Rainy Days and Fumigation Delays: What is a Grower to Do?

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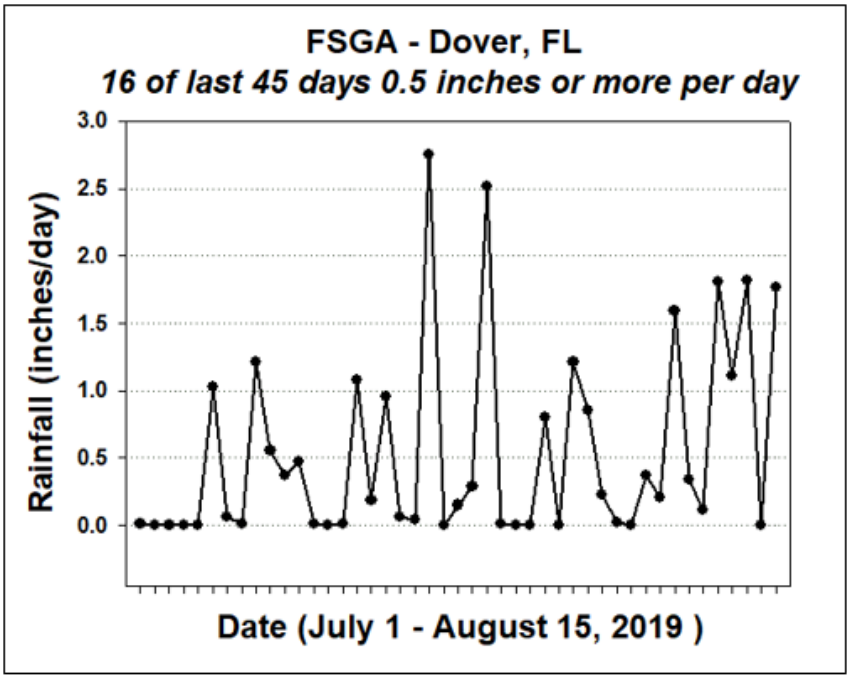
I have to confess that in semi- retirement the phone doesn't ring as often and there is an important other who now wants more of your time and potential productivity. It's a good thing that I haven't lost my ability to ponder when cruising the waters of Tampa Bay. The request I have been asked to ponder is how do you advise growers on how, when, and where to apply a soil fumigant when it won't stop raining and you sink up to your ankles when you walk into a field. The answer is definitely don't try to fumigate now, it will have to wait. So, given that we have some time to ponder, let's explore your options for the future.

First let's summarize our past rainfall. Figure 1 below shows us that we have not been wanting for rainfall in the last 45 days, with a total of over 24 inches during the period. Fawn weather for the Dover station (https://fawn.ifas.ufl.edu/) indicates that we have received more than half an inch of rainfall per day in 16 of the previous 45 days since July 1, 2019. There was another 10 days during the period in which a quarter of an inch fell per day, if for no other apparent reason but to exacerbate the problem and to compensate for any evaporative losses which might have occurred from the field during the few days when it did not rain ☺.



As you might expect, the cumulative rainfall we have received during the previous 45 day period is well above historical averages, and the latest seven day National Weather Service (NWS) precipitation forecast shows two main areas at risk for heavy rain through early next week (August 20) include the Gulf Coast and Southeast U.S. The forecast for Aug 15 calls for an additional 1.5 inches of total rainfall for the next 7 day period. Other NWS long term forecasts (8-14 days) calls for a 40% probability of above normal precipitation. So, it really doesn't appear that there will be any major change in expected rainfall for the Tampa Bay area in the near term. I would not get too puckered yet, given there is in rough terms, 40 days remaining before an October 1 planting and the long term 3-4 week NWS forecast is for below normal average precipitation into early September. Let's think positive that it is going to let up at some point.

So, let's assume that the winds start coming from cardinal directions other than the westerly's we have been getting. Fumigants and plastics have been ordered and are now likely, or soon shall be delivered. I bring this up now because there are fumigant and mulch options which can be considered which might help you to minimize problems of fumigant retention in soil and crop damage potential.

