

EFFECT OF SOIL MOISTURE ON EMISSIONS AND DISTRIBUTIONS OF FUMIGANTS IN COLUMNS

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Introduction: Soil fumigants are intensively used for pest control to achieve high crop yield. 1,3-dichloropropene (1,3-D) and chloropicrin (CP) are increasingly being used as alternatives to methyl bromide (MeBr); however, their emissions following application contribute to air pollution and may endanger workers and bystanders. Irrigation prior to fumigation was found to reduce fumigant emissions at lower costs than plastic tarp (Gao and Trout, 2007). However, the optimum range of soil water content that can lead to a reduction of emissions and achieve good fumigation efficacy is not clearly defined. The objective of this study was to determine the effects of soil moisture conditions at or below field capacity prior to fumigation on fumigant emission and distribution in soil using soil column tests.

Materials and Methods: A Hanford sandy loam soil (coarse-loamy, mixed, superactive, nonacid, thermic Typic Xerorthents) was used for this study. Surface soils were collected and air-dried to a water content of 5.1% (w/w) and sieved through a 4 mm screen. Soil was packed to a total depth of 23 cm at a uniform bulk density of 1.4 g cm⁻³ into closed-bottomed stainless steel columns (25 cm height x 15.5 cm i.d.).

After packing the columns, different amounts of water were added to the soils to achieve soil water content at 30% (no water addition), 45%, 60%, 75%, 90% and 100% of field capacity (17% w/w), representing treatment W30, W45, W60, W75, W90 and W100, respectively. All treatments were tested in duplicate columns. The columns were sealed with aluminum film after water addition and allowed to equilibrate for 6-wk to achieve a uniform soil moisture condition throughout the column. A flow-through gas sampling chamber was placed on the top of the soil column and sealed with sealant-coated aluminum tape. A constant air flow rate of 100 ml min⁻¹ was established through the chamber. Then, 250 μ L fumigant containing equal proportions *cis*-1,3-D, *trans*-1,3-D, and CP was injected into the column center at the 10-cm depth through a long needle syringe. Fumigant emissions and the fumigant in the soil-gas phase were determined for 14 days at laboratory temperature (22 \pm 3°C). Residual fumigants and soil water content were determined at the end of the experiment.

Results: Emission results of *cis*-1,3-D, *trans*-1,3-D and CP showed similar patterns with relatively higher emissions of 1,3-D than CP. Presented here are only the CP data. Peak of emission flux of CP was 69 μ g m⁻² s⁻¹ occurring 4 h

after fumigant injection in the driest soil -W30 (Figure 1). The peak emission rate generally decreased and was delayed as soil water content increased. The emission flux peak was $11 \mu\text{g m}^{-2} \text{s}^{-1}$ and appeared 17 h after fumigant injection in the W100 treatment. After the peak, fumigant emissions decreased rapidly in W30 but more slowly with higher soil water contents, which resulted in higher emission rates at later times.

Cumulative emissions of CP are shown in Figure 2. Total emission losses from the water treatments were 38% of applied CP for W30 and were not further reduced for W45, W60, and W75, and were slightly lower for W90 (36% of applied CP) and substantially lower for W100 (32% of applied CP). Although higher soil moisture conditions reduced emissions in the initial hours, continuous emissions at later time resulted in much smaller cumulative emission reductions.

The highest concentration of fumigant in the soil gas was at the first sampling time (3 h) near the injection depth (10 cm) in all treatments (Figure 3) and the CP concentration (7.2 mg L^{-1}) was lowest in the driest soil (W30) probably because the driest soil had the earliest and highest emissions (Figure 1). As soil water content increased, a longer time was required to achieve uniform fumigant distribution in the soil column indicating that soil water content slowed fumigant diffusion. The averaged CP concentration in soil gas for the whole column was greater with higher soil water content, especially for W90 and W100, which may be due to the reduced fumigant diffusion from soil to the surface. At the end of the experiment, no CP was detected in the soil gas phase.

The residual CP in soil solid/liquid phases increased with the increasing soil water content but generally with a low concentration ($<0.01 \text{ mg kg}^{-1}$). Soil water content distributed uniformly throughout the soil columns (data not shown). The averaged values were 4.4%, 7.1%, 9.6%, 12.1%, 14.5%, and 16.3% (w/w), respectively following the increasing order of water treatments.

Conclusion: Results from this column study suggest that moist soil field capacity reduces the potential risk of fumigation to workers and bystanders by reducing peak emissions, although cumulative emission losses may not be significantly reduced. Fumigant concentration in the soil gas phase was slow to distribute uniformly throughout the column but with a higher average value in the higher water treatment soils, indicating fumigation efficacy may be improved with soil moisture. Although the results from this column study may not represent field conditions, the relationship between soil water content and fumigant emissions and fumigant distribution in soil are well demonstrated.

