Resolving Performance Inconsistencies in Nematode Control via Targeted Fumigant Placement and Vertical Management Zones

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This is not my first International Research Conference on Methyl Bromide Alternatives and Emissions Reductions talking and writing about nematodes and soil fumigants. Most of these former papers and presentations describe 1) the importance of plant parasitic nematodes to tomato crop production in Florida; 2) the importance of soil temperature, soil moisture, and soil compaction, and their effects on of inhibiting movement and or dissipation of fumigants from soil; 3) transition strategies from methyl bromide to the alternative fumigants with a focus on yield and pest control efficacy, and 4) the differences in chemical characteristics between the different fumigants and the vulnerability of the alternative fumigants to suboptimal environmental conditions. As previously reported, the two biggest differences in chemical characteristics between methyl bromide and the alternative fumigants are vapor pressure and boiling point. Because of the significantly lower vapor pressure (sometimes as much as a hundred fold) and higher boiling points, the alternatives volatilize to gas and diffuse through soil much more slowly, and do not race through the vertical soil profile like that of methyl bromide.

The presence of a traffic pan observed to occur just below the base of the raised, plastic mulch covered bed is another formidable barrier to diffusion of the alternative fumigants into deeper soil. In practical terms, the compacted traffic pan occurs just below the depth of the deepest tillage implement used in the field and has been shown to unavoidably cause changes in soil hydraulic conductivity, diffusion of fumigant gases, and thus soil fumigation efficacy and field distribution of nematodes and crop damage. We believe it is the presence of the traffic pan coupled with the differences in vapor pressure and boiling point which so limit soil movement and spatial distribution of the fumigant in soil which has resulted in the increase in root-knot nematode problems being reported in tomatoes and for the severe and reoccurring problems associated with sting nematode in Florida strawberry to specifically name but a few. The focus of today's presentation and proceedings paper is therefore to simply discuss new research tools being used that quantify the spatial distribution of nematodes and soil fumigants concentrations in soil air and how each of these factors are interrelated and contribute to what we believe are the inconsistencies in crop yield response to the alternative fumigants in Florida agriculture. It will conclude with the justification and need for developing new fumigant placement strategies that view nematode management as a composite and integration of vertical management zones **(Figure 1)**. Additional information describing specific studies, sampling results, and statistical analyses which support the comments and conclusions drawn can be found in the senior author and coauthors MBAO 2014 and 2015 proceedings papers and slide presentations (https://mbao.org/).

In reflecting on the current state of fumigant use in Florida strawberry, we think it is fair to say that we have failed to provide a consistent and satisfactory level of sting nematode control, regardless of fumigant, rate or method of application, impermeability of the plastic mulch used, or combinations of the fumigant compounds and other IPM tactics employed. In many situations the stunting from the nematode is observed shortly after the fumigant has dissipated from soil and transplants are place into the ground and before they have even completed their watering in, or *living-in* production phase. This is a scenario has worsened since the CUE for methyl bromide expired in strawberry in 2012. To address the problem, our research focus in strawberry has been to determine where sting nematodes originate from that recolonize the raised plant bed after fumigant application, and where fumigants go, and more importantly, don't go after they are applied. Last year at these meetings I described the purpose, use, and utility of the *Probinator*, a deep core soil sampling system which allowed us to quantitatively assess soil population densities of nematodes and concentration of fumigants in soil air with soil depth. More importantly and unknowingly, the *Probinator* allowed us to study the causes of fumigant treatment inconsistency.

The results from the very first deep core Probinator sample was very informative. What the results showed us was that Sting nematode could be found at depths of 3 feet, the maximum depth the system was capable of procuring a sample, and that they were found at these depths in <u>every</u> nematode infested field we sampled. The presence of root-knot nematode has similarly been detected in deep flatwood soils under tomato and eggplant. It also told us that these nematodes could occur at high density in deep soil even in the total absence of plant roots (food). I think it is worthy to note that these nematodes are occurring at soil depths that are seldom, if ever, sampled for nematode population assessment. After learning that the nematodes were occurring at such depths we decided to start examining the impact of crop termination treatments on soil population densities of nematodes with soil depth. For these trials, we used the *Probinator* to monitor soil air concentrations of drip applied 1,3 D at 4 inch increments from the soil surface to a depth of 36 inches using a MiniRae 2000 VOC meter. The results from these studies demonstrated that drip delivery of the fumigant achieved high fumigant concentrations in soil air above the traffic pan situated 1 to 2 inches below the level of the row middle and bottom of the plant bed. These results and those of previous studies clearly showed that 1, 3-D was <u>incapable</u> of diffusion through the traffic pan into the deeper soil depths where the nematode reside. Previous surveys of grower fields we have conducted have documented that every field which is not subsoiled contains a traffic pan located just below the depth of the deepest tillage implement used in the field. So the crop termination drip fumigation treatment would have done a good job of controlling nematodes within the confines of the raised plant bed but <u>nowhere</u> else.

