New Technologies to Study the Spatial Distribution and Management of the Sting Nematode in Florida Strawberry with Soil Fumigants

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The sting nematode is the most economically important nematode pest of strawberry in Florida. In recent years, none of soil fumigants including formulations of methyl bromide and chloropicrin (50/50) have consistently provided season-long protection from the sting nematode, *Belonolaimus longicaudatus*. In many of these fields with reoccurring problems with Sting nematode, additional fumigant treatment including spring crop termination and summer broadcast applications of 1, 3-D (Telone) have been used to mitigate the sting nematode problem. New problems with sting nematode have continued to emerge however. In order to determine the cause for such poor and inconsistent crop performance after soil fumigation with a variety of individual and coapplied soil fumigants, field surveys were conducted of sting nematode problem fields. In a survey of 8 bedded fields, a compacted zone (traffic pan) was observed to occur just below the base of the raised bed. In this field survey, soil profile differences in physical characteristic, soil texture and penetration resistances were all demonstrated to impact patterns of nematode field distribution, plant damage, and soil fumigation efficacy. The presence of subsurface traffic pans (a dense, highly compacted soil layer), was also shown to unavoidably cause changes in hydraulic conductivity, permeability to fumigant gases, and root penetration into soil. In practical terms, the compaction zone occurs just below the depth of the deepest tillage operation or implement used in the field. Previous research has demonstrated that unless completely destroyed by deep ripping or subsoiling prior to soil fumigant injection, the presence of an undisturbed soil compaction layer restricts downward diffusion in soil of 1,3-D when applied above the restrictive layer. New technologies such as the deep core soil sampling system developed and operationalized by Dr. David Wright, University of Florida, Quincy, FL were needed to continue the study of the spatial distribution and management of the Sting with soil fumigants.

The objectives of the studies reported herein were to evaluate a new deep coring, soil sampling system (**Figure 1**) capable of removing a 4 inch diameter by 40 inch soil core using a specialized probe and hydraulic ram system tractor mounted as a 3 point attachment. The Probinator (A), a hydraulically operated deep soil probe which is being used to study the depth distribution of nematodes, spatial movement of soil fumigants from their points of emission, and to identify causes of fumigant treatment inconsistency and origins of bed recolonizing populations of nematodes.

Materials and Methods: The new Probinator system is being used to collect monthly census samples for soil population density and depth distribution of the Sting nematode, *Belonolaimus longicaudatus*, observed within 1 foot soil increments at the Florida Strawberry Growers Research and Education Foundation Farm (FSREF) Dover, FL. June 2014 data reported here derive from soil samples procured from an overall depth of 3 feet, from uncovered fallow, stale beds. For each sampling date, 8 replicate samples were randomly collected from the field and means and standard error computed for depth comparisons. Additional soil samples for nematode population density determination were collected from the David Barber Farm, Plant City, FL. Soil cores were again collected from 8 random locations within the bare fallow field on June 26, 2014. Following the previous strawberry crop, a drip fumigation treatment with Telone EC (18 gpa) was applied as a crop termination treatment to reduce Sting and Root-knot nematode populations which had severely damaged the crop in this field.

The Probinator was also trialed in spring experiments during 2014 to evaluate the diffusion of 1,3 dichloropropene fumigant gases throughout the surface to 36 inch soil depth. In the first experiment, Telone EC (12 gpa) was applied on April 2, 2014 as a drip fumigant to terminate the strawberry crop which had been severely damage by the Sting nematode. In the second fumigation experiment, Telone II (18 gpa) was custom applied using deep ripper shanks spaced on 12 inch spacing to a depth of 15 inches. Following shank application, the soil was rolled to establish a soil seal over the shank trace to minimize premature escape of fumigant gases.

