

# EVALUATION OF PLANTPRO 45 AND PLANTPRO 20EC AS ALTERNATIVES TO METHYL BROMIDE SOIL FUMIGATION FOR TOMATO PRODUCTION IN FLORIDA

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## ABSTRACT

N. Kokalis-Burelle and D. W. Dickson. 2003. Evaluation of Plantpro 45 and Plantpro 20EC as alternatives to Methyl Bromide soil fumigation for tomato production in Florida. *Nematologica* 33:171-178.

Two formulations of a water-soluble, iodophor were evaluated as potential alternatives to methyl bromide soil fumigation by assessing their effects on growth, disease and yield of tomato. Three field trials evaluating Plantpro 45 and Plantpro 20EC were conducted in 2001 at two locations in central Florida. Plantpro 45 and Plantpro 20EC were applied through two drip irrigation lines and methyl bromide was shank applied in the bed. Methyl bromide treated soil consistently produced plants with increased shoot height, shoot weight, and root weight early in the season, healthier root condition and lower gall ratings throughout the season, and greater yields compared to both Plantpro formulations in two of three experiments. Both Plantpro formulations resulted in root-knot nematode populations in soil similar to the nontreated control soil in all studies. In fall experiments at both locations, plants in methyl bromide treated soil had less galling at the end of the season than both Plantpro formulations.

*Abbreviations:* Methyl Bromide (MeBr), days after planting (DAP), Plantpro 45 (PP45), Plantpro 20EC (PP20)

*Key words:* *Meloidogyne incognita*, methyl bromide, Plantpro, root-knot nematode, tomato.

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## INTRODUCTION

The Florida fresh market tomato industry is valued at approximately \$660 million per year (Florida Department of Agriculture and Consumer Services, 2002). The success of the current tomato production system used in Florida is dependent on the availability of an efficacious and cost effective management program for the control of nematodes, soilborne pathogens, and weeds. Over the past 40 years this has been accomplished by pre-plant soil fumigation of plastic mulched, raised planting beds with combinations of methyl bromide and chloropicrin.

The eventual phase-out of production and use of methyl bromide due to its designation as an ozone depleting substance has resulted in an intensive search to identify chemicals and combinations of strategies as alternatives. Although alternative

fumigants are considered the most promising short-term replacement for methyl bromide, none of the currently registered compounds control all of the important pathogens and pests without being combined with either nematicides, herbicides, or fungicides. Some of these chemicals may also be subject to future regulatory policies due to toxicological and environmental concerns, leaving growers vulnerable to further limited availability of pathogen control options. Development of production systems not dependent on the use of methyl bromide or other chemicals that are harmful to the environment or human health will require an integrated approach utilizing combinations of biological, cultural, and reduced risk technologies to maximize yield and maintain pathogen damage below an economic threshold. However, it is imperative that all

strategies including reduced risk or lower risk chemical alternatives receive vigorous field testing to insure growers that reliable and consistent levels of pathogen control can be achieved.

Plantpro™ (Ajay North America, Powder Springs, GA), a water soluble iodine-based compound, is currently being investigated for potential as a reduced-risk methyl bromide alternative for control of nematodes and soil-borne pathogens. Two formulations of this compound Plantpro 45™ (PP45), a 3% iodine formulation, and Plantpro 20EC (PP20), a 20% iodine formulation were tested in three field trials during two growing seasons in two Florida locations.

Preliminary laboratory and greenhouse studies indicated that PP45 effectively inhibited fungal growth *in vitro*. At less than or equal to 5 parts per million active ingredient (ppm) PP45 suppressed hyphal growth of *Fusarium moniliforme in vitro*, and at 250 ppm it reduced hyphal growth from infested maize by 50% without reducing seedling survival or development (Yates *et al.*, 2000). Hyphal growth of *Fusarium oxysporum* f. sp. *basilici* was also inhibited by PP45 *in vitro* at 300 ppm, while seed treatments of 800-1000 ppm eliminated fungal contamination of basil seed and resulted in taller and healthier basil seedlings (Adams *et al.*, 2002). *In vitro*, PP45 reduced hyphal growth of *Fusarium*, *Pythium*, and *Phytophthora* spp. at 60-300 ppm (Adams *et al.*, 2000). Also, in field trials at sites naturally infested with *Fusarium*, crown rot of tomato disease was reduced with PP45 applications of 80 and 120 ppm, although the pathogen was isolated from the soil treated with these rates of Plantpro (Adams *et al.*, 2000).

