# Minimize Emissions and Improve Efficacy with Low Permeability Tarp, Reduced Rate, and Deep Injection in Soil Fumigation

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## Issues

- Soil fumigation continues to be important for replanting orchards in controlling soil-borne pests and diseases.
- Environmental regulations target emissions because of the high volatility of fumigants. High emissions will not only deteriorate air quality but also adversely impact efficacy.
- Strategies to increase fumigation efficiency and minimize emissions: using low permeability tarp such as total impermeable film (TIF), reduced rates, and deeper injection.

## Objectives

- Demonstrate the ability of totally impermeable film (TIF) to reduce emissions, improve fumigation efficacy, or allow using reduced rates, and improve tree performance including yield.
- Evaluate deep injection and biochar amendment on fumigation efficiency, nematode control, and tree establishment.

## Fumigation Trials for Almond Replanting since 2012

1. **Merced Trial**, Nov 29, 2012, Bluff Ranch, Merced, CA; Soil: Snelling Sandy loam (Fine-Loamy, mixed, superactive, thermic Typic Haploxeralfs).
2. **Ballico Trial**, Dec 3, 2014, Littlejohn Farm, Ballico, CA; Soil: Delhi sand (Mixed, thermic Typic Xeropsamments).
3. **Hughson Trial**, Nov 14, 2016, Hicks Farm, Hughson, CA; Soil: Hanford Sandy Loam.

2012 Merced

2014 Ballico

2016 Hughson

| Telone® C-35 rate\sealing*,** | Bare | Std PE | TIF |
|---|---|---|---|
| 0 (control) | x | x | x |
| 33% (16 gal/ac) | x | x | x |
| 66% (32 gal/ac) | x | x | x |
| 100% (48 gal/ac or 610 kg/ha) | x | x | x |

* 2014 Ballico Trial: eliminated 33% rate; added 100% rate in a deep injection at 28" depth to compare with regular 18" injection depth

** 2016 Hughson Trial: Tested two injection depths (18" vs 26") for both 66% and 100% rate and biochar amendment on emissions in comparison with TIF.

For all three trials, data on fumigant emissions and movement in soil, efficacy on nematodes, and tree performance including yield are monitored:

- Two years of yield data have been collected for Merced Trial.
- Two years of tree growth data have been collected for Ballico Trial.
- All data for Hughson trial are still being collected.

## Emissions

- TIF always produced the lowest emissions with or without rain based on all our field trials conducted.
- When rain event occurred following fumigation, higher emissions were observed from standard PE tarped plots (**Fig. 1**).
- Lower emission from the bare soil than PE tarp were due to that rain received during the trial had a water seal effect.
- Chloropicrin emissions are always lower than 1,3-D from Telone® C35 application because chloropicrin dissipates much faster than 1,3-D in soil in addition to the amount applied.

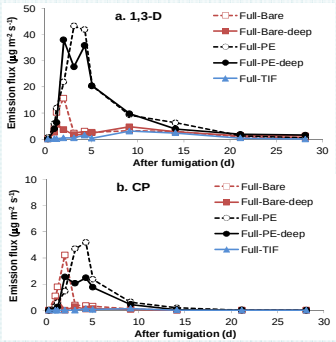


**Fig. 1.** Emission flux of 1,3-D and chloropicrin in 2014 Ballico trial.

## Fumigant concentration in air under tarp

- TIF is able to retain much higher concentrations than standard PE tarp (**Fig. 2**).
- The lower fumigant concentration under PE was due to the high emissions through the tarp (e.g., **Fig. 1**).
- The data provides evidence that reduced rate can be applied under TIF that should still provide equivalent pest control compared to full rate using PE tarp or no tarp.

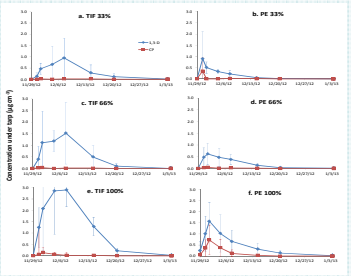


**Fig. 2.** 1,3-D and chloropicrin concentration under tarp in 2011 Merced trial.

## Fumigant distribution profile in soil-gas phase (Fig. 3)

- Deeper injection resulted in the maximum concentration near 60 cm depth compared to the 45 cm soil depth from regular injection depth.
- The deeper injection resulted in higher concentrations at 100 or 125 cm depths in bare soil (no tarp), but this effect was not evident in soils under TIF.
- The better movement of fumigants in this soil could be due to its coarse texture (sandy soil).
- Chloropicrin (not shown) showed similar distribution pattern as 1,3-D except at lower concentration levels.

