EFFECTS OF REDUCED RATES OF TELONE C35 AND METHYL BROMIDE IN CONJUNCTION WITH VIRTUALLY IMPERMEABLE FILM ON WEEDS AND ROOT-KNOT NEMATODES

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ABSTRACT

Hamill, J. E., J. E. Thomas, L.-T. Ou, L. H. Allen, Jr., N. Kokalis-Burelle, and D. W. Dickson. 2008. Effects of reduced rates of Telone C35 and methyl bromide in conjunction with virtually impermeable film on weeds and root-knot nematodes. Nematropica 38:37-46.

Two field trials were conducted in Florida in 2004 to test the efficacy of reduced rates of the fumigants methyl bromide (67% methyl bromide plus 33% chloropicrin) and Telone C35 (1,3-dichloropropene (1,3-D), 65% plus chloropicrin 35%) in combination with virtually impermeable film (VIF) and standard low density polyethylene (LDPE) film. In spring grown tomato, reducing rates of methyl bromide by 25% under VIF provided comparable control to full rates with regard to nutsedge (mixture of purple and yellow). All fumigants performed better with regard to nutsedge control under VIF than under LDPE. Root-galling, caused by *Meloidogyne* spp. juveniles (J2) in soil, and marketable yields in reduced rates of methyl bromide were also similar to the full rate regardless of film type. Plots treated with Telone C35 at 327 liters/ha in conjunction with VIF reduced nutsedge densities, had lower gall ratings, and had higher marketable yields than nontreated plots, but were not comparable to methyl bromide. Reducing rates of Telone C35 by 25 and 50% had negative impacts on yield compared to all methyl bromide treatments and Telone C35 at 327 liters/ha, regardless of film type. In double-cropped cucumber, none of the treatments had gall-ratings different than nontreated plots. In autumn grown squash, all methyl bromide treatments and Telone C35 treatments had higher marketable yields and lower gall ratings than nontreated plots. Plots treated with Telone C35 using VIF had the lowest nutsedge densities. All methyl bromide treatments under VIF had lower nutsedge densities than nontreated plots. Plots that were treated with chloropicrin or chloropicrin plus metam potassium as an in-bed treatment had higher nutsedge densities than nontreated plots.

Key words: 1,3-dichloropropene, chloropicrin, cucumber, *Cyperus* spp., K-Pam, *Meloidogyne* spp., metam potassium, methyl bromide, nutsedge, root-knot nematode, Telone C35, squash, tomato, virtually impermeable film, VIF.

RESUMEN

Hamill, J. E., J. E. Thomas, L.-T. Ou, L. H. Allen, Jr., N. Kokalis-Burelle, and D. W. Dickson. 2008. Efectos de dosis reducidas de Telone C35 y bromuro de metilo en combinación con plástico virtualmente impermeable sobre malezas y nematodos agalladores. Nematropica 38:37-46.

Se condujeron dos ensayos en Florida en 2004 para evaluar la eficacia de dosis reducidas de los fumigantes bromuro de metilo (67% bromuro de metilo y 33% cloropicrino) y Telone C35 (1,3-dicloropropeno (1,3-D), 65% y cloropicrino 35%) en combinación con plástico virtualmente impermeable (virtually impermeable film, VIF) y polietileno tradicional de baja densidad (low density polyethylene, LDPE). En tomates de primavera, la dosis reducida de bromuro de metilo (reducción del 25%) en conjunto con VIF dio el mismo control de coquito (mezcla de *Cyperus rotundus* y *C. escu-*

