

Use of Composted Animal Manures to Reduce 1,3-Dichloropropene Emissions

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Atmospheric emission of the soil fumigant 1,3-dichloropropene (1,3-D) has been associated with the deterioration of air quality in certain fumigation areas. To minimize the environmental impacts of 1,3-D, feasible and cost-effective control strategies are in need of investigation. One approach to reduce emissions is to enhance the surface layer of a soil to degrade 1,3-D. A field study was conducted to determine the effectiveness of composted steer manure (SM) and composted chicken manure (CKM) to reduce 1,3-D emissions. SM or CKM were applied to the top 5-cm soil layer at a rate of 3.3 or 6.5 kg m⁻². An emulsified formulation of 1,3-D was applied through drip tape at 130.6 kg ha⁻¹ into raised beds. The drip tape was placed in the center of each bed (102 cm wide) and 15 cm below the surface. Passive flux chambers were used to measure the loss of 1,3-D for 170 h after fumigant application. Results indicated that the cumulative loss of 1,3-D was about 48% and 28% lower in SM- and CKM-amended beds, respectively, than in the unamended beds. Overall, both isomers of 1,3-D behaved similarly in all treatments. The cumulative loss of 1,3-D, however, was not significantly different between the two manure application rates for either SM or CKM. The results of this study demonstrate the feasibility of using composted animal manures to control 1,3-D emissions.

Key Words: Chemigation; Composted manure; 1,3-Dichloropropene; Fumigant pesticide; Soil fumigation; Volatilization.

INTRODUCTION

The practice of soil fumigation to control plant-parasitic pathogens began well over a century ago and is now an essential component of modern agriculture.^[1] Many of the soil fumigants, though, are inherently volatile and toxic and are a major source of atmospheric pollution. As a result, regulatory measures to

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restrict or suspend their use have been instituted. Methyl bromide (MeBr), the most widely used fumigant, will be shortly phased out of use in the United States, and very few alternative fumigants are available for replacement. Use of the soil fumigant 1,3-dichloropropene (1,3-D) or 1,3-D in combination with chloropicrin is expected to increase as the ban on MeBr takes effect. 1,3-dichloropropene is a potent nematicide, which consists of two isomers (cis and trans) with a vapor pressure of 4.5 and 3.1 KPa, respectively. Because of 1,3-D's relatively high vapor pressure, a significant fraction of the fumigant is volatilized after application. High ambient air concentrations of 1,3-D have been detected near application sites and associated with the deterioration of air quality.^[2] Field studies using subsurface drip application (also known as chemigation) revealed that as much as 66% and 57% of the applied 1,3-D was lost from shallow (2.5 cm) and deep (20.3 cm) drip plots, respectively.^[3] Due to the expected increase in the use of 1,3-D, management techniques are needed to help reduce emissions and prevent potential off-site air pollution.

Traditional methods for controlling fumigant emissions include plastic tarping, deep injection, and increasing the soil water content and bulk density.^[4] Since the movement of a fumigant pesticide in soil is largely driven by vapor diffusion, these methods increase the residence time of the fumigant and allow more time for degradation to occur. Therefore, less fumigant is volatilized into the atmosphere. The degradation of fumigant pesticides in soil, however, is generally slow with half-lives ranging from days to over a month.^[5] Another potential approach to reduce fumigant emissions is to enhance the capacity of the soil, especially the soil's surface, to degrade the fumigant before it enters the atmosphere.^[6] The incorporation of organic wastes, such as composted animal manures, into soil is known to accelerate the biological and chemical degradation of 1,3-D and other fumigant pesticides.^[7,8] Conceivably, as fumigant passes through an organically amended surface layer of a fumigated field, it should be degraded at a higher rate, resulting in lower emissions. The objective of this study was to determine the effectiveness of composted steer manure (SM) and composted chicken manure (CKM) to reduce 1,3-D emissions from raised soil beds under field conditions.

