ASSESSING STING NEMATODE IMPACT AND SOIL FUMIGANT PERFORMANCE USING MEASURES OF STRAWBERRY CANOPY GREENNESS 2014-15

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In Florida, the Sting nematode (Belonolaimus longicaudatus) infests an estimated 40% of strawberry acreage. Any loss of nematode control typically results in a higher incidence of plant stunting in the field. For purposes of justifying necessity of fumigant treatment, some record of strawberry yield in combination with an end of season assessment of nematode distribution and stunted plants within the field would be required. Previous research using or of an analysis of hyperspectral reflectance data from strawberry canopy providing estimate of strawberry yield loss and distribution of nematode stunted plants. Strawberry field research to support the use of these technologies for nematode crop loss assessment within Florida strawberry industry has been well documented within the annual conference and Proceedings Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions for many years. Reports within these proceedings repeatedly indicate that plant stunting and yield losses by the Sting nematode were well correlated with final harvest soil population density of the nematode. Ground truth surveying of crop yield impacts have repeatedly demonstrated the accuracy of in-field, remotely sensed hyperspectral reflectance information using GreenSeeker® (Trimble Navigation Limited, 935 Stewart Drive, Sunnyvale, California 94085). In these previous studies, strawberry yields from commercially hand harvested large plots were well correlated with relative yield values determined from plants of different sizes within the plots. For studies reported herein the experimental objective were to 1) compare strawberry yields determined from commercial harvest of fumigant treated plots with NDVI (Normalized Difference Vegetation Index) using GreenSeeker®, a plant reflectance optical sensor measuring canopy cover; and 2) to relate differences in NDVI to surrogate measures of canopy cover using digital imaging and greenness analysis to provide a quantitative measure of strawberry yield.

Methods: Two grower field studies focused on a co-application approach of different fumigants, herbicides, and other alternative tactics to achieve pest control efficacy and crop growth response similar to that of methyl bromide. Among the sites, chisel applied soil treatments included broadcast equivalent methyl bromide (67%) chloropicrin (33%) (350 lb/ta), methyl bromide (50%) chloropicrin (50%) (350 lb/ta), Telone C35 (35 gpta), Telone C35 (35 gpta) plus a deep shank (15 inches) Telone II (18 gpta), Pic Clor 60 (300 lb/ta), Paladin (DMDS 79%) plus Chloropicrin (21%) (40 gpta), Paladin (DMDS 79%) plus

Chloropicrin (21%) (25 gpta), Trifecta (44% DMDS, 33% Chloropicrin, 23% 1,3-d)(300 lb/ta) in addition to five drip applied fumigants including metam potassium (as KPam, 60 gpta), allyl isothiocyanate (AITC)(Dominus 25 gpta); Paladin EC (DMDS 79%) plus Chloropicrin EC (21%) (40 gpta); Dominus (67%) plus 33% Chloropicrin (325 and 400 lb/ta), propylene oxide (67%) plus Chloropicrin (33%) (400 lb/ta) and propylene oxide (40%) plus Chloropicrin (40%) plus Telone II (20%) (400 lb/ta); at the Florida Strawberry Growers Association (FSGA) Research and Education farm in Dover, FL (**Table 1**). At all field locations, the highly gas retentive Pliant VIF Blockade or Raven Industries Vaporsafe® TIF was installed immediately after Paladin, Dominus, methyl bromide chloropicrin or propylene oxide. All fumigants were applied with commercial grower equipment. Calibration procedures were followed at each experimental location. Certified applicators and pesticide label requirements for buffers, posting, rates of use, and personal protective equipment requirements were closely followed.

For the FSGA studies, digital imaging and multispectral reflectance were used to characterize plant stunting and strawberry yield losses to within row, green vegetative cover. A tractor mounted GreenSeeker® (Trimble Inc., Sunnyvale, CA) optical sensor was used to scan strawberry rows to provide estimates of green canopy cover (NDVI) against a backdrop of black plastic mulch covering the raised bed. Strawberry yields from each treatment replicate plot was then statistically compared with NDVI, and both values used to independently compare differences between various soil fumigant treatments and commercial strawberry fruit harvests conducted on a 2-3 day schedule over a December to April harvesting season. Close-up, geo-referenced, digital photographs of the strawberry bed were also automatically and systematically collected at preset separations along the plant row from a boom mounted USB camera. Close up visual evaluation of individual images after downloading to computer monitor quickly demonstrated a variety of quality defects including washouts (overexposure), interior shading of green vegetative tissues (under exposure), bed shading from the camera boom extending over the plant row, as well as images which included off-target areas of the row middles due to changes in camera alignment in the plant row. Digital images were also collected from a compact digital camera operating in 30 Hz video mode. Camera image greenness and Greenseeker NDVI were then compared using regression analysis with and without regard to digital image quality. Percent green ground cover for each image was measured using green pixel counts using the image analysis tools of SigmaScan Pro 5 (Systat Software, Inc., San Jose, CA).

