EFFECT OF SOIL MOISTURE ON EMISSIONS AND BEHAVIOR OF FUMIGANTS IN DIFFERENT TEXTURED SOILS

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Introduction. Regulations on fumigant emission control are getting more stringent in order to protect air quality and reduce potential environmental hazards in California. Using water is a low-cost strategy in comparison with other methods for fumigant emission control, and is thus applicable to a wide range of commodity groups, especially those with low-profit margins. A column study packed with a sandy loam soil demonstrated that increasing the soil water content (up to field capacity, FC) has a linear relationship to the decrease of the emission peak flux while the fumigant concentration in the soil is not reduced (Qin et al., 2008). The water-holding capacity of a soil largely depends on its texture. This research was to investigate how soil moisture levels affect fumigant emissions as well as fumigant behavior in different soils. The specific objective was to determine the effects of increasing soil water content on emission reduction from soil fumigation and the distribution or concentration changes of fumigants 1,3-dichloropropene (1,3-D) and chloropicrin (CP) in different textured soils.

Materials and Methods. Three different textured surface soils (0-30 cm) were collected in Fresno and Merced Counties, air-dried, sieved through a 4-mm sieve, and mixed thoroughly before use. The three soils were Delhi sand (mixed, thermic Typic Xeropsamments); Hanford sandy loam (coarse-loamy, mixed, superactive, nonacid, thermic Typic Xerorthents); and Madera loam (fine, smectite, thermic Abruptic Durixeralfs). The soil was packed into closed-bottomed stainless steel columns (25-cm height and 15.5-cm i.d) at a bulk density of 1.5, 1.4, and 1.3 g cm^{-3} for the sand, sandy loam, and loam, respectively. Details about the column design are described in Qin et al. (2009). Duplicate columns were established for each treatment. Different amounts of water were added to the soil surface to achieve targeted soil water contents throughout the column. For the Madera loam, the target treatments were to achieve final water contents of 30, 45, 60, 75, 90 and 100% (w/w) of field capacity, represented as treatments W30, W45, W60, W75, W90 and W100, respectively. The Hanford sandy loam was treated at W30, W60, and W100 according to its FC. For the Delhi sand soil, because of its low FC, we chose 60% FC as the lowest level for the test and two additional water treatments (100% and 200% FC).

After a uniform soil moisture was achieved for each column, a sampling chamber for monitoring emissions was installed at the top of the column followed by an injection of a mixture of 150 µl fumigant solution containing 67 mg (≈ 35 kg ha^{-1}) each of *cis*-1,3-D, *trans*-1,3-D, and CP into the column center. A constant air flow rate of 110±10 ml min^{-1} was maintained through the sampling chamber by applying a vacuum to the discharge port, and was monitored with a flow meter. Fumigant emissions from the soil surface and the fumigant in the soil-gas phase were sampled for 11 d (12 d for the Madera loam) at laboratory temperature (22 ± 3°C). Upon termination of the experiment, soil samples were collected to determine residual fumigants and soil water content.

Results and Discussion. All soils demonstrated that the increase of soil moisture decreased the emission peak flux although the reduction in the sandy soil was small. Dramatic peak flux reduction was observed in the finer-textured soils. For the Madera loam, a linear correlation between the peak emission flux and soil water content was observed: $Y = -0.33X + 80.97$ for *cis*-1,3-D ($R^2 = 0.98$); $Y = -0.21X + 51.24$ for *trans*-1,3-D ($R^2 = 0.98$); and $Y = -0.13X + 38.41$ for CP ($R^2 = 0.88$), where Y is the peak flux in $\mu g\ m^{-2}\ s^{-1}$ and X is soil water content ($g\ kg^{-1}$). Reduction in cumulative emission loss was not as significant as the reduction in the peak flux. The Delhi sand showed no reduction in cumulative loss for the 1,3-D isomers with some reduction (24%) in CP from 60% to 200% FC. For the other two soils, reductions in total losses were relatively small (1-18%) when soil water increased from 30% to 60% FC; but much larger reductions (24-49%) were observed when water increased to 100% FC.

Fumigant gas concentrations in the soils with high water content were consistently higher than those in the drier soils. This was due to more retention and slower emission rates in the moist soils. However, the benefits of increasing soil water content to a certain level would diminish at a certain point because excess amounts of water could significantly reduce the diffusion rate, resulting in non-uniform distribution of fumigants and affecting fumigation efficacy. Thus, it is unknown if it is adequate to raise soil water content to FC without compromising efficacy. The laboratory findings need to be confirmed via field tests with efficacy investigations. Residual fumigants were found to increase with the soil water content, with a maximum of 3% of total applied. Higher degradation amounts were associated with higher moisture levels.

Despite soil textures, there appears to be a linear relationship between the air-filled porosity and emission loss of 1fumigant compound, integrating data from all the columns: $Y = 1.69X + 9.66$ for *cis*-1,3-D ($R^2 = 0.68$); $Y = 2.12X - 13.44$ for *trans*-1,3-D ($R^2 = 0.78$); and $Y = 0.81X - 0.98$ ($R^2 = 0.25$) for CP, where Y is the total emission loss (% of applied) and X is air-filled porosity (%).These data may suggest that reducing the air-filled space to a proper level may be the key to ensuring emission reduction in different types of soils. The correlation between the CP emission losses and air porosity was less profound than in the 1,3-D isomers.

Conclusion. This study shows that increasing soil water content (up to FC) can significantly reduce peak emission flux and cumulative emission loss for sandy loam and loam soils. Much higher soil water content is likely needed to reduce emissions in sandy soils. Higher gaseous fumigant concentrations were also found in soils with high soil water content, indicating a potential benefit for good efficacy. A proper air-filled porosity may be used as an indicator for ensuring emission reduction while not reducing fumigant diffusion in the soil. It has been rare to fumigate soils at FC levels in the field. Therefore, the laboratory findings need to be tested further under field conditions to conclude how high soil water content can be used in soil fumigation to achieve maximum emission reduction and efficacy results.

Reference

Qin, R., Gao, S., Wang, D., Hanson, B.D., Trout, T.J., Ajwa, H. 2009. Relative effect of soil moisture on emissions and distribution of 1,3-Dichloropropene and Chloropicrin in soil columns. Atmos. Environ. 43: 2449-2455.