Fumigant Movement

Let me provide a brief description of the fumigation process including a superficial review of the movement, fate, and disappearance of fumigants from soil. After application to soil as a liquid, fumigants quickly become partitioned into liquid, gas, and adsorbed soil phases (clinging to soil particles). Initially, and immediately after soil injection, fumigant movement in soil is driven by density and pressure gradients from a narrow, linear band of concentrated product deposited directly below the 3 chisels down the row. As the fumigant's partial pressure falls, soil movement via mass flow becomes less important than by simple gas diffusion processes, i.e., movement of gases through open air passages between soil particles. Fumigant persistence, volatility, and degradation are influenced by many factors, including chemical properties of the fumigant, soil properties, and environmental conditions. A partial listing of some of the physical and chemical properties of the primary soil fumigants available in Florida is provided below in Table 1.

Volatilization continues as long as the fumigant remains in soil and upward movement of the fumigant occurs as long as a concentration difference exists between the soil surface and soil atmosphere. Vapor pressure is a measure of the tendency of a fumigant compound to change into the gaseous or vapor state. The temperature at which the vapor pressure at the surface of a liquid becomes equal to the pressure exerted by the surroundings is called the boiling point of the liquid. The lower the boiling point, the more volatile the fumigant compound. Note the differences between methyl bromide and all the other fumigants listed, and the high boiling points of the alternative fumigants. Hot and dry soil conditions favor more rapid escape of all of the fumigants, particularly within surface soil horizons. Fumigant products with high solubility and low vapor pressures are typically better suited for drip application rather than shank, which is why metam sodium, potassium and allyl isothiocyanate are typically described as being better suited for drip fumigation.

Fumigant movement from the three 8 to 10 inch deep injection streams per bed are driven by soil and environmental processes. Fumigants are volatile liquids that change into gases upon injection into the soil. The most important point to recognize is that fumigant gases / **vapors can only move through continuous soil air space.** **T**he volatile release of fumigant gases from the liquid phase to the gas phase in soil air matrix between sand particles is determine primarily by

temperature and soil moisture. If the soil is completely saturated with water, volatilization of gases from the parent liquid ceases, subjecting the 3 fumigant stream to dilution, hydrolytic degradation, and subsequent movement by gravitational water flow.

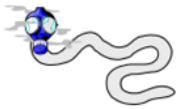
It is pretty safe to say based on previous observations, that fumigants can persist for an extended period (45-60 days) when maintained under saturated / flooded conditions. Every grower I have ever talked to can recite stories and observations of plant damage and fumigant persistence, particularly at the drainage ends of fields with products like Paladin or Telone. The rates of disappearance, dissipation, and or degradation are not clearly defined under these conditions of extended periods of saturation caused by high frequency of heavy rainfall. The old saying "if you shoot into the mud, it stays in the mud" applies, particularly after repeated rainfall. To point out the positive again, given the typical production practices of fumigants, application rates, and mulches used, it generally does not take long under dry to dryer conditions to aerate the soil under the plastic. Fumigant labels conservatively estimate a 14-21 day requirement to purge the fumigant from soil. It is possible it could be sooner, but growers should adopt at least a 14 day separation of fumigation and planting, ensuring that multiple soil cores to the depth of injection are acquired and '**smell tested' for the presence of the fumigant** before proceeding with planting. Growers should also be reminded that the nose or MiniRae VOC detection systems do not measure fumigant concentrations in soil when the fumigant is still in the water phase.

In Florida seep irrigated agriculture, soil moisture at the time of bedding is frequently in excess of 150 to 200% of field capacity during fumigation. Even in Hillsborough County, if you continue to tamp the ground with your foot you can see how wet the soil can be at fumigation even on strawberry land. High soil moisture content is architecturally necessary in Florida to hold the single grain structure of a fine sand together to form a raised bed. Now imagine covering that wet soil with TIF. When it doesn't rain excessively after bedding and soil fumigation, soil aeration of the fumigant can occur pretty rapidly, particularly under hot summer conditions. I have measured bed temperature in the range of 140° to 150 degrees 8 inches deep on the shoulders of a black plastic covered bed. Under a dryer climatic scenario, Dominus (allyl isothiocyanate) is pretty quick to disappear from soil, and there have been times when it could not be detected in soil 4 -7 days

after application. (Please do not construe this comment as a recommendation for Dominus). Recognizing a fumigant is needed for pest control and strawberry yield, **I think strawberry growers might want to consider fumigant mixes which emphasize Chloropicrin in the mix, such as a formulation of Pic Chlor 80 (320 lb/ta or less) to addresses, as best they can, fears of future plant phytotoxicity.**

