28, and 32 days after the experiment began. Unreacted alkali in the KOH traps were titrated with 1 N HCl to determine CO_2-C (Anderson 1982).

Soil subsamples were collected 4, 8, 12, 16, 20, 24, 28, and 32 days after the experiment began and stored at 4°C. Atrazine extraction and subsequent quantification by high performance liquid chromatography (HPLC) was conducted as described by Haney et al. (2002). Atrazine extraction efficiency was 86% ±11. Samples were corrected for percent recovery.

All treatments were replicated three times. Means and standard errors were generated by analysis of variance. Relationships among variables were assessed by linear regression. Model adequacy was based on residual plot analysis. Treatment means within each incubation interval were separated using Fisher's LSD at the 5% level of significance (SAS Institute 1990).

Results and discussion

Atrazine degradation was defined as the disappearance of the solvent-extractable parent compound. At 4 days, 88% of the parent compound was recovered from all treatments and statistical differences were not observed (Fig. 1). Soil atrazine degradation was significantly different among treatments at 8 days when 87% of the atrazine was degraded in the 0× treatment. In the same time period, atrazine degradation in the 1, 2, 3, 4, and 5× treatments was 77%, 69%, 60%, 61%, and 52%, respectively. Moreover, the 3, 4 and 5× treatments significantly decreased atrazine dissipation compared to the 0× treatment. By 12 days, approximately 97% of the initially added atrazine was degraded in all treatments and significant differences among treatments were no longer observed.

The relationship between Roundup Ultra and percent atrazine remaining was assessed using linear regression (Fig. 2). A significant linear relationship between Roundup Ultra and percent atrazine remaining was evident at 8 and 12 days. At both time periods, atrazine degradation was inversely correlated with glyphosate added. As described above, there was not a significant relationship between parameters at other sampling periods.

These results indicate that Roundup Ultra reduced atrazine degradation. The effect appears to be transient and undetectable statistically after 8 days of incubation. Moreover, these results are in agreement with published literature where the herbicides metolachlor (Moorman et al. 2001) and cyanazine (Gebendinger and Radosevich 1999) suppressed atrazine degradation. Conversely, Haney et al. (2002) concluded that glyphosate either had no effect or slightly stimulated soil atrazine degradation. Discrepancies among studies may indicate that suppressed herbicide degradation in multi-pesticide systems is concentration dependent.

Microbial activity was evaluated from the kinetics of cumulative soil C mineralization. Increased soil C mineralization compared to the control was attributed to Aatrex and Roundup Ultra mineralization, assuming no interactions occurred between indigenous and exogenous organic matter. Both Aatrex and Roundup Ultra stimulated soil microbial activity. However, cumulative soil C mineralization was significantly higher in the Roundup Ultra treatments compared to the 0× treatment (Aatrex only). Moreover, there was a strong linear relationship

