

Evaluation of fumigant and non fumigant nematicides in Florida strawberries

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Summary

All of the preplant fumigants we currently rely upon and utilize are not without liability or some kind of shortcoming of one sort or another (efficacy, label restriction, worker safety, emission reduction, odor, continued availability). The requirement for gas impermeable TIF mulches, fumigant management plans, and extensive buffers is currently limiting the use of some fumigant alternatives such as Kpam, Vapam, and Paladin (the latter was actually recently pulled from the US, and will no longer be evaluated in future years). It is possible and likely that in the future more grower constraints could be added to the current list of grower use requirements. Because of regulatory requirement and the uncertainties of continued availability of soil fumigants, California strawberry growers identified “Farming without Fumigants” as a research priority area as long ago as 2008. University, USDA, and California Strawberry Commission staff members have been conducting research on nonfumigant chemical and cultural practices to mitigate soilborne disease to help growers stay profitable and rely less on soil fumigants. This project has as a primary objective to further expand the evaluation of non-fumigant approaches and to evaluate the practicality of these methods in a large-scale, treatment-replicated, demonstration trial. Adoption of alternative chemical and supplemental fumigation strategies with these other nonfumigant IPM practices is likely to be expedited only if utility can be economically justified and appropriate guidelines and recommendations for nematode and disease control continue to be developed which minimize performance inconsistency and grower uncertainty. A summary of treatments and experimental objectives follows.

Methods

A single field study was conducted at the Florida Strawberry Growers Research and Education Foundation (FSREF) Research and Education farm in Dover, FL. Treatments are listed in **Table 1**. They include Telone C35, Pic Clor 80, as well as shank applications of Paladin Pic (79:21%) with and without deep shank applications of 1,3-dichloropropene (Telone II™; 12 gpta) or Paladin to a depth of 15 inches. Kpam (62 gpta) was evaluated along with the new nonfumigant nematicide Nimitz (Fluensulfone). An untreated control with and without the deep shank Telone II™ (18.4 L/ha) treatment will also be included for comparison to demonstrate the benefit of the deep shank only treatments. Treatments new to the program in their second year of evaluation include minicoulter applications of KPam as supplemental treatments with Telone C35 and Pic Clor 80 for enhanced control of weeds and charcoal rot.

All treatments will be arranged within their respective experimental areas as a completely randomized block design with 4 replications per treatment. Plot size will be 2 rows -approximately 240 feet long, or 0.05 acres per plot. An untreated control is included as a replicated treatment for comparison.

NonFumigant Nematicidal Compounds (Treatments 8,9,12,13): Further, field scale evaluation of new nonfumigant nematicidal products such as **Nimitz** (Fluensulfone) in both drip and spray boom incorporated application methods, preplant and postplant applications of the new nematicide Velum (Fluopyram), and the utility of biological nematicides such as Majestene, Dazitol, Nemakill, and or Meloncon will also be considered.

Chloropicrin Use Rates: This year, like last, marks a continued research focus on evaluating an increased use rate of Chloropicrin to manage *Macrophomina phaseolina*

(Charcoal rot) disease incidence and severity. Treatments in this third year of evaluation will now only include Telone C35 (85 lb Pic/a) and Pic Clor 80 (160 lb Pic/a), using the two different formulations of Telone and Chloropicrin and the scaling of the different use rates per acre of Telone and Chloropicrin. The differing formulations being evaluated will allow evaluation of increasing the chloropicrin use rates to determine whether both Sting nematode and Charcoal Rot, caused by *Macrophomina phaseolina* can be effectively managed simultaneously.

Vertical Management Zones: This research project will also continue to evaluate new deep shank and deep drip supplemental fumigation strategies within different vertical management zones to control the Sting nematode, *Belonolaimus longicaudatus*. A new, more durable and ridged Netafim drip tubing was installed in 2017 to compare deep drip treatments with the deep shank application method. This research will also continue the 2nd year of evaluation of Paladin® (Dimethyl disulfide, DMDS) in combination with chloropicrin using TIF with and without deep shank Paladin. The deep shanking Paladin work needs to be continued into a second year of research to determine the value and benefit of the deep shank application but also to establish whether Paladin provides a viable alternative to Telone II in the event severe shortages of the Telone product occur in the future as they have previous years. Unfortunately, we recently learned that Paladin will be withdrawn from the US, so the studies reported here will be the last ones.

