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Impact of Solarization and Soil Fumigants on Hot Pepper Production in High-Tunnels

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Abstract: High-tunnel studies were conducted in La Ceiba, Alajuela, Costa Rica, to examine the effect of fumigants and solarization on soilborne pest control and Campana hot pepper (*Capsicum frutescens* L.) marketable yield. Fumigant treatments were: (a) methyl bromide plus chloropicrin (MBr + Pic 98:2 w/w) at a rate of 500 kg ha^{-1}, (b) emulsifiable concentrate of 1,3-dichloropropene (1,3-D) plus Pic at 275 L ha^{-1}, (c) emulsifiable concentrate of metam sodium (metam-Na) at 275 L ha^{-1} and (d) non-treated control. Soil was either solarized for 8 weeks (average maximum temperature ≈ 60°C) or not solarized. Solarization reduced the weed densities, but not rootknot nematode populations (*Meloidogyne* sp.). Similarly, there was no solarization effect on hot pepper yield. Among the fumigants, MBr + Pic and 1,3-D + Pic had the best performance controlling the nematode. Pepper yield in 1,3-D + Pic-treated plots was equal as with MBr + Pic.

Key words: *Capsicum*, *Meloidogyne*, methyl bromide, soilborne diseases, nematodes, 1,3-dichloropropene, chloropicrin, metam sodium

INTRODUCTION

In Costa Rica, vegetable production under tunnels has steadily increased during the last several years. Small and medium-size coffee growers have mostly developed this activity, hoping to compensate with agricultural diversification for the current low international coffee prices. Intensive vegetable production, mainly with crops in the Solanaceae family, has become a permanent activity in Costa Rica's Central Valley and in many cases has replaced coffee. Although official statistics are lacking, current estimations indicate that there are 1080 tunnels (covering approximately 180 ha) within the Central Valley, which benefit about 340 growers, 38% of which have more than 0.1 ha (J.E. Mora, personal communication).

The most important problem in the Costa Rican vegetable tunnel production is managing soilborne pests. The main soilborne diseases are *Phytophthora* sp., *Phytium* sp. and *Rhizoctonia solani* Kuhn, as well as bacterial species from the *Ralstonia* (*Pseudomonas*) genus and nematodes such as *Meloidogyne* sp. and *Pratylenchus* sp. Preliminary soil samples collected in the production area showed *Meloidogyne* populations of 25,000 juveniles/100 mL soil. These nematode genera occur naturally in coffee fields without causing apparent economic damages. However, as the vegetable production intensifies, nematode populations have abruptly increased, causing significant yield losses.

Chemical control, mainly with Methyl Bromide (MBr), has been the main tool to reduce the incidence of soilborne pests in tunnel production. This fumigant is widely utilized in for both muskmelon (*Cucumis melo* L.) and cutflower production. However, in compliance with the Montreal Protocol, methyl bromide has been removed from most agricultural markets due to its ozone-depleting properties (Watson *et al*., 1992). Because of this situation, additional research must be conducted to identify alternatives for soilborne pest control in vegetable crops grown under tunnel conditions.

Soil solarization is a non-chemical soilborne pest management method which provided adequate yellow and purple nutsedge control when used in the summer months (Chase *et al*., 1997a, b; Chellemi *et al*., 1997). This methodology has been proposed as a non-chemical alternative to MBr fumigation. Soilborne pest control with solarization is accomplished by heating the soil prior to crop establishment. High soil temperatures lethal to soilborne pest propagules are obtained by covering the soil with transparent polyethylene film for 6 to 8 weeks. Other experiments obtained 100% mortality of nutsedge tubers with soil temperatures between 50 and 55°C (Chase *et al*., 1999). However, other results have been

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variable and inconsistent (Gilreath *et al*., 2005). Therefore, more research is needed to validate this methodology for commercial settings. The objective of this study was to compare the combination of soil solarization and chemical methyl bromide alternatives for soilborne pest control in hot pepper.

MATERIALS AND METHODS

Two tunnel studies were conducted in 2004 and 2005 at Alajuela, Costa Rica, located at 1100 m above sea level. The experiment was established in a 10 m high 4500 m^2 clear-plastic tunnel. The soil in the experimental site is a deep Andosol with adequate drainage, medium fertility and high phosphorus retention. This soil was used for coffee production during more than 50 years. Raised beds inside the tunnel were 1.0 m wide by 0.25 m tall. Campana hot pepper seedlings were transplanted 0.5 between plants and double rows. Planting beds were 1.2 m apart from centers.