As indicated, the sampling platform and hydraulic cylinder used to drive the soil probe into soil was built and mounted on a steel frame attached at 3 points to the rear of a tractor, with the soil probe raised and lowered using tractor supplied hydraulics. During the sampling operation, 4 inch diameter cylindrical soil cores were separately acquired using a hydraulically raised and lowered coring probe at replicate and center locations on the plant bed for drip fumigations or between adjacent ripper shanks for summer broadcast application to a depth of 15 inches. Each soil core, collected intact to a soil depth of 36-40 inches, was typically subdivided into 12 inch increments for nematode population density determinations and into 4 inch soil increments for monitoring fumigant gas concentrations in soil air with depth. After drip and or deep shank fumigant application, distribution of 1, 3-dichloropropene gases always proceeded from the bottom of the probe upwards to the soil surface using a MiniRae® 2000 PID VOC meter. For these two field studies, mean VOC concentrations for each fumigant treatment and depth location were averaged from 8 random measurements from each experimental field location. For these studies, peak concentration measurements from the MiniRAE 2000 over a 30 second sampling period were used to characterize soil atmosphere gas concentrations, retention characteristics of fumigants over time, as well as relative differences in vertical, gas phase movement of the fumigant with time. For most field locations, fumigant concentrations were monitored until soil disappearance (typically 5-7 days).

RESULTS: The nematode assay results from soil census sampling at FSGREF from the fallow, stale (uncovered) beds showed that Sting nematodes could be detected at low levels to a depth of 36 inches from the soil surface (**Figure 2**). Highest nematode population densities were observed immediately below the traffic pan in the 13 to 24 inch soil depth category. Soil population density and depth distribution of the Root-knot nematode *Meloidogyne hapla* within the same 12 inch soil increments at the DB Farm in Plant City, FL is illustrated in **Figure 3**. The results from these samples show the absence of nematode in the surface 12 inches of soil following a Telone EC crop termination treatment in April 2014 and after a 2 month bare fallow period (**Figure 3**). Surprisingly, highest populations of Root-knot nematode were observed the deepest soil depth of 25 to 36 inch soil depth. It would appear the *M. hapla* migrates to deeper soil during the summer months.

Comparison of 1, 3-D gas concentrations (estimated by isobutylene) in soil strata above and below the 14 inch traffic pan at the MB farm is illustrated in **Figure 4**. At 3 days post application, highest 1,3-D concentration were contained within the covered plant bed, with concentration diminishing toward the plant holes within the plastic at the surface. Very low soil air concentrations were observed below the traffic pan positioned at a 14 inch soil depth below the top crown of the 12.5 inch raised plant bed. These data would strongly suggest only very limited movement Telone EC in the water phase or as gas diffusion through the highly impermeable traffic pan. An example of typical fumigant concentrations in soil air observed above and below a compacted strawberry traffic pan shortly after drip or shank application of the bed to a soil depth of 8 to 12 inches is illustrated in **Figure 5**. The 14 inch traffic pan forms a very effective impermeable layer to gas diffusion defining the fumigant treated zone as primarily the plant bed and not penetrating to the deep soil profiles where nematodes reside. Similarly, 1,3-D concentrations with the shank trace and midway between ripper shanks to a depth o f36 inches is presented in **Figure 6**. These data would suggest that highest 1.3-D soil air concentrations occur at or near the 15 inch depth of application. Very little of the gas diffuse either laterally or into deep soil below the injection depth and that the majority of soil gases move up and out of the bed via the poorly sealed shank trace. These results appear to demonstrate that not all growers may benefit from deep shank application methods that destroy the gas impermeable traffic pan because of the rapid escape of gases up the improperly sealed shank trace. These observations suggests that the search for new factors contributing to fumigant inconsistency must continue.

KEY POINTS:

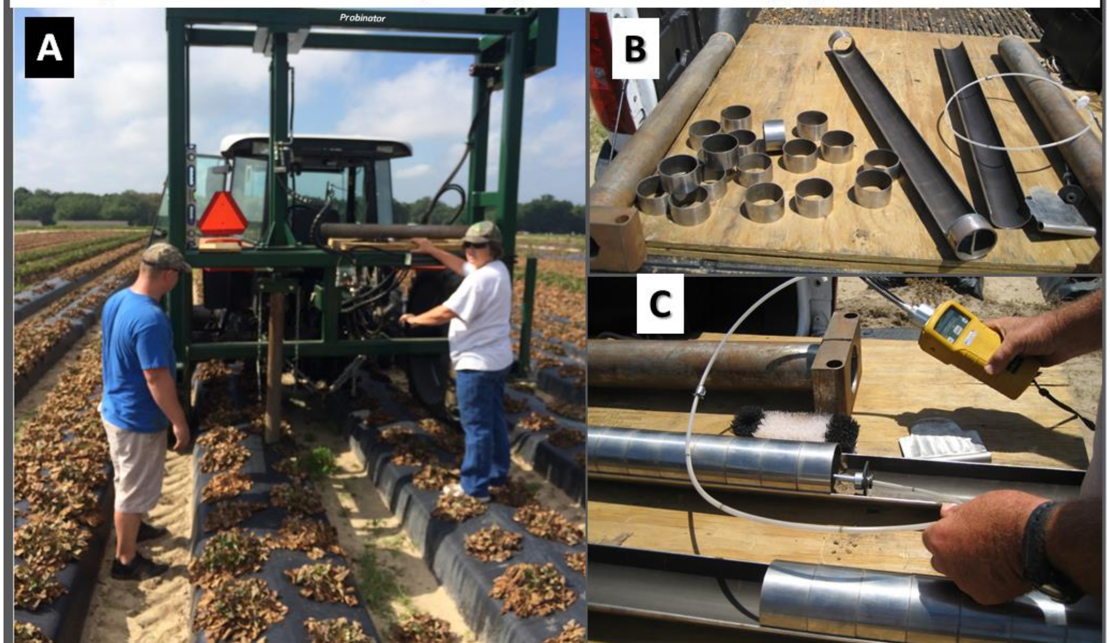
- Incremental analysis of the soil cores with soil depth was critical to characterizing the spatial dimensions of nematode and fumigant gas movement.

- As a prebedding operation, deep shank applications to the flat significantly (P=0.05) improved gas distribution and observed peak concentration of 1,3-D soil air concentration to the depth of application, but unless the shank traces are compressed and properly sealed, gas movement appears to be primarily upwards and out of the bed from the depth of application.

- These results suggest that new, even deeper application and sealing methods will be required to force fumigant movement deeper in soil to improve overall nematode control, particularly in deeper soil horizons, and also improve crop yield response consistency.

- Further evaluations of the seasonal population dynamics and depth distribution of both nematodes as well as fumigant application methods will not only provide season long nematode control but improve overall strawberry crop response.

Figure 1. The Probinator (A), a hydraulically operated deep soil probe (B) used to study the depth distribution of nematodes, spatial movement of soil fumigants (C), and to identify causes of fumigant treatment inconsistency and origins of bed recolonizing populations of nematodes.



http://www.crec.ifas.ufl.edu/extension/saap/videos/video.zip

Figure 2. Soil population density and depth distribution of the Sting nematode, *Belonolaimus longicaudatus,* observed within 1 foot soil increments at the Florida Strawberry Growers Research and Education Foundation Farm Dover, FL. Soil samples procured from an overall depth of 3 feet, from uncovered fallow, stale beds. Data represent the means and standard error of 8 replicate samples.