lentus) que la dosis completa del fumigante. Todos los fumigantes fueron más eficaces en el control de malezas bajo VIF que bajo LDPE. El agallamiento, la cantidad de juveniles de segundo estadio (J2) de *Meloidogyne* spp. en el suelo, y la producción mercadeable bajo dosis reducidas de bromuro de metilo también fueron similares a los obtenidos con la dosis completa. En los lotes tratados con Telone C35 a razón de 327 litros/ha en conjunto con VIF se observaron densidades más bajas de coquito, menores índices de agallamiento y mayor producción que en los lotes no tratados, pero estos resultados no fueron comparables con los obtenidos con bromuro de metilo. La reducción del 25 y 50% de las dosis de Telone C35 tuvo efectos negativos en la producción comparado con todos los tratamientos de bromuro de metilo y con la dosis completa de Telone C35, para ambos tipos de cobertura. En pepino, ninguno de los tratamientos mostró diferencias en agallamiento con respecto a los lotes no tratados. En calabaza de otoño, todos los tratamientos de bromuro de metilo y de Telone C35 aumentaron la producción mercadeable y redujeron los índices de agallamiento con respecto a los lotes no tratados. Las densidades más bajas de coquito se observaron en los lotes tratados con Telone C35 y VIF. Todos los tratamientos de bromuro de metilo bajo VIF mostraron menor densidad de coquito que los lotes no tratados. Los lotes que fueron tratados con cloropicrino o mezcla de cloropicrino y metam postasio aplicado en las camas tuvieron mayor densidad de coquito que los lotes no tratados.

Palabras clave: 1,3-dicloropropeno, bromuro de metilo, calabaza, cloropicrino, coquito, *Cyperus* spp., K-Pam, *Meloidogyne* spp., metam potasio, nematodo agallador, pepino, plástico virtualmente impermeable, Telone C35, tomate, VIF.

INTRODUCTION

For approximately the past 38 years vegetable growers in the southern United States have been using methyl bromide very effectively as a part of a polyethylene film production system (Locascio *et al.*, 1999; Noling and Becker, 1994). This system includes raised beds tightly covered with polyethylene film, high fertility rates, and drip or subsurface irrigation. Often, the system entails double cropping (a primary crop followed by a second crop on the same beds). Double cropping is very important to the economic success of this production system in Florida and the southern United States (Gilreath *et al.*, 1999). A primary soil treatment is needed before the first crop that will also provide for satisfactory production of a second crop or rotational crop that is planted on the original polyethylene film covered beds. In Florida, fresh market tomato (*Solanum lycopersicon* L.) is generally considered as a primary crop followed by cucumber (*Cucumis sativus* L.), bell pepper (*Capsicum annuum* L.), or eggplant (*Solanum melongena* L.). Tomato is valued at more than $600 million and represents nearly 30% of the total value of all vegetable crops grown in Florida (Anonymous, 2003).

Growers depend on methyl bromide as part of the plastic film production system because it provides economical management of nematodes, most soilborne diseases, and weeds (Noling and Becker, 1994), and is especially effective in controlling yellow (*Cyperus esculentus* L.) and purple (*C. rotundus* L.) nutsedge as compared to other preplant treatments (Locascio *et al.*, 1999; Gilreath *et al.*, 2004; Gilreath and Santos, 2004). The fumigant is generally injected into the soil 15 to 20 cm deep in preformed beds killing nematodes, fungi, and weed seeds (Lembright, 1990). After injection into beds, methyl bromide 98% with 2% chloropicrin (mbr 98:2) rapidly dissipates allowing for a short re-entry period and planting 48 hours following application. When methyl bromide is formulated with higher rates of chloropicrin (e.g. 33% chloropicrin) the latter remains in the soil solution and soil air pores for a longer period of time.

Methyl bromide has been identified as an ozone-depleting substance and has been phased out under the Montreal Protocol (Lehnert, 2006; Martin, 2003; Rich and Olson, 2004). Currently, under the United States nomination and critical use exemption (CUE) program, growers are allowed to continue using a specified allocation of methyl bromide (Anonymous, 2005; Lehnert, 2006). These nominations are evaluated yearly and granted to commodity groups who have demonstrated attempts to reduce rates and emissions of the product. The lower production rate of methyl bromide, a requirement of the phase-out, is increasing cost substantially.

