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Developing mitigation measures for 1,3-dichloropropene applications: An overview of the Pilot Studies

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In late 2020, the California Department of Pesticide Regulation (DPR) began a series of field studies to evaluate the effectiveness and practicality of several application methods to reduce emissions comparable to totally impermeable film (TIF) tarps for the agricultural fumigant 1,3-dichloropropene (1,3-D). The project was initiated following multiple cases of elevated 1,3-D air concentrations detected during routine ambient air monitoring conducted by DPR (Brown and Gonzalez 2018, Gonzalez 2019, Gonzalez 2020, King 2019); this in turn indicated a need for lower-emission application methods—possibly in combination with other mitigation methods—to reduce potential bystander exposure. Emission modeling identified several potential options to reduce 1,3-D emissions (Kandelous and Brown 2019, Brown 2019a;b), and DPR consulted with growers, applicators, and researchers to select the most practical of those options. The objective of these field studies was then to verify the effectiveness of a subset of the emission reduction options identified initially through computer modeling, test the feasibility of those options, and to compare emissions from these new methods to those of a commonly used, higher-emission method (i.e., Field Fumigation Method [FFM] 1206: untarped broadcast shank application made at an 18-inch depth).

Three basic mechanisms to reduce emissions were initially identified in computer modeling exercises: increased application depth, partial use of TIF tarps, and elevated soil water content. In every case, the goal of these interventions is to slow the escape of 1,3-D gas from the soil surface and increase its residence time in the soil, allowing additional time for the fumigant to degrade: increased application depth increases the distance traveled by fumigant molecules to the soil surface; use of TIF tarps creates a physical barrier at the soil surface to slow the escape of fumigant; and a higher soil water content restricts fumigant movement by reducing the available volume of air-filled pore space within the soil column through which fumigant travels most rapidly. A set of options tailored to meet emission reduction targets were then developed based on leveraging one or more the above mechanisms (CDPR 2020).

Some changes to the preliminary set of mitigation options were made following discussion with stakeholders—due either to concerns about practicality, or to incorporate ideas that had not been considered in the early stages of the project design. For instance, one method common in scholarly publications—post-application sprinkler irrigation—was rejected by growers and applicators in early conversations due to its logistical complexity and expense. Likewise, DPR had initially recommended a minimum soil water content threshold of 70 percent of field capacity (FC) prior to fumigant application, which was rejected based on the expected difficulty of application equipment to traverse such a field; a threshold of 50 percent FC was later recommended. Conversely, DPR agreed to collect additional data on surface soil compaction, which was not necessarily supported by DPR modeling as an effective mitigation measure, based on its potential benefit and simple implementation. Industry experts also identified surface amendment with biochar as a potential mitigation option but desired additional time to test the technology in laboratory studies prior to deployment at the field scale.

Mitigation options ultimately chosen for use in the study were: elevated soil water content of at least 50 percent FC (an increase from the label minimum of 25 percent FC), an increased injection depth of 24 inches, a partial surface seal using TIF tarp, and combinations thereof. Methods were chosen based on their novelty (i.e., little or no pre-existing data), high emission reduction potential, interest expressed by stakeholder groups, and cost-effectiveness.

The first of five field studies began in late November 2020, with the final study completed in November 2021. Table 1 provides a brief description of each field study. Field sites were located throughout the California Central Valley, with study site availability made possible following coordination between DPR, county agricultural commissioners, applicators, and private growers. Each study monitored air concentrations of 1,3-D around the perimeter of a treated field for 7 days with samples collected in 6-to-12 hour intervals. On-site meteorological data collection assisted in the estimation of the field-average flux rate (i.e., emission rate) during each monitoring interval using the back-calculation method (Ross et al. 2022) carried out using the AERMOD air dispersion model.

Table 1. Basic overview of application parameters in the field flux studies carried out as part of the DPR-sponsored 2020-2021 Pilot Study.

Location	Year	Depth (inches)	Soil Moisture	Tarp	Other
Shafter	2020	18	>50% FC	None	
Denair	2021	24	>50% FC	None	
Shafter	2021	24	>50% FC	None	Surface compaction
Atwater	2021	24	>50% FC	None	
Rio Oso	2021	18	>50% FC	50% TIF	

Results from the 2020-2021 field studies fell within the range of model-predicted peak emission estimates for 24- and 72-hour time periods, one of the main quantities of interest in DPR's rulemaking for acute mitigation (Figure 1). Substantial field-to-field variation in observed emissions demonstrated the importance of accounting for the environmental conditions associated with each application; for example, a deeper application in fast-draining sand in Atwater, CA yielded higher emissions than more shallow application in a loam with greater water retention in Shafter, CA. DPR's emission modeling accounts for such variability in field conditions by simulating each application method across a growing dataset of measured soil properties, thereby allowing field-to-field variation in emissions to be considered in the rulemaking process.

