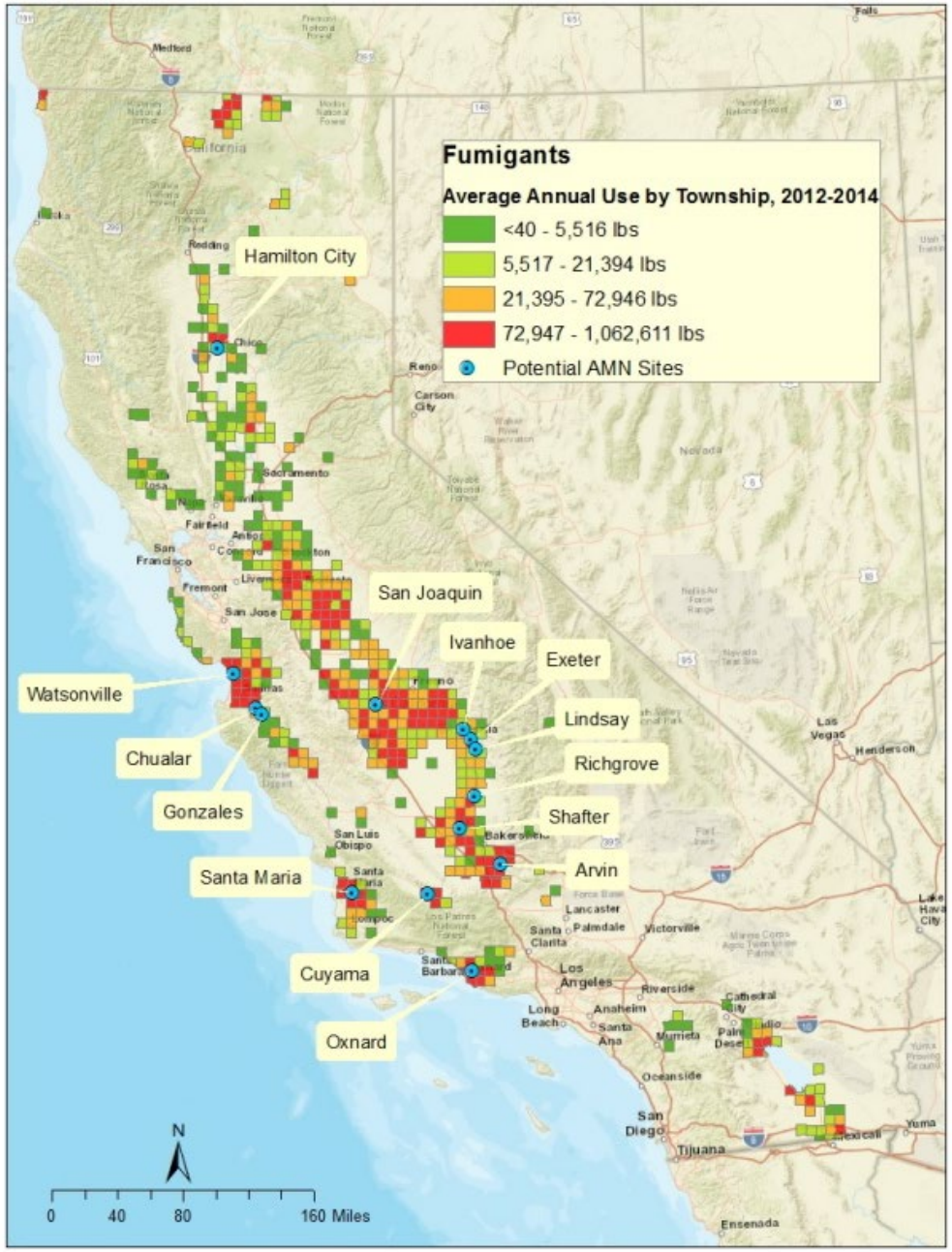
Correcting the Myths of Soil Fumigation

Mike Stanghellini
Director of Research & Regulatory Affairs
mstanghellini@trical.com