MATERIALS AND METHODS

Raised Soil Beds, 1,3-D Application, and Composted Manures

The following field experiment was conducted at the University of California, Riverside, Agricultural Experiment Station between December 9, 2002, and December 16, 2002, and was designed to simulate preplant fumigation of raised soil beds with 1,3-D. The raised beds were prepared using a commercial bed shaper and each soil bed was 5.0 m long \times 1.02 m wide \times 0.15 m

high. The soil is an Arlington sandy loam (coarse-loamy, mixed, thermic, Haplic Durixeralf) and consists of approximately 64% sand, 29% silt, and 7% clay. A single line of drip tape (4 L h^{-1} emitter $^{-1}$, emitter spacing of 30 cm, 16 mm dia., Toro Co., Madera, CA, USA) was shank installed in the center of each bed and 15 cm below the surface of each bed. An emulsifiable formulation of 1,3-D (InLineTM, 60.8% 1,3-D, Dow AgroSciences LLC, Indianapolis, IN, USA) was mixed in a 0.25 m^3 tank and injected into an irrigation system at an application rate of 130.6 kg ha^{-1} ($76.6\text{ kg 1,3-D ha}^{-1}$). Water flow to each bed was set at 0.8 L min^{-1} and lasted for 3 h during the injection of the 1,3-D. After the injection of 1,3-D was completed, water application continued for an additional 0.42 h to flush residual 1,3-D from the irrigation system.

Composted steer manure (SM, Hyponex Corp., Marysville, OH, USA) and composted chicken manure (CKM, Kellogg Supply Inc., Carson, CA, USA) were incorporated within the top 5 cm of the raised beds at a rate of 5% or 10% (dry wt. basis, 3.3 or 6.5 kg m^{-2}). The organic carbon content of the SM and CKM was 21.6% and 22.6%, respectively. The composted manures were applied the day before 1,3-D application and were sprinkler irrigated once daily to keep them moist during the experiment. Duplicate beds were prepared for each treatment.

Flux Measurements

To measure 1,3-D emissions, a galvanized-steel passive flux chamber (surface area of $1,077\text{ cm}^2$ and vol. of $14,200\text{ cm}^3$) was placed on the top of each bed for 30 min to trap the fumigant. The technique is similar to that described by Gao and Yates.^[9] After 30 min, a 100-mL sample of the chamber air was pulled through a coconut-based charcoal tube (ORBO-32, Supelco, Bellefonte, PA, USA). After the sample was drawn, the charcoal tubes were capped on both ends and frozen at -20°C until analyzed by gas chromatography. The flux chambers were aerated between each measurement.

Sample Analysis

To extract 1,3-D residues from the charcoal, the contents of each charcoal tube were carefully placed into a 10-mL headspace vial and 3 mL of acetone was added. The vials were immediately capped with Teflon-lined septa and then shaken for 0.5 h on a horizontal shaker ($150\text{ oscillations min}^{-1}$). The extract was transferred to a GC vial and analyzed by gas chromatography (Hewlett-Packard 5890 with a microelectron capture detector). The GC operating conditions were: capillary column, DB-VRX (30 m, $0.25\text{ mm} \times 1.4\ \mu\text{M}$, Agilent Technologies, Palo Alto, CA, USA); carrier gas, He, 1.4 mL min^{-1} ; column temperature, 45°C rising at $2.5^\circ\text{C min}^{-1}$ to 76°C after 2 min, 76°C for 0.3 min. then rising at $35^\circ\text{C min}^{-1}$ to 120°C for 1 min; injector temperature, 240°C ; detector temperature, 290°C . 1,3-D (49.9% [*cis*] and 46.8% [*trans*], Dow AgroSciences LLC, Indianapolis, IN,

USA) standards were prepared in acetone and then added to charcoal tubes using a gas-tight syringe. The charcoal tube standards were then extracted as described above. Data were subjected to ANOVA analysis followed by the Holm-Sidak method with a significance level of 0.05.