Results: Accurate maps of fumigant treatment performance, GPS location, and sting nematode stunting severity of strawberry plants was visually and statistically well described by NDVI field mapping at FSGA (**Figure 1**). In general, severe stunting of strawberry plants were linearly expressed usually along the entire length of most 2 row plots within the propylene oxide and untreated control treatments. Strawberry yields (**Figure 2**) from commercially hand harvested large plots (lb /220 linear feet of row) were well correlated (r^2 = 86%) with NDVI field assessment for each different fumigant treated plot (**Figures 3**). These results again illustrate how NDVI can be quantitatively used as a numerical indicator of strawberry yield derived from measurements utilizing the GreenSeeker®, a plant reflectance optical sensor measuring canopy cover. No meaningful differences (P=0.05) in strawberry yield or NDVI were observed between the different drip and shank applied fumigants including different formulations, application rates, and types of plastic mulch films used with methyl bromide chloropicrin, Telone C35, Pic Clor 60, or of DMDS (**Figure 2, 3, 4**). Significant differences (P=0.05) in strawberry yield, canopy cover expressed by NDVI were observed between these fumigant treatments and the untreated control treatments in Dover, FL during 2014-15.

Even though image quality was quite poor, percent vegetative cover computed from green pixels within color digital images was still very descriptive of NDVI, explaining 75% or more of the variation between the two parameters. Regression analysis using images which minimize boom or interior shading, washout, or images which include large portions of the row middle (off center) removed much of the variation and improved descriptive capability to 91%. Overall, field scale changes in strawberry crop productivity due to sting nematode and chemical treatment were again effectively determined from post-harvest assessments using NDVI measurement and simple counts of green pixels from digital color images. The NDVI methodology is currently being used to provide growers guidance and quantitative performance data on alternatives to methyl bromide soil fumigation for nematode management. Accurate maps and assessments of fumigant treatment performance, GPS location, and sting nematode stunting severity of strawberry plants was well described by digital imaging and NDVI field mapping of experimental fields. These results illustrate how digital imaging and greenness analysis can be used in lieu of NDVI to provide a quantitative measure of strawberry yield and to provide growers guidance on suitable alternatives to methyl bromide soil fumigation for nematode management. We are also confident that the USB cameras will add value to automated field surveys of differences in strawberry canopy size, disease and insect feeding damage, and may eventually serve as real-time sensors for on-the-go smart spraying in Florida strawberry.

Key Points: Lessons learned and Problems to Resolve:

- ***A tarp is required to eliminate the shadow from the camera boom and to minimize washout from intense incident light.***
- ***Supplemental lighting is required to illuminate camera view of the plant bed below to minimize interior shading within the strawberry plant canopy***
- ***Orientation and centering of camera view over bed center is critical.***
- ***Calibration of color settings and exposure prior to and during mapping is critical.***
- ***Processing images in real time is required to make computerized decisions for smart-spraying.***

Table 1. Fumigant treatment list for the Florida Strawberry Growers Research and Education Foundation Farm, Dover, FL. Fall 2014

1.	MBr + PIC 67/33 (350 lb/ta)	SHANK	+ TIF VaporSafe	1 tape	4 reps
2.	MBr + PIC 50/50 (320 lb/ta)	SHANK	+ TIF VaporSafe	1 tape	4 reps
3.	Telone C35 (35 gpta)	SHANK	+ LDPE	1 tape	4 reps
4.	Pic-Clor 60 (300 lb/ta)	SHANK	+ LDPE	1 tape	4 reps
5.	DMDS + PIC (40 gpta)	SHANK	+ TIF Vaporsafe	1 tape	4 reps
6.	DMDS + PIC (25 gpta)	SHANK	+ TIF Vaporsafe	1 tape	4 reps
7.	DMDS+PIC+Telone II (TE3)(300 lbs/ta)		+ TIF Vaporsafe	1 tape	4 reps
8.	DMDS EC+PIC (40gpta)	DRIP	+ TIF Vaporsafe	1 tape	4 reps
9.	Kpam (62 gpta)	DRIP	+ LDPE	1 tape	4 reps
10.	Dominus + PIC (400 lb/ta)	DRIP	+ LDPE	1 tape	4 reps
11.	Untreated	--	+ LDPE	1 tape	4 reps
12.	Telone C35 (35gpta) +deep Drip Telone II (18gpta)	SHANK	+ LDPE	1 tape	4 reps
13.	Dominus (25 gpta)	DRIP	+ Blockade	1 tape	4 reps
14.	Dominus+PIC 67/33 (325 lb/ta)	DRIP	+ Blockade	1 tape	4 reps
15.	PO + PIC (67/33) (400 lb/Ta)	SHANK	+ Blockade	1 tape	4 reps
16.	PO+Telone+PIC (40/40/20)(400lb)	SHANK	+ Blockade	1 tape	4 reps

16 treatments x 4 reps x 2 row plots = 128 rows x 240 ft /row

Figure 1. NDVI field analysis showing distribution of Sting nematode, *Belonolaimus longicaudatus*, stunted plants (red areas) at the Florida Strawberry Growers Association Research and Education Foundation Farm, Dover, FL. March 20, 2014. Strawberry canopy cover differences can be observed to the row among the different fumigant treatments evaluated within the large scale field trial.