For all of the fumigant and nonfumigant treatments, a highly gas retentive totally Impermeable film (TIF) will be installed immediately after fumigant application (see **Table 1**). All fumigants will be applied with commercial grower equipment (Florida Ag Research) and calibration procedures followed for each fumigant applied. Certified applicators and pesticide label requirements for buffers, posting, rates of use, personal protective equipment requirements, etc., will be closely followed. Drip fumigants will be applied via specifically designed and constructed manifolds to ensure appropriate concentration and product distribution among replicated plots within the field. Florida Ag Research will be largely responsible for providing adequate quantities of fumigants, Netafim drip tape, and LDPE, VIF, and TIF plastic mulch which will be

required to compare alternative strategies on a small, but replicated field scale basis.

Beds will measure 30 inches wide, 10 inches in height, with rows spaced on 4 foot centers. Actual per acre fumigant use rates represent 62.5% of the broadcast or reported per treated acre (ta) rates expressed in **Table 1**. Bare root 'Sweet Sensation' transplants from Canadian nurseries will be planted between 4 to 5 weeks following fumigant treatment. Water and nutrients will be supplied to each plant row with Netafim drip tape (0.40 gpm/100 ft row) on at least a daily/ twice daily basis (unless sufficient rainfall occurs) for much of the season. Fertigation rates will be seasonally defined based on crop growth stage and university and grower recommendation. Fertilization rates will be generally based on a near field equivalent of 225 lbs NPK per acre per season. Other pest and disease control measures will be maintained primarily on both a prophylactic and as needed basis.

Data Collection: Assessments of plant growth will be made as appropriate during the course of the season to characterize differences in plant size, health, and vigor. Ground cover was measured weekly using a handheld GreenSeeker™ during the first four weeks of crop establishment.

Impact of each chemical treatment on nematode population densities within treated blocks also will be determined at planting, at mid season and at final harvest by collecting twelve soil cores 1 inch in diameter by 12 inches deep from the root zone of each replicate block, extracting the nematodes from them and counting them by genera. Disease incidence (i.e., Anthracnose, Charcoal root rot, etc.) and severity also will be visually determined and recorded at periodic intervals within each of replicate blocks by row and sprinkler section within each the different, chemically treated areas. Statistical analyses and treatment comparisons will be determined statistically using SAS ANOVA (t-Test comparisons) ($P < 0.05$).

Weed densities were also monitored and recorded on a periodic basis to determine any differences in weed control between fumigant treatments.

Strawberry fruit within each treatment replicate were commercially hand harvested on a 2-3 day basis from November 2018 to April 2019 for fruit yield comparisons by

Mr. Mike Lott and his designated field personnel. Strawberry yields will be expressed as lb/plot or lb/row, and the numbers of individual flats (8 lb/flat and 10,890 linear ft/a) determined. Yield information will derive from the inside planted rows of each 2 row 240 foot long plot. Harvested fruit will conform to all USDA size and grade standards.

Remote Sensing / Relative Strawberry Yield: In addition to hand harvesting of fruit, relative strawberry yields will also be estimated via assessment of strawberry plant sizes and using drone acquired digital imaging of strawberry plant canopy. The numbers of plants in four plant size categories will be systematically enumerated and recorded at 40 ft intervals in each row. For this assessment, plant size categories, measured as average canopy diameter, will be dead (0), small (<20 cm canopy diameter), medium (>20 and < 30 cm) and large (>30 cm). Using plant sizes, fumigant treatment evaluations based on relative yield will be determined from damage relationship developed from studies conducted previously in commercial fields with recurring histories of sting nematode problems. Digital field imaging technology will also be used to characterize and relate differences in relative strawberry crop yield (based on plant sizing) to within row, green vegetative cover. A Phantom 3 and or Phantom 4 Pro quad copter drone will be used to scan strawberry rows to provide estimates of green canopy cover. The new digital imaging technologies to scan strawberry rows will be used to estimate canopy density using greenness analysis against the black background of the plastic mulch to serve as a surrogate measure of NDVI and an independent assessment of plant stunting caused by the Sting nematode. Preliminary results from end of season comparisons of Relative Yield, NDVI, percent greenness analysis of digital images compared with hand harvest yields are very promising, and very well correlated with each other. The additional benefit derived from the camera digital images are that they can be archived for future reference and analysis, for example, directly interrogated for late season diseased induced mortality of strawberry

plants by *Macrophomina phaseolina*, causal agent of Charcoal rot. Cumulative differences in plant numbers and relative yield contribution within each plant size category will then be statistically compared with greenness, and the values used to independently compare differences between various soil fumigant treatments and will independently obtained commercial, hand harvest, yield estimates. Plant stunting and yield losses have also been determined to be very well correlated with final harvest soil population density of the sting nematode.

