Correct Project Number: 10-AIR5-Gao

Minimize Emissions from Soil Fumigation using TIF Tarps

Project No.: **11-AIR5-Gao**

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Objectives:

The goal of the project is to develop field management practices using low permeable tarps (e.g., the commercially named totally impermeable film or TIF) to reduce emissions, improve efficacy, and reduce fumigant application rates that can help maintain the use of fumigants for agriculture. Specific objectives are:

1. Demonstrate the potential of TIF to reduce emissions and improve fumigant distribution in soil from broadcast application with alternative fumigants to methyl bromide (MeBr).
2. Determine the potential of using reduced fumigant application rates in achieving good efficacy under the TIF tarp.
3. Determine fumigant persistence under the TIF tarp over time from different fumigant application rates and evaluate the effects on the waiting period between application and tarp-cutting to minimize exposure risks.

Interpretive Summary:
Successful orchard (including almonds) replanting in many situations still depends on soil fumigation for control of soil-borne pests and replanting diseases in California. Additionally, perennial nursery growers also depend on soil fumigation to meet the state’s Nursery Stock Nematode Control Program requirements. However, since the phase out of MeBr, the main alternative fumigants 1,3-dichloropropene (1,3-D) and chloropicrin (CP) are highly regulated in use because of emissions that increase exposure risks and degrade air quality. Management strategies that minimize emissions

and improve pest control efficacy are needed and the use of low permeability tarp, such as the commercially named totally impermeable film (TIF), is promising in this regard. We have conducted field trials since fall 2009 to test the TIF tarp performance in emission reduction and efficacy improvement by investigating fumigant distribution in soil, as well as the potential of using reduced rates for broadcast application of Telone C35 under conditions applied to perennial fields. The data showed significant emission flux reduction (>90%) by TIF in comparison with standard polyethylene (PE) film. Total emission reduction will require further field measurements. Surging emissions were observed after tarp-cutting but the intensity can be significanly reduced by increasing tarp-covering time. Generally higher fumigant concentrations in soil under TIF tarp were observed, i.e., higher concentration and time (CT) exposure indices that is beneficial for better pest control compared to PE film. Reduced fumigant rates to half or 0.25 of full rate showed similar pest control efficacy due to nearly 100% kill of nematode in all fumigated treatments and variations among pests. This research continues to determine the possibility of reduced but effective rates under TIF tarp for control of soil-borne pests. A fumigation trial with residential nematodes in the field is planned. This research is collecting field data/information to help the adoption of TIF tarp technology in soil fumigation for perennials.

Introduction

Control of soil-borne pests and replantdiseases still relies on pre-plant soil fumigation for establishing healthy trees (including almonds) in California. Open-field perennial nursery growers depend largely on soil fumigation to meet the requirements of the CDFA's Nursery Stock Nematode Control Program, i.e., to deliver nematode-free crops (CDFA, 2008). Since the phase-out of methyl bromide, alternatives such as 1,3-dichloropropene (1,3-D) and chloropicrin (CP) have been increasingly used. These alternatives, however, are highly regulated to minimize potential exposure risks and contribution of VOCs to the air through emissions (USEPA, 2009; CDPR, 2009). Management strategies that reduce emissions and improve pest control efficacy offer the best hope for maintaining the availability of fumigants to the commodities in the prospective short-term and intermediate future. Low permeability tarp technology (e.g., virtually impermeable film or VIF) has shown promise in meeting these requirements. However, the VIF tarp has also shown vulnerability to damage from tearing or stretching in field applications.

A new film, the commercially named totally impermeable film (TIF), claims to have lower permeability to fumigants and more advantages in preserving its integrity and is less prone to damage than VIF in field installations (Chow, 2008). Our earlier tests demonstrated the effectiveness of TIF on emission control and efficacy improvement by more uniform distribution of the fumigant in the soil profile and increased concentrations compared to standard PE tarp in soil fumigation for annual crop, i.e., when fumigants were applied to shallow depth.(Qin et al., 2011). The benefits of TIF in soil fumigation for perennial crops are to be determined under this research project. The previous field test also showed that a spike in emissions after tarp-cutting can be a great concern for exposure risk. The possible solutions are increasing tarp-covering time and/or reducing application rates. The latter is possible because TIF can effectively retain fumigants under the tarp and increase residence time in soil. This project was designed to evaluate the potential of TIF in reducing emissions, improving efficacy by retaining and enhancing fumigant distribution in soil profile, and reducing application rates in deep-rooted perennial soils.