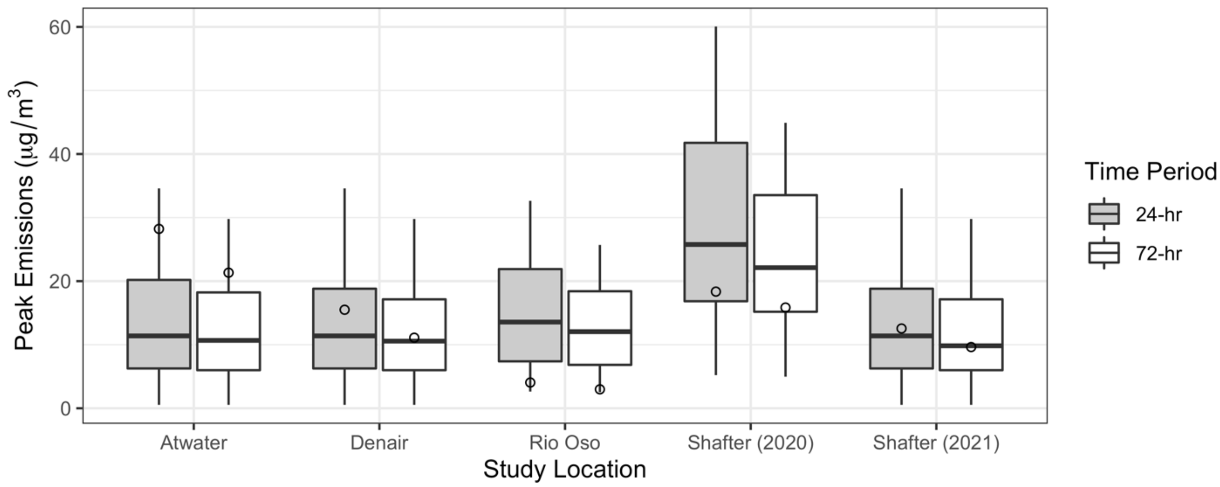

Figure 1. Comparison of peak 24-hour and 72-hour emissions for different applications as estimated from field data (points) or emissions modeling of the method using a soil variability dataset (box-and-whisker plots). Modeled emission estimates are those from Brown (2022) and presented based on a maximum broadcast-equivalent application rate of 332 lb/ac).

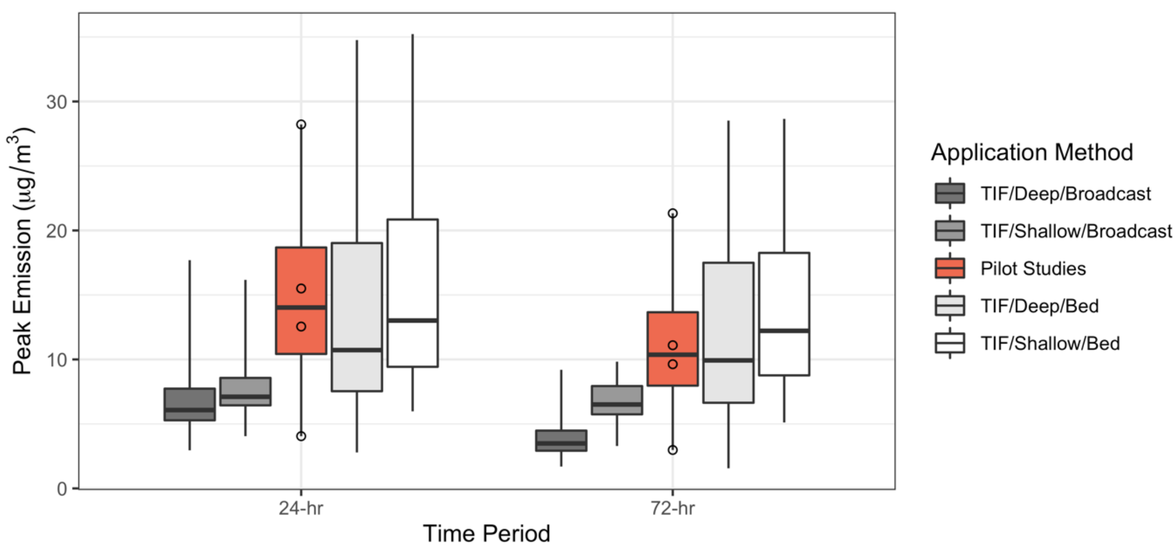

Figure 2. Comparison of peak 24-hour and 72-hour emissions estimated from the pilot study compared to modeled emission estimates for select application methods utilizing totally impermeable films (TIF). Points represent individual field estimates for 24-inch broadcast injection and 50% TIF methods. Modeled emission estimates are those from Brown (2022) and presented based on a maximum broadcast-equivalent application rate of 332 lb/ac).

Results from the field studies additionally provide much-needed data for two new application methods: 24-inch broadcast injection, and 18-inch broadcast injection with 50% TIF. Emissions for these methods are comparable with the range of emission estimates for select TIF methods (Figure 2). The results additionally provide support for three variants of the studied methods, including a 24-inch 50% TIF method, a 24-inch broadcast method using polyethylene tarp, and an untarped 24-inch application using a strip application configuration. The results also provide data which may be used to assess the effectiveness of elevated soil water content as a method to mitigate fumigant emissions. Prior to the above studies, the primary option to reduce 1,3-D emissions as compared to FFM 1206 was the use of a full TIF seal. While very effective in reducing emissions, the cost of TIF tarp is considered by many growers to be prohibitively expensive, and use of TIF additionally generates a large amount of plastic waste; to that end, the methods studied here may offer one set of alternatives. Where the emission reductions associated with these alternative application methods are not sufficient to meet acute mitigation targets in isolation, they may be paired with increased setback distances, application rate reduction, or decreased application acreage.

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