RESULTS AND DISCUSSION

The emission of *cis*-1,3-D and *trans*-1,3-D from unamended, SM-amended, and CKM-amended beds was measured for 170 h after InLine was injected 15 cm below the surface. The average fluxes and cumulative losses for both isomers are given in Figures 1, 2, and 3. Maximum volatilization of 1,3-D in unamended and manure-amended beds occurred 2 and 4 h after application, respectively, and

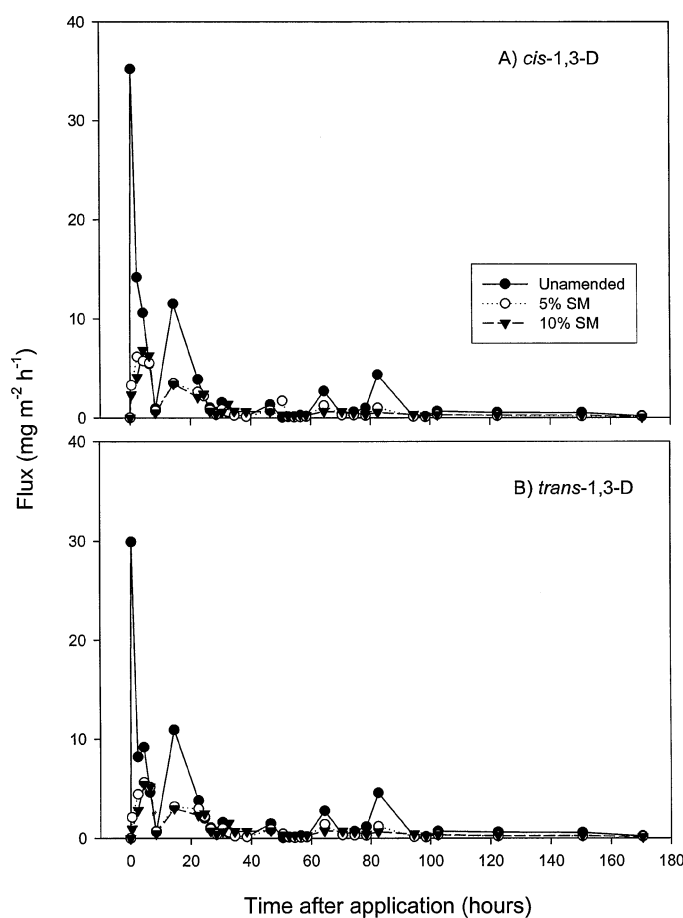


Figure 1: Volatilization of (A) *cis*-1,3-D and (B) *trans*-1,3-D from raised soil beds after subsurface drip application of InLine at 130.6 kg ha⁻¹ and surface application of composted steer manure (SM) at 5% and 10% (dry wt. basis).

decreased rapidly after this point. When the surface (top 5 cm) of the raised bed was amended with either SM or CKM at a rate of 5% or 10% (dry wt. basis), 1,3-D emissions were lower when compared to the unamended bed. In the unamended beds, the maximum flux of *cis*-1,3-D was slightly higher than that of *trans*-1,3-D (Figs. 1 and 2). This can be attributed to the fact that the *cis* isomer is slightly more volatile and less soluble in water than the *trans* isomer. In the SM-amended beds, there was little difference between the maximum flux (at 4 h) for *cis*-1,3-D and *trans*-1,3-D at either manure application rate (Fig. 1). However, in the CKM-amended beds, the maximum flux for *cis*-1,3-D and *trans*-1,3-D at the highest manure application rate was about one-half that of the lowest manure application rate (Fig. 2). Apparently, increasing the amount of CKM enhanced the degradative capacity of the surface layer during the first 4 h, though the difference diminished thereafter.