Results

Nematode populations were low throughout the test, and showed no difference among treatments throughout the season (Table 1). The dominant nematode was lesion nematode (*Pratylenchus* spp.) for which the pathogenic potential on strawberries in Florida has not been established. Sting nematode populations were low during the entire season. Plant vigor and ground cover data were significantly different among treatments (Table 2, 3; Fig. 4, 8, 9).

Nutsedge counts were higher in non-fumigated treatments (Table 3, Fig. 5).

Fruit yield responded well to fumigant treatments, and correlated well with canopy cover and crop vigor data (Fig. 7-11).

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Table 1. Nematode populations throughout the season

Treatment	Initial Nematodes per 200 mL Soil					
	Bacterial	Fungal	Omnivorous	Sting	Lesion	Spiral
1	17	19 ab	0	1	1	0
2	25	9 ab	1	1	4	0
3	46	11 ab	1	0	16	0
4	10	7 b	2	0	4	0
5	31	19 ab	0	0	5	0
6	43	32 a	1	1	11	0
7	34	5 b	1	0	2	0
8	34	11 ab	1	0	1	0
9	30	2 b	1	0	3	0
10	19	4 b	0	0	9	0
11	21	6 b	1	0	4	0
12	14	10 ab	2	0	3	0
13	21	7 b	1	0	5	0
14	10	7 ab	1	0	5	0
15	25	4 b	1	1	5	0
16	21	5 b	1	1	3	0
P-value	0.065	0.001	0.502	0.274	0.837	-

Treatment	Mid-Season Nematodes per 200 mL Soil					
	Bacterial	Fungal	Omnivorous	Sting	RLN	Spiral
1	111	34 b	2	2	8	4 ab
2	92	46 ab	0	3	17	2 b
3	163	52 ab	5	0	10	1 b
4	80	43 ab	0	3	17	6 ab
5	87	55 ab	0	1	4	2 b
6	111	124 a	2	1	18	8 ab
7	102	24 b	0	8	19	4 ab
8	92	19 b	3	1	4	12 a
9	163	17 b	1	1	19	2 ab
10	141	42 ab	0	2	41	5 ab
11	104	35 b	2	0	30	1 b
12	111	19 b	1	0	74	1 b
13	30	10 b	4	1	3	0 b
14	95	23 b	2	6	15	0 b
15	62	17 b	1	2	4	0 b
16	82	21 b	1	2	9	2 b
P-value	0.187	0.006	0.694	0.345	0.716	0.006

Treatment	End-of-Season Nematodes per 200 mL Soil						Lesion per g root
	Bacterial	Fungal	Omnivorous	Sting	RLN	Spiral	
1	124	13	0	0	63	43	20
2	69	7	0	0	91	7	14
3	87	19	0	1	56	8	18
4	125	23	0	0	58	32	33
5	91	9	0	1	24	29	43
6	89	5	0	0	41	6	9
7	112	10	0	2	54	11	22
8	115	9	0	0	75	9	18
9	93	12	1	0	34	11	11
10	116	23	1	4	64	10	14
11	88	5	0	2	27	7	23
12	147	11	0	0	26	1	38
13	107	7	0	0	44	0	3
14	124	23	0	2	122	2	11
15	124	7	1	1	50	6	7
16	72	1	0	4	44	0	16
P-value	0.675	0.137	0.605	0.729	0.504	0.273	0.623

