CHLOROPICRIN RATES FOR CONTROL OF CHARCOAL ROT (*MACROPHOMINA PHASEOLINA*) IN FLORIDA STRAWBERRY

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Macrophomina phaseolina, causal agent of charcoal rot of many crops worldwide, has become more prevalent in Florida strawberry fields since methyl bromide was phased out in 2013. The pathogen survives in the soil and on strawberry debris producing resistant structures, known as microsclerotia, facilitating its long-term survival and dispersal. Symptoms on strawberry are characterized by reddish-brown necrotic areas in the vascular rings of the crown leading to plant wilting, death of older leaves and plant collapse. Charcoal rot can cause severe losses of early season plant stands and reach more than 80% plant mortality by the end of the season when conditions are favorable and proper disease management is not adopted (Mertely et al. 2018).

Charcoal rot is usually controlled by a combination of cultural practices, such as the use of tolerant cultivars, and pre-plant fumigation of soil. Chemical soil fumigation is the most common method used by strawberry growers, and often provides effective control of weeds, nematodes, and soilborne pathogens. Since methyl-bromide was phased out, disease management has relied upon application of alternative broad-spectrum fumigants, mostly containing chloropicrin as one of the active ingredients. However, these products have not been as effective as methyl bromide, especially due to inherent differences in chemical properties and the lack of proper distribution in the soil profile.

Trials have been conducted over the past six strawberry seasons (2012-13 to 2017-18) at the Florida Strawberry Growers Association's field research facility in Dover, FL. Product formulations containing 21, 35, 60, 80, and 99% chloropicrin (V:V) (Table 1) were applied by shank injection during the fall of each year. Actual per acre fumigant use rates represent 62.5% of the broadcast or reported per treated acre (ta) rates expressed in Table 1. Totally impermeable plastic mulch film (TIF) was used in the 2016-17 and 2017-18 seasons for all the products, whereas low-density polyethylene plastic (LDPE) was used for Telone C35 and Pic-Clor60 from the 2012-13 to 2015-16 seasons. DMDS+Pic was always applied under TIF plastic. At FSGA, raised mulch covered beds measured 30 inches wide, 10 inches in height, with rows spaced on 4 foot centers. *M. phaseolina* inoculum was produced and buried in small bags under the plastic-mulched raised beds at 7.6 and 20.3 cm in the center of the bed. Additional inoculum was buried at 7.6

cm deep on the side of the beds (except for the 2012-13 season). Inoculum was prepared following the methods of Chamorro et al. (2016), and buried 5-15 min after shank applications. After 15-30 days, samples were recovered, processed in the laboratory, and plated on RB semi-selective medium to quantify the survival of *M. phaseolina* inoculum. Pathogen population was calculated as colony forming units per bag (CFU bag^{-1}). A split-plot analysis was conducted considering *M. phaseolina* inoculum burial placement (depth and location) the whole-plot and fumigant treatments the split-plot. Statistical analysis was performed using PROC GLIMMIX in SAS 9.4 (SAS Institute Inc., Cary, NC) and generalized linear mixed models for *M. phaseolina* CFU bag^{-1} were fit.

DMDS+Pic reduced *M. phaseolina* inoculum compared to the non-treated control in some cases, but not as well as Telone C35. Surprisingly, Pic-Clor60 was not effective in reducing inoculum in four of the six trials. Pic-Clor80 and Pic-C100 reduced inoculum in both seasons they were applied, indicating that a higher rate of chloropicrin might be needed for reducing *M. phaseolina*. In some cases, pathogen suppression was compromised when artificial inoculum was placed on the sides of the beds, likely due to the limited lateral movement of these fumigants when compared to methyl bromide. Only data from the 2016-17 and 2017-18 seasons are presented within this summary (Tables 2 and 3); however, additional information for each strawberry season will be presented at the meeting including different statistical analysis approach.

Literature cited:

Chamorro, M., Seijo, T. E., Noling, J. C., De los Santos, B., and Peres, N. A. 2016. Efficacy of fumigant treatments and inoculum placement on control of *Macrophomina phaseolina* in strawberry beds. Crop Prot. 90: 163-169.