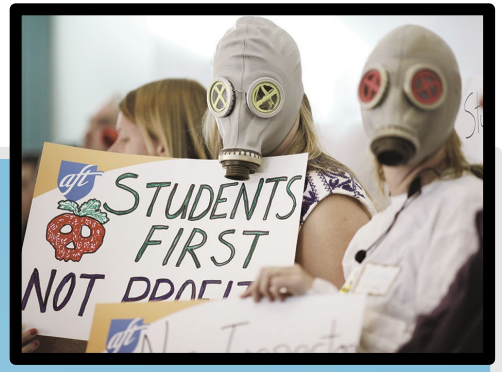
Conventional Ag & Conflicting Interests

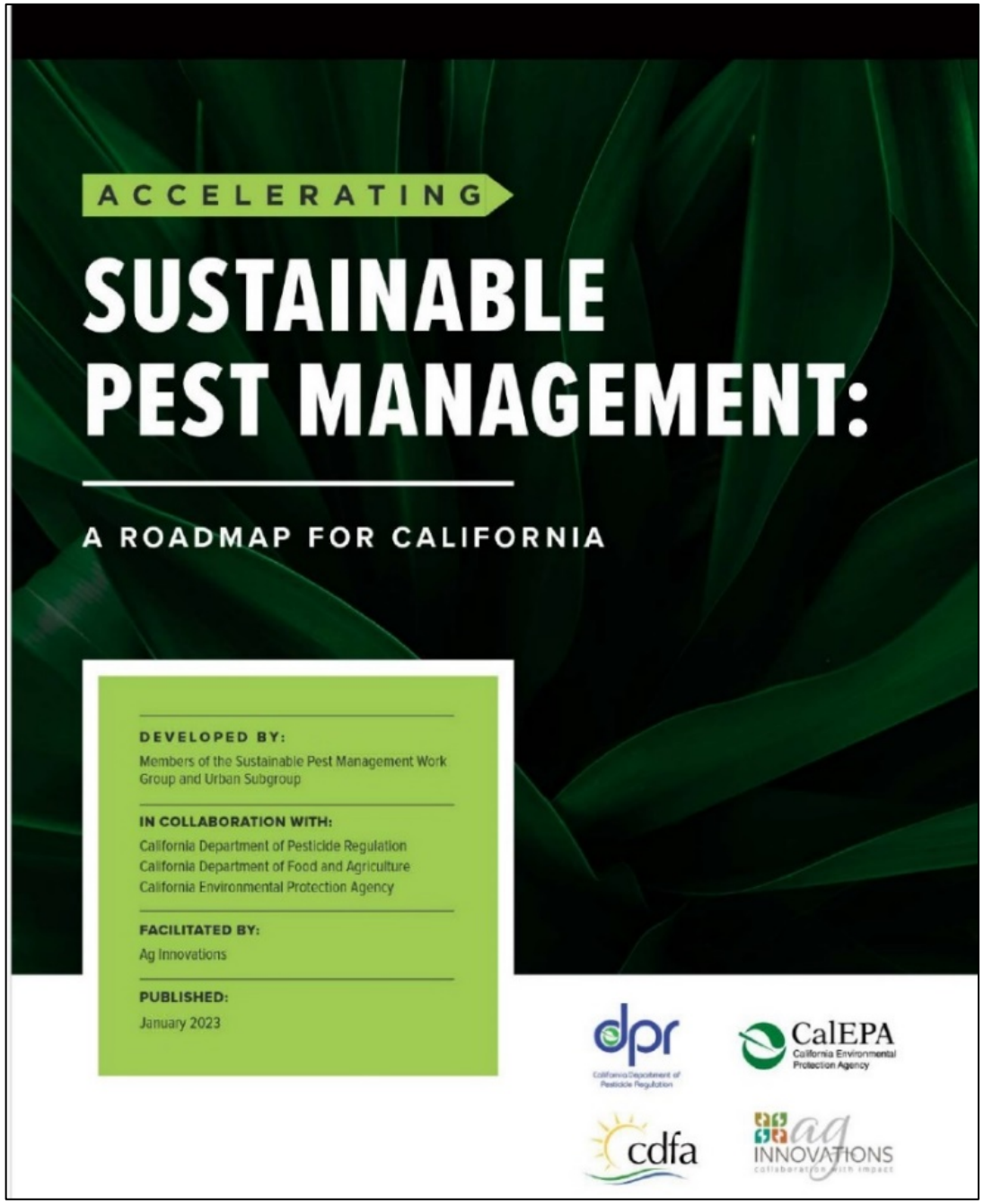


Growers, Applicators, and Registrants

Federal and State Regulatory Agencies

Anti-Pesticide Activists





Eliminate ‘priority pesticides’.

European Union “Farm-to-Fork” Green Initiative

- Adopted May 2020.
- By 2050, reduce the use and risk of chemical pesticides by 50%.
- By 2030, reduce the use of more hazardous pesticides by 50%.

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SCIENCE NOT IDEOLOGY

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Reckoning for European Green Deal ‘Farm to Fork’ strategy: EU lawmakers side with farmers and consumers, bury plan to cut chemical pesticide use by 50%

Bill Wirtz | RealClearMarkets | November 29, 2023

EU “Farm-to-Fork” Regulations withdrawn due to farmer protests.

Will resurface in the future.

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Home / News / Agrifood / Pesticides / EU Commission chief to withdraw the contested pesticide regulation

EU Commission chief to withdraw the contested pesticide regulation

By Olivia Gyapong | Euractiv Est. 4min Feb 6, 2024 (updated: Feb 7, 2024)

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Content-Type: News

European Commission President Ursula von der Leyen announced Tuesday (6 February) that she will ask to withdraw the Sustainable Use Regulation (SUR), to halve pesticide use by 2030, dealing a major blow to the EU's Green Deal and Farm to Fork framework. [EPA-EFE/RONALD WITTEK]

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5. Slovak PM Fico's assassination possibly not a 'lone wolf' attack

To the activists, Sustainable Pest Management means Organic Production.

UCCE reports ~25% lower yields for organic strawberry.
To convert all CA strawberry to Organic, but maintain current production levels, we will need:

- 9,714 additional acres devoted to strawberry,
- 5.4 billion additional gallons of potable water,
- 3.33 million additional gallons of diesel,
- 1.72 million additional gallons of gasoline,
- 3-18 million additional pounds of agricultural plastics (and organic cannot use biodegradable films),
- 1.6 billion additional pounds of organic fertilizers,
- and these additional material inputs to support organic-only production will generate an additional 49.3 million pounds of greenhouse gases (carbon dioxide equivalents) per year.

Others report 35-65% lower yields for organic strawberry.

Maybe ASD and Steam can make up some of the difference?

Regulators needs to be mindful of economic, food security, biosecurity, and environmental impacts.

>$1B spent on finding alternatives to Methyl Bromide

Alternative Soil Fumigants

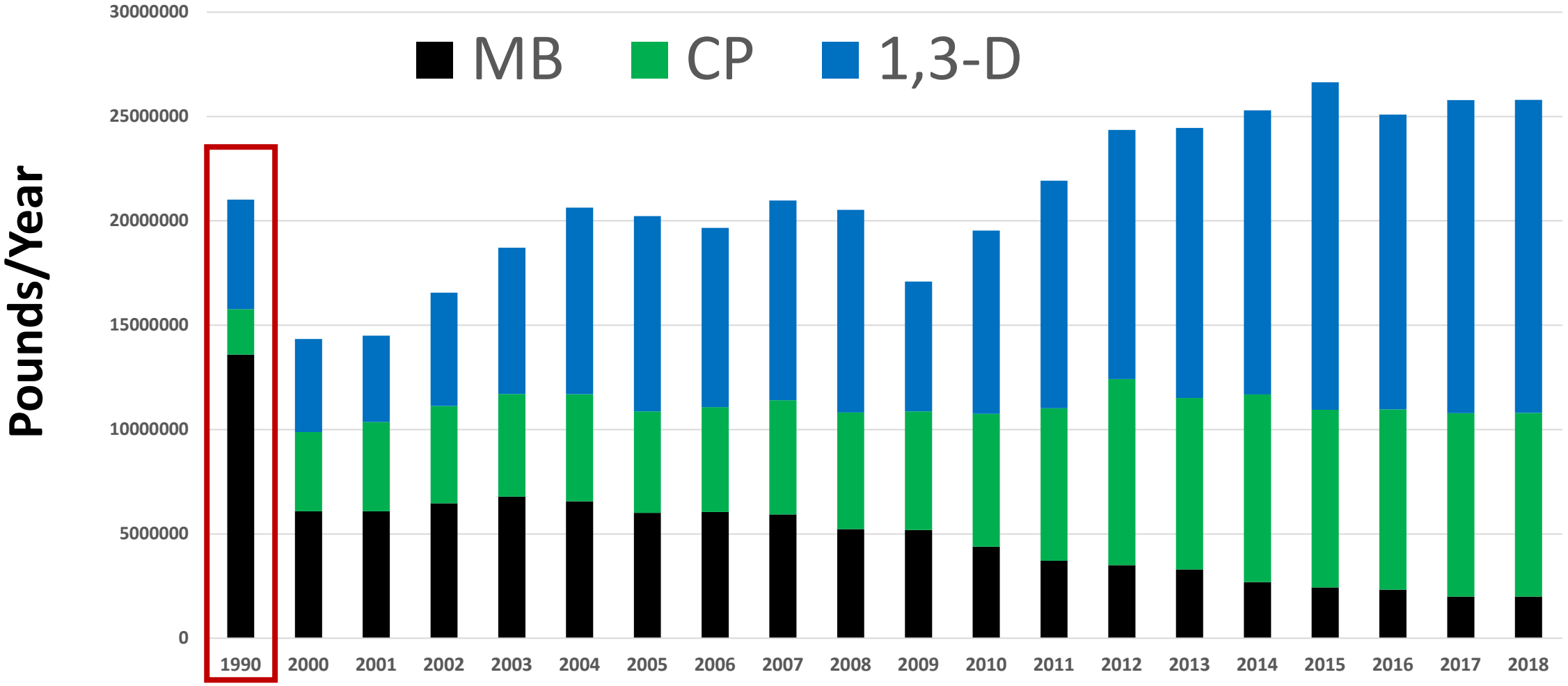
Available
- 1,3-Dichloropropene
- Chloropicrin
- MITC (metam)