Table 2. Plant vigor (NDVI) as measured with handheld GreenSeeker

Treatment	Plant Vigor (NDVI value)			
	23-Jan-19	8-Feb-19	22-Feb-19	8-Mar-19
1	0.78 ab	0.77 a-c	0.78 a-c	0.73 ab
2	0.78 ab	0.77 a-c	0.78 a-c	0.74 a
3	0.79 ab	0.76 a-d	0.79 ab	0.76 a
4	0.80 a	0.76 a-d	0.80 a	0.74 ab
5	0.80 a	0.78 a	0.81 a	0.75 a
6	0.81 a	0.81 a	0.80 a	0.77 a
7	0.76 a-d	0.77 a-d	0.77 a-d	0.71 a-d
8	0.79 a	0.75	0.77 a-d	0.73 a-c
9	0.78 a-c	0.78 ab	0.78 a-c	0.73 a-c
10	0.80 a	0.78 a	0.80 a	0.75 a
11	0.80 a	0.77 ab	0.80 a	0.76 a
12	0.71 de	0.66 e	0.70 de	0.64 cd
13	0.72 c-e	0.68 de	0.71 c-e	0.65 b-d
14	0.69 e	0.69 b-e	0.67 e	0.62 d
15	0.72 b-e	0.73 a-e	0.72 b-e	0.65 b-d
16	0.70 de	0.69 c-e	0.68 e	0.62 d
P-value	<0.001	<0.001	<0.001	<0.001

Table 3. Total Fruit yield, relative yield, nutsedge count, % greenness, and canopy cover

Treatment	Fruit yield		Relative	Nutsedge		Canopy
	Lbs/row	SE		(count)	(diameter)	Greenness
1	173.5	10.5	0.8622	16	95	68.5
2	165.25	4.96	0.8649	42	93	70.32
3	160.25	5.74	0.8828	14	94	71.613
4	182.5	14.8	0.8992	27	90	73.15
5	172.5	7.04	0.9253	46	93	74.272
6	159	3.03	0.9092	10	92	75.81
7	166.25	6.01	0.8735	4	95	70.31
8	147	5.45	0.8345	4	97	69.276
9	153.5	9.65	0.8225	3	94	67.38
10	178	3.65	0.911	24	90	70.43
11	157.25	7.2	0.8905	10	96	71.472
12	149.75	7.98	0.7314	315	68	57.313
13	150.5	8.49	0.7364	168	72	59.12
14	140.25	3.28	0.7388	334	59	57.91
15	149.3	12.5	0.7361	353	66	60.98
16	145.25	5.78	0.6866	271	63	57.351
P-value	<0.01		<0.01	<0.01	<0.01	<0.01

SE = standard error; harvesting data are from Jan 2 – Feb 23 (early harvest data not recorded)

Figure 1. List of treatments FSGA 2018 - 2019

TREATMENTS FSGA 2018-2019					
	Application Rate	Fume	Non Fume	Multi Tactic	Deep Shank
1 Telone C35	30 gpta	X			
2 Telone C35+Deep Telone II	30 gpta+12 gpta	X		X	X
3 Telone C35+Deep Telone II +KPam	30 gpta+12gpta+62gpta	X		X	X
4 Pic Clor 80	320 lb/ta	X			
5 Pic Clor 80+Deep Telone II	320 lb/ta+12gpta	X		X	X
6 Pic Clor 80+Deep Telone II +KPam	320 lb/ta+12gpta+62gpta	X		X	X
7 Kpam alone	62 gpta	X			
8 Kpam + Dazitol Majestene + Nemakill	62 gpta + the other treatments as needed	X	X	X	
9 Kpam + Velum	62 gpta+6.5 oz/a	X		X	
10 DMS+PIC	40 gpta	X		X	X
11 DMS+PIC + Deep Paladin	40 gpta	X		X	X
12 Nimtz+ Goal + Velum + Ridomil	5 pt/ta+2pt+6.5oz+1pt		X	X	
13 Nimtz + Nimitz-Deep + Goal + Velum + Ridomil	5pts/ta+ 2 pts/ta + 6.5 oz+1pt		X	X	
14 Untreated Control	-----				
15 Check + Deep Shank Telone II	12 gpta	X		X	X
16 Check + Deep-Drip-KPAM	62 gpta				

Advancing New Fumigant and Nonfumigant Tactics-ALL treatments utilized Berry TIF plastic.