The use of virtually impermeable film (VIF) technology coupled with lower rates of methyl bromide may serve to lower emissions from the soil and maintain the same efficacy against soilborne pests and pathogens (Noling, 2004). Virtually impermeable film has been shown to be at least 75-fold less permeable to methyl bromide than conventional low-density polyethylene films (LDPE) and may be as much as 500- to 1,000-fold less permeable than LDPE films (Yates *et al.*, 2002). The benefits of using VIF are that it allows for the reduction of fumigant rates yet allows for the maintenance of suitable marketable vegetable yields, and equivalent reductions of root-knot nematode galling, nutsedge densities, and vascular wilt diseases comparable with that obtained by standard films (Nelson, *et al.*, 2000; Locascio *et al.*, 2002; Gilreath *et al.*, 2004).

One alternative to methyl bromide for high value vegetable production in Florida is 1,3-D formulated with 35% chloropicrin (Telone C35, Dow AgroSciences LLC, Indianapolis, IN). Virtually impermeable film has been shown to retain larger amounts of methyl bromide, 1,3-D, and chloropicrin in the root zone, with longer residential time in subsurface field soil than LDPE after application by standard chisel injection, by Avenger coulter injection (Yetter, Colchester, IL) (Anonymous, 2001a,b), or by drip irrigation (Ou *et al.*, 2005). With the improved retention, concentrations of 1,3-D and chloropicrin in the VIF covered beds were greater than in the LDPE covered beds after application of Telone C35 (Ou *et al.*, 2005). However, no data are available on the effects of VIF on efficacy of Telone C35, whether applied at labeled rates or lower rates. Our objectives were to determine the efficacy of lower rates of methyl bromide 67-33 and Telone C35 compared to standard rates under LDPE vs. VIF, and metam potassium applications via drip irrigation for the double crop. Telone C35 applied at lower rates was included to provide growers information on its effectiveness as an alternative to methyl bromide.

MATERIALS AND METHODS

Experimental Design

Experiments were conducted at the University of Florida Plant Science Research and Education Unit, located near Citra, FL. Field dimensions were 21 m wide by 183 m long. The site used in spring 2004 was artificially inoculated in the summer of 1999 by distributing tomato cv. Rutgers roots infected with *Meloidogyne arenaria* (Neal, 1889) Chitwood, 1949 in 25-cm-deep plowed furrows spaced 7 m apart. The site used in autumn 2004 was inoculated with tomato roots infected with *M. javanica* (Treub, 1889) Chitwood, 1949. Over time, both sites have become infested with mixed populations of *Meloidogyne* spp. Endemic plant-parasitic nematode populations of *Trichodorus* spp. and *Criconemoides* spp. also were present at the time of each experiment. Root-knot nematodes were maintained at uniform, high levels by planting okra, *Hibiscus esculentum* L. cv. Clemson Spineless across the field the previous season where experiments were conducted the following year. The field sites also had moderate to heavy infestations of both purple and yellow nutsedges. Classification of soils in the field ranged from Arredondo fine sand to Sparr fine sand, both loamy, siliceous, hyperthermic Grossarenic Paleudults with characteristics of 95% sand, 3% silt, 2% clay, 1.5% OM, and pH 6.5.

Treatments were arranged in a split-plot design with four replicates. Fumigant treatments comprised the main-plots and film type (VIF and LDPE) comprised the sub-plots. All treatments were applied in raised beds 23 cm tall, 91 cm wide, 12 m long and spaced on 1.8-m centers. Raised beds were preformed using a Kennco Powerbedder (Kennco Mfg., Ruskin, FL). Immediately before bed formation a 6-17-16 (N-P_2O_5-K_2O) fertilizer mix was broadcast over the plots at 842 kg/ha. After the beds were preformed, a Kennco Mini-Combo unit (Kennco Mfg., Ruskin, FL) was used to apply the fumigants and cover the beds with film. The virtually impermeable film was 1.4-mil black on white (Hytibar Flex, Klerks Plastic Products Mfg., Richburg, SC), LDPE film was 1.0-mil black embossed (Pliant Plastics, Muskegon, MI). A single drip tube (8 mil, 30-cm emitter spacing) with a flow equivalent of 1.9 liters/minute/30.5 m of row (Roberts Irrigation Products, San Marcos, CA) was inserted ca. 5 cm deep into the bed center at the same time the beds were fumigated and cover with film. All fumigant treatments were applied with three chisels per bed, 26.4-cm spacing, 26.4-cm deep. Remaining N and K_2O were applied via drip tube as ammonium nitrate and muriate of potash, respectively, in 8 weekly applications divided equally to deliver a total of 168 kg/ha N and 168 kg/ha K_2O for the crop. Foliar fungal pathogens were managed using alternating spray applications of chlorothalonil, mancozeb, and azoxystrobin, and insect pests were managed using alternating spray applications of methomyl and esfenvalerate (Olson and Simonne, 2005). Sprays were applied two to three times weekly.