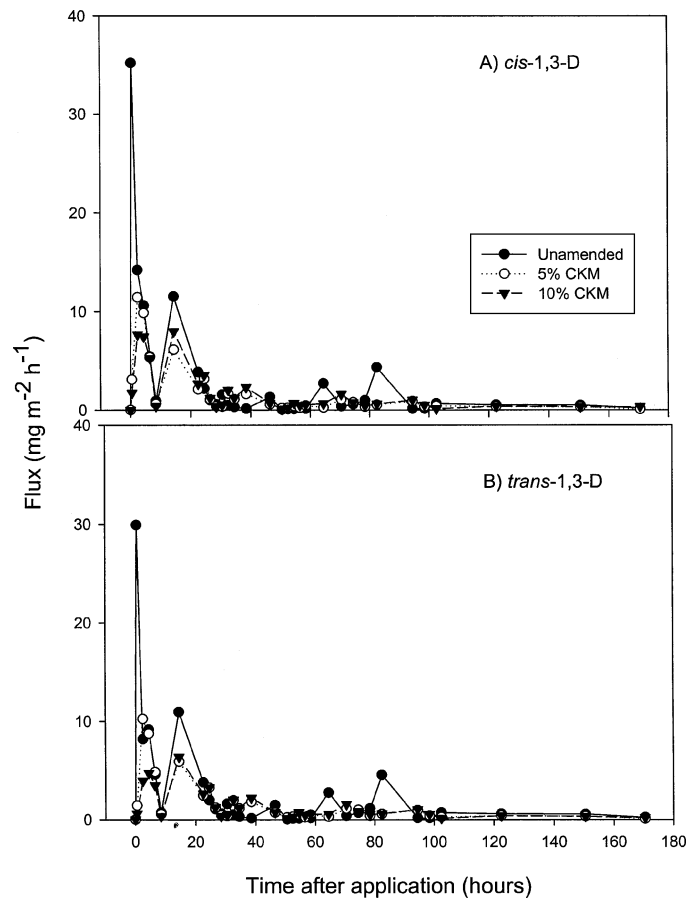


Figure 2: Volatilization of (A) *cis*-1,3-D and (B) *trans*-1,3-D from raised soil beds after subsurface drip application of InLine at 130.6 kg ha^{-1} and surface application of composted chicken manure (CKM) at 5% and 10% (dry wt. basis).

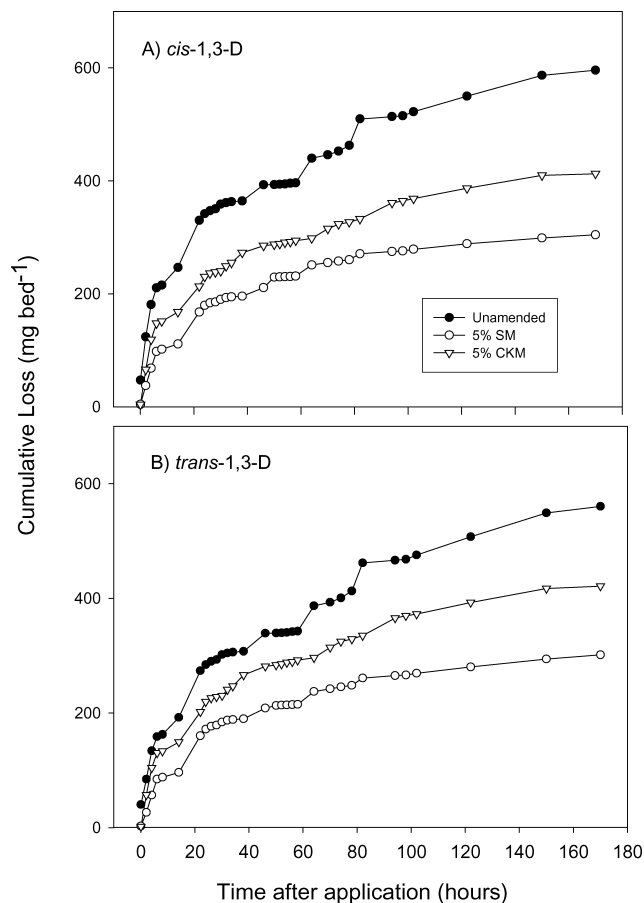


Figure 3: Cumulative loss of (A) *cis*-1,3-D and (B) *trans*-1,3-D from beds amended with 5% (dry wt. basis) composted steer manure (SM) or composted chicken manure (CKM).

