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SUBJECT: DETAILS OF HYDRUS MODELING OF SHANK TRACE SAMPLING RESULTS

In brief, the shank trace study was designed to measure the decrease in bulk density which may be caused by dragging a fumigant shank through the soil. This zone of reduced bulk density above the injection point may provide a mechanism for quicker atmospheric volatilization of a fumigant. Hydrus 2D/3D Version 2.01.1090 was used to model the field results from the shank trace study (Johnson in preparation). Johnson (in preparation) found a statistically significant ($p<.05$), but small decrease in bulk density where the shank moved through the soil. The overall bulk density outside of the shank line was 1.146 g/cm^3 compared to 1.108 g/cm^3 for samples taken in the shank line.

Methods

Hydrus modeling utilized 1,3-dichloropropene (1,3-d) for modeling the chemical properties. The soil was a loam soil, based on laboratory texture analysis (Fabio Sartori, personal communication). After initial simulations a hypothetical case was simulated for comparison. Cresswell et al. (1991) found a minimum bulk density in a silt loam of 0.8 g/cm^3. This value was used as a low bulk density to compare to the simulations based on the measured bulk density.

Three scenarios were simulated: (1) the soil with uniform properties (bulk density at 1.146 g/cm^3, no shank trace; (2) same as (1) except a zone of reduced bulk density (1.108 g/cm^3) representing the measured shank trace (Figure 1A); (3) same as (2) except shank trace bulk density set to 0.8 g/cm^3 , strong shank trace. The primary parameter settings are listed in Table 1. The chemical specific settings reflect parameters for the fumigant 1,3-d. The location of the shank trace and initial fumigant application is shown in Figure 1. The shank trace was configured to be 6 x 30 cm since the sampling tube was 6 cm in diameter and the application shanks were configured to go to a depth of 30 cm (12 inches). The fumigant application was modeled with an initial concentration of 10 ug/cm^3 arranged in a roughly rectangular zone 30cm x 10 cm below the shank trace column (Figure 1B). The initial 1,3-d mass of 2888 ug reflects the somewhat irregular shape of selected nodes and feathering in the neighboring region. That is why there is not an initial mass of 3000 ug. Scenario (3), the strong bulk density case, used the following parameters for the shank trace column: θs=0.7, bulk density 0.8 g/cm^3, solid fraction 0.3, initial water content 0.11.

Results

Mass balance errors for three scenarios were all less than 0.2%. The cumulative emissions for the shank trace scenario (2) were 38.7% compared to 38.5% of applied mass for the nonshank trace scenario (1). The magnitude of these emissions were lower than shallow shank field studies of 1,3-d which estimated cumulative emissions of 65% (Gillis and Dowling 1998). Decreasing the bulk density in the strong shank trace scenario (3) increased emissions to 44.1%. The flux profiles of the no shank trace (1) and shank trace (2) scenarios were largely indistinguishable (Figure 2). The strong shank trace scenario (3) showed a quicker flux increase and higher peak flux (Figure 2).

Discussion

Though the bulk densities differences between the shank trace and nonshank trace were statistically significantly different, the magnitude of the difference was small. This small difference was reflected in the volatilization simulations which predicted very little difference between the scenarios with and without a shank trace. The measured bulk densities were notably lower than the 1.5 g/cm^3 loam soil mean bulk density based on saturated water content found in Carsel and Parish (1988) for loam soil. This suggests that the cultivation and soil workup before application in the Lost Hills study created a ‘fluffy’ , low density soil and volatilization would not be affected by small differences in bulk density due to the shank application.

The strong shank trace scenario suggested that if there was sufficient bulk density reduction in the shank trace, an effect on volatilization could occur. The measured bulk density differences, however, were not enough to produce such an effect.

References

Carsel, Robert F. and Rudolph S. Parrish. 1988. Developing joint probability distributions of soil water retention characteristics. Water Resources Research 24(5),755-769.

Cresswell, H.P. D.J. Painter and K.C. Cameron. 1991. Tillage and water content effects on surface soil physical properties. Soil Tillage Res. 21, 67-83.

Gillis, Matthew J. and Kathryn C. Dowling. 1998. Effect of broadcast and row application methods on 1,3-D emissions. Dow AgroSciences LLC, 9330 Zionsville Road, 308/2E. Indianapolis, Indiana. Bolsa Research Project #:BR730, Dow AgroSciences Study Identification number: HEA95177.