Registered in other States or Countries. All failed.
- Iodomethane
- Dimethyl Disulfide
- Allyl Isothiocyanate
- Ethanedinitrile

Commercially inviable
- Sodium Azide
- Propargyl Bromide
- Propylene Oxide
- Furfural
- Etc.

Non-Fumigants:
- Conventional Contact Pesticides
- Breeding
- Grafting
- Steam Treatment
- Anaerobic Soil Disinfestation
- Radiation
- Controlled Atmospheres
- Bio Controls
- Biostimulants
- Solarization
- Biosolarization
- Substrate Production
- Etc.

CA use of Methyl Bromide (MB), Chloropicrin (CP), and 1,3-Dichloropropene (1,3-D): 1990, 2000-2018



Activists Propagate Myths:

“Chloropicrin is a carcinogen!”

“Chloropicrin and Telone are banned in 27 countries!”

“Soil fumigants sterilize the soil!”

“Greenhouse gases from fumigation are high!”

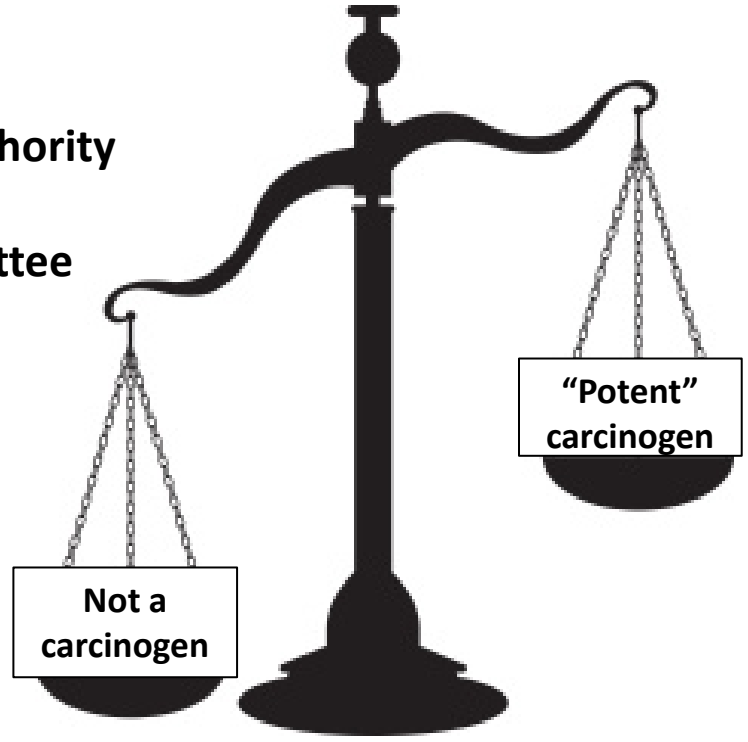
Chloropicrin is a sensory irritant, primarily eye irritation

- **Highly transient, fully reversible, no lasting damage**
- **In CA, occurs once every ~6,000 applications, or 0.018% of the time**
- **Some causes in last decade**
  - **Irrigation system failure: leaks during chemigation**
  - **Buffer zone violations**
  - **Improper bed formation**
  - **Weather**
  - **Applicator error**

Chloropicrin

Not a Carcinogen

- USEPA Human Health Effects Division
- National Toxicology Program
- European Food Safety Authority
- AUS Pesticide & Veterinary Medicines Authority
- Japanese Ministry of Agriculture
- USEPA Cancer Assessment Review Committee
- Mexico
- Chile
- New Zealand
- South Africa
- Argentina
- >30 more countries
- CDPR (earlier reviews, same data)



Is or may be a Carcinogen

- Most activists
- Some Cal-EPA personnel

Telone (1,3-dichloropropene) is intensely regulated in California

CalEPA
California Environmental Protection Agency

Cal-EPA uses different toxicological end-points than the USEPA: different studies, interpretations, and uncertainty factors.

Results in significantly different risk estimates and regulations.

Exposure Period	USEPA end-points (ppb)	Cal-EPA end-points (ppb)	Difference
Acute (≤24 hrs)	2,519	55	45-fold
Longterm/Lifetime	30.52	0.21 to 0.56	54- to 145-fold

Everyone in this room is directly and personally responsible for the existence of 1,3-D

- 1,3-D is a co-product of epoxy manufacturing
- Epoxy is used in many ways, e.g., kitchen appliances (ovens, stoves, refrigerators, etc.)
- Every household, including activist and regulator, contributes

- Options for 1,3-D:
  - Incinerate it: costly and wasteful
  - Store in drums, forever, and hope for they don't leak or rupture
  - Incorporate it at 0.0018% or less into soil (332 lbs/acre for 18" soil depth), benefit from the pre-plant nematicidal properties, and allow nature to render it inert

MYTH:

"Chloropicrin and 1,3-D (Telone) are banned in 27 countries!"

The reality: these fumigants are going through Annex I listing in the European Union (akin to USEPA registration), and cannot be registered in individual member states (the 27 countries of the EU) until Annex 1 is finalized.

Similar: no pesticide can be registered in a State without first getting USEPA registration.