Materials and Methods:

Since October 2009, three field trials have been conducted and a fourth trial is planned for October 2011 at the USDA-ARS research center, Parlier, CA. The soil is Hanford sandy loam (coarse-loamy, mixed, superactive, nonacid, thermic Typic Xerorthents), a typical soil type for perennial crops in the region. Brief information about these trials is provided in **Table 1**. For all three trials, Telone C35 was shank-applied 18 inch deep with a 20 inch shank spacing (=injection nozzle spacing) using a conventional Telone rig. The first trial in fall 2009 tested three fumigation rates (full or maximum rate at 48 gallons or 540 lbs/ac, 0.75 full rate, and 1/2 full rate) plus a non-fumigated control and two types of plastic tarps, standard PE and TIF (VaporSafe™, 1-mil thickness, clear, Raven Industries, Sioux Falls, SD, USA).

Table 1. Summary of field trials: treatment, monitoring and efficacy study component.

Field Trial	*Treatment (shank injection of Telone C35)*	*Field Measurement*	*Efficacy study*
Fall 2009 (Oct. 27−Nov. 9)	Rate: Full rate (48 gallon/acre), 0.75* and 0.5 full rate Tarp: Standard PE, TIF	Emissions Air under tarp Residual fumigants	Nematodes weeds
Summer 2010 (June 9 - July 1)	Rate: Full rate, 0.5 rate Tarp: Standard PE, TIF	Air under tarp Gas fumigant distribution in soil	None
Fall 2010 (Sept. 8 – Oct. 13)	Rate: Full rate, 0.5 and 0.25 full rate Tarp: Standard PE, TIF	Air under tarp Gas fumigant distribution in soil Fumigant concentration in soil air where pest bags buried	Nematodes pathogens weeds

*The 0.75 rate was over applied to close to full rate and data from this treatment were integrated with the full rate treatment.

For all trials, three replicates were used for testing each treatment. TIF used was 10.5-ft wide for the first trial and 13-ft wide for the other two trials. Two sheets of TIF were joined by gluing for the 1st trial, a single sheet was used for the 2nd trial, and three sheets were glued for the 3rd trial in treatment plots corresponding to two, one, and three fumigation passes, respectively. Field measurement and monitoring are also described in **Table 1**. During the 1st trial, over-application of the 0.75 rate occurred, which resulted in little difference from the full rate. Problems with clogged emitters led to failure in collection of soil-gas data and calculation of total emission loss as percent of total applied. The second trial conducted in summer 2010 on the same soil focused on monitoring fumigant distribution in the soil profile and air under the TIF tarp at the full and half rate compared to standard PE at the full rate. The third trial conducted in fall 2010 tested full (540 lbs/ac), 0.5, and 0.25 rates under both PE and TIF tarps. Soil gas concentration data at surface locations with pest bags were collected in the 3rd trial to closely monitor fumigant concentration time (CT) exposure indices. Sampling for emission, air under tarp, and soil gas followed established procedures as described in Gao et al., (2009, 2011).

Results and Discussions

Fumigant concentration in air under tarp:

During the fall 2009 field trial, 1,3-D concentrations under the TIF tarp were three times higher than that under PE film at the full rate (**Fig. 2A**). 1,3-D concentrations under the TIF at the half rate were similar or higher than that under the PE film at the full rate. Prior to tarp-cutting, concentrations as high as 1 µg cm^{-3} were still observed under the TIF film as compared to 0.2 µg cm^{-3} under the PE film at the full rate. For chloropicrin, however, because of a faster degradation rate, its concentration at the half rate under TIF was lower than the full rate under PE film. During the summer 2010 field trial, based on an average of 12 samples of each treatment plot (**Fig. 3**), the highest 1,3-D concentration was measured at full rate under TIF tarp after one week of fumigant application,, followed by the half rate under TIF, and the lowest concentration was measured with the full rate under standard PE. The results support the hypothesis that TIF can effectively retain fumigants under the tarp and increase residence time, at least, near the soil surface.