Figure 2. Treatment Layout and Experimental Design. FSGA 2018 -2019

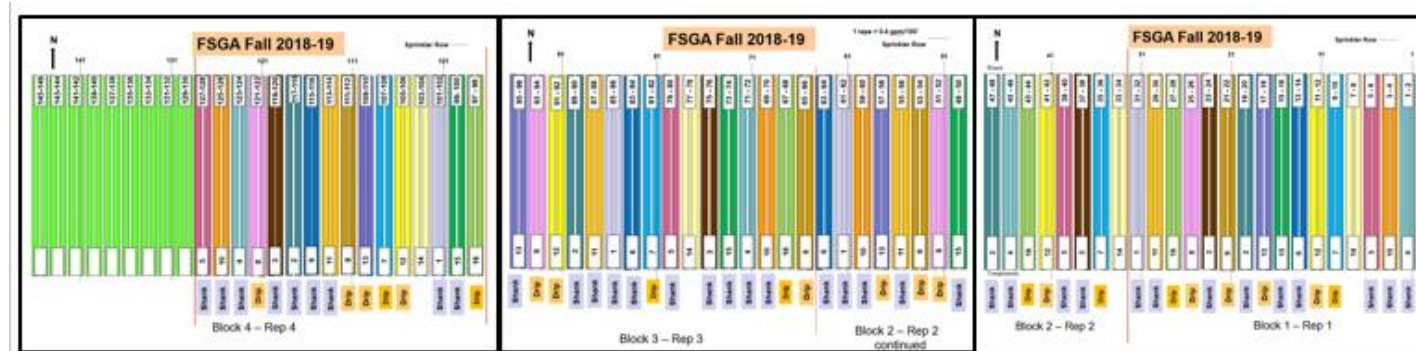


Figure 3. Treatment Application Dates and Rates of Application FSGA 2018 -2019

Figure 4. Early to Mid-Season Strawberry Canopy Growth and Convergence- FSGA 2018 -2019

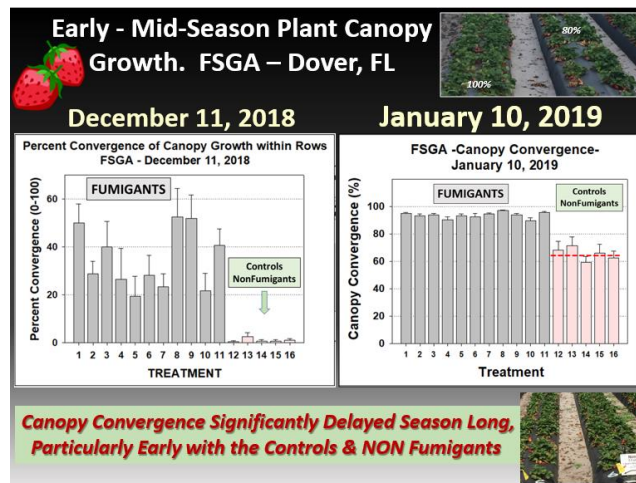
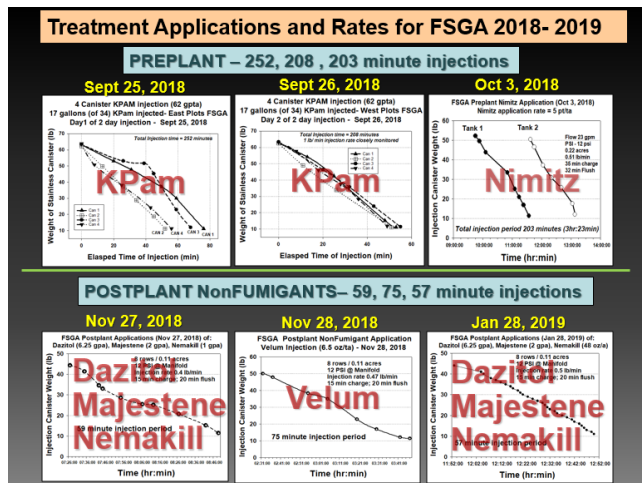


Figure 5. Fumigant and NonFumigant Weed Control:
Nutsedge as barometer. FSGA 2018-2019