There are other options as well regarding the fumigant selection process under the currently wet scenario and forecast for more of the same. As many of our strawberry double croppers know, drip fumigation after bedding with KPam has been a viable and well used option for years. Personally my preference has always been for shank applied products which generally perform from shoulder to shoulder, unlike most of the drip applied fumigants (Paladin EC was clearly an exception). **Avoiding the shank fumigation process during bedding and relying on drip fumigation at some future time, allows growers to bed as they can now when soil conditions within the field allow.** I think having the field bedded can provide much needed field drainage, shedding water down middles to ditches, allows the bedded soil to achieve simple field capacity sooner. This could help growers take advantage of drip fumigation opportunity sooner as well.

Properties of Soil Fumigants



Fumigant	Boiling Point °C	Vapor Pressure 20° C	Solubility In Water	Soil Half Life
Methyl Bromide	4	1420	13400	12-22
Chloropicrin	112	18	2270	1-2
1, 3-D	120	28	2250	3-5
Metam Sodium	112	0.04	578290	4–5*
Metam Potassium	114	24	complete	4-5*
Dimethyl Disulfide	110	28.7	3000	3-5

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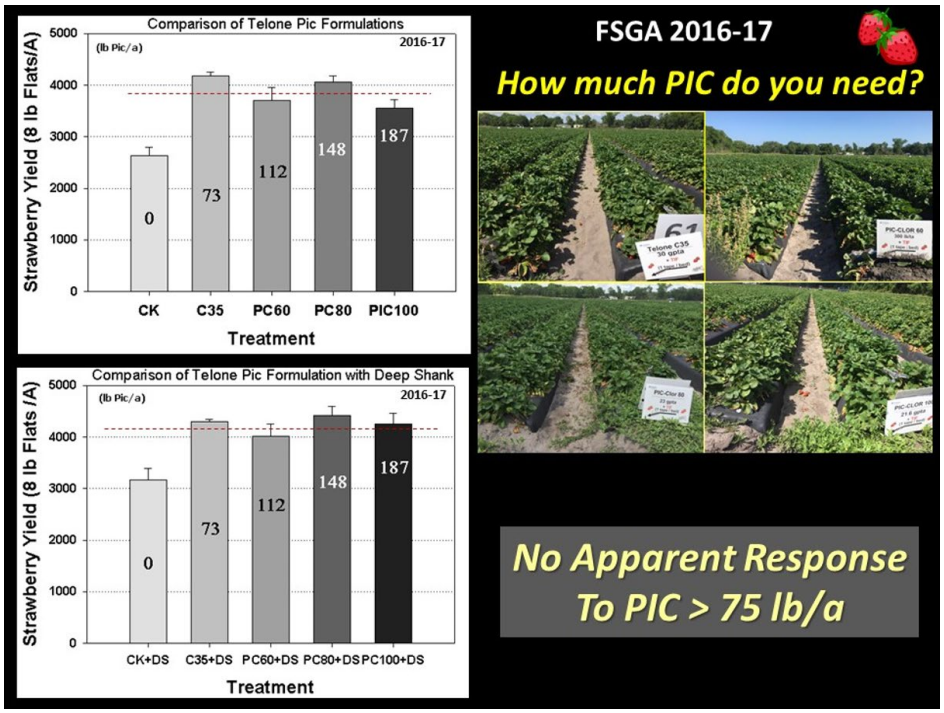
They require higher temperature and volatilize to gases much more slowly, and then move thru soil much slower than MBr

Avoiding Plant Phytotoxicity

All of the fumigants contained in Table 1, including the gas and water phases of these fumigants, are toxic to plants. Soil dissipation and the persistence of toxic residues is strongly influenced by environmental conditions. Any change in soil condition which promotes a cooling and or a wetter soil condition will typically delay dissipation of **any** fumigant from soil. As a result, soil applications must always be made well in advance of a seeding or planting date to ensure sufficient time for dissipation of fumigant residues from soil. The problem is usually most severe with fumigants of low vapor pressure, where longer term planning horizons must be adopted to avoid problems of phytotoxicity or to avoid long unscheduled delays in planting after the plants have arrived from the nursery. Growers who now use the alternative fumigants, typically adopt planning horizons which consider beginning field preparation and soil application two to three weeks earlier than normal to avoid problems of potential phytotoxicity that may result from use of impermeable mulches such as TIF, or after a **repetitive stream of storm fronts** producing abundant rainfall completely saturating and flooding fields.