Air under tarp concentrations during the fall 2010 trial (**Fig. 4**) demonstrated again the highest concentration under TIF at the full rate. There were little differences among the half rate under TIF, full rate under HDPE, and the quarter rate under TIF. At the same rate, 1,3-D concentrations under the tarp appear much higher in the first few days, but degraded much faster in 2010 compared to the data in 2009. This is most likely due to higher temperature in Sept. 2010 that led to higher volatility of fumigants and higher degradation rate in comparison with that in the Oct. 2009 field trial. The results may indicate that temperature is an important factor to consider in determining fumigant fate, thus affecting the tarp-cutting time for safe removal, i.e., a shorter waiting period at higher temperature is expected than at lower temperature under similar soil conditions.

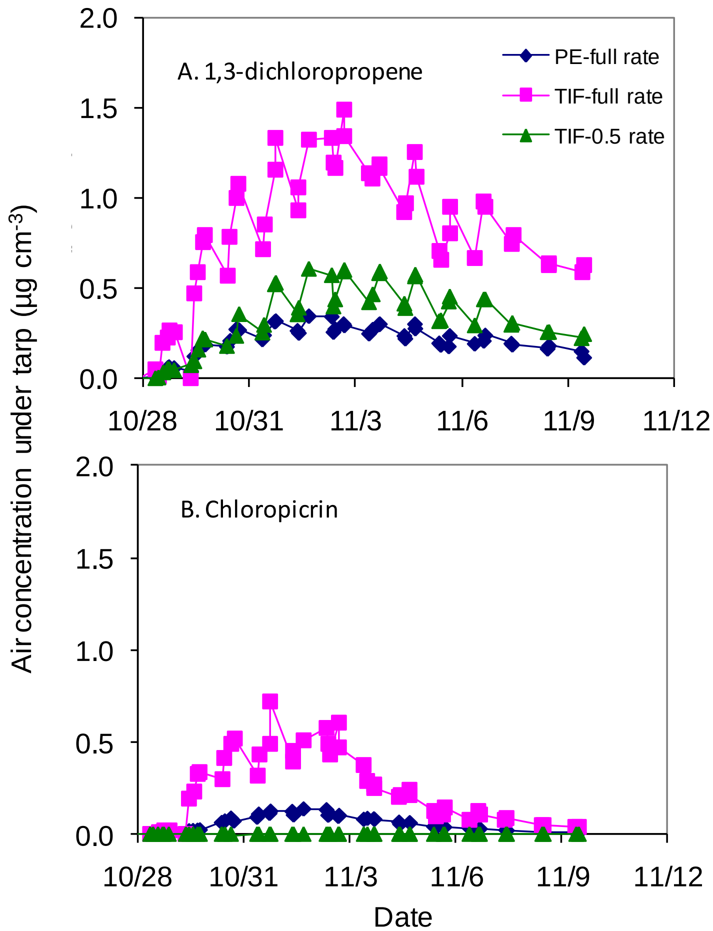

Figure 2. Fumigant (A, 1,3-dichloropropene; B. Chloropicrin) concentration changes in air under tarp in fall 2009 field trial.

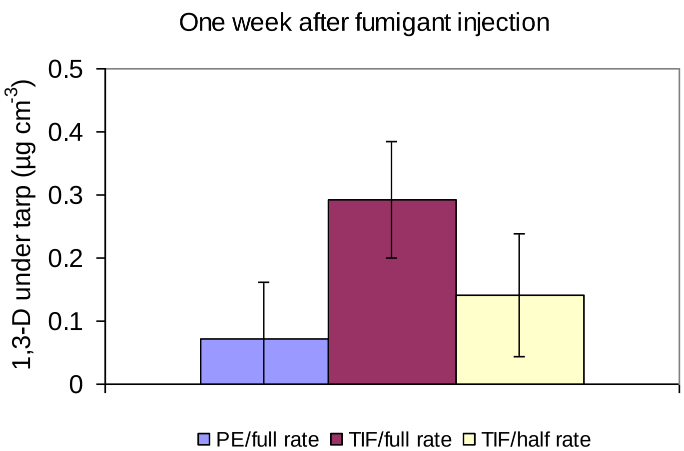

Figure 3. 1,3 dichloropropene concentration changes in air under tarp one week after fumigant application in summer 2010 field trial. Error bars are standard deviation of the mean (n=12)