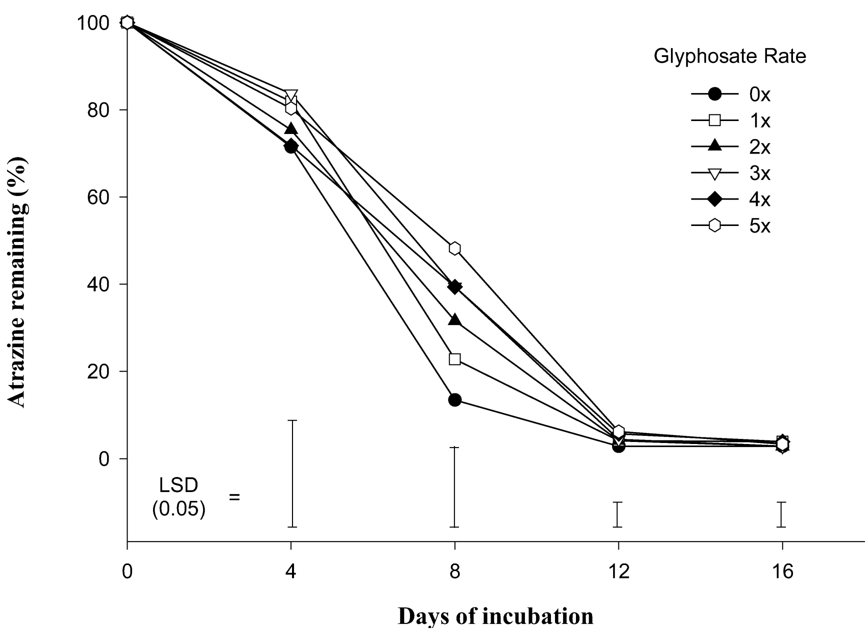
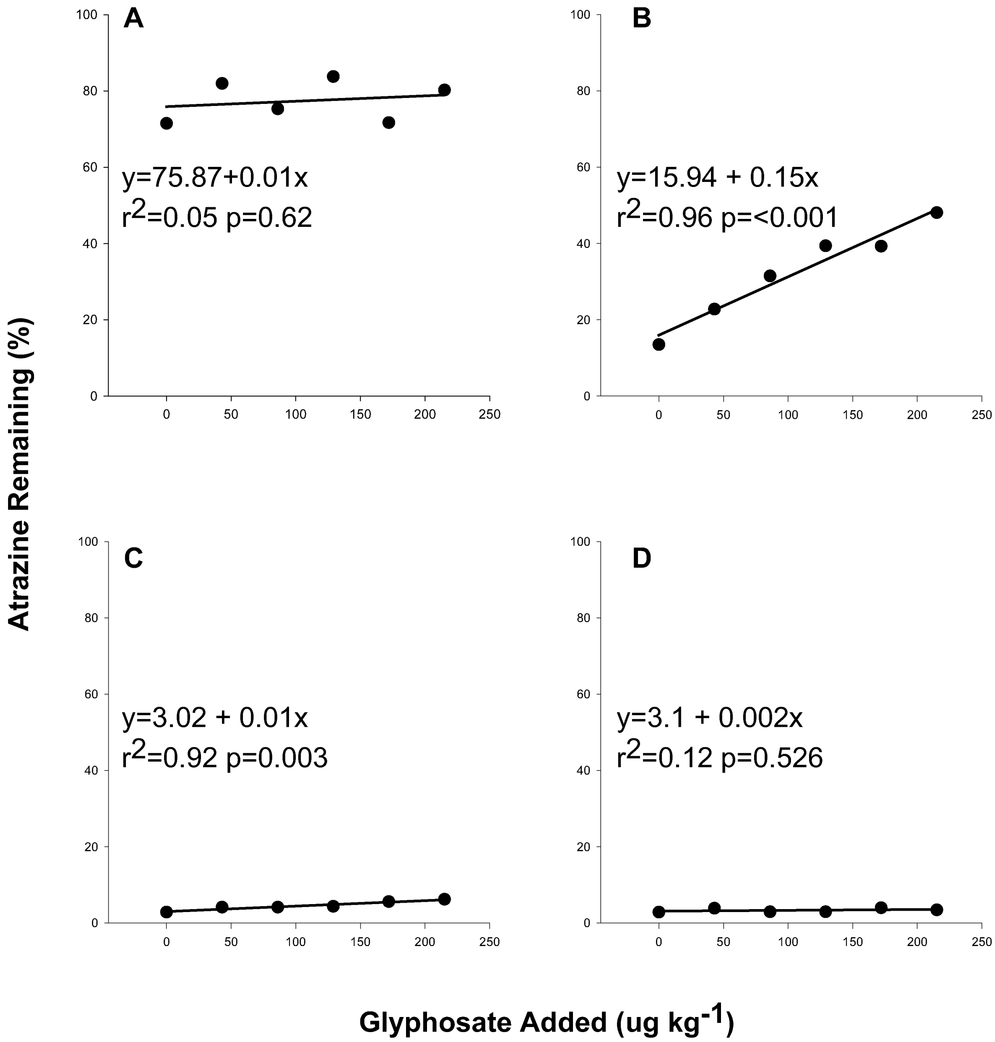


Fig. 1 Effect of Roundup Ultra rate on atrazine degradation from soil during 32 d of incubation. Bars indicate LSD (0.05) among treatments at a single sampling time

Fig. 2 Relationship between Roundup Ultra rate and percent altrazine remaining at A) 4 days B) 8 days C) 12 days D) 16 days



between C mineralized and glyphosate added (r^2 =0.99). A significant linear relationship between C mineralized and glyphosate added suggests that glyphosate was directly mineralized or made other resources proportionally available for mineralization (Haney et al. 2000).

A significant linear relationship between microbial activity and atrazine degradation was evident at 8 (r^2 =0.97) and 12 days (r^2 =0.92). Similar to the comparison between atrazine degradation and glyphosate added, microbial activity was inversely correlated with atrazine degradation. Others have reported an inverse relationship between atrazine degradation and microbial activity (Houot et al. 1998). Although the mechanism for reduced atrazine degradation in multi-pesticide systems has not been elucidated, the C mineralization data indicates the process is likely to be linked with microbial populations. The proposed mechanism for reduced herbicide degradation in a multi-pesticide system is decreased enzymatic activity (Abdelhafid et al. 2000a, 2000b;Yassir et al. 1998) and/or suppressed herbicide degrader populations (Martins and Mermound 1998; Moorman et al. 2001).

Roundup Ultra repressed soil atrazine degradation. Reduced degradation was transient and detected by ANOVA only at 8 days. Moreover, regression analysis indicated that atrazine degradation was inversely proportional to both glyphosate added and microbial activity. These results suggest that the suppressed atrazine degradation in this multi-pesticide system was microbially mediated. Although the suppression mechanism has not been elucidated, it is likely that the process is linked with microbial population dynamics.

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