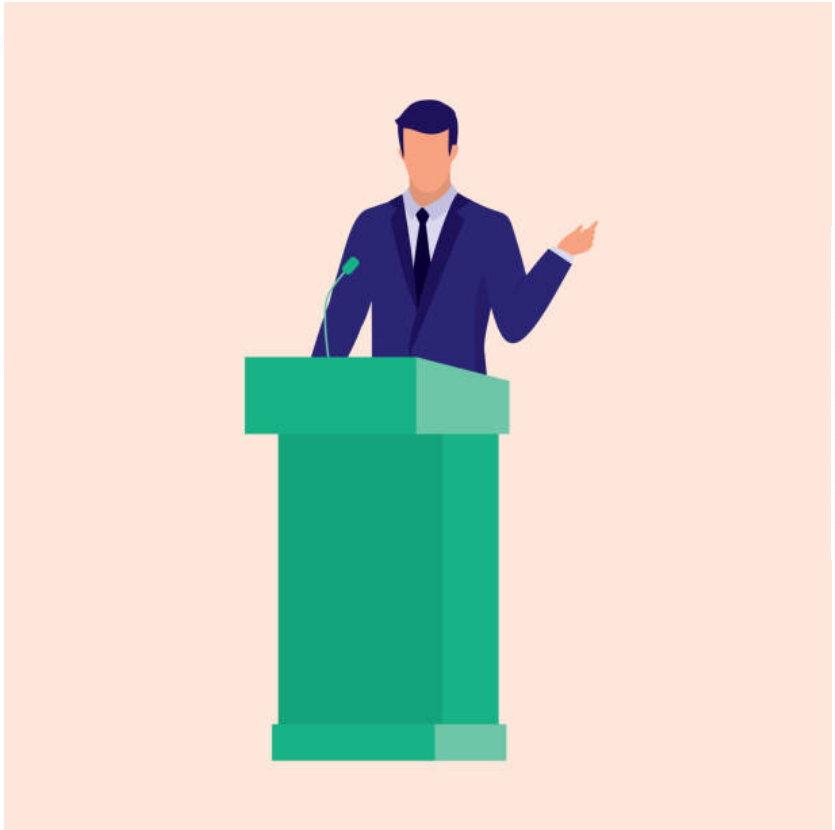
Several EU countries routinely use these fumigants under Emergency Use provisions while Annex I is in progress.

Major soil fumigant use in Morocco,
which exports > 1 million metric tons of fruits and vegetables to the EU each year.

MYTH: “*Fumigants sterilize the soil*” **is most often said by:**

Activists have an agenda

Some regulatory officials have an agenda or just uneducated



Someone trying to sell you something

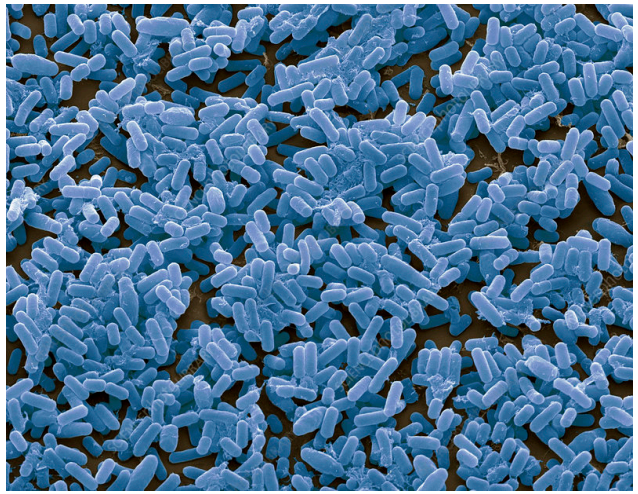
Myth: "*Soil fumigants sterilize the soil*" or "*Soil fumigants destroy beneficial microbes*"

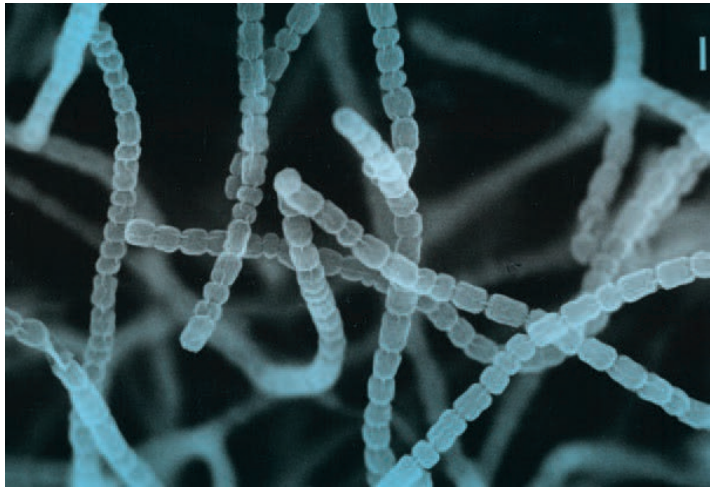
FALSE

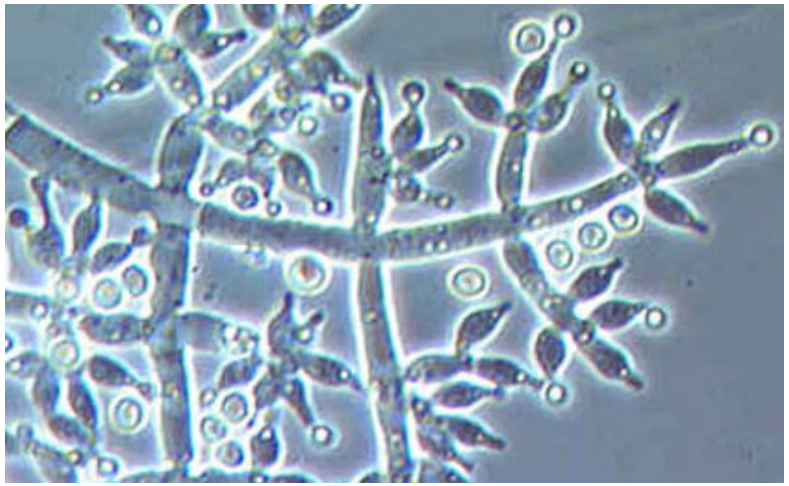
Many microbial populations <u>increase</u> after soil fumigation

Bacillus
Pseudomonas
Streptomyces
Many PGPRs
Trichoderma
Mycorrhizae

- Produce antibiotics
- Parasitize other fungi
- Phytohormone production
- Compete with pathogens
- Induce of systemic resistance
- Improves nutrient cycling / uptake
- Produce metabolites / signaling compounds