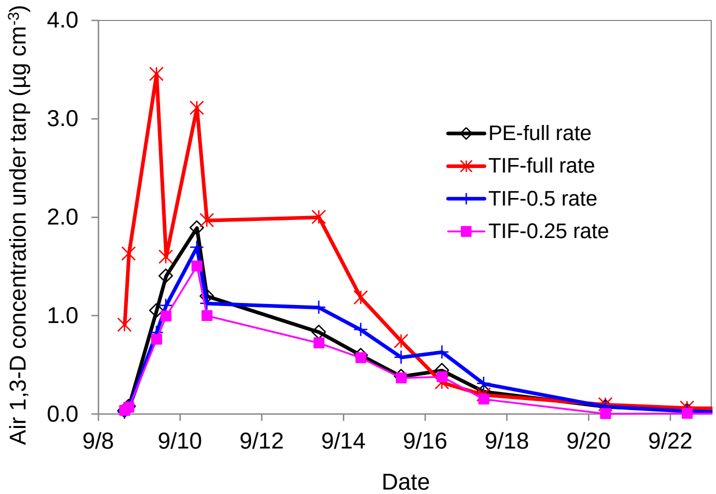

Figure 4. 1,3-dichloropropene concentration changes in air under tarp in fall 2010 field trial.

Emission reduction by TIF:

Measured emission flux and cumulative emission loss of 1,3-D- during fall 2009 field trial are shown in **Figure 5** and **Figure 6**, respectively. Relative differences in emissions between tarping treatments were compared here. TIF tarp resulted in >95% emission reductions in both emission flux and cumulative loss in comparison with standard PE tarp during the tarp-covering period of two weeks. Surging emissions with much higher rates from the TIF plots than the PE plots were observed after tarp-cutting, but the flux values after tarp-cutting are substantially lower than those determined from a trial when tarp-cutting occurred 6 days after fumigant application as reported in Qin et al. (2011). The data indicate as tarp-covering time increases, the intensity of surging emissions after tarp-cutting will be significantly reduced as fumigant is subject to degradation. Emissions for chloropicrin (data not shown) are generally much lower than for 1,3-D because of its much shorter half-life.

Fumigant distribution in soil-gas phase and concentration x time (CT) exposure indices:

Figure 7 shows average soil-gas concentrations for treatments from the fall 2010 field trial. The sampling locations were midway between two injection lines where potentially the lowest fumigant concentration could be found in the soil. The data show that TIF in the 2010 field trial resulted in generally higher 1,3-D concentrations throughout the profile than HDPE at the full rate at various sampling times. This supports the hypothesis that TIF tarp could improve pest control because of the increased fumigant concentration in soil. Reduced rates resulted in much lower fumigant concentrations than the full rates and lower concentration-time (CT) exposure index values (**Fig. 8**). Whether these reduced values still provide satisfactory pest control will require more efficacy tests under field conditions. Again, the TIF tarp has less impact on chloropicrin compared to 1,3-D,most likely due to its faster degradation rate in soil (**Figure 8**).

Residual fumigant:

At the end of the field trial (two weeks after fumigant application) in fall 2009, the highest residual fumigant concentration in the soil was from the TIF-full rate (**Fig. 9**). This further indicates that TIF tarp increases fumigant residence time in soil.

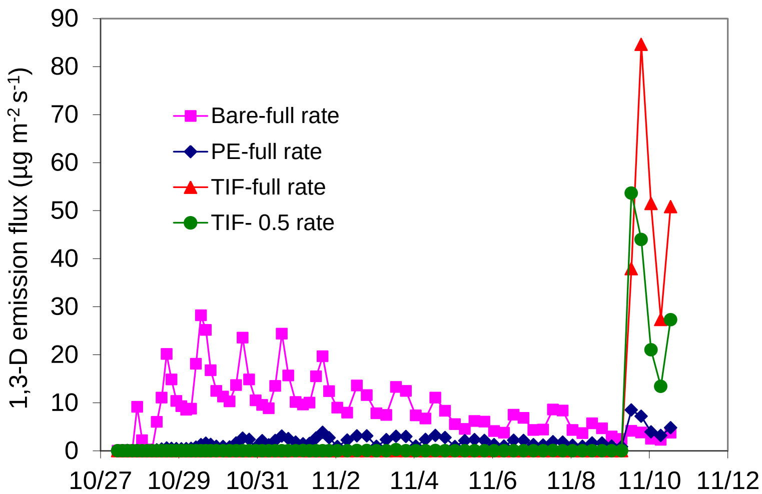

Figure 5. Emission flux of 1,3-dichloropropene measured in fall 2009 field trial.