Overall, both isomers behaved similarly in all treatments, as shown in Figure 3, and the cumulative loss of 1,3-D was substantially lower in the SM- and CKM-amended beds. There was no significant difference, however, between the two manure application rates (10% data not shown in Fig. 3). Our results agree with those obtained by Dungan, Gan, and Yates,^[7] who found that degradation of 1,3-D at 20 and 30°C was not significantly different between SM rates of 5% and 10% for either isomer. Compared to a 2% and 10% SM application rate, it was determined that optimum degradation of 1,3-D occurred at the 5% application rate. At 40°C, the degradation of *cis*-1,3-D and *trans*-1,3-D at 10% SM was reported to be 36% and 33% greater, respectively, than at 5% SM. However, during this field study the average temperature at the soil surface and 2.5 and 5 cm below the soil surface was 11.1, 12.0, and 12.1°C, respectively, with a daily high of 26.7, 23.0, and 20.2°C during the seven-day study. The degradation rate of 1,3-D changes by a factor of about 2 for each 10°C change in

Table 1: Percent reduction of cumulative 1,3-D emissions 170 hours after application.

Treatment	Isomer	
	<i>cis</i>	<i>trans</i>
1,3-D only	—	—
1,3-D + 5% SM	48.7	46.2
1,3-D + 10% SM	49.6	46.7
1,3-D + 5% CKM	31.9	24.8
1,3-D + 10% CKM	26.6	30.8

temperature.^[7] Since the soil surface is generally subject to larger temperature fluctuations and the degradation of 1,3-D increases with temperature, higher rates of 1,3-D degradation can be expected to occur in the surface layers than in the subsurface layers.

In the 5% SM- and CKM-amended beds, the loss of *cis*-1,3-D and *trans*-1,3-D was reduced by about 49% and 46% and 32% and 25%, respectively, after 170 h (Table 1). The results from our SM-amended beds are similar to those obtained by Gan et al.^[10] Gan and coworkers amended the top 5 cm of a soil column with 5% composted steer manure (w/w) and found that the cumulative loss of *cis*-1,3-D and *trans*-1,3-D was 47% and 44% lower, respectively, than in an unamended soil column. The same treatment was also effective in reducing MeBr emissions by 12% and almost completely eliminating the atmospheric emission of methyl isothiocyanate (MITC).^[10] Of the two composted manures tested, it is apparent that SM is more biologically and/or chemically active than the CKM, since less 1,3-D was volatilized from the SM-amended beds. In Arlington sandy loam soil, the degradation of 1,3-D was 1.5 times faster when amended with 5% SM than when amended with 5% CKM.^[7] Composted chicken manure was found to be very effective in accelerating the degradation of the fumigant pesticide MITC.^[8]

CONCLUSIONS

This field study demonstrated that incorporating composted animal manures into the soil's surface may be a feasible method to reduce atmospheric emissions of 1,3-D. The composted manures accelerate the degradation of 1,3-D, resulting in a substantial reduction in emissions and will not compromise efficacy in the subsurface soil layers. This emission control strategy would be especially useful in soils with little capacity to degrade fumigants and where gas-phase diffusion is rapid, such as a sandy soil. However, the use of organic amendments to reduce fumigant emissions may be better suited for agricultural production systems that do not use raised soil beds, as significant fumigant losses can also occur through the sides of the bed. Increasing the depth of the drip tape, below that used in this study, should also allow for further decreases in the

amount of 1,3-D emitted. Additional studies should be conducted to determine the environmental and economic benefits of using this emission control strategy on a larger scale.

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