The next field in which we surveyed with the Probinator was one in which a crop termination treatment had been applied in early April (Vapam, 75 gpta) which was then followed by 3 months of bare fallow in preparation for a summer broadcast fumigant treatment of Telone II (15 gpa) for nematode control. The results of this field survey showed the absence of nematode (imagine that) in the surface 12 inches of soil that had received the crop termination treatment in the preceding crop and fallow treatment but showed high populations of root-knot nematode (Meloidogyne sp.) at the intermediate and deepest soil depths between 1 to 3 feet. Soil population densities of root-knot nematode were observed at levels in excess of 500 juveniles per 100 cc soil at the deepest soil depth (2-3 feet). Following the pretreatment soil sampling for nematodes, the field was then broadcast treated with Telone II (15 gpa) to a depth of 14 inches using a chisel plow rig, after which the field was rolled to help seal the soil and slow the upward movement of Telone II from soil. The Probinator was then employed to monitor soil air concentrations of 1, 3-D at 4 inch increments to a depth of 3 feet at 2 to 3 day intervals until final disappearance of the fumigant from soil. The results of these samples indicated that the diffusion of 1, 3-D was primarily upward, back up through the shank trace, and that there was little fumigant penetration into the deeper soil profile below the level of injection and to where root-knot nematode was residing. In this field we were able to show that a dry top soil that was simply rolled failed to provide a conducive environment for radial expansion of gases into deeper soil from the point of injection, and in this case mostly upward. Again the Probinator demonstrated where fumigant gases go and more importantly where they do not go.

To further study the impact of subsurface compacted traffic pans and deep soil residence of nematodes, new deep placement fumigant application technologies were developed to study the spatial distribution and management of root knot and sting nematode. The research currently underway is testing a new deep shank fumigant delivery system so as to target soil treatments to the depths where nematode occur in soil. The new systems (**Figure 2**), developed by Mirusso Enterprises Inc., Boynton Beach, FL, are capable of either making a deep shank fumigant application to a depth of 15 inches and or installing a subsurface drip irrigation line to a depth 15 inches as well. Fumigation was conceived of as a 2 step, sequential process consisting of targeted delivery of fumigants to two different soil depths or what we now consider vertical management zones **(Figure 1)**. As a prebed treatment, the deep shank unit injects the fumigant to a depth of 15 inches to the flat which is then immediately followed by a grower application of their separately applied fumigant to the raised plant bed during the bedding operation. The bed is firmly pressed (sometimes twice) and the drip tape and mulch (usually an impermeable film) installed as a covering over the bed. The covering of the deep shank trace by the formation of the raised plant bed serves to impede rapid escape of deeply placed fumigant gases out of the bed. At the same time, the injection of the grower standard applied fumigant fills the raised bed with fumigant occupied airspace with their soil treatment. The covering of the bed with an impermeable mulch film not only serves to impede fumigant outgassing from the bed but we believe when coupled with the other factors, serves to encourage radial expansion of the deep shank applied fumigant into the deeper soil profiles where nematodes reside. These are 3 reasons why we believe the new Prebed Deep Shank treatment appears to push fumigants into deeper soil profiles.

During June 2015, five different experiments within nematode infested fields were deep drip fumigated using a subsurface drip line buried approximately 21 inches below the top of the mulch covered bed. The buried drip tape was installed 15 inches deep to the flat prior to bedding during fall 2014. For all experiments, Telone EC (15 gpta) was injected over a 3.5 hour injection period followed by a 30 minute flush. After injection, soil air concentrations of 1, 3-D was monitored at 6 inch increments from the soil surface to a depth of 36 inches using a series of soil probes hammered to the appropriate depth and gases measured with the MiniRae VOC meter. The results from these experiments clearly demonstrate the ability to move toxic concentrations of Telone EC via the irrigation stream into deeper soil profiles (36 inch) to the levels where pathogenic nematodes reside. There was also clear indication that some upward, probably capillary movement of fumigant in the water phase, occurred given the measurement of Telone EC gases well above the depth of injection and to the soil surface.