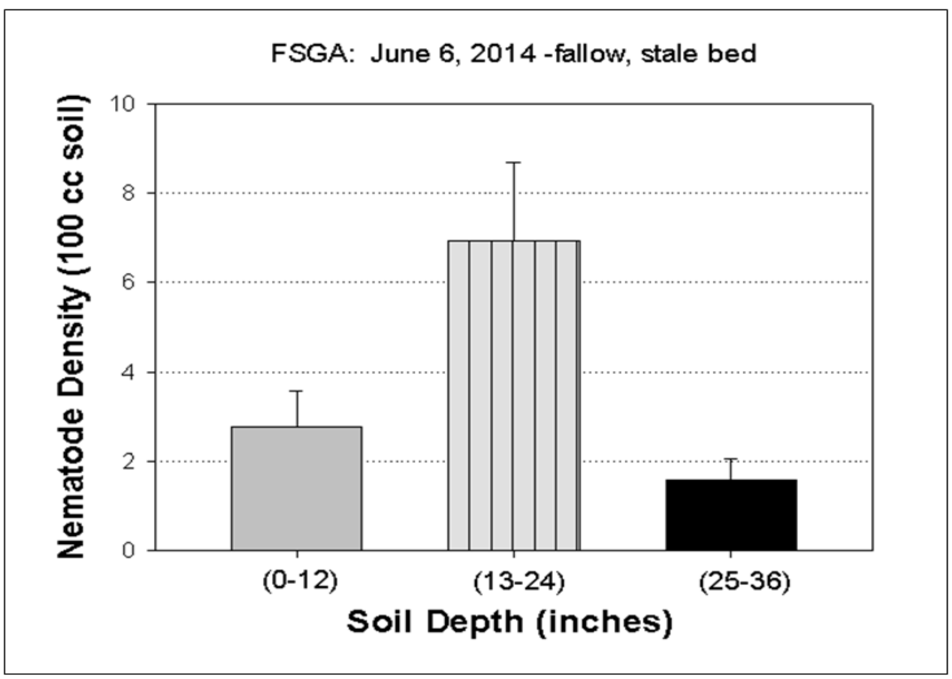


Figure 3. Soil population density and depth distribution of the root-knot nematode, *Meloidogyne hapla,* within 1 foot soil increments at the DB Farm, Plant City, FL. Soil samples procured to an overall soil depth of 3 feet following crop termination-drip fumigation treatment (April) and two month period of bare summer fallow. Data represent the means and standard error of 8 replicate samples.

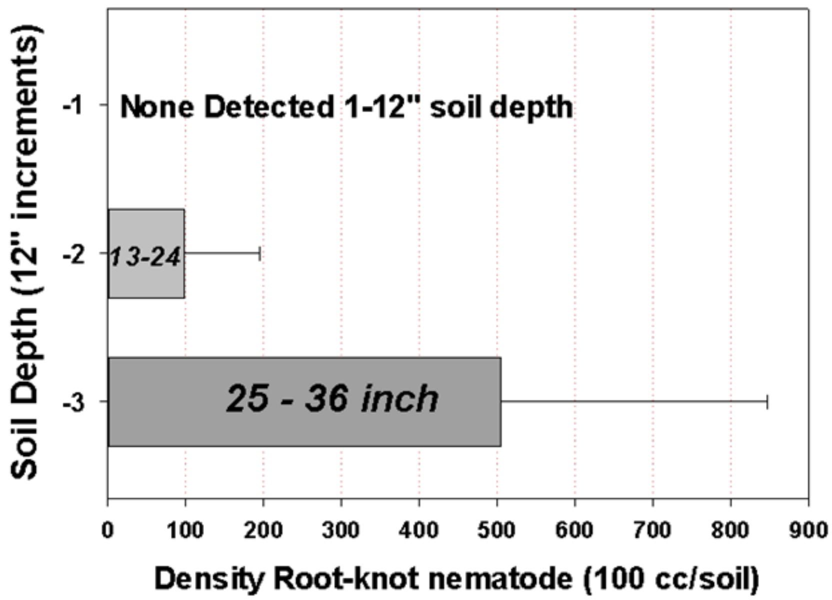


Fig. 4. Concentration Isobutylene in soil strata above and below a 14 inch traffic pan. Soil air measurement obtained thru center of a $12^{1/2}$ " raised, mulch covered bed 3 days post application Telone EC (12 gpa). Data points are means & S.E. 8 reps MB farm, Dover, FL

