The long-term impact of fumigants on vineyard microbes

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November 8, 2021

The Long-Term Impact of Fumigants on Vineyard Microbes--CSA News

- Grapevines, and the grapes they produce, are an important specialty crop in the California landscape.
- In 2005, the primary pre-planting fumigant to control soilborne pathogens, methyl bromide, was phased out of use.
- Two USDA-ARS scientists studied alternative fumigants and their long-term impacts on soil microbes and grapevine health, publishing their findings in the *Soil Science Society of America Journal.*

A well-tended grapevine in a modern vineyard produces a bountiful harvest for at least two decades. In fact, a winery in Maribor, Slovenia claims the oldest vine in the world, planted along the city wall in the 17th century. The wall no longer skirts the city, but you can still see the mayor of Maribor ceremoniously harvest The old vine's green grapes, which are fermented and bottled in miniature bottles, according to a **website** for the adjacent winery known as the The Old Vine House.

Most vineyards can't boast of harvests from a vine that's been through both World Wars, but viticulturists still hope to plant seedlings that will stay healthy and produce grapes as long as possible. And a healthy permaculture crop starts with healthy roots.

Modern vineyard managers rely on soil preparation methods like fumigation to make sure grape seedlings—*Vitis vinifera* L.—get a vigorous start. Methyl bromide (MeBr) used to be a key tool in the viticulturist's kit. It effectively knocked back parasitic nematodes and pathogenic species of *Pythium* and *Fusarium* microbes, which cause root rot and fusarium wilt, respectively. But on 1 Jan. 2005, MeBr—a potent greenhouse gas—was phased out from agricultural use when the U.S. signed the **Montreal Protocol**

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Soil sampling in the vineyard at the San Joaquin Valley Agricultural Sciences Center in 2018. Photo by Sadikshya Dangi.

“We knew, back in 2005, that MeBr was *the* major compound for fumigating,” Dong Wang says. “It was our aim with the USDA to find compounds that can still do the job but easily dissipate and degrade without causing atmospheric problems.”

This phaseout spurred Wang, a USDA-ARS research leader, and Sadikshya Dangi, an ARS microbiologist, to ask: what can vineyard managers use instead? And how do different fumigants impact the soil microbes in the long term?

In a 10-year project, Dangi and Wang teamed up to test the effectiveness of alternative fumigants compared with MeBr. They evaluated the microbial communities in an active vineyard before and after planting seedlings in soil treated with three different fumigants and various application techniques, publishing their findings in the *Soil Science Society of America Journal* (SSSAJ; **https://doi.org/10.1002/saj2.20186**).

Dangi and Wang found that there are good alternatives to MeBr and that the initial impacts of fumigants do, indeed, change the microbial population structure in vineyard soil—impacting the overall health of grapes, an important permaculture crop.

The oldest grape vine in the world growing outside the Old Vine House, with a daughter vine to the right, in Maribor, Slovenia. Photo courtesy Dudva/Wikimedia Commons.

Planting Grapevine Seedlings

California is the number one grape-growing state in the U.S. with grape acreage in 2020 totaling 895,000 acres according to the **USDA National Agricultural Statistics Service**. Wine-type grapes made up 620,000 of those acres.

Though wine grapes like Chardonnay and Cabernet Sauvignon can return a hefty profit once they turn into value-added products (namely, wine), planting out new acreage is incredibly costly. Seedlings, soil preparation, fumigation, labor, and infrastructure like posts and trellises for the vines all rack up costs in record time. In 2015, the **University of California–Davis Cooperative Extension** estimated that planting a single acre of vines costs about $20,000, with maintenance expenses over the next four years totaling another $14,300 per acre.

Fumigation is an important first step for quick-growing, healthy grapevines. Fumigation eliminates excess stress to the roots by preventing pathogenic fungi and bacteria from attacking the root systems at their most vulnerable stages right after planting.

Poor establishment translates to small, persistent yield losses. Over time—decades, even—those losses can mean a shortfall in revenue for the growers.

Wang and Dangi's research seeks alternatives to the once-ubiquitous MeBr. One powerful combination pairs the compounds 1,3-Dichloropropene and chloropicrin, sold in different formulations for different application methods. They selected two to test: Telone C35 and InLine, each with about 60% 1,3-Dichloropropene and 34% chloropicrin.

Telone C35 is applied through shank injection, in which a machine with licensed operators drags a hunk of metal (the shank) through the soil about 45 cm below the surface. The liquid form of 1,3-Dichloropropene and chloropicrin is ejected from the shank, and with their low boiling points, turn to gas when they hit the soil, dispersing throughout the root zone. Another formulation, InLine, applies the chemicals in water through subsurface drip.

For the long-term SSSAJ study, Wang compared these two 1,3-Dichloropropene treatments with the traditional MeBr fumigant applied through shank injection. The team also left the soil bare or covered it with virtually impermeable film (VIF). For MeBr, the application area was covered with high-density polyethylene (HDPE) film to minimize greenhouse gas movement into the atmosphere.

Shank injection of Telone C35 in the unplanted fields of the San Joaquin Valley Agricultural Sciences Center in 2007, prior to planting grapevines. Photo by Dong Wang.

By 2009, grapevine plants in soil treated with Telone C35 (left) show increased growth compared with plants in untreated soil (right). Photo by Dong Wang.