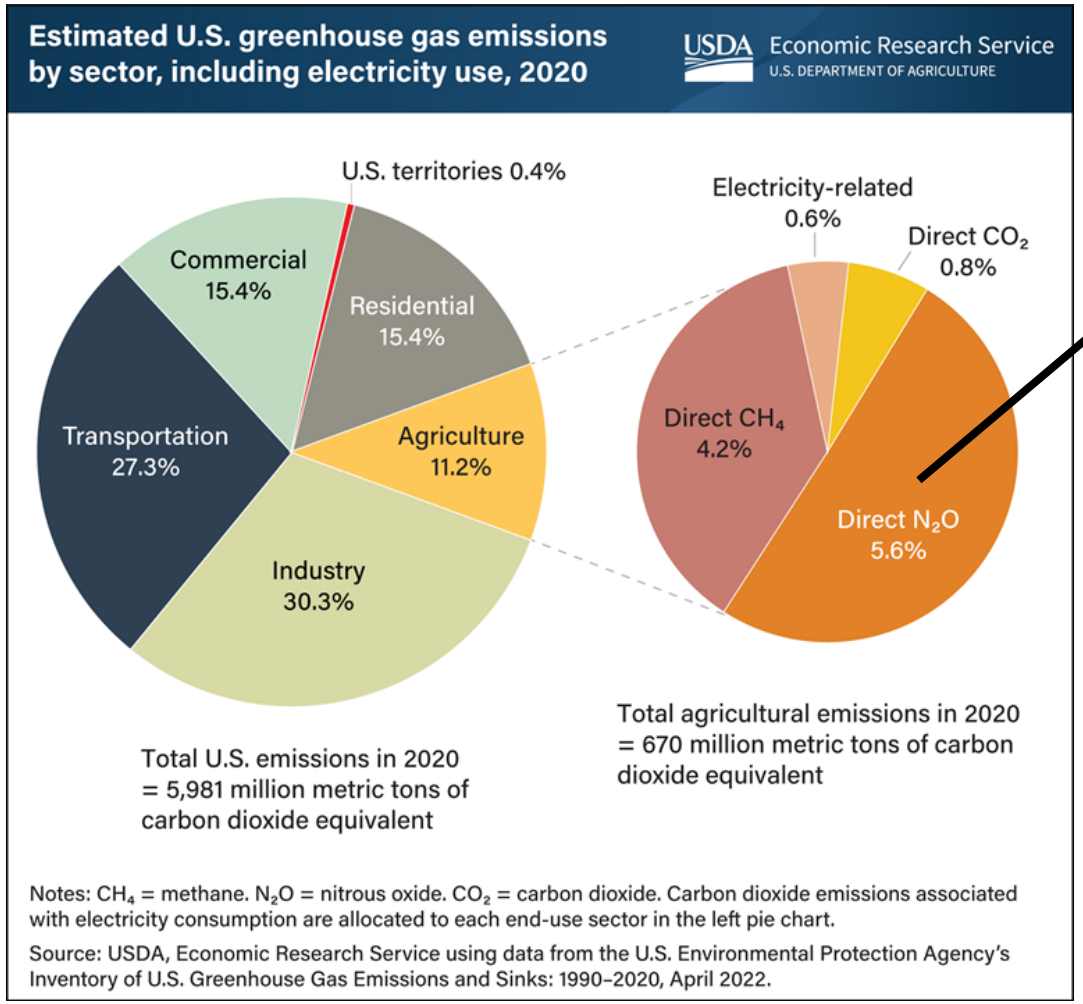


Scientific Literature is loaded with research that supports Soil Microbial Community Health after Fumigation:

- Welvaert (1974): chloropicrin resulted in a **5-fold increase in *Trichoderma*** compared to untreated soil.
- Csinos et al. (2000): chloropicrin treated soil had a **21-fold greater *Trichoderma*** population than nontreated soil.
- Rosado-May et al. (1994): chloropicrin resulted in **6- to 19-fold greater root colonization by *Trichoderma*** versus organic system soil.
- Duniway (2000) and Ridge (1976): **10-10,000-fold higher populations of fluorescent *Pseudomonas*** after chloropicrin.
  - Pseudomonads consume chloropicrin, multiply; and are known Plant Growth-Promoting Rhizobacteria.
- Menge et al. (1983): grape vines growing in **1,3-D fumigated soil had significantly greater arbuscular mycorrhizal colonization** on the roots than did vines growing in non-fumigated soil.
- Enebak et al. (1990) 5-year study: **1,3-D/chloropicrin treated soils had higher arbuscular mycorrhizae** than did the organic crop. Organic field had excessive phosphorus applications; negates dependency on mycorrhizae for P assimilation.
- Dozens of other papers, worldwide crops

Myth: “Chloropicrin generates too much Greenhouse Gas!”

Agriculture and Greenhouse Gas (GHG) Emissions



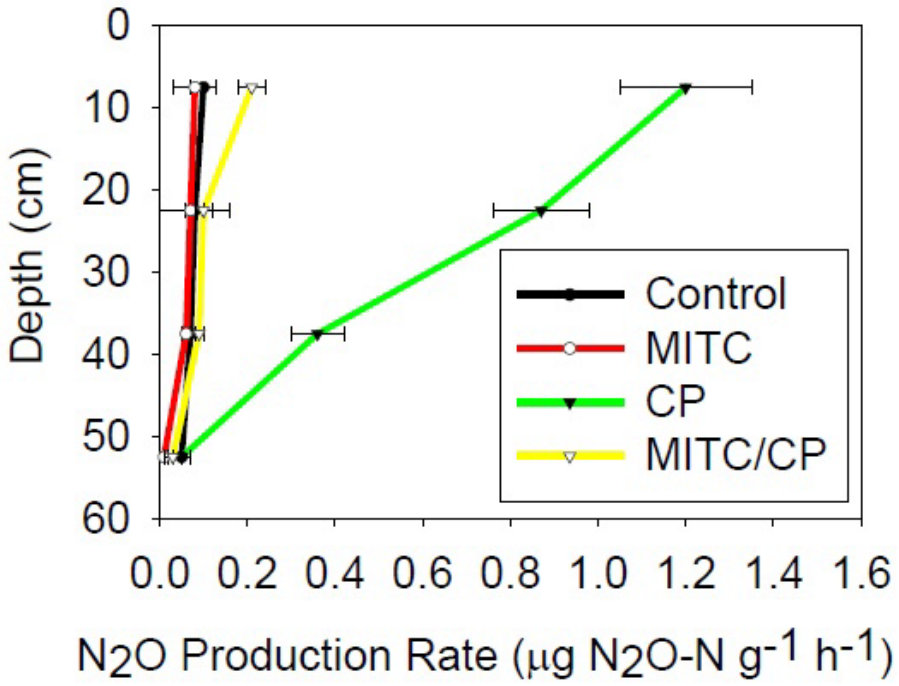
https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=104206

- Agriculture (all sources) accounts for ~11% of total sources
- Cropland soil management accounts for 50% of ag source (5.5% of total)
- Nitrous oxide: 275X more potent than CO2
- Nitrous oxide emissions occur during:
  - Tillage
  - Landplaning
  - Irrigation
  - Chemical fertilizer application
  - Compost incorporation and assimilation, etc.
  - Soil fumigation
  - Anaerobic Soil Disinfestation
  - Steam?

Myth: “Chloropicrin generates too much Greenhouse Gas!”

Spokas et al. 2003-2007.

- **Chloropicrin-treated soil had significantly greater generation of nitrous oxide than <u>untreated</u> soil.**



California has 27 million acres of actively managed cropland.

Conventional and organic crop soils emit N2O.

Chloropicrin is applied to ~45,000 acres/year (0.17% of total).

Spending taxpayer funds to research and potentially regulate something that represents 0.17% of CA acres?

Research not done using TIF or deeper injection like we use in California.
Researchers reported that N_2O production was due to presence of fungi in the chloropicrin-treated soil.

Comparing fumigation to untreated is a false comparison.