Further laboratory, greenhouse and field studies indicated that PP45 was effective in controlling root-knot nematodes (*Meloidogyne* spp.). At 60 ppm PP45

reduced root-knot nematode egg viability *in vitro* by 75% compared to the control, and significantly reduced galling on tomatoes in the greenhouse at rates of 60-120 ppm compared to the untreated control (Kokalis-Burelle and Fuentes, 2000). Additionally, in tomato field trials PP45 reduced root-knot nematode populations in soil to levels comparable to methyl bromide at 17-35 days after planting (DAP) (Kokalis-Burelle and Fuentes 2000).

The objective of this research was to assess the field performance of two formulations of Plantpro for effects on plant growth, root-knot nematode infection, and yield of tomato in two different growing seasons and at two locations in Florida.

## MATERIALS AND METHODS

### *Field experimental design:*

Two field trials were conducted in the spring and fall of 2001 at the Uniroyal Chemical Company Inc., Florida Research Station, Sanford, FL and one trial was conducted in the fall of 2001 at the University of Florida Research and Education Station, Citra, FL. Tomato (*Lycopersicon esculentum* Mill.) cultivar Solar Set was used in the Sanford trials and cultivar Florida 47 was used in the Citra trial. Seedlings for all trials were produced by Speedling, Inc. (Sun City, FL) according to their standard transplant production practices for tomato.

Previous cropping history at the Uniroyal Chemical Company's Research Station in Sanford, FL included ten years of vegetable production without methyl bromide application, resulting in evenly distributed, high levels of plant pathogenic nematodes (primarily *Meloidogyne incognita*) and soilborne fungal pathogens including *Fusarium oxysporum* f. sp. *lycopercici* (FOL), *Fusarium oxysporum* f. sp. *radici-lycopercici* (FORL), and *Sclerotium rolfsii*. The

University of Florida Research Station in Citra, FL was a newly established farm previously maintained as weed fallow with low levels of pathogenic nematodes. The experimental design for all studies consisted of four soil treatments arranged in a randomized complete block design with four replications. Soil treatments were: 1) nontreated soil; 2) methyl bromide (MeBr) shank injected at bedding at 309-353 kg/ha (67:33 MeBr:chloropicrin); 3) PP45 applied after bed formation through two drip irrigation lines at 144 l/ha; and 4) PP20 applied after bed formation through two drip irrigation lines at 17-26 l/ha. The application rates for PP45 and PP20 ensured that both treatments had approximately 4.5 l/ha active ingredient. Drip irrigation lines were laid 5 cm below the soil surface and Plantpro applications were applied a minimum of 10 days before planting. All beds were covered with 30- $\mu$ m-thick, co-extruded white on black low-density polyethylene mulch. In the Sanford trials, both irrigation lines were left in place in all plots after treatment application and used for irrigation throughout the season. In the Citra trial, a third irrigation line was laid slightly off-center in each row and was used for irrigation throughout the season. For all trials, approximately 2267 kg/ha 8-2-12 fertilizer were broadcast over the field immediately prior to bedding.

Beds were between 9-15 m long and oriented north-and-south, 20 cm in height, 0.9 m wide and spaced 1.8 m apart. Tomatoes were planted in single rows with 25-30 plants per plot spaced at a minimum of 50 cm. The Sanford trials were planted on April 2, 2001, and September 7, 2001, and the Citra trial was planted on September 6, 2001.