Here, a licensed commercial company in California tarps soil after methyl bromide fumigation of test plots at the San Joaquin Valley Agricultural Sciences Center in 2007, prior to planting grapevines. Photo by Dong Wang.

The end goal, of course, was to knock back the microbes that prevent grapevines from producing healthy roots, shoots, and fruits. But there might be unintended consequences.

“Of course, the soil is a biome. By adding these highly toxic chemicals at high doses, it kills pathogenic microbes, but at the same time, you have a sterile soil system,” Wang explains. “That’s good for the short term, but it could be very bad long term—we just didn’t know.”

So the team set out to sample the soil after fumigation, tracking the death and return of microbes—beneficial and hostile—over a decade.

Vineyard Soil Microbes

Way back in 2007, Wang and his team at the USDA-ARS San Joaquin Valley Agricultural Sciences Center in California blocked off 2.3 ha where existing grapevines showed root damage from nematodes and soil-borne pathogens. They removed the vines, deep-tilled the soil, and created eight treatment plots (see Table 1).

Table 1. Fumigation treatments established in 2007 and 2008 at the USDA-ARS San Joaquin Valley Agricultural Sciences Center in California

Treatment No.	Chemical	Rate (kg/ha)	Application	Surface Cover
1	Control	NA	NA	Bare soil
2	Cover Crop	NA	NA	White mustard
3	Methyl bromide	448	Shank	HDPE[a]
4	Telone C35	610	Shank	Bare Soil
5	Telone C35	305	Shank	Bare Soil
6	Telone C35	305	Shank	VIF[b]
7	InLine	305	Subsurface drip	VIF
8	InLine	305	Subsurface drip	Bare soil

- [a] HDPE, high-density polyethylene.
- [b] VIF, virtually impermeable film.

Because the treatments were in areas with documented pathogen presence, the team waited until after fumigation to sample soil microbes, comparing samples to the untreated control. Wang documented post-fumigation levels of nematodes and fungal pathogens in 2007–2009 after fumigating and planting out blocks.

The analysis of these soil samples showed that MeBr, Telone C35, and InLine effectively knocked back plant parasitic nematodes compared with the control. Treatments without surface cover showed greater levels of nematodes below 100 cm. Only the MeBr effectively controlled *Fusarium*, but *Pythium* was lower in all the fumigated plots.

"It could be that the Telone and InLine killed the active *Fusarium* hyphae in the soil but did not kill the spores," microbiologist Edith Allen of University of California–Riverside (who was not an author on this paper) explains. Because of the soil sample method and timing, it's tough to fully understand what's happening with *Fusarium* in the plots. Pre-treatment soil samples were not taken prior to fumigation, and the first soil sample was one year afterward. "It could be that within six months or so, before that first soil sample was taken, the population of *Fusarium* rose again from the spores."

Dangi took the lead for the second round of soil sampling in 2017 and 2018. She used phospholipid fatty acid (PLFA) analysis to separate out five new groups: gram-positive bacteria, gram-negative bacteria, actinomycetes, saprophytic fungi, and arbuscular mycorrhizal fungi (AMF). In PLFA, the researcher can better understand microbial biomass and community structure by isolating the fatty acids from the soil, then running the resulting fatty acid methyl esters through a gas chromatograph to see specific signatures associated with certain types of soil microbes. By calculating the amount of corresponding fatty acid methyl ester for each group in relation to the weight of soil, researchers can better estimate the proportion of soil microbes in each gram of soil.

Their findings noted that bacterial community populations were higher in the 0- to 30-cm soil depth in all fumigated and nonfumigated plots—the bacteria returned, regardless of treatment. But for fungi, plots treated with MeBr had higher levels of AMF compared with InLine, Telone, and control plots. Plus, there was a significant increase in the amount of fungi at deeper depths in the soil fumigated in 2007.

“These deep-rooted grapevines influenced the fungal populations at lower depths,” Dangi explains. “We think that the grapevines might have supplied carbon to these deeper layers, which is why we’re not seeing much change in the fungal populations compared with the bacterial population.”

It comes down to the pair’s original question: are Telone C35 and Inline reasonable alternatives to MeBr?

The grapevines in the San Joaquin Valley Agricultural Sciences Center test fields in 2014, at least seven years after planting. Photo by Dong Wang.

“From a pathology perspective, the combination of chloropicrin and 1,3-Dichloropropene is quite effective,” Wang answers.

For vineyards taking on the incredibly expensive process of fumigation, from deep-tilling soil to setting up infrastructure, the long-term results of Wang and Dangi’s work makes a strong argument for using some form of fumigation early in the process, particularly with covered soil.

Next on their list?

“We collected crop response data in these systems, too,” Dangi says. “We want to analyze that data and see, exactly, how fumigation impacted yield in grapevine.”

From their preliminary data, though, Wang and Dangi are hopeful that growers will see the benefits of fumigation during the grapevine's establishment, providing vineyards with healthy grapes for years to come. And who knows? Maybe a vine in San Joaquin is next on the list to become a centuries-old attraction, giving lucky future wine lovers a taste of the terroir of this gorgeous California valley.

Dig Deeper

Read Sadikshya Dangi and Dong Wang's paper in the *Soil Science Society of America Journal*: "Soil Microbial Community Characteristics in a Vineyard Ten Years after Fumigation," here: **https://doi.org/10.1002/saj2.20186**.

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