Fumigated

Untreated

Fumigation must be compared to another soil pest control tactic.

Maeda et al. (2015) identified *Trichoderma* spp. (crop neutral or beneficial) and *Fusarium* spp. (crop neutral or pathogenic) as the two fungal genera most responsible for the production of nitrous oxide from soils.

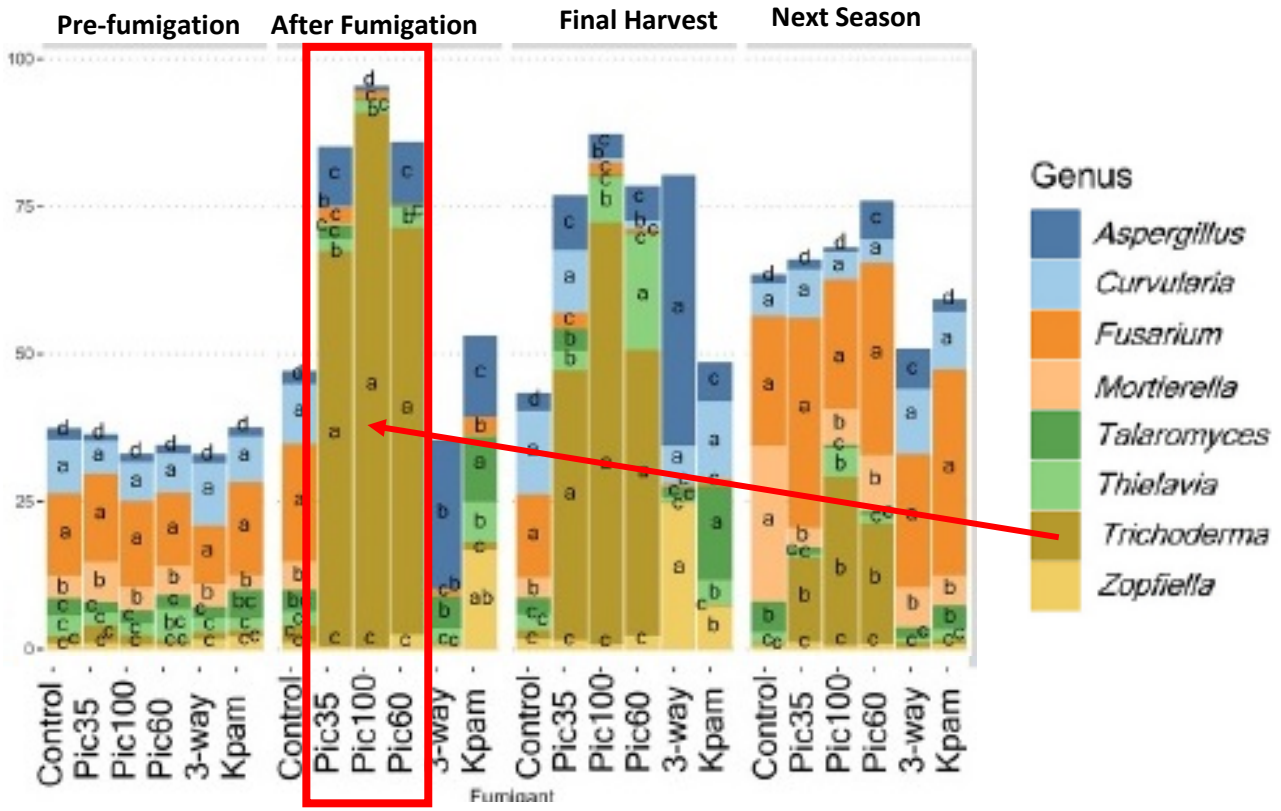
Chloropicrin greatly reduces *Fusarium* populations.

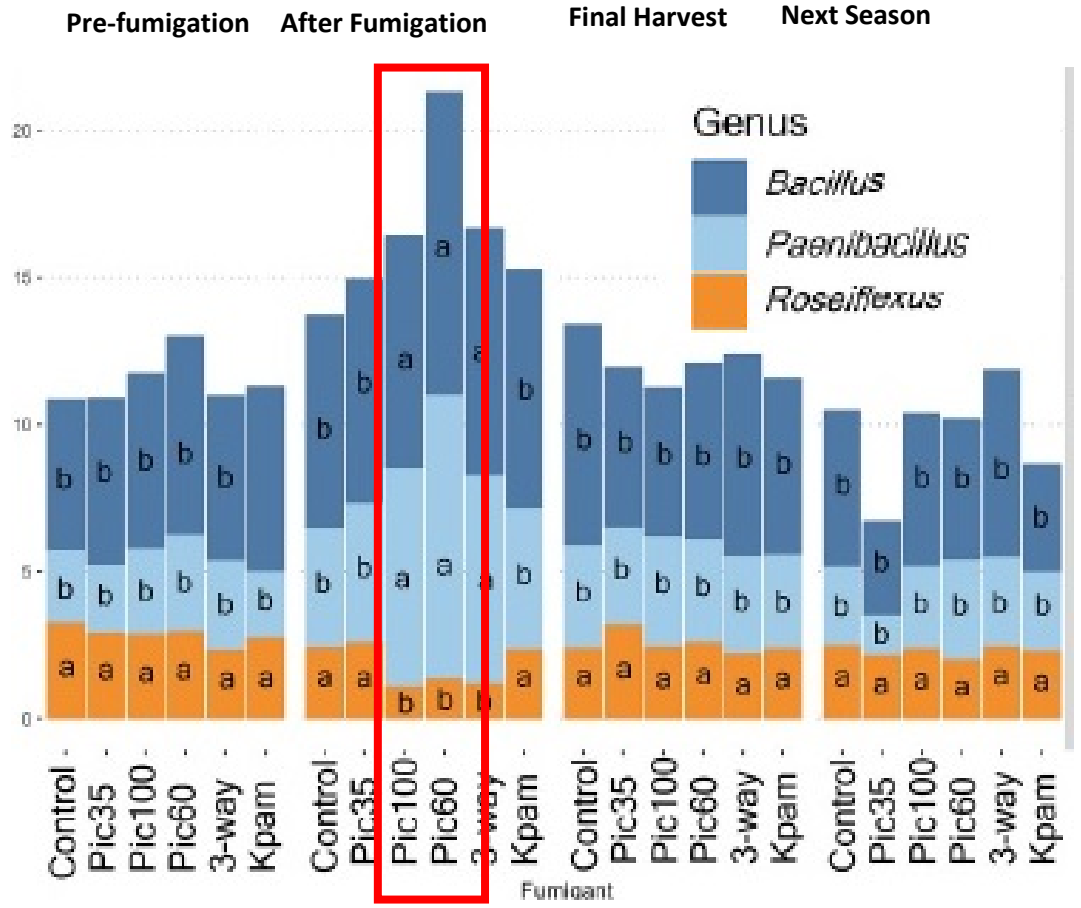
Chloropicrin greatly increases *Trichoderma* populations.