Spring Tomato Crop

Fumigants evaluated include methyl bromide 67% and chloropicrin 33% (mbr 67:33) at 197, 295, and 393 kg/ha and Telone C35 at 164, 243, and 327 liters/ha. The calibration of rates was done by weight with a closed system (the fumigant was shunted into a spare cylinder during the calibration process). A nontreated control bed was included for a total of seven treatments. Tomato cv. Tygress seedlings were transplanted mid-March 2004. Fruit was harvested and root-knot nematodes in soil and root galling were rated in late June 2004. The number of nutsedge plants per replicate (4 weeks after transplanting) was recorded. Tomato fruit from each treatment were graded (Kerian Speed Sizer, Kerian Machines, Grafton, ND) into extra-large, large, medium, and culls, with each of the first three categories weighed for marketable yield in two harvests. After the final harvest, six plant root systems (chosen arbitrarily) per plot were subjected to a root-gall rating based on a 0 to 100 scale where 0 = no visible galls, 10 = 10% of root system galled, . . . and 100 = 100% of the root system galled (Barker *et al.*, 1986). Nematode population densities in soil were assessed before fumigant application and at the end of the growing season for each crop. Six soil cores were taken to a depth of 20 cm in each subplot using a 2.5-cm-diam cone-shaped soil probe and combined. A 100-cm^3 subsample was used to extract nematodes using the Baermann technique.

All plant-parasitic nematodes in samples were counted.

Double Crop Spring Tomato-Autumn Cucumber

After the final spring tomato harvest, a broadcast application of a non-selective herbicide (paraquat) at 630 g ai/ha was sprayed over the area. Two weeks later all dead tomato plants were manually removed from the beds. In early August the black plastic film was hand sprayed with white Kool Grow paint (Suntec Paints, Gainesville, FL) at 38 liters product in 379 liters water. On 12 August 2004 each bed was seeded with cucumber cv. Dasher II at a rate of two seed per plant hole with ca. 23 plant holes per bed. Beds were fertilized five times at weekly intervals via drip irrigation with 13.4 kg/ha N and K_2O formulated as ammonium nitrate and muriate of potash, respectively. All fungicide and insecticide applications were made as mentioned above for the spring tomato crop. Cucumber fruit were harvested once or twice weekly for 6 weeks beginning 55 days post plant and marketable fruit weighed for yield. Root-knot nematode population densities in soil and root galling were determined as stated above.

Autumn Squash

Methods in the autumn squash trial were the same as the spring, except that a white on black polyethylene film was used. The VIF was the same Hytibar flex, but laid with the white side exposed on the surface. The LDPE was 1.0-mil white on black embossed (Pliant Plastics, Muskegon, MI). Fumigants evaluated were (i) methyl bromide 67:33 at 393, 295, and 197 kg/ha, (ii) 98% methyl bromide plus 2% chloropicrin (mbr 98:2) at 197 kg/ha, (iii) Telone C35 at 327 liters/ha, (iv) chloropicrin at 136 kg/ha, and (v) chloropicrin at 136 kg/ha plus metam potassium (K-Pam, American Vanguard, Newport Beach, CA) applied via the drip system at 561 liters/ha, plus (vi) a nontreated control for a total of eight treatments. Fumigant treatments comprised the main-plots and film type comprised the sub-plots. Squash fruit was picked two or three times weekly for a period of 5 weeks. After the final harvest plant roots were removed to determine the degree of galling as stated above. Nutsedge penetrating the polyethylene film was counted as stated above. Experiments were initially designed to be conducted with tomato and then double cropped with squash, but the tomato seedlings that were initially transplanted in August 2004 were severely injured by strong winds and heavy rainfall from two hurricanes. Soil nematode counts were not taken on this experiment due to hurricane damage to the USDA laboratory in Ft. Pierce, FL in fall 2004.