Table 1. Main parameter settings for Hydrus 2D/3D shank trace simulation model				
Domain:	200 cm wide by 100 cm high			
Shank trace:	6 cm wide by 30 cm deep			
Fumigant Application zone:	30 cm wide by 10 cm deep at 30 cm below surface			
Simulation Duration	14d			
Soil Matrix	Loam (Clay 19.2%,Sand 43.7%)			
	Bulk density (g/cm^3)	1.146 matrix, 1.108 shank trace		
	Θ_s	0.568 matrix, 0.582 shank trace		
Soil Heat	Default for Loam			
	Solid fraction	0.432 matrix, 0.418 shank trace		
Fumigant 1,3-d:	Kd	0.16	cm^3/g	
	Kh	0.055	(dimensionless)	
	k	-0.124	1/d	
	Diffusion water	0.735	cm^2/d	
	Diffusion air	6888	cm^2/d	
	Activation Disp Water	18035	J/mole	
	Activation Disp Gas	4560	J/mole	
	Activation Henry	32085	J/mole	
	Activation k	0	J/mole	
Surface boundary layer thickness	0.5	cm		
Evaporation	0.2	cm/d		
Initial Conditions	Soil water (Vol)	0.166 matrix, 0.161 shank trace		
	Temperature	22^{o}C		
	Concentration	10ug/cm^3 in application zone		
	Initial 1,3-d mass	2888	ug	
Boundary Conditions	Water - Atmospheric at surface			
	Solute - Volatile Type			
	Heat - sine wave 8^{o}C amplitude			