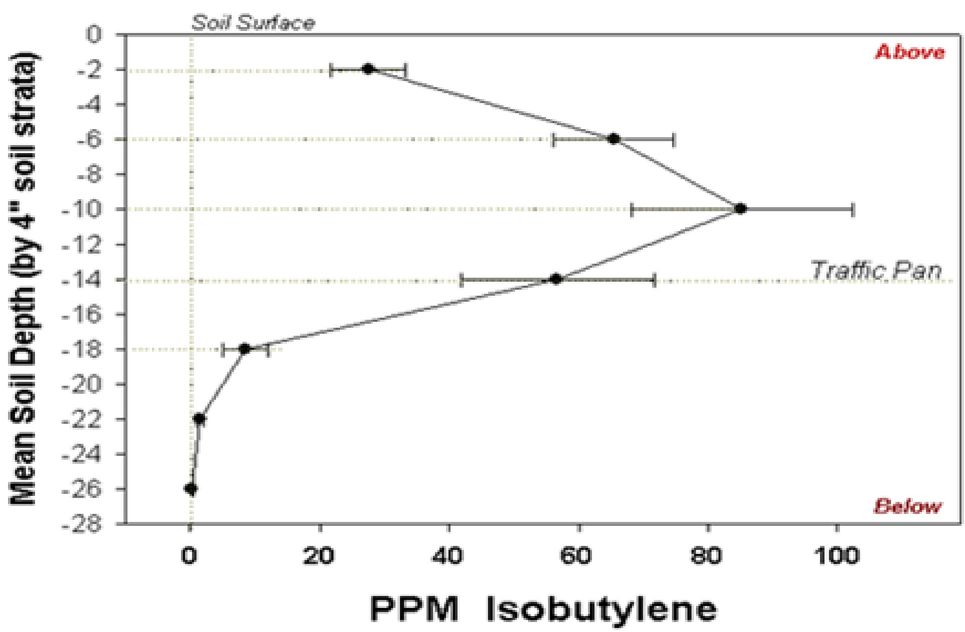


Figure 5. Illustrated example of typical fumigant concentrations in soil air observed above and below a compacted strawberry traffic pan shortly after drip fumigation or shank injection to a soil depth of 8-12 inches. Thecompacted traffic pan acts as a very effective impermeable layer to fumigant gas diffusion into deep soil profile.

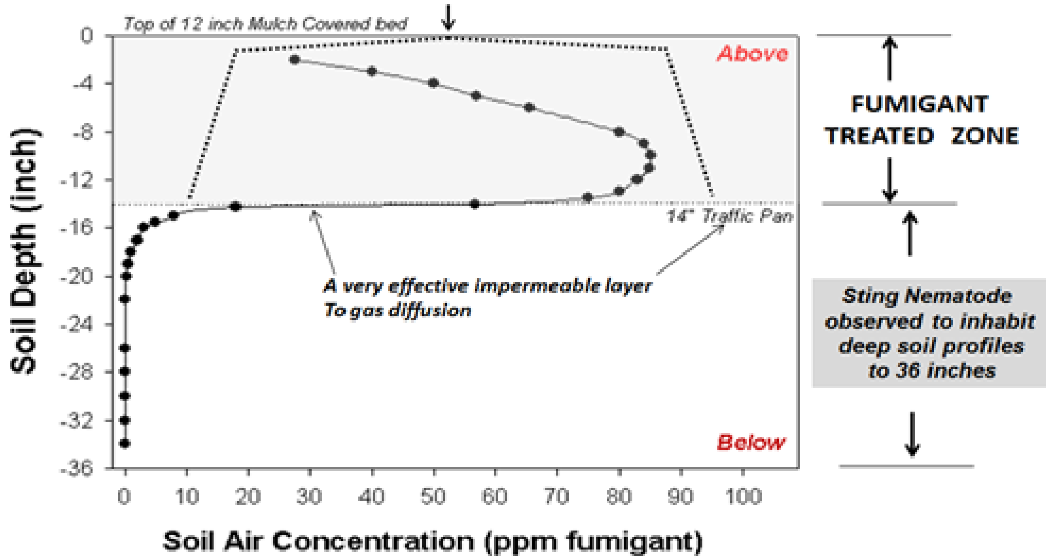


Figure 6. Fumigant Gas Concentration within the Shank Trace and midway between ripper shanks to a soil depth of 36 inches. Telone II fumigant broadcast and deep ripper shank applied (18 gpa) to a 15 inch soil depth. Datapoints are means and standard errors of 4 replicate observations. Plant City, FL. 1 DAA - July 12, 2014