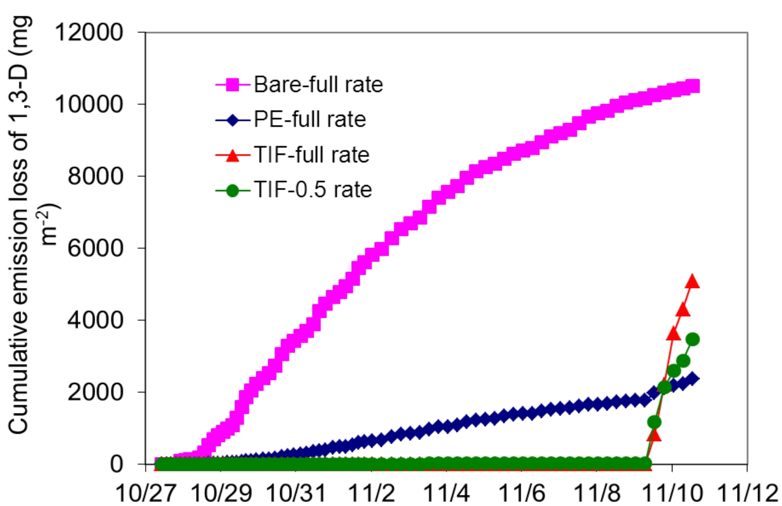

Figure 6. Cumulative emission loss of 1,3-dichloropropene in fall 2009 field trial.

Efficacy

Efficacy data from the fall 2009 and fall 2010 trials are not detailed here. Some of the results will be reported in Cabrera et al. (2011). As a summary, all fumigated treatments regardless of application rate and type of the tarp provide 100% kill (relative to nonfumigated control) of root-knot and citrus nematodes that were buried in different soil depths. For residential pin nematodes in soil, the half rate under both TIF and standard PE provided 98% and 96% control, respectively; but not significantly different from the full rate treatments. In the fall 2010 trial, the efficacy on citrus nematodes of the 0.25 rate was 95% in the shallow depth (15 cm) under HDPE; but again it was not significantly different from that under TIF for 100% control. The rest of the soil depths were all 100% effective against citrus nematodes in the buried bags. Generally, all reduced rates under TIF tarps provided similar efficacy as the full rate. Similar statistical analysis results were obtained for weed control. There is a great need to assess the possibility of using reduced but effective rates under TIF to control soil-borne pests, which is the focus of our on-going research