#### *Evaluations for effects on disease and yield*

Plants were evaluated for growth at early, mid, and late season intervals and for

yield. Early season is defined as 20-35 DAP, mid-season 35-46 DAP, and late season 54-70 DAP. Damage from disease was assessed by performing subjective root ratings using a 1-5 scale for root condition where 1 = healthy and 5 = 100% necrotic. Root galling was assessed using a root gall index based on a scale of 1 to 10, with one representing no galls and 10 representing severe (100%) galling (Zeck, 1971). At 35 and 70 DAP all experiments were sampled for soil nematode populations. Six soil cores were taken from the plant root zone in each plot using a 2.5 cm-diameter soil probe to a depth of approximately 30 cm. Soil cores from each plot were combined and nematodes were extracted from a 100 cc subsample using the Baermann funnel technique. Root-knot and nonparasitic nematodes were counted. The primary root-knot nematode species occurring in all fields was *Meloidogyne incognita*.

Tomatoes were harvested two or three times during the season in each trial. Mature green or red tomato fruit were harvested, culled and graded for size (small – extra large) using a standard grading line.

#### *Statistical analysis*

Data were statistically analyzed according to standard procedures including SAS general linear model (GLM) and least significant difference (LSD) (SAS Institute, Cary, NC). Unless otherwise stated, all differences referred to in the text were significant at the 5% level of probability.

## RESULTS

#### *Effects of soil treatments on tomato growth and disease*

In the Sanford spring study, methyl bromide and PP20 treated plants had the heaviest shoot weights early in the season (Table 1). Shoot weight was heaviest in the

Table 1. Effect of soil treatment on shoot weight early in the season for all trials.

Treatment	Shoot Weight (g)		
	Sanford Spring	Sanford Fall	Citra Fall
Untreated	53.41 b <sup>c</sup>	234.50 b	104.63 b
MeBr	99.13 a	540.34 a	215.30 a
PP45	87.65 ab	173.53 b	111.34 b
PP20	114.33 a	236.51 b	82.75 b
LSD (0.05)	37.34	117.84	58.04

<sup>c</sup>Means with the same letter are not significantly different.

methyl bromide treated plants for both fall studies, while PP45 and PP20 were not different from the untreated control (Table 1).

In the Sanford spring study early in the season, there were no significant differences among treatments for mid- and late season plant growth ratings (Table 2). No height data were collected for the Citra fall study. In the Sanford fall study, methyl bromide treated plots produced taller plants throughout the season, while plants in soil treated with PP45 and PP20 were not different from plants in untreated soil.

In the Sanford spring study there were no significant differences in root weight early in the season, while PP45 treated

plots had the greatest root weights late in the season (data not shown). These increased root weights in PP45 treated soil were associated with increased root gall ratings in that treatment (Table 3). For both fall studies methyl bromide treated plots had the greatest root weight early in the season, while PP20 and PP45 treated plots had the lowest root weights early in the season (data not shown). In the Citra fall study root weights did not differ among treatments late in the season (data not shown), which is probably due to low root-knot nematode pressure resulting in low rates of galling at that location (Table 3).

Table 2. Effect of soil treatment on shoot height throughout the season for Sanford trials.

Treatment	Shoot Height (cm)					
	Sanford Spring			Sanford Fall		
	Early	Mid	Late	Early	Mid	Late
Untreated	25.13 ab <sup>c</sup>	36.50 a	50.63 a	79.88 b	66.50 b	62.13 bc
MeBr	26.38 a	39.75 a	52.63 a	98.25 a	84.00 a	98.38 a
PP45	23.50 bc	40.25 a	51.38 a	76.38 b	50.38 c	51.00 c
PP20	22.63 c	38.50 a	51.13 a	79.88 b	61.50 bc	67.63 ab
LSD (0.05)	2.38	NS	NS	10.12	14.13	13.59

<sup>c</sup>Means with the same letter are not significantly different.

Table 3. Effect of soil treatment on root-knot nematode (*Meloidogyne incognita*) gall rating at 35 and 70 DAP in all trials.

Treatment	Gall Rate <sup>y</sup>					
	Sanford Spring		Sanford Fall		Citra Fall	
	Early	Late	Early	Late	Early	Late
Untreated	0.75 ab <sup>x</sup>	3.17 b	2.56 a	7.03 a	1.97 a	3.81 a
MeBr	0.36 ab	3.53 b	0.00 c	3.64 b	0.00 b	0.00 b
PP45	1.40 a	5.28 a	1.34 ab	7.30 a	1.67 a	3.08 a
PP20	0.27 b	4.23 ab	0.83 bc	7.95 a	1.87 a	3.43 a
LSD (0.05)	1.08	1.74	1.29	1.40	1.21	1.55

<sup>y</sup>Gall rate is a 1 to 10 scale with 1 = no galls and 10 = severe galling (Zeck, 1971).