Statistical Analysis

All data in all tests were subjected to ANOVA and mean differences were separated by Fisher's protected least significant difference test ($P \leq 0.05$).

RESULTS

Spring Tomato

There was an interaction between fumigants and film type for densities of nutsedge plants/m^2, thus comparisons were made only within film types ($P \leq 0.05$). Under VIF, all fumigant treatments except Telone C35 at 164 liters/ha (lowest rate) had lower nutsedge densities than nontreated plots ($P \leq 0.05$) (Table 1). More importantly, reducing the rate of methyl bromide by 25% under VIF controlled nutsedge as well as the full rate under VIF. Under LDPE film, only higher treatment rates of methyl bromide at 393 and 295 kg/ha and Telone C35 at 327 liters/ha had lower nutsedge densities than nontreated plots ($P \leq 0.05$) (Table 1).

Table 1. Effects of film type and in bed fumigant rates of methyl bromide and Telone C35 on reduction of nutsedge, root-knot nematode galling and second-stage juveniles (J2), and increases in marketable yield of spring grown tomato at the Plant Science Research and Education Unit, Citra, FL.

		Nutsedge plants/m^2				
		Film type				
Treatment	Broadcast rate/ha[v]	VIF[x]	LDPE[y]	Gall rating[w] mean	J2/100 cm^3 soil	Total marketable yield kg/ha
Nontreated	—	33.0 a[z]	50.0 a	31.6 a	9.9 b	3,319 d
Methyl bromide	393 kg	0.8 d	1.3 d	1.4 d	21.3 b	8,745 ab
Methyl bromide	295 kg	0.8 d	5.3 c	2.0 d	31.2 b	8,183 b
Methyl bromide	197 kg	1.8 c	28.3 ab	6.8 c	63.8 ab	9,105 a
Telone C35	327 liters	5.8 bc	11.8 b	15.2 b	53.9 b	7,962 b
Telone C35	243 liters	6.0 bc	32.5 a	17.0 b	46.8 b	7,315 c
Telone C35	164 liters	16.3 ab	32.3 a	45.1 a	158.8 a	5,936 c

[v]Rates based on 1.8-m row spacing.
[w]Gall rating is based on a 0 to 100 scale, where 0 = no galls, 10 = 10% of root system galled . . . 100 = 100% of root system galled.
[x]Virtually impermeable film 1.4-mil black on white.
[y]Standard commercial polyethylene film 1.0-mil black embossed.
[z]Data are means of four replicates. Means within columns with the same letter are not different according to Fisher's protected least significant difference test ($P \leq 0.05$).

For marketable yield of tomato fruit and galling of tomato roots there was no interaction ($P > 0.05$) between fumigants and film type, therefore the data were combined for analyses. All fumigant treatments had higher marketable yields of tomato fruit as compared to nontreated plots ($P \leq 0.05$) (Table 1). Also, reducing rates of methyl bromide did not result in reduced yield, which ranged from 2.5 to 2.7-fold greater than that in nontreated control plots. Yield in plots treated with Telone C35 ranged from 1.8 to 2.4-fold greater than the nontreated control and were reduced when rates of Telone C35 were reduced. All treatments, except Telone C35 at 164 liters/ha, had gall ratings lower than nontreated plots ($P \leq 0.05$) (Table 1). The root-knot nematode juvenile densities were highly variable with no differences among them except for higher numbers extracted in the plots treated with Telone C35 at 164 liters/ha ($P \leq 0.05$).