Reference: Gao, S. and T.J. Trout. 2007. Surface seals reduce 1,3-dichloropropene and chloropicrin emissions in field tests. *J. Environ. Qual.* 36:110-119.

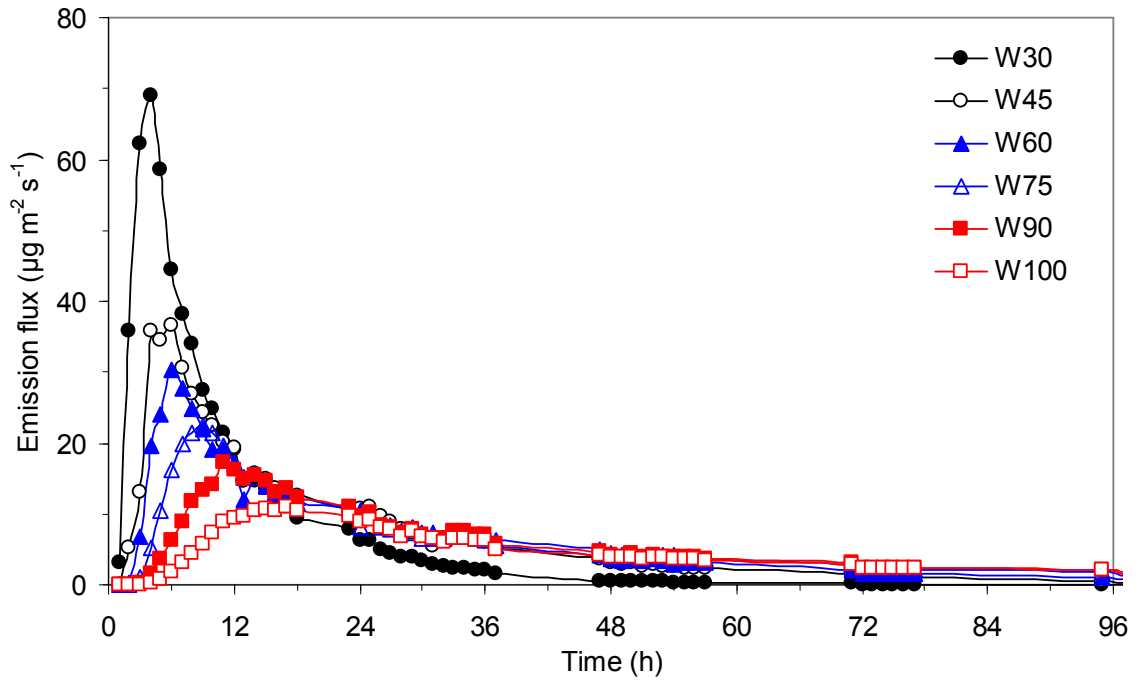


Figure 1. Effects of soil water content on emission flux of chloropicrin (CP) in columns. Plotted are averages of duplicates.

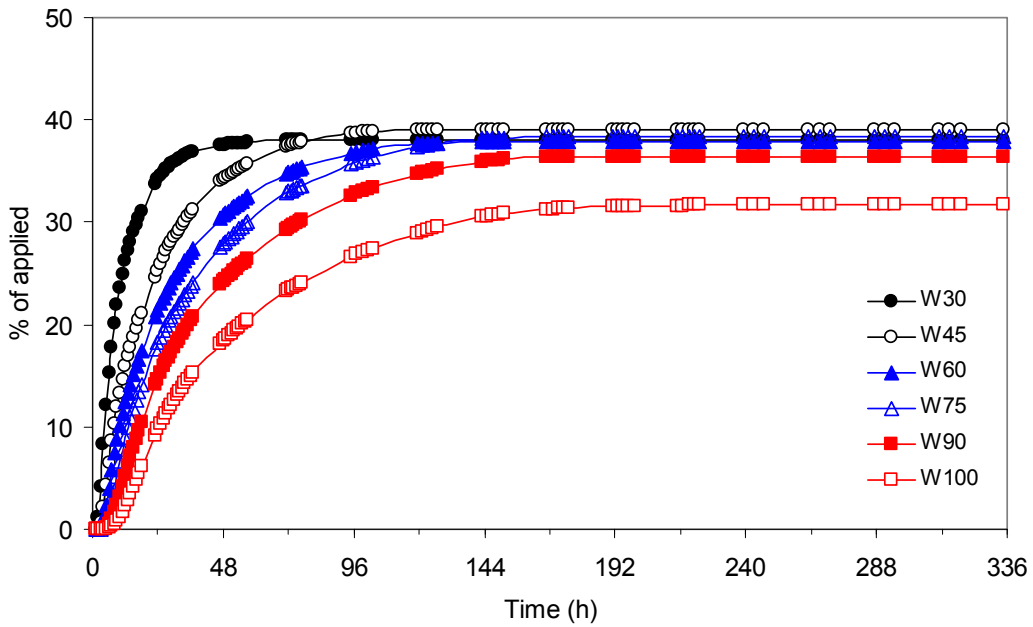


Figure 2. Cumulative emission losses of chloropicrin (CP) from the soil with different water content. Plotted data are averages of duplicates.