Summary

What these studies have told us is that most of the alternative fumigants with low vapor pressure and high boiling point are unable to distribute vertically in the soil below the traffic pan (and oftentimes horizontally to the bed shoulders)with current delivery and application methods originally developed for methyl bromide. Our research focus now focuses conceives of nematode control as a composite of vertical management zones for nematode control and for sustaining optimum crop production (**Figure 1**). The new approach separately targets fumigant treatments to areas above (Zone 1) and below the traffic pan (Zone 2). The potential importance of the deeply distributed reservoir of nematodes and their effects on subsequent plant growth are now being considered within the testing phases of new deep shank and subsurface drip application technologies for soil fumigants. These new systems are expected to improve fumigant penetration, overall nematode control and crop yield response consistency. Our results suggest that nematode damage potential to a given crop occurs from migrating individuals from soil depths below which fumigants distribute. Based on these findings, we believe we have identified the root causes of yield and nematode control inconsistencies associated with the alternative fumigants, and have the new technologies under evaluation which can help resolve these problems.

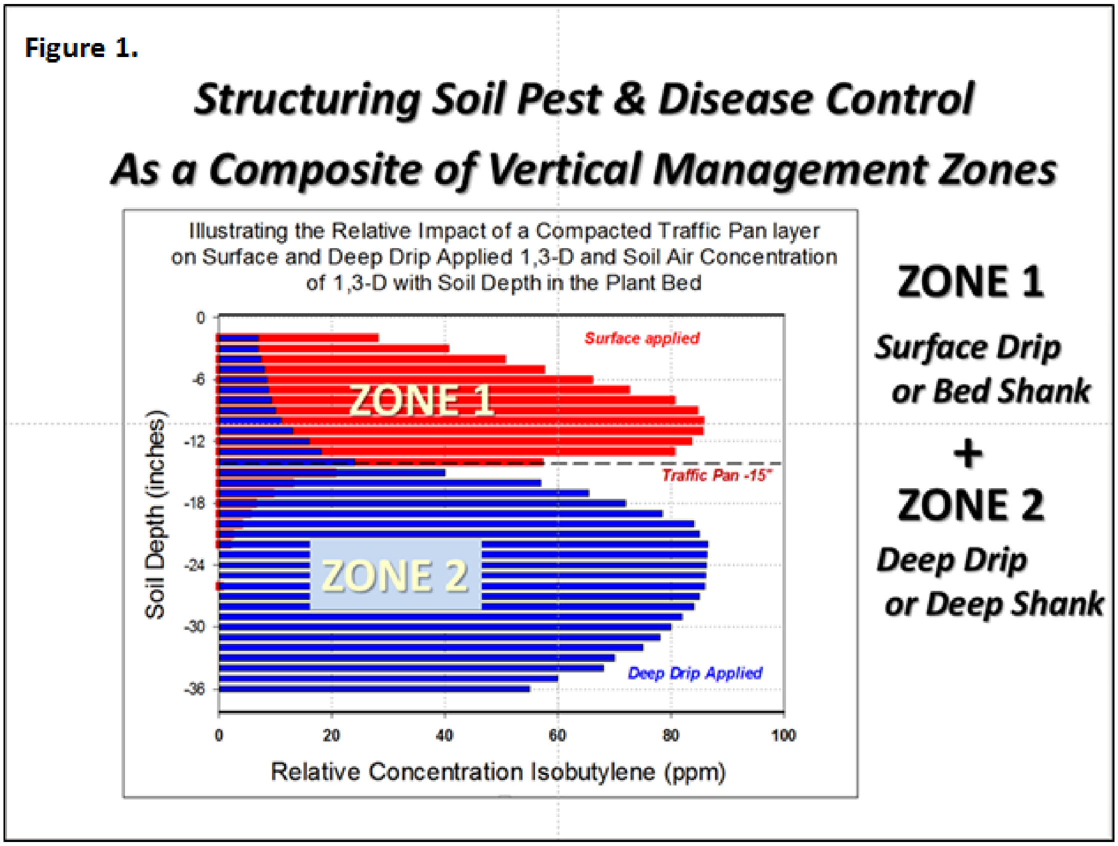
Figure 1.
Structuring Soil Pest & Disease Control
As a Composite of Vertical Management Zones
Illustrating the Relative Impact of a Compacted Traffic Pan layer on Surface and Deep Drip Applied 1,3-D and Soil Air Concentration of 1,3-D with Soil Depth in the Plant Bed
Surface applied
ZONE 1
Traffic Pan -15"
ZONE 2
Deep Drip Applied
Soil Depth (inches)
Relative Concentration Isobutylene (ppm)
ZONE 1
Surface Drip
or Bed Shank
+
ZONE 2
Deep Drip
or Deep Shank


FIGURE 2 : NEW TECHNOLOGY for DEEP APPLICATION
Many Thanks Jerry Nance Dow AgroSciences
Auto Reset – Deep Drip
Auto Reset - Deep Shank w/ Wings