Double Cropped Autumn Cucumber following Tomato

No interactions were detected between fumigants and film type for marketable yield of cucumber fruit or galling of cucumber roots, thus the data from the two film types were combined. All fumigant treatments had higher marketable yields than nontreated plots except methyl bromide at 393 kg/ha ($P \leq 0.05$) (Table 2). In double-cropped cucumber, the lower rates of Telone C35 produced higher yields than the two highest rates of methyl bromide. However, this increase in yield was not due to a reduction in galling, which did not differ among treatments ($P \leq 0.05$), or J2 isolated from soil (Table 2).

Table 2. Main effects of fumigant rates of methyl bromide and Telone C35 (mean of VIF[v] and LDPE[w] films) on marketable yield, root galling, and root-knot nematode second-stage juvenile (J2) population densities in soil in autumn of a double-cropped cucumber crop following a primary spring crop of tomato in a trial at the Plant Science Research and Education Unit, Citra, FL.

Treatment	Broadcast rate/ha[x]	Total marketable yield (kg/ha)	Gall rating[y] mean	J2/100 cm^3 soil
Nontreated	—	3,098 d[z]	80.0 a	62.4 b
Methyl bromide	393 kg	1,001 e	88.7 a	85.1 b
Methyl bromide	295 kg	5,845 c	92.5 a	129.0 ab
Methyl bromide	197 kg	6,336 ab	80.9 a	269.3 ab
Telone C35	327 liters	6,171 bc	96.1 a	443.7 a
Telone C35	243 liters	8,570 a	84.1 a	150.3 ab
Telone C35	164 liters	8,919 a	87.7 a	51.0 b

[v]Virtually impermeable film 1.4-mil black on white.
[w]Standard commercial polyethylene film 1.0-mil black embossed.
[x]Rates based on 1.8-m row spacing.
[y]Based on a 0 to 100 scale, where 0 = no galls, 10 = 10% of root system galled . . . 100 = 100% of root system galled.
[z]Data are means of four replicates. Means with the same letter are not different according to Fisher's protected least significant difference test ($P \leq 0.05$).

Autumn Squash

All fumigant treatments had higher marketable yields than nontreated plots except both chloropicrin treatments (with and without metam potassium) ($P \leq 0.05$) (Table 3). Correspondingly, all fumigant treatments had lower gall ratings than nontreated plots except the two chloropicrin treatments (with and without metam potassium) ($P \leq 0.05$) (Table 3). There was an interaction between fumigant and film type for nutsedge density per treatment and thus treatments were compared only within film type ($P \leq 0.05$). Under VIF film, all treatments except chloropicrin or chloropicrin plus metam potassium controlled nutsedges better than the control ($P \leq 0.05$) (Table 3). There was a higher density of nutsedge following chloropicrin plus metam potassium than in the nontreated control ($P \leq 0.05$). Under LDPE film none of the treatments were different than the nontreated control except chloropicrin plus metam potassium which had higher nutsedge densities ($P \leq 0.05$).

DISCUSSION

In these experiments we planned to demonstrate the advantage of using virtually impermeable film technology to enhance fumigant efficacy when applied at labeled rates as well as determining the effects of these fumigants applied at a 25 and 50% reduction of labeled rates. To date, formulations containing 1,3-D plus chloropicrin have shown the most promise as alternatives to methyl bromide (Gilreath and Santos, 2004), however the lack of consistent activity of this chemical mixture against weeds remains an impediment to its use as a drop-in replacement for methyl bromide. In the spring tomato trial, treatments containing Telone C35 at 327 liters/ha in conjunction with both VIF and LDPE films provided significant reductions in nutsedge densities, root galling, and increased

Table 3. Effects of film type and methyl bromide and Telone C35 fumigant rates on marketable yield, gall ratings, and control of nutsedge in autumn-grown squash in a trial located at the Plant Science Research and Education Unit, Citra, FL.