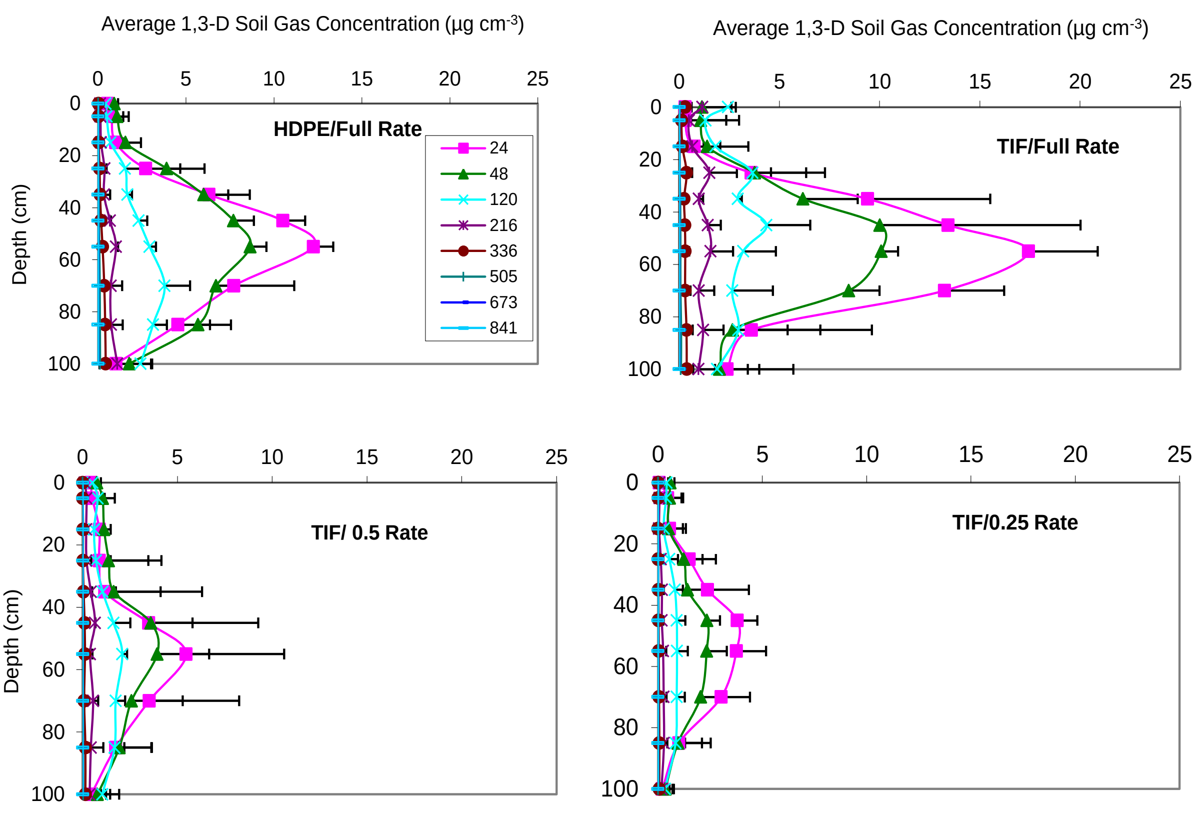

Figure 7. 1,3-D concentration changes in soil-gas phase after fumigation of Telone C35 in fall 2010 field trial. Error bars are standard deviation of the mean (n=3).

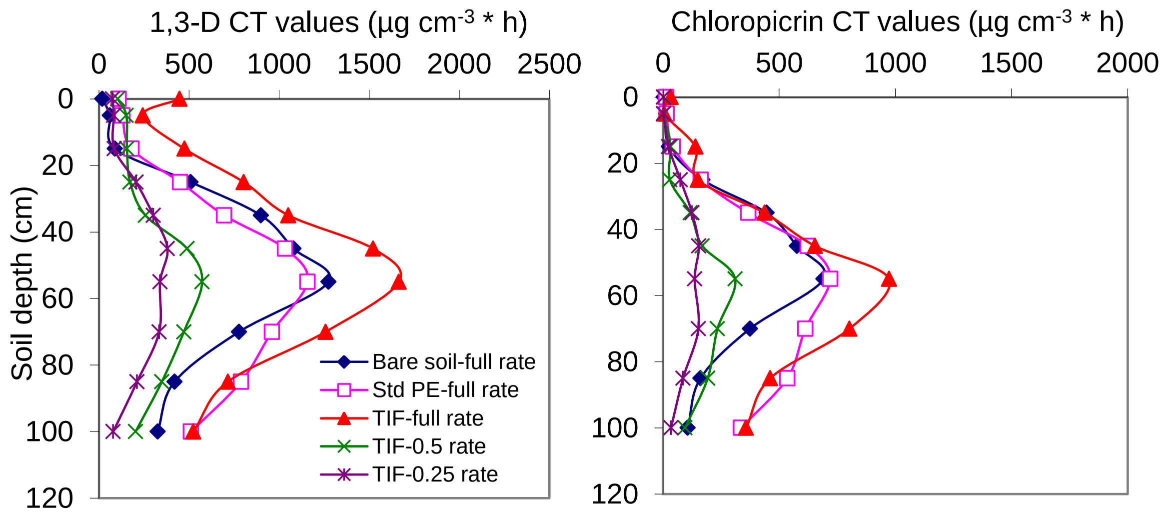

Figure 8. Concentration x time (CT) exposure indices of treatments in fall 2010 field trial.