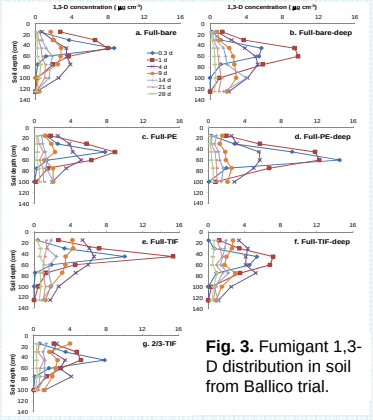


**Fig. 3.** Fumigant 1,3-D distribution in soil from Ballico trial.

## Nematode control

- In Merced trial, all fumigation treatments at 66% or 100% rates provided good control on nematodes in soil above 100 cm (3 ft) depth, but no fumigation treatment provides 100% control in soil below 100 cm depth in the sandy loam soil (**Fig. 4**).
- In Ballico trial, all fumigation treatments provided 100% kill in all soil samples down to 1.5 m (5 ft) depth in comparison with non-fumigated controls that had survival of Ring, Lesion, Root-knot, Pin, and Stubby nematodes following fumigation.

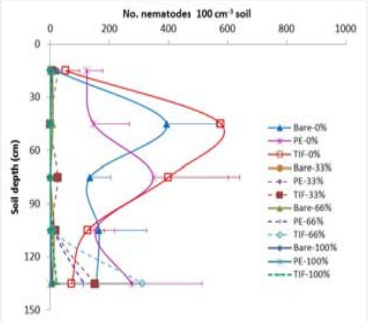


**Fig. 4.** Nematode survival after fumigation in Merced trial.

## Nematode recovery in young orchard after fumigation (Fig. 5)

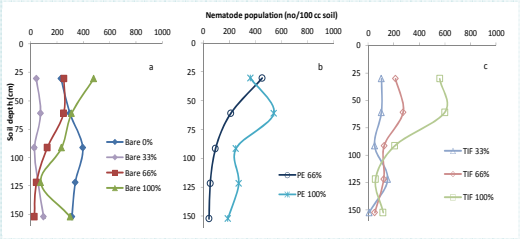


**Fig. 5.** Total population of parasitic nematodes (ave. 29% ring, 70% pin, <1% stubby root, and <1% lesion) detected three years after fumigation in Merced trial.

## Almond yield after fumigation and replanting in Merced trial (Fig. 6)

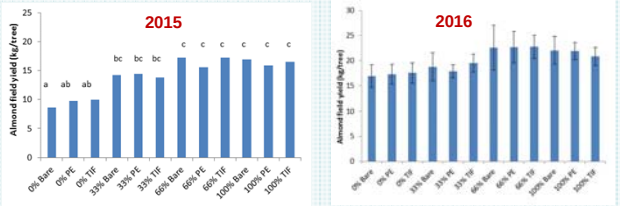


**Fig. 6.** The first and second year yield data after fumigation and replanting in Merced trial. The yield from 66% rate regardless tarp was not significantly different rom those at 100% rate. Both rate treatments were significantly better than fumigated control in 2015. Different letters in the same column indicate significance at P<0.05.

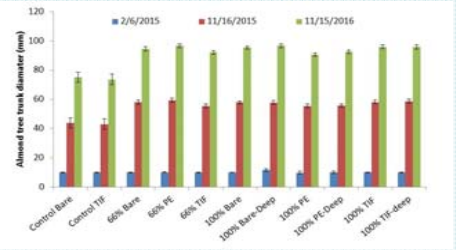


**Fig. 7.** Tree growth after fumigation and replanting in Ballico trial. All fumigated treatments resulted in much bigger trees than non-fumigated control. The results are consistent with the Merced trial data.

## Conclusions

- TIF is most effective in reducing emissions under any field/weather conditions.
- At 66% Telone® C-35 rate, tree growth and yield are comparable to that at the full rate.
- Although there are difficulties in delivering fumigants deeply to control nematodes, plus there is a faster nematode recovery after fumigation treatments, the negative impact of nematodes on tree growth or yield was not apparent.
- Long-term monitoring of orchard performance after fumigation treatment would be helpful to verify the results.

## Acknowledgements

Technical support from Robert Shenk, Aileen Hendratna, Julio Perez, Zac Shenk, Jim Gartung, & Stella Zambrzuski at USDA-ARS, Parlier & Andrew Ray, and Vivian Lopez at UCCE, Merced; In-kind donation from TriCal & field operation by Littlejohn's Farm, Bluff Ranch, and Hicks Farm.

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*The Almond Conference, December 6-8, 2016, Sacramento, CA*