				Nutsedge plants/m²	
				Film type	
Treatment	Broadcast rate/ha[v]	Total marketable yield (kg/ha)	Gall rating[w] mean	VIF[x]	LDPE[y]
Nontreated	—	4,705 b[z]	20.6 a	19.1 b	18.0 bc
Methyl bromide 67:33	393 kg	7,274 a	1.9 cd	3.9 d	15.9 c
Methyl bromide 67:33	295 kg	6,677 a	4.4 cd	6.5 cd	21.5 bc
Methyl bromide 67:33	197 kg	8,665 a	8.2 bc	11.9 cd	24.0 bc
Telone C35	327 liters	8,843 a	5.0 cd	0.0 d	11.4 d
Methyl bromide 98:2	197 kg	9,829 a	0.0 d	2.4 d	12.8 d
Chloropicrin	136 kg/ha	4,672 b	17.6 a	23.9 ab	29.6 ab
Chloropicrin + metam potassium	136 kg/ha 561 liters	4,219 b	11.9 ab	35.1 a	40.9 a

[v]Rates were based on 1.8-m row spacing.
[w]Based on a 0 to 100 scale, where 0 = no galls, 10 = 10% of root system galled . . . 100 = 100% of root system galled.
[x]Virtually impermeable film 1.4-mil white on black.
[y]Standard commercial polyethylene film 1.0-mil white on black embossed.
[z]Data are means of four replicates. Means within columns with the same letter are not different according to Fisher's protected least significant difference test ($P \leq 0.05$).

marketable yields of primary grown crops. Although good nutsedge control was obtained with Telone C35 in our trial such results are inconsistent from year to year (Dickson, unpubl.). In the spring trial we attempted to reduce the rates of this treatment to 243 and 164 liters/ha. In all instances the densities of nutsedge plants emerging through the plastic increased, the root-gall indices increased, and the marketable yield decreased. Thus, in the autumn of 2004 we purposely omitted the reduced rates of Telone C35.

In spring grown tomato, reducing the rate of methyl bromide applied under VIF made it possible to reduce nutsedge densities and root-knot nematode galling while maintaining yields comparable to those obtained under standard dosage regardless of film type. Similar findings were reported with half-rates of methyl bromide under VIF in spring grown tomato (Nelson *et al.* 2000). In autumn grown squash, all methyl bromide treatments led to larger marketable yields of fruit and lower root-knot nematode gall ratings regardless of film type.

Double-cropping has become essential to the economic survival of vegetable growers in Florida (Gilreath *et al.*, 1999). In our experiments we hoped to demonstrate the efficacy of reduced rates of methyl bromide and 1,3-D in conjunction with VIF against root-knot nematodes in double-cropped cucumber. The results that we obtained were unexpected. In general, treatments that had the lowest marketable yields of tomato had the highest marketable yields of cucumber. No treatment, rate, or film type demonstrated any control of root-knot nematode in double cropped cucumber. All treatments had gall ratings greater than 80%. We had attempted, in a separate experiment, to demonstrate that applying either 65% 1,3-D plus 35% chloropicrin (Inline) or metam potassium before planting would provide control of root-knot nematodes on the second crop. However, this experiment was ruined by a succession of three hurricanes that hit Florida in the autumn of 2004. Further experiments should be designed to utilize these two fumigants applied via drip irrigation before a second crop is planted, and compare their efficacy with the use of *Mi-1* resistance gene in tomato, as a primary crop, to limit nematode reproduction on the first crop (Rich and Olson, 2004).

Because the film on covered beds was left undamaged by the hurricanes, squash was planted in mid-October. The late planting of squash and the lack of a primary crop led to lower than expected root-knot nematode galling of roots. One interesting observation in the autumn study concerned nutsedge densities in each of the treatments. In treatments where chloropicrin was applied in-bed followed by metam potassium via drip irrigation, nutsedge densities were significantly greater than nontreated plots. Nutsedge plants in all plots treated with chloropicrin were notably more vigorous and healthier than nutsedge plants in nontreated plots. It appears that chloropicrin in combination with K-Pam, at the rates that were tested, has a stimulating effect on nutsedge rather than a herbicidal effect.

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