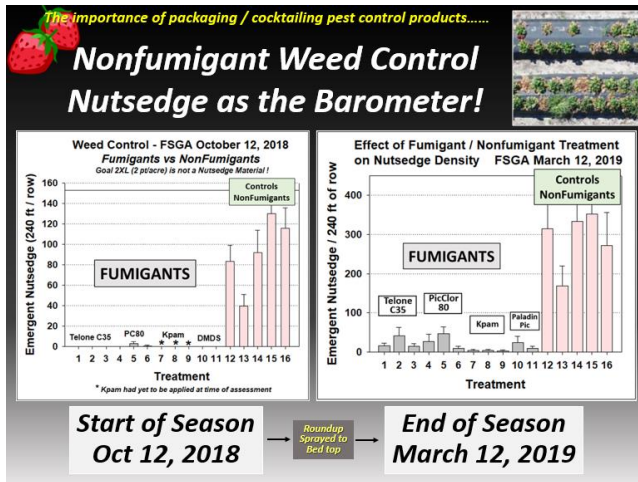


Figure 6. Fumigant and NonFumigant Strawberry Yield
(Flats per acre) FSGA 2018-2019.

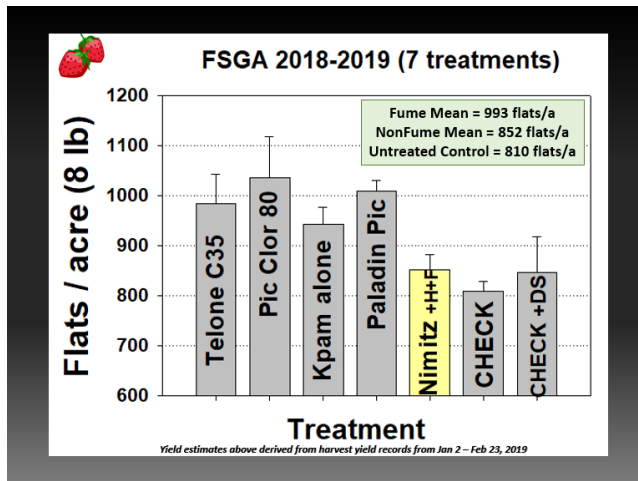


Figure 7. Fumigant and NonFumigant Strawberry Yield as a
percentage of control. FSGA 2018-2019.

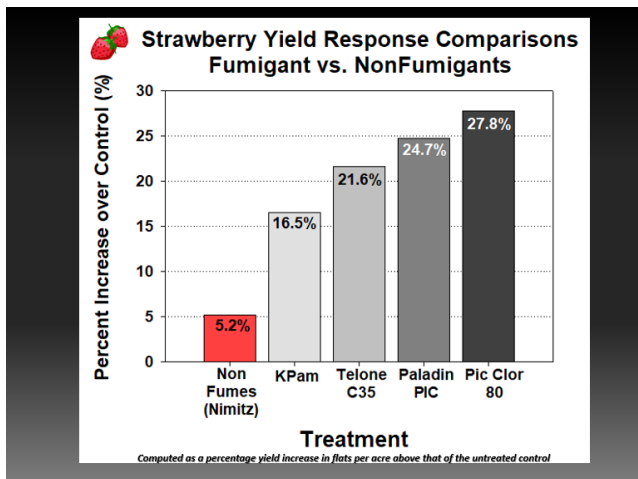


Figure 8. Fumigant and nonfumigant plant frequencies
among plant size categories. FSGA 2018-2019.

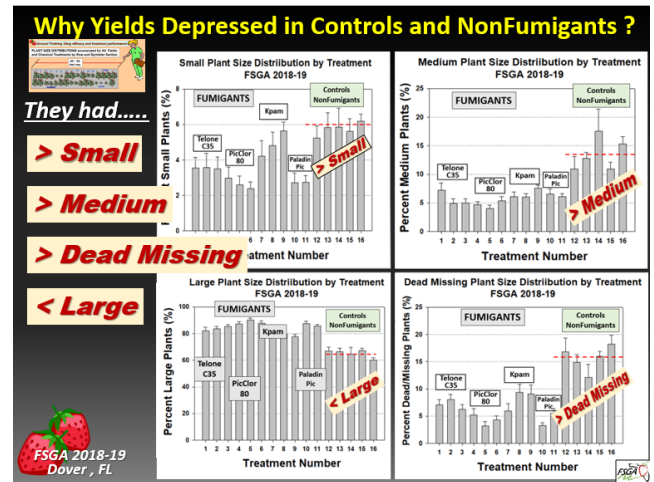


Figure 9. Relative Strawberry Yields and Percent Canopy
Greenness among treatments. FSGA 2018-2019.