Castellano-Hinojosa et al. 2024. *Science of the Total Environment* 919: 170659

- **Tri-Clor (Pic100) and Pic-Clor 60:**
  - **Controlled Fusarium**
  - **Triggered a massive bloom of native *Trichoderma***
  - **Significant increase in native *Bacillus***

- **Chloropicrin farms the good microbes adapted to your soil.**
- **Much more effective than 'bugs-in-a-jug' products.**





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EDITED BY
Jeanette M. Norton,
Utah State University, United States

REVIEWED BY
Pengfa Li,
Nanjing Agricultural University, China
Yanmeng Bi,
Tianjin Chengjian University, China

*CORRESPONDENCE
Wensheng Fang
fangwensheng@caas.cn
Shuijin Huang
sjhuang@aliyun.com

†These authors have contributed equally to this work

Mechanisms by which chloropicrin fumigation promotes soil potassium conversion and absorption

Yang Sun[1†], Rong Zeng[1†], Wensheng Fang[2*], Jvling Hua[1], Shuijin Huang[1*], Qiuxia Wang[2], Aocheng Cao[2], Feng Zhu[3] and Haiyan Zhang[3]

[1]Institute of Plant Protection, Jiangxi Academy of Agricultural Sciences, Nanchang, China, [2]Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing, China, [3]Institute of Plant Protection, Guizhou Academy of Agricultural Sciences, Guiyang, China

Increase in Bacillus after chloropicrin resulted in greater potassium use efficiency.

Other papers show some crops can reduce N fertilizer by 25% due to crop-favorable rhizobiome after chloropicrin.

Latest Chloropicrin R&D outside California:

Leveraging the soil microbial shift:

- Ultra-low rate (~3 gpa)
- No-till or reduced-till fields

- 300% increase in green bean production
- Greater rhizobium nodulation (N-fixation)

- Grower reduced land used to grow this crop, yet maintained total yield.

- Cascading benefits of land reduction:
  - Used significant less:
    - Water, fertilizer, post-plant pesticides, diesel, gasoline, labor, etc.

    - New trials on crops typically not fumigated, like sweet corn, other legumes, etc.

Science of the Total Environment 785 (2021) 147307

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journal homepage: www.elsevier.com/locate/scitotenv

Anaerobic soil disinfestation with incorporation of straw and manure significantly increases greenhouse gases emission and reduces nitrate leaching while increasing leaching of dissolved organic N

Yiming Zhao [a], Shan Lin [a,c,*], Li Wan [a,b], Waqas Qasim [b], Jing Hu [a], Tongxin Xue [a], Haofeng Lv [a], Klaus Butterbach-Bahl [b,d]

HIGHLIGHTS

- Anaerobic soil disinfestation (ASD) results in enormous environmental N losses.
- ASD with organic matter triggered tremendous N_2O losses of >30 kg N ha^{-1} $month^{-1}$.
- Approx. 50% of incorporated organic matter C lost by respiration within one-month.
- N leaching losses for ASD ranged from 20 to 35 kg N ha^{-1} $month^{-1}$.

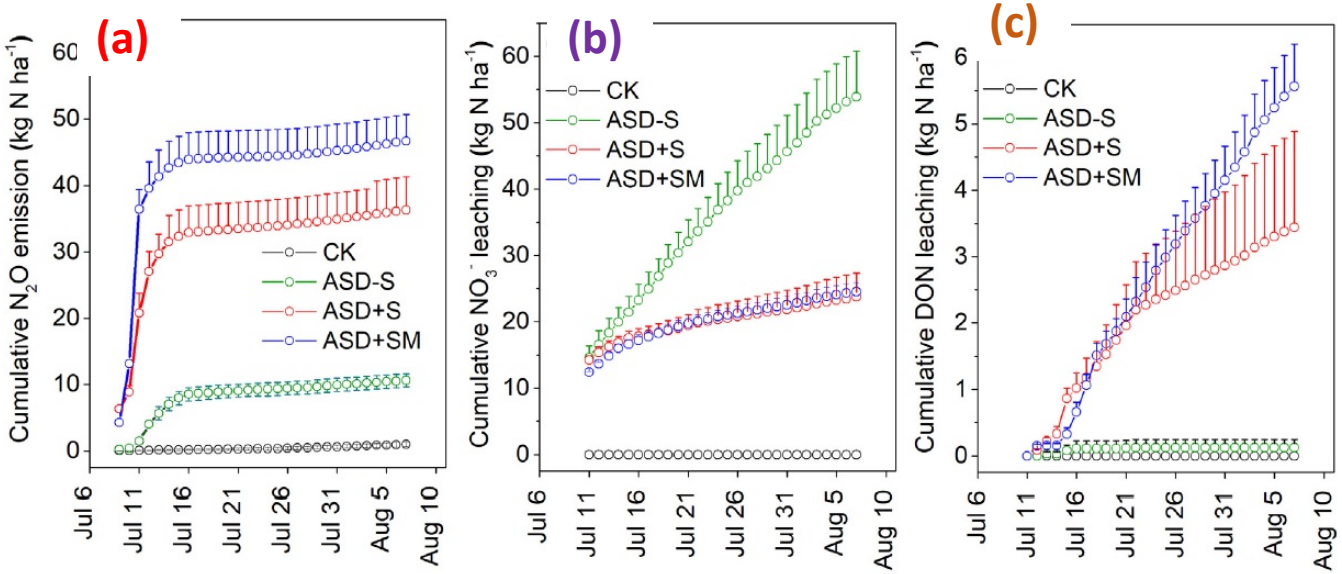

Fig. 6. Mean ± SE (N = 3) cumulative (a) N_2O emission, and (b) NO_3^- and (c) dissolved organic N (DON) leaching losses for the different treatments investigated. CK: control treatment, ASD-S: anaerobic soil disinfestation (ASD) without straw, ASD+S: as before but plus straw, ASD+SM: plus straw and manure.

(a) ASD resulted in 5-25 times greater N_2O emissions

(b) ASD resulted in 20-55 times greater nitrate leaching

(c) ASD resulted in 3-5 times greater dissolved nitrogen leaching

Comparing ASD to Untreated is also a false comparison!

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DOI: 10.1002/jeq2.20324

Journal of Environmental Quality

TECHNICAL REPORTS

Atmospheric Pollutants and Trace Gases

Quantifying the effects of anaerobic soil disinfestation and other biological soil management strategies on nitrous oxide emissions from raised bed plasticulture tomato production

Zhuona Li[1] | Francesco Di Gioia[2,3] | Bodh Paudel[4] | Xin Zhao[4] | Jason Hong[5] | Cristina Pisani[6] | Erin Rosskopf[5] | Patrick Wilson[1]

Pic-Clor 60 had lower, or similar, N_2O emissions than the untreated and ASD.