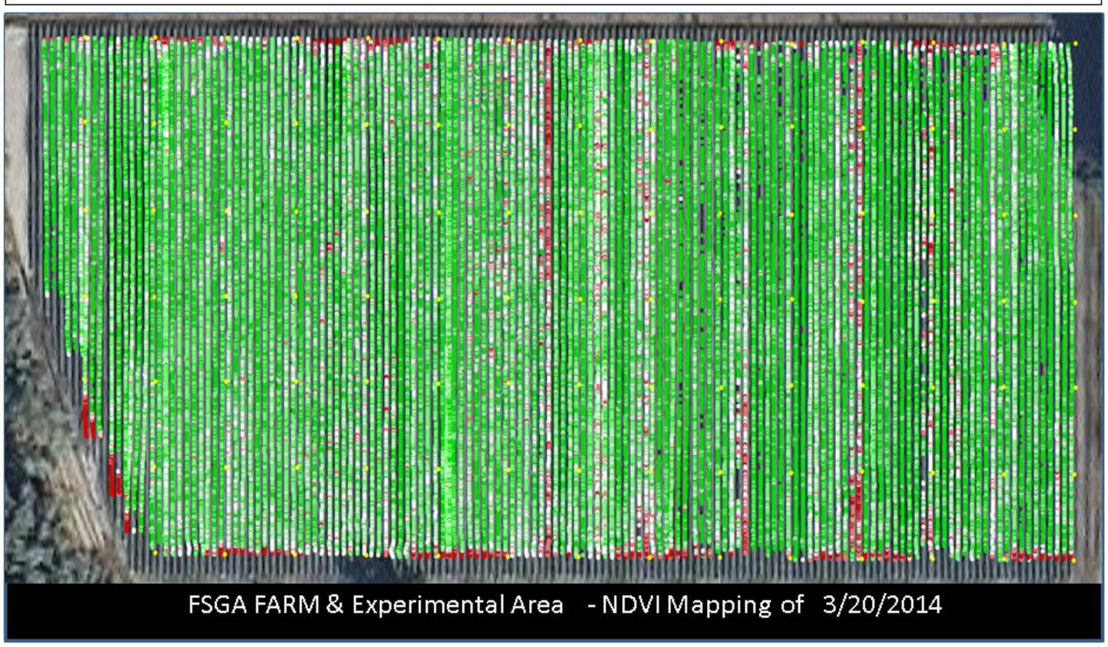


Figure 2. Strawberry fruit yields (lb/plot) for 16 different fumigants, rates of application, types of plastic mulch applied via shank or drip tape delivery at the Florida Strawberry Growers Association Research & Education Farm in Dover, FL during Fall 2014-Spring 2015. Treatments not followed by the same letter differ significantly P≤ 0.05) from one another.