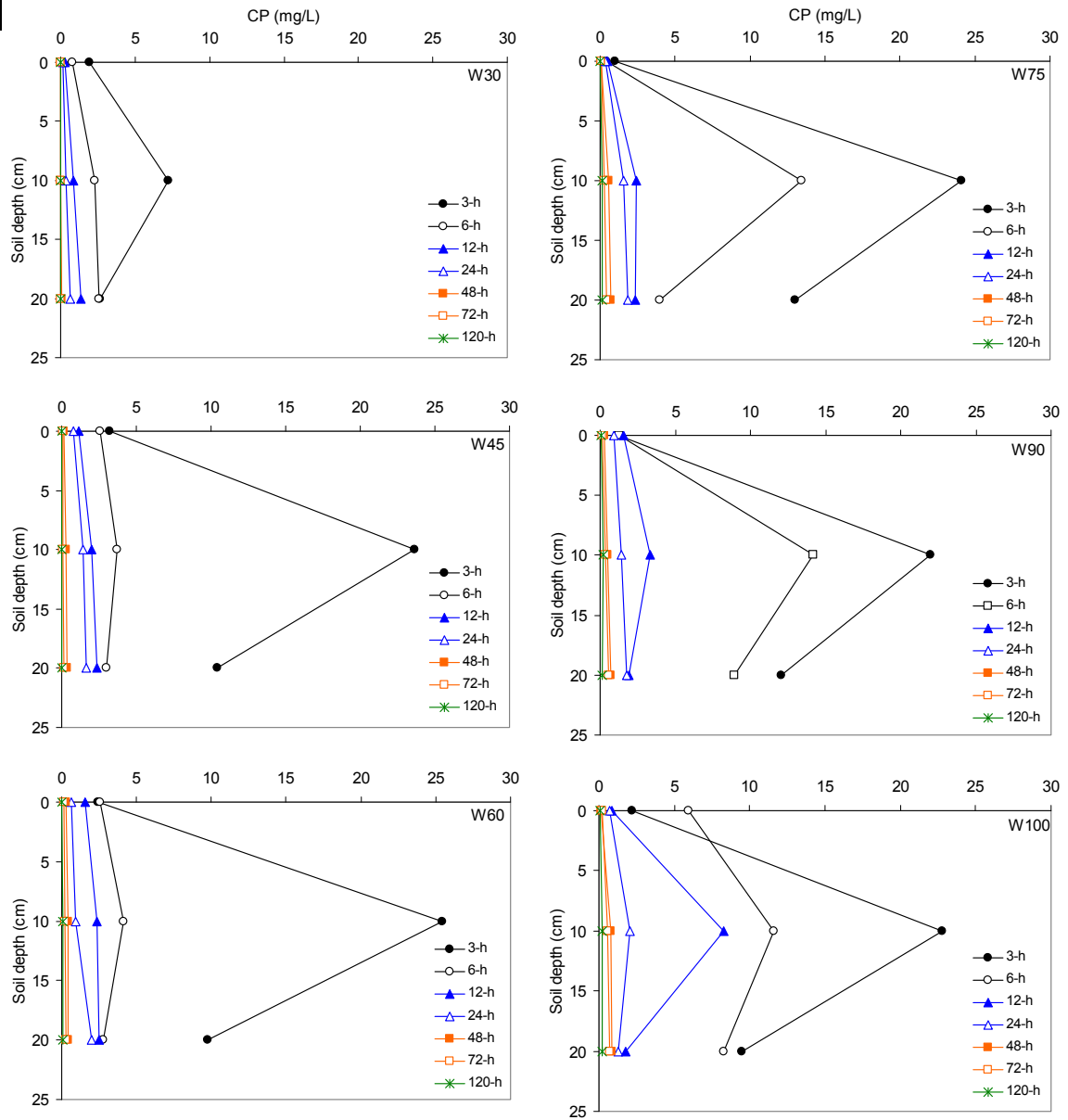


Figure 3. Soil gas phase distribution of chloropicrin (CP). Plotted data are averages of duplicates.