Peres, N. A.; Baggio, J. S.; Mertely, J. C. 2018. Charcoal Rot of Strawberries Caused by Macrophomina phaseolina. Electronic data information source. PP242. UF/ IFAS Extension. Available at: https://edis.ifas.ufl.edu/pdffiles/PP/PP16100.pdf

Table 1. Treatments applied in Dover, FL (USA), during the fall of 2012-13 to 2017-18 seasons.

Treatments	**Seasons**	**Active ingredient (%)**	**Rate ranges of chloropicrin (lb/ta)**
DMDS+Pic	2012-13, 2013-14, 2016-17, 2017-18	Dimethyl disulfide:Chloropicrin (78/21)	60 - 90
Telone C35®	2012-13 to 2017-18	1,3-dichloropropene:Chloropicrin (63/35)	117 - 136
Pic-Clor60®	2012-13 to 2017-18	1,3-dichloropropene:Chloropicrin (39/60)	180
Pic-Clor80®	2016-17 to 2017-18	1,3-dichloropropene:Chloropicrin (20/80)	237 - 256
Pic-C100	2016-17 to 2017-18	Chloropicrin (99)	293 - 320
NTC	2012-13 to 2017-18	Non-treated control	-

Table 2. Treatments applied to soil by shank injection in a field at the Florida Strawberry Growers Association's facility in Dover, FL (USA) in the fall of 2016 and their effects on inoculum of *Macrophomina phaseolina* at different bed locations.

Treatments[v]	**Rate**		***M. phaseolina* (CFU bag^{-1})**[x] **7.6 cm center**	**20.3 cm center**	**7.6 cm side**	**Pr>F**[z]
MeBr50	320	lb/ta	0 d	0 d	0 d[y]	1.000
Telone C35	30	gpta	0 d	0 d	0 d	0.983
Pic-Clor60	300	lb/ta	122 b	559 bc	77 bc	0.057
Pic-Clor80	23	gpta	0 d	0 d	0 d	1.000
Pic-C100	21.6	gpta	11 c	48 c	24 bc	0.568
Metam potassium	62	gpta	0 d	1 d	1 cd	0.963
DMDS+Pic	30	gpta	248 a	518 ab	374 a	0.757
DMDS EC+Pic EC	30	gpta	0 d	0 d	76 bc	0.012
AITC	30	gpta	0 d	0 d	138 b	0.004
NTC	-		530 a	577 a	484 a	0.976
Pr>F[w]			<0.0001	<0.0001	<0.0001	

"MeBr50" = Methyl Bromide + Chloropicrin (50/50), "AITC" = Allyl isothiocyanate, "Metam potassium" = Potassium N-methyldithiocarbamate.

[w] Probability of a greater F value: Probability associated with type III test of fixed effects for treatments within each location.

[x] *M. phaseolina* colony-forming units per bag or crown (CFU bag^{-1}).

[y] Treatments followed by the same letter within a column are not significantly different according to Fisher's Protected LSD test (*a* = 0.05).

[z] Probability associated with test of effect slices for local*treatment interaction, sliced by treatment.

Table 3. Treatments applied to soil by shank injection in a field at the Florida Strawberry Growers Association's facility in Dover, FL (USA) in 2017 and their effects on inoculum of *Macrophomina phaseolina* at different bed locations.

Treatments[v]	**Rate**		***M. phaseolina* (CFU bag^{-1})[x]**			**Pr>F**[z]
			7.6 cm center	**20.3 cm center**	**7.6 cm side**	
Telone C35	30	gpta	0 c	0 c	0 d[y]	1.000
Pic-Clor60	300	lb/ta	0 c	0 c	0 cd	0.919
Pic-Clor80	320	lb/ta	0 c	0 c	0 d	0.963
Pic-C100	320	lb/ta	0 c	3 c	25 bc	0.042
Metam potassium	62	gpta	0 c	0 c	1 cd	0.748
DMDS+Pic	40	gpta	36 b	85 b	58 b	0.056
NTC	-		197 a	192 a	520 a	0.152
Pr>F[w]			<0.0001	<0.0001	<0.0001	

"Metam potassium" = Potassium N-methyldithiocarbamate.

[w] Probability of a greater F value: Probability associated with type III test of fixed effects for treatments within each location.

[x] *M. phaseolina* colony-forming units per bag or crown (CFU bag^{-1}).

[y] Treatments followed by the same letter within a column are not significantly different according to Fisher's Protected LSD test (a = 0.05).

[z] Probability associated with test of effect slices for local*treatment interaction, sliced by treatment.