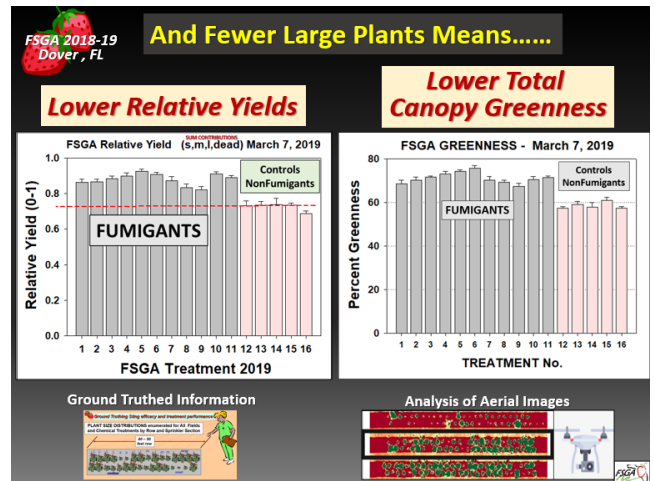


Figure 10. Correlations between Aerial and Ground
truthing survey of Percentage Greenness and Relative Yield.

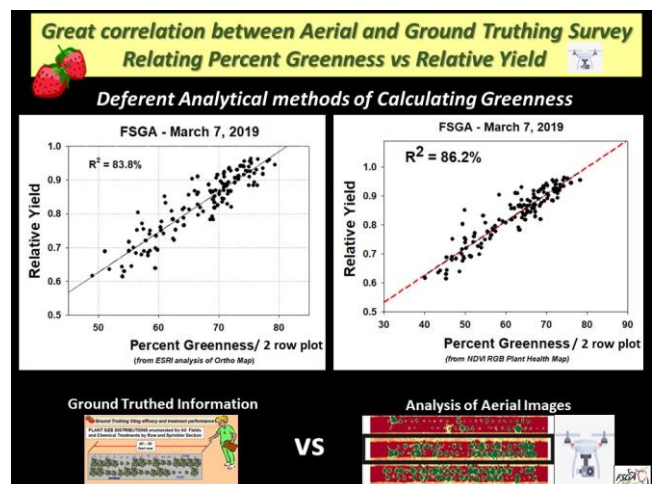
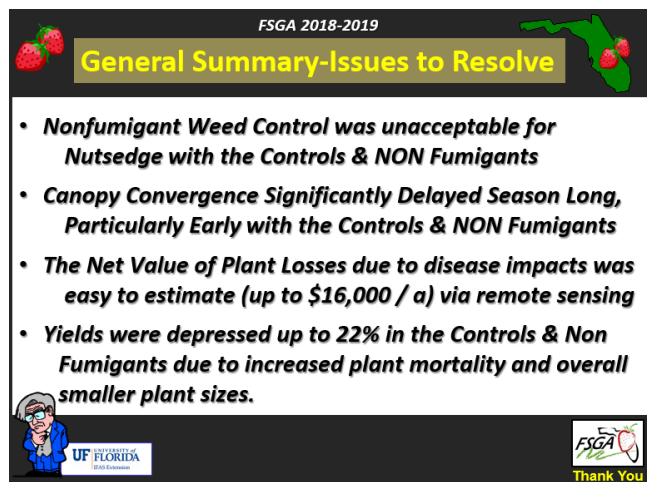




Figure 11. General Summary and Issues to resolve based on experimental findings. FSGA 2018-2019.



FSGA 2018-2019

General Summary-Issues to Resolve

- ***Nonfumigant Weed Control was unacceptable for Nutsedge with the Controls & NON Fumigants***
- ***Canopy Convergence Significantly Delayed Season Long, Particularly Early with the Controls & NON Fumigants***
- ***The Net Value of Plant Losses due to disease impacts was easy to estimate (up to \$16,000 / a) via remote sensing***
- ***Yields were depressed up to 22% in the Controls & Non Fumigants due to increased plant mortality and overall smaller plant sizes.***

Thank You