<sup>x</sup>Means with the same letter are not significantly different.

In the Sanford spring trial, PP45 had healthier root condition ratings than the PP20 formulation (Table 4). However, this improved root condition did not persist through the season and late in the season root ratings for PP45 were worse than those for plants in methyl bromide treated soil (Table 4). Early season gall ratings were higher for the PP45 treatment than for the PP20 treatment, which had the low-

est gall rating early in the season (Table 3). Late in the spring Sanford trial the PP45 treatment had more galling than both the untreated and methyl bromide treated plots (Table 3).

In the Sanford fall trial, methyl bromide was the only treatment with root condition ratings that were better than the untreated control (Table 4). Both methyl bromide and PP20 had lower gall ratings

Table 4. Effect of soil treatment on root condition rating at 35 and 70 DAP in all trials.

Treatment	Root Condition <sup>y</sup>					
	Sanford Spring		Sanford Fall		Citra Fall	
	Early	Late	Early	Late	Early	Late
Untreated	1.20 ab <sup>x</sup>	2.51 ab	1.39 a	1.73 ab	1.33 a	1.70 a
MeBr	1.18 ab	1.90 b	1.05 b	1.09 b	1.00 a	1.03 b
PP45	1.12 b	2.93 a	1.23 ab	2.44 a	1.39 a	1.71 a
PP20	1.29 a	2.48 ab	1.30 ab	2.33 a	1.46 a	1.55 a
LSD (0.05)	0.16	0.69	0.27	1.11	NS	0.48

<sup>y</sup>Root condition rating is a 1-5 scale for root condition where 1 = good condition and 5 = poor condition.

<sup>x</sup>Means with the same letter are not significantly different.

early in the season than the untreated control. Root condition ratings at the end of the season were better for methyl bromide treatments than both Plantpro formulations (Table 4). Methyl bromide was the only treatment that reduced galling at the end of the season.

In the fall Citra trial, there were no differences in root condition ratings among treatments early in the season (Table 4). However, later in the season, plants from methyl bromide treated plots had healthier roots than those from all other treatments. Methyl bromide was the only treatment that reduced galling early and late in the season for this trial (Table 3).

#### *Effects of treatments on nematode populations in soil*

For all studies, soil treatments had no effect on root-knot nematodes in soil at mid-season (data not shown). There were no root-knot nematodes isolated from soil in the spring Sanford trial, which is not unusual because sampling for soil nematodes in spring is done in early March when soil temperatures are low (data not shown). In the deep sand soils that occur on the central Florida ridge, nematodes can move

down through the soil profile to avoid cooler temperatures. The failure to detect root-knot nematodes early in the fall Citra study (data not shown), and only to a limited degree later, is also not unexpected because this land was new to vegetable production. Late in the season for the Sanford fall study, PP45 and PP20 treated soil had greater numbers of root-knot nematodes than methyl bromide treated soil (Table 5). Late in the season for both the Citra fall and Sanford spring studies, there were no significant differences in root-knot nematode populations in soil (Table 5).

Unexpectedly, methyl bromide treated soil had the highest non-plant parasitic nematode counts throughout all studies at both sampling times, with the exception of early season in the Sanford spring study, where there were no significant differences among soil treatments (data not shown). The occurrence of non-plant parasitic nematodes in soil treated with PP45 and PP20 was not different from the untreated control for all studies at all sampling times (Table 5).

#### *Effects of treatments on yield*

In fall studies at both locations, methyl bromide treated plots had greater yields

Table 5. Effect of soil treatments on root-knot (*Meloidogyne incognita*) and non-parasitic nematode populations (nematodes per 100 cc soil) late (70 DAP) in the season for all trials.