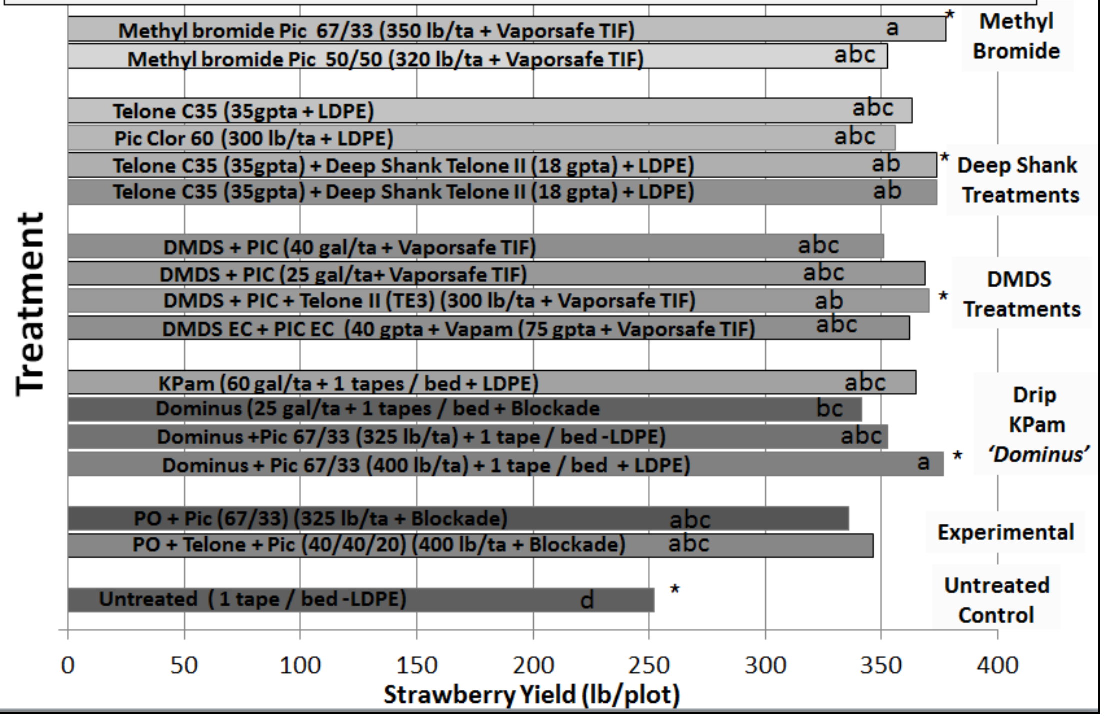
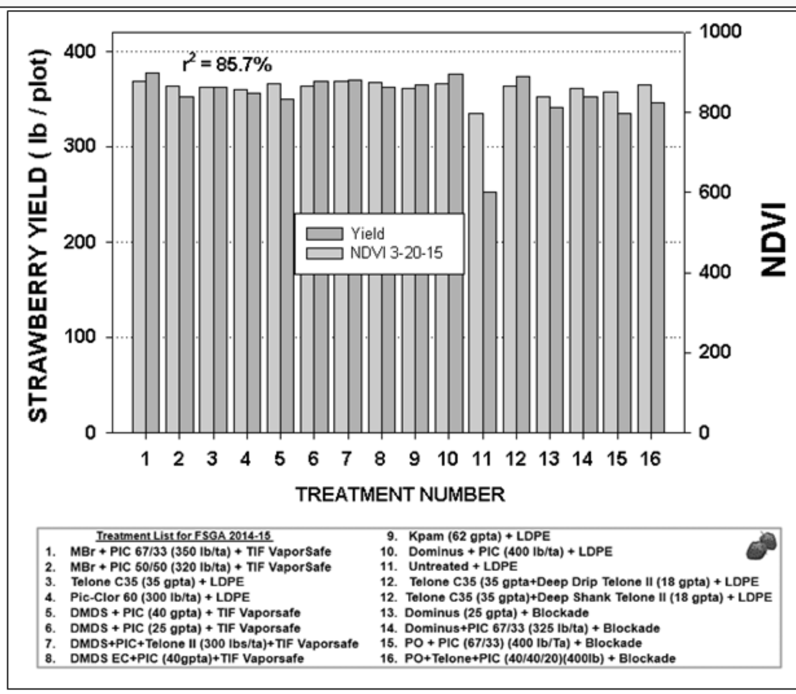


Figure 3. Comparison of mean strawberry yields (lb/plot) and NDVI assessments for 16 different fumigants, rates of application, types of plastic mulch applied via shank or drip fumigation delivery at the Florida Strawberry Growers Association Research and Education Foundation Farm in Dover, FL. NDVI assessment made March 3, 2015 to estimate treatment impact to yield.



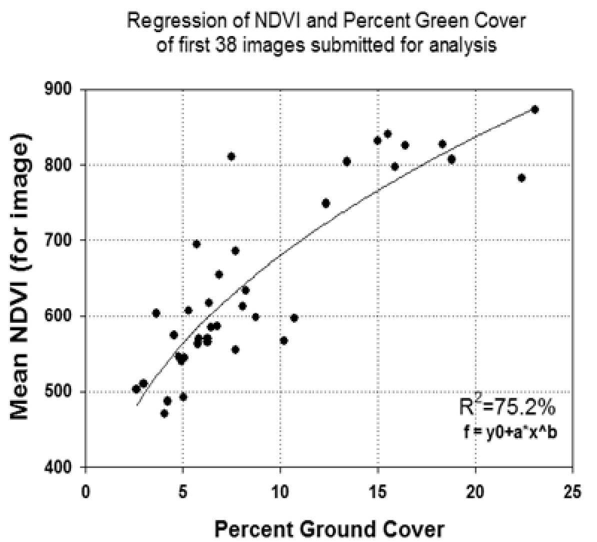


Figure 4. Regression Analysis and comparison of mean NDVI (Normalized Difference Vegetation Index) computed from individual images with Percent Ground Cover based on green pixel content without regard to image quality.

Figure 5. Regression Analysis of mean NDVI and Percent Green Ground Cover using images which minimize boom or interior shading , washout, or images which include large portions of the row middle (off center).