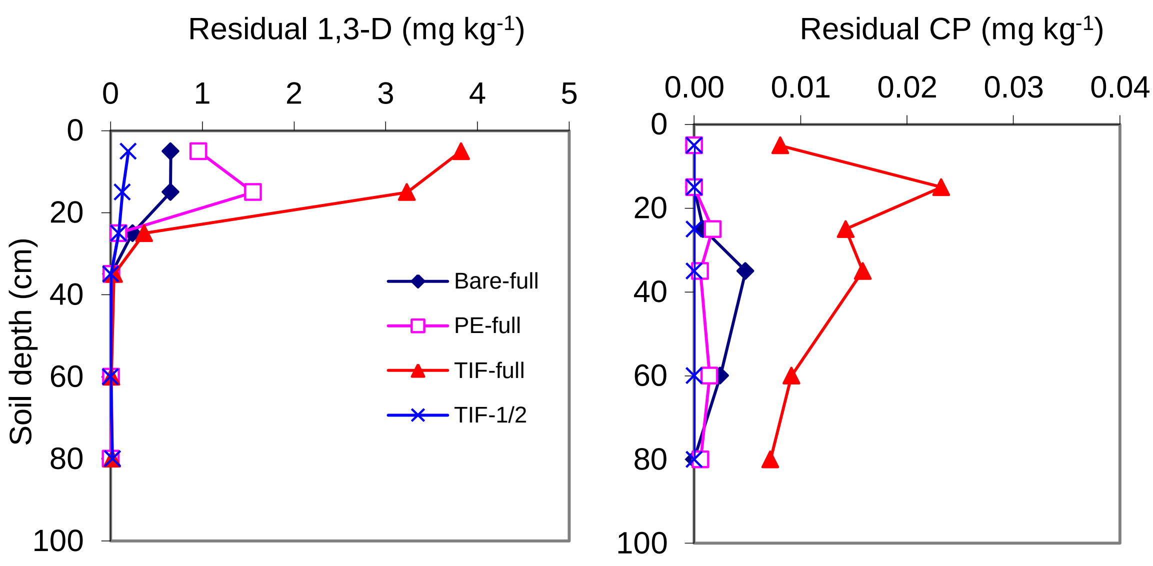

Figure 9. Residual soil fumigants (1,3-dichloropropene and chloropicrin) at the end of fumigation trial in fall 2009 field trial.

Conclusion

- When installed successfully without damage, the TIF tarp effectively reduced fumigant emissions by retaining fumigants under the tarp, but the tarp needs to remain in the field for a longer period of time than standard tarp to avoid significant surge of emissions upon tarp-cutting.
- TIF tarp is also shown to increase fumigant concentration in surface soils and in soil profile that provides better pest control compared to a standard tarp. It can be concluded that TIF tarp improves efficacy because of its ability to increase fumigant concentration and residence time in the soil.
- Although reduced fumigation rates showed good efficacy on nematodes, the conclusion on the effectiveness of reduced rates on pest control cannot be made for Telone C35 in soil fumigation for perennials and will require additional field research.
- Reducing fumigation rates will provide both environmental benefits and reduced fumigation costs. On-going research will collect field data to determine reduced fumigation rates under TIF and correlations with pest control.

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Research Effort Recent Publications

Gao, S. B.H. Hanson, D. Wang, G. Brown, R. Qin, H. Ajwa, S.R. Yates. 2011. Methods evaluated to minimize emissions from pre-plant soil fumigation. Calif. Agric. 65(1):41–46.

Gao, S., R. Qin, A. Cabrera, B. Hanson, J. Gerik, D. Wang, and G. Browne. 2010. Demonstration of low permeability tarp technology in soil fumigation for perennials. Ann. Int. Res. Conf. on MeBr Alternatives and Emission Reductions, Orlando, Nov. 2-5, 2010. p. 26-1–26-4. http://www.mbao.org/2010/Proceedings/026GaoSPerennialTIFPAW.pdf.

Qin, R., and S. Gao. 2010. Effect of soil moisture on emissions and behavior of fumigants in different textured soils. Ann. Int. Res. Conf. on MeBr Alternatives and Emission Reductions, Orlando, Nov. 2-5, 2010. p. 87-1–87-3. http://www.mbao.org/2010/Proceedings/087QinR.pdf.

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Qin, R., S. Gao, H. Ajwa, D. Sullivan, D., Wang, and B.D. Hanson. 2011**.** Field evaluation of a new plastic film (Vapor Safe™) to reduce fumigant emissions and improve distribution in soil. J. Environ. Qual. 40:1195–1203.

U.S. Environmental Protection Agency (USEPA). 2009. Implementation of Risk Mitigation Measures for Soil Fumigant Pesticides. Available at: http://www.epa.gov/oppsrrd1/reregistration/soil_fumigants/#ammendedreds.