Treatment	Sanford Spring		Sanford Fall		Citra Fall	
	Root-Knot Nematodes	Non-Parasitic Nematodes	Root-Knot Nematodes	Non-Parasitic Nematodes	Root-Knot Nematodes	Non-Parasitic Nematodes
Untreated	68.06 a <sup>c</sup>	85.08 b	904.68 ab	204.19 ab	0.00 a	73.74 b
MeBr	45.38 a	187.18 a	119.11 b	371.52 a	11.34 a	181.50 a
PP45	51.05 a	53.88 b	1763.99 a	136.13 b	5.67 a	73.74 b
PP20	62.39 a	104.93 b	1698.76 a	204.19 ab	0.00 a	51.05 b
LSD (0.05)	NS	80.24	902.30	219.28	NS	85.87

<sup>c</sup>Means with the same letter are not significantly different.

than both Plantpro formulations which did not differ from the untreated control (Table 6). In the Sanford spring study, there were no statistical differences among treatments in yield, which were extremely low due to the late season influx of fungal diseases in all treatments. In all studies, yields from PP45 and PP20 treated plots were not different from the untreated control (Table 6).

DISCUSSION

Plantpro treatments did not consistently improve plant growth with respect to shoot height, shoot weight, and root weight compared to the untreated control treatment. In some cases, plant growth was reduced at early and mid season in Plantpro treatments compared to the control, which may indicate a need to increase post application planting intervals to avoid phytotoxicity.

There was a marked difference in yield between the Sanford and the Citra field sites. Heavy pathogen pressure in Sanford is the most probable cause of lower shoot heights, shoot weights, and yields. Varietal differences may have also contributed to differences in yield. The spring study in Sanford had the greatest fungal pathogen

pressure late in the season, and characteristically low root-knot nematode populations compared to fall trials. This may have masked treatment effects on galling and yield in this study. On the other hand, the Citra farm site which had lower levels of pathogens present due primarily to less history of vegetable production than the Sanford site, resulted in the most distinctive treatment differences with respect to soilborne pathogens and nematodes.

In general, PP45 and PP20 did not produce results that were different from the control although some of our data indicate tendencies for phytotoxicity that may have contributed to higher disease and consequently, reduced yields. In addition, PP45 and PP20 treated plants were not different from each other, indicating that formulation differences have not affected the potency of the active ingredient. It is possible that differences at the Sanford farm were due to interactions between aggressive high initial pathogen populations and the Plantpro treatments.

Although preliminary data from laboratory, greenhouse, and small field experiments indicated that PP45 had potential as an alternative soil treatment to methyl bromide (Adams *et al.* 2000; Kokalis-Burelle and Fuentes, 2000), the more stringent

Table 6. Effect of soil treatments on total yield.

Treatment	Yield (kg/ha)		
	Sanford Spring	Sanford Fall	Citra Fall
Untreated	2,971 a <sup>z</sup>	8,155 b	27,826 ab
MeBr	7,552 a	21,218 a	30,553 a
PP45	7,336 a	3,684 b	26,801 b
PP20	4,083 a	6,127 b	26,104 b
LSD (0.05)	5288	8848	3496

<sup>z</sup>Means with the same letter are not significantly different.

replicated field studies presented here on tomato, and elsewhere on two seasons of strawberry field trials including Plantpro formulations (Kokalis-Burelle, 2003), resulted in smaller, less healthy root systems, and lower yields than the methyl bromide treatments. Variations in application rates, methods, and planting intervals, are currently being investigated to improve pathogen control, increase yield, and improve the performance of this product for use as a soil treatment.

#### ACKNOWLEDGMENTS

This research was supported by a Cooperative Research and Development Agreement between USDA, ARS and Ajay North America LLC (CRADA #58-3K95-9-739). Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the United States Department of Agriculture. The authors would like to acknowledge Uniroyal Chemical Company, Inc. for use of their research farm, Mary (Sissy) Ivey for technical field assistance, and Amanda Rinehart for assis-

tance with data analysis and manuscript preparation.

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*Received:*

28.II.2003

*Accepted for publication:*

27.IX.2003

*Recibido:*

*Aceptado para publicación:*