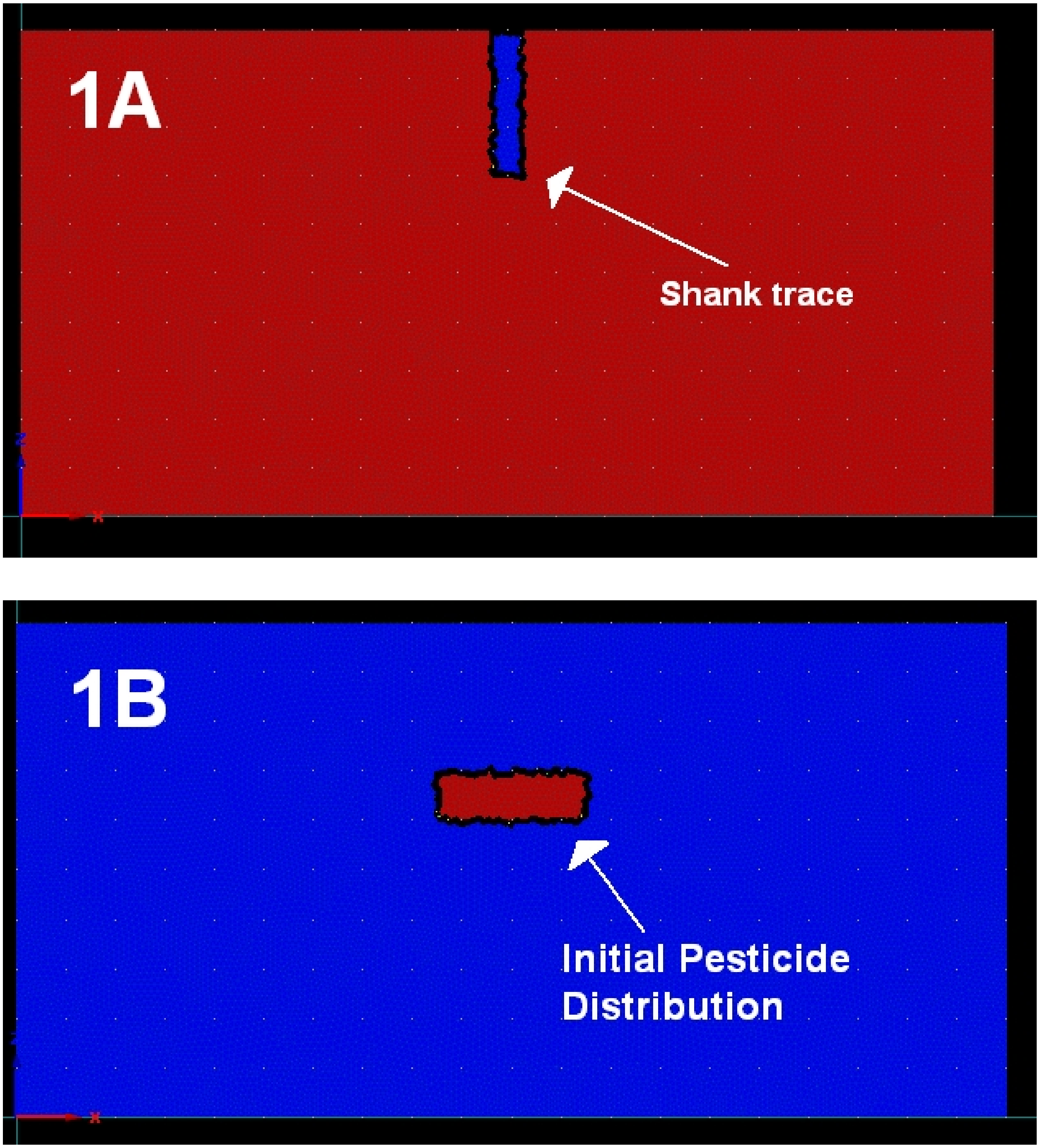

Figure 1. 200 cm x 100 cm domain showing shank trace zone (1A) and initial distribution of fumigant (1B).

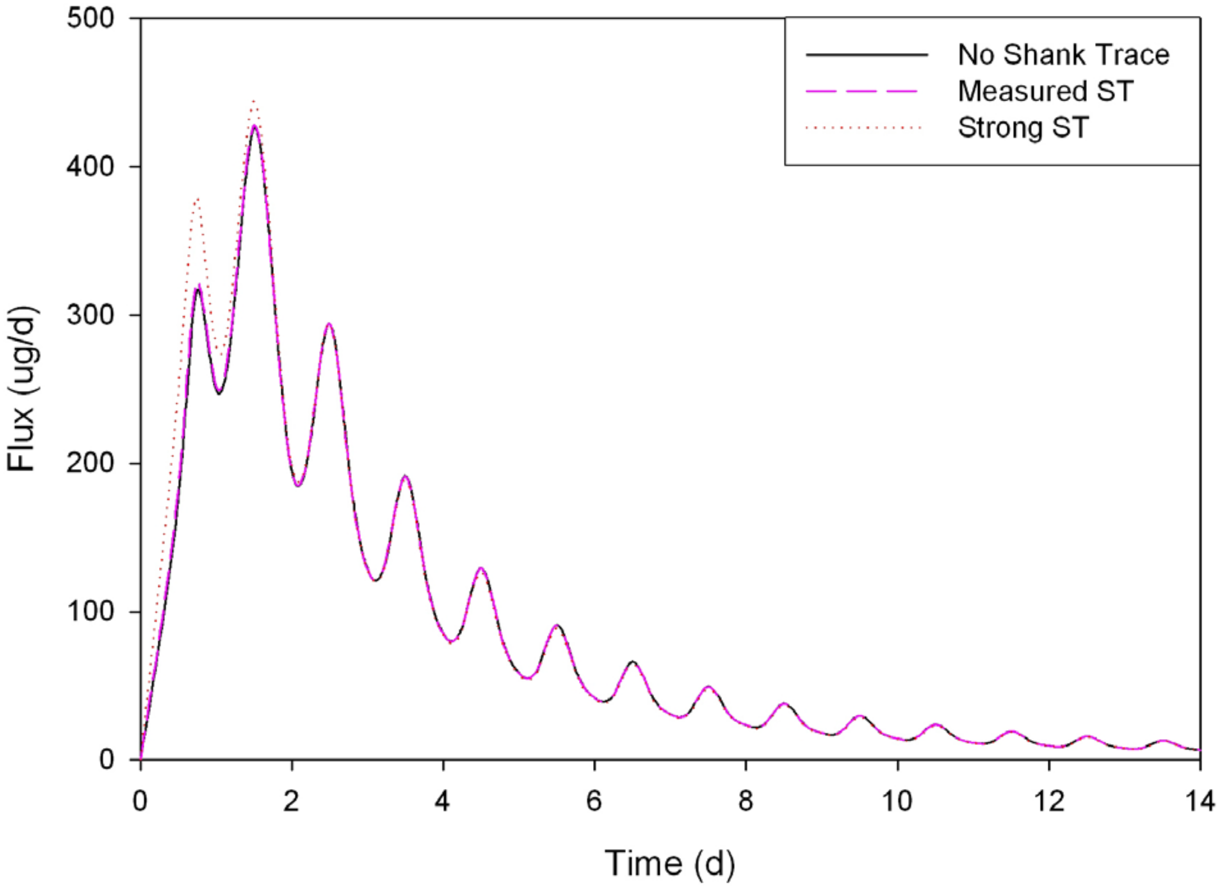

Figure 2. Simulated flux profiles from no shank trace, measured shank trace and strong shank trace scenarios.