Treatments were distributed in a split-plot design with 4 replications. Each experimental unit was 12 m^2. Main plots had either solarized or non-solarized soil. In the subplots, the fumigant treatments were: (a) non-fumigated control, (b) MBr + chloropicrin (Pic) 67:33 (v/v) at a rate of 450 kg ha^{-1}, (c) emulsifiable formulation of 1,3-dichloropropene (1,3-D) + Pic 65:35 (v/v) at 500 L ha^{-1} and (d) emulsifiable formulation of metam-Na at 600 L ha^{-1}. The fumigants were applied 3 weeks before transplanting. Soil solarization was achieved by covering the corresponding plots with clear plastic mulch for 8 weeks.

Weed control by species, nematode population in the soil and hot pepper plant height were recorded at 7 WAT. Weed control (0-100% scale, where 0 = no control and 100% = total control) data was related to the MBr + Pic plots, which were weed-free throughout the season. Soil samples for nematode identification and enumeration were collected with a 2.5 cm-wide probe inserted 20 cm into the soil within the root zone of 8 to 10 plants per plot. Nematodes were separated from 100 mL of soil using a standard sieving and centrifugation procedure (Jenkins, 1964). At the end of the cropping season, the commercial fruit yields of eight harvests were added and analyzed with analysis of variance (ANOVA). Weed and nematode data were transformed before ANOVA by using a $\log_{10}$ + 1 transformation to stabilize variances. Treatment means were separated using the least significant difference comparison procedure at the 5% significance level (SAS Institute, 2000).

RESULTS AND DISCUSSION

Solarized soil reached a maximum daily temperature of 60°C, which was significantly higher than the average maximum temperature for non-solarized soil (30°C). Weed control in the solarized plots without fumigation was about 100%, whereas in the non-solarized and non-fumigated treatments the weeds *Digitaria* sp., *Panicum trichoides* Sw., *Eleusine indica* (L.) Gaertn, *Commelina diffusa* Burm., *Portulaca oleracea* L., *Ricardia scabra* L., *Galinsoga parviflora* Cav. and *Sonchus oleraceus* L. were the most dominant species in the transplanting holes (data not shown).

There was no significant solarization effect on plant height, rootknot nematode populations and hot pepper yield. However, fumigant treatments affected all these variables. For hot pepper plant height, plots treated with either MBr + Pic or 1,3-D + Pic had the tallest plants with 103 and 101 cm, respectively (Table 1). There was no metam-Na effect on plant height as compared to the non-treated control, which was approximately 10% shorter than the plants fumigated with MBr + Pic.

Fumigation with MBr + Pic resulted in the lowest rootknot nematode populations (60 juveniles/100 mL soil), followed by 1,3-D + Pic (1,200 juveniles/100 mL soil). The non-treated control and metam-Na had the highest nematode populations (Table 1). The nematode population in the 1,3-D + Pic treatment (1,200 juveniles/100 mL soil) appeared to be below the damage threshold, whereas the nematode population in the control plots (2,580 juveniles/100 mL) reduced yield by approximately 23%. This suggested that the critical nematode population threshold occurred between 1,200 and 2,580 juveniles/100 mL. For marketable hot pepper weight, the application 1,3-D + Pic (118 t ha^{-1}) resulted in higher yield than the non-treated control (91 t ha^{-1}) and

Table 1: Effect of soil fumigants on rootknot nematode (*Meloidogyne* sp.) populations and hot pepper (*Capsicum frutescens*) plant height and marketable yield, Alajuela, Costa Rica

Fumigant	Rate (per ha)	Plant height[a] (cm)	Rootknot nematode (juveniles/100 mL)	Marketable yield (t ha^{-1})
Non-treated control	-	89[b]	2,580[a]	91[b]
MBr + Pic (67:33)	450 kg	103[a]	60[c]	109[a]
1,3-D + Pic (65:35)	500 L	101[a]	1,200[b]	118[a]
Metam-Na	600 L	91[b]	2,900[a]	93[b]

[a]: Plant height and rootknot nematode data collected at 50 days after transplanting. Values separated within columns by LSD multiple comparison procedure. Values with the same letter(s) within columns do not differ at the 5% significance level within each year

metam-Na (93 t ha^{-1}), but equal to MBr + Pic (109 t ha^{-1}). There was no yield difference between metam-Na and the non-treated control.

These results indicated that under the conditions of this trial, solarization had a significant impact on weed densities, which agrees with previous reports on the effect of this practice on weed control (Chase *et al*., 1997a, b; Chellemi *et al*., 1997). However, it was not sufficient to reduce nematode populations and to increase hot pepper fruit yield, which could indicate that soil temperatures in the solarized plots might not have been high enough to affect nematode populations. In contrast, 1,3-D + Pic proved to be a valuable means to control soilborne pests in tunnel hot pepper production.

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