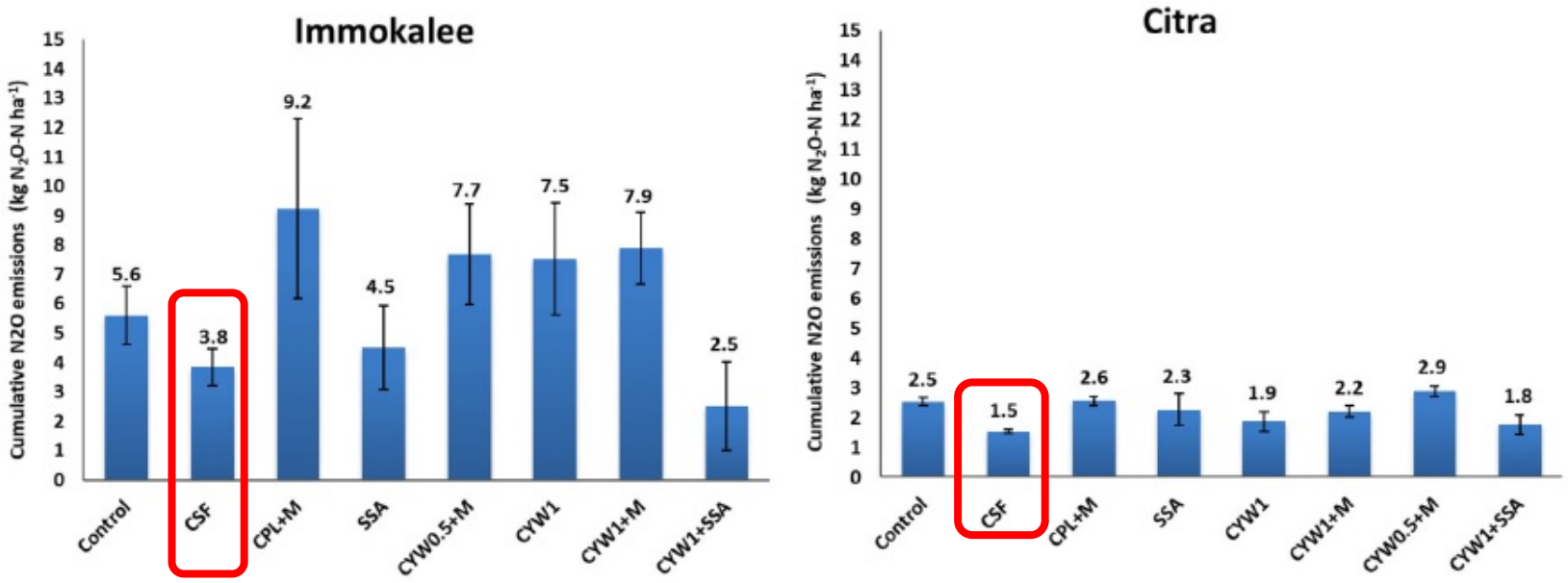

FIGURE 10 Cumulative N_2O emissions at Immokalee and Citra. Soil treatments included: chemical soil fumigation (CSF), composted poultry litter (CPL), Soil Symphony Amendment (SSA), molasses (M), and composted yard waste (CYW). Error bars indicate SE

Article

Analysis of Trace Volatile Compounds Emitted from Flat Ground and Formed Bed Anaerobic Soil Disinfestation in Strawberry Field Trials on California's Central Coast

Gas Species	fASD Aerobic	fASD Anaerobic	MSM (2018)	bASD Aerobic (2019)	bASD Anaerobic (2019)	FUM (2021)	UTC (2021)
1,2,3-Trimethylbenzene		0.842				1.475	0.666
1,3,5-Trimethylbenzene			1.320				
1-Butanethiol				5.203	6.042		
1-Butene	1.730	5.706	1.158	1.102		0.654	
1-Heptene	1.055	1.080		0.319			
1-Hexanol	1.439	2.303	1.174			0.103	
1-Methylimidazol		7.672					
1-Pentanol		1.966					
1-Pentene	1.475	1.306	0.538		0.938	0.175	0.178
2,3-Dimethylpyrazine	1.290			0.571	0.029		
2,3-Heptanedione		0.417			0.163		
2,3-Hexanedione		1.221					
2-Ethylhexanol		1.895					
2-Methylpyrazine				0.237	0.238	0.073	
3-Chloro-2-methyl-1-propene	1.190						
4-Ethyltoluene							1.505
4-Methyl-3-penten-2-one	1.154						
Allylcyanide-3-butenenitrile	1.312						
Ammonia						0.023	0.229
Butylamine-1-butanamine		5.842	1.799	2.845			
Carbon dioxide	49,690	82,123	883	10,335	48,227	12,863	11,952
Carbon monoxide	0.129	0.733	0.001				
Cis-2-Butene					0.205		
Cis-2-Pentene					1.020		
Cyclohexane			2.830				
Dimethyl disulfide	0.875	1.468					
Dimethyl sulfide	5.868	3.952					
Dodecane	7.082	1.090					
Ethanol	4.2	41.0					
Ethanolamine		0.793					
Ethyl chloride						0.861	0.855
Ethyl fluoride		15.957					
Heptane		12.927	2.652				
Hexane			0.428				
Hexanoic acid		5.646					
Hexene	4.566	0.998	0.838		1.040	1.464	0.197
Hexylamine	2.930	1.260	1.250				
Isobutanol		1.530					
Isohexane		36.378					
Isopentane			1.247				
Methane	1545.48	679.86	1.82	1.78	15.87	1.68	1.71
Methyl chloride		20.347					
M-Xylene						0.639	
Nitrogen dioxide		13.308					
Nitrous oxide	9.54	8.34	0.34	33.82	5.38	4.09	2.07
Nonane			5.937				
O-Cresol						0.603	0.584
Pentane		1.113	2.538				
Propene	1.399		1.153				
Propylamine		0.797		0.080			
Propylene oxide	3.192	4.148	0.444	0.036	0.963	2.038	0.374
t-Butanol		2.050					
Tetrahydrofuran							0.233
Tetrahydrothiopene	1.910						
Undecane			1.374	9.532			

Prescott et al (2023). California

- Soil fumigation, bed ASD, broadcast ASD
- GHG and other gases monitored under TIF
- Data represent *potential* emissions
  - TIF traps greenhouses gases, fumigants, etc.
  - Emissions would have occurred if polyethylene tarp was used

Greenhouse gases measured under TIF (ppm)

GHG	Untreated	Fumigated	Bed ASD	Broadcast ASD
CO2	11,962	12,863	58,562	131,813
CH4	1.71	1.68	17.65	2,224.86
N2O	2.07	4.09	39.2	17.88

TriCal is the only commercial entity in CA offering Broadcast ASD deployment of drip tape and TIF.