SWS 01- 1 8

Soil and Water Science

Research Brief

University of Florida Institute of Food and Agricultural Sciences

Fumigation of Plastic-Covered Soil Beds with Methyl Bromide

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Methyl Bromide (MeBr) is a broad-spectrum pesticide that is highly effective as a fumigant in eradicating a variety of pests in strawberry, tomato and other high-value crops. Since MeBr has been shown to be a significant stratospheric ozone-depleting substance, agricultural use of MeBr was recently banned in the United States. However, recent investigations imply that MeBr should not accumulate in the atmosphere. The economic value and efficacy of MeBr fumigation to control pests in agricultural soils warrant renewed research efforts. Modeling MeBr fate and transport during agricultural use (soil fumigation) is potentially helpful in providing improved insight of system dynamics with regard to atmospheric emissions resulting from MeBr fumigation and to provide guidelines for future research needs.

Simulations reported in the literature for describing MeBr fate and transport in soil during fumigation often use unrealistic assumptions such as isothermal and constant water content 2 conditions. The model used here represents several improvements over earlier efforts. Chemical transport through liquid and gaseous phases of the soil matrix was coupled with transient flows of both heat and water. Flows of water in liquid and vapor phases in unsaturated soil, as well as heat flow, occur in response to gradients of both water pressure head h and temperature T. Effects of non-isothermal conditions on chemical transport were considered through inclusion of T effects on transport parameters. Transient water flow in variably saturated soil was also included. A realistic energy-balance approach that includes optical properties of the plastic film in the energy balance was used to describe the soil-film-atmosphere interface. Heat exchange at that interface significantly alters the thermal regime within the soil bed. Effects of improved T and 2 estimates upon chemical transport were considered for both liquid and gaseous phases.

The coupled water-heat and chemical transport model was used to describe the fate and transport of MeBr fumigant in soil beds covered with black polyethylene plastic film. The model utilized finite-element discretization of the soil domain in two dimensions. A schematic for the cross section of one-half of a soil bed is given in Fig. 1. Arredondo fine sand soil with 5 horizons was used. Simulations utilized weather data for February at Green Acres Farm near Gainesville. Average daily temperature was 11.6 ^{o} C and temperature amplitude was 7.7 ^{o} C. No-flow boundary conditions for mass and energy were imposed vertical symmetry lines AF and DE. The lower boundary FE was designated with zero T gradient and unit gradient of h.

Fumigant was assumed to be applied at 450 kg ha^{-1} with a 3-shank applicator at 9:00 AM. Seven-day simulations were made. Three injection depths were utilized: 33 (standard practice), 50, and 66 cm. Four soil water regimes were imposed: 54, 46, 38, and 30 % of profile saturation.

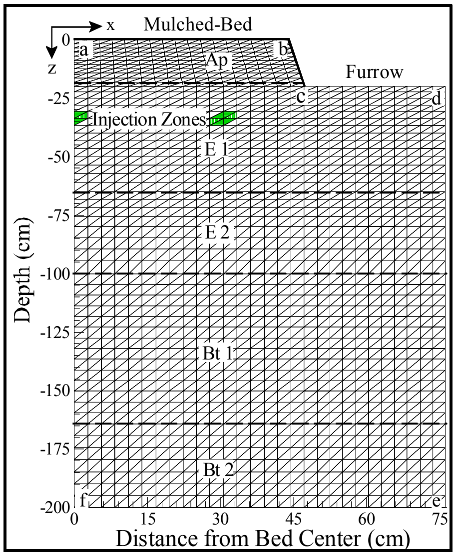

Fig. 1. Schematic of soil domain from Shinde et al. 2000

Non-isothermal soil conditions were shown to be especially important for simulated fate/transport of volatile MeBr fumigant (Fig.2). Simulations for isothermal conditions at 11.6 ° C approximated the non-isothermal case, but simulations at 22.5 ° C overestimated atmospheric loss of MeBr from the soil.

Simulations revealed that water-saturation regimes within the bed and different depths of fumigant injection were important factors. Various scenarios revealed that large amounts (20-44%) of applied MeBr were lost over a 7-day period from the un-mulched furrows between the beds. Plastic-mulching of the bed was found to be only partially effective (11-29% emission losses over a 7-day period) in reducing atmospheric emissions. Saturating the soil with water (Fig. 3) and deeper fumigant injection showed increased retention of methyl bromide within the soil and less emission to the atmosphere. However, deeper injection (50 and 66 cm depths) was not found to be conducive for sterilization of the crop root zone (Fig.2).

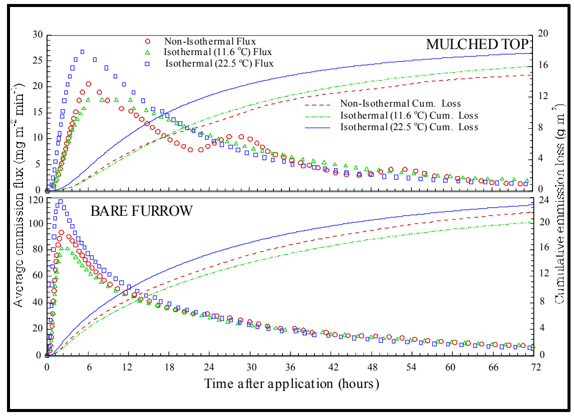

Fig. 2. MeBr emission fluxes during isothermal/nonisothermal conditions from Shinde et al. 2000

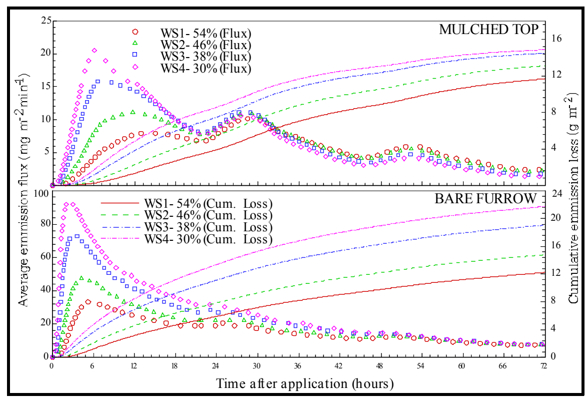

Fig. 3. MeBr emission fluxes for 4 water saturation scenarios from Shinde et al. 2000

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This research was supported by the Florida Agricultural Experiment Station and was published as

Shinde, Dilip, A. G. Hornsby, R. S. Mansell, and M. R. Savabi. 2000. A Simulation Model for Fate and Transport of Methyl Bromide in Vegetable Plastic-Mulched Soil Beds. Pest Management Science 56:899-908.