In-soil Degradation of Fumigants:

Recent studies have also demonstrated that the addition of some fumigants like chloropicrin in the fumigant mix can destroy microbial populations in soil that are responsible for digesting the fumigants as food, and thereby contribute to longer persistence in soil with potential delays to plant back into the bed. In general, Chloropicrin degradation rate in soil decreases (disappears more slowly) with increasing application rate, regardless of soil temperature and soil moisture content. This is likely attributable to decreased microbial numbers and activity (i.e., degradation) at high (toxic) rates of application. This is not necessarily the case for the in-soil degradation processes for all fumigants. Soil degradation of Chloropicrin, DMDS (Paladin), and MITC (Vapam, KPam, Dominus) are considered attributed primarily to biological mechanisms (bacteria) and then to abiotic factors, whereas degradation of Telone (1,3-D) is attributed principally to abiotic factors such as temperature and chemical hydrolysis in saturated soil. In some different Florida studies, microbial degradation accounted for 55 to 91% of the overall degradation of Chloropicrin in soil. For fumigants like chloropicrin, o**ne way to possibly expedite soil disappearance and avoid plant injury or plant back delay is to avoid use of high rates of chloropicrin application.** Please be aware that recent studies we have conducted at FSGA have demonstrated little benefit to strawberry yield, did little or nothing to reduce end of season plant mortality due to disease, or was any additional herbicidal activity provided against nutsedge above a **Chloropicrin use rate of 75 lb per acre Figure 2**.



DO YOU HAVE TO USE TIF?

After a fumigant is applied, the treated bed is now usually tarped with a totally impermeable mulch film (TIF) to provide an additional measure of fumigant containment to soil. Growers are using TIF to enhance fumigant efficacy at reduced rates of fumigant application and to benefit from as much as a 60% label credit to reduce buffer zone distances. Sixty percent is a lot, particularly if you have residential borders and you're going to use Chloropicrin or Metam and treat 20-40 acres per day. With TIF, fumigant use rate reductions of 25 to 30% are generally considered achievable without compromising pest efficacy or strawberry yield. It should come as no surprise however that a rapid loss of fumigants from bedded soil occurs when beds are covered with the old, **low density polyethylene (LDPE),** particularly when soil moisture within the bed is suboptimally low (i.e., dry, not wet). It is not clear how the benefit of LDPE would be expressed/ i.e., play out under periods of frequent heavy rainfall. I don't like confessing it, but it could help expedite the aeration process if rainfall amounts and frequency would ever restore to normal summer patterns. **Holes could also be punched** into the plastic after the label required period to help expedite soil aeration.

Summary

I have laid out a number of options to deal with and address our current flooded condition and immediate forecast for more of the same. Soil moisture exceeding field capacity and TIF film were specific factors that increase retention of fumigants in soil. Thus, for our strawberry raised-bed plastic mulched production systems, it is expected that fumigant retention in sandy textured soil will be increased due to frequent showers and heavy rainfall. Higher water content reduces subsurface dispersion of Telone 1,3-D and Chloropicrin and increases their residence time in soil. Extending fumigant retention in soil through the use of TIF can increase the potential for high concentrations of fumigant vapors to remain in soil at the time of planting. To mitigate the unintended consequences of excessive fumigant retention in soil, application rates associated with TIF should be adjusted lower if possible, emphasizing fumigant mixes with chloropicrin which disappears relatively fast if dryer conditions ever prevail. Given grower and site specific conditions, more of a reliance upon drip fumigation as the method of fumigant application might be warranted to allow bedding to occur as needed when suitable conditions prevail. I think it worthy of mentioning, that planting schedules are not etched in stone and have some flexibility, limited as it might be by the timing of arrival of plants and benefits associated with early season fruit pricing.