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Biofumigation for Management of Root-knot Nematode in Home Gardens

Investigator:

Becky B. Westerdahl
Extension Nematologist/Professor of Nematology
Department of Nematology
University of California, Davis
One Shields Avenue
Davis, CA 95616
Phone: (530) 752-1405
Fax: (530) 752-5674
E-mail: bbwesterdahl@ucdavis.edu

Introduction:

Plant-parasitic nematodes are microscopic roundworms that cause problems for home gardeners. Few control measures are available to California gardeners other than two years fallow, planting a trap crop, or planting nematode resistant tomatoes. Commercial tomato growers are experiencing increasing problems with the selection of resistance breaking races following repeated planting of nematode resistant varieties (Chuck Rivara, California Tomato Research Institute, personal communication) indicating the need for rotation with other crops, or with susceptible varieties of tomatoes. The root-knot nematode, *Meloidogyne* sp., causes the most serious problem as

its effects are readily visible to home gardeners by the presence of knots or galls visible on roots, as in the carrot pictured above (Fennimore et al., Westerdahl et al.).

This proposal explored the feasibility of using biofumigation with broccoli residue as a tool for home gardeners to manage root-knot nematode. For example, home gardeners could grow broccoli in their gardens during the fall and winter, then till in the crop residue, allow it to decompose and release biofumigant for several weeks, and then follow with a root-knot nematode susceptible crop.

Plant allelochemicals toxic to nematodes represent an alternative to synthetic nematicides. Plants in the Brassicaceae produce secondary chemical compounds know as glucosinolates (Larsen, 1981) that are considered part of the plant's constitutive defensive mechanisms (Rask, 2000). As distinguished on the basis of side-chain chemistry, there are more than 100 glucosinolates (Brown and Morra, 1997). Glucosinolates (GLS) can be hydrolyzed, with the specific products produced depending on the side-chain chemistry, but nitriles, isothiocynates, epithionitriles, and thiocynates are common (Gardiner et al., 1999; Rask et al., 2000). Hydrolysis can occur by different paths, but plant enzymes, thioglucosidases (denoted myrosinases) catalyze the degradation. The isothiocyanates are volatile toxins, and are considered to have the highest biological activity (Smolinska and Horbowicz, 1999), and, synthetic isothiocynates (metam sodium) are used as commercial nematicides. Accordingly, the GLS-myrosinase system has received attention for use in biofumigation to suppress soil-borne pathogens and pests through the biocidal compounds released by Brassica residue decay in soil (Kirkegaard et al., 2000). It has been suggested that the bio-fumigant properties of crucifer tissues result from a combination of low quantities of highly toxic isothiocynates, and large quantities of mildly toxic non-glucosinolate derived, volatile S-containing compounds produced during decomposition (Bending and Lincoln, 1999). Whatever the exact chemical moieties involved in the mode of action, the GLS-myrosinase system holds some promise. It has been noted of the compounds produced by the system that "their toxicity and quick dispersal and degradation to more innocuous compounds make glucosinolate hydrolysis products and the plants that produce them potential alternatives to the synthetic soil fumigants, many of which have been banned because of adverse environmental effects" (Gardiner et al., 1999).

Because of the toxic nature of GLS byproducts, different Brassicas have been assessed as organic soil amendments to suppress plant pests, including fungi and nematodes, with some success (e.g., Donkin et al., 1995; Olivier et al., 1999; Lazzeri et al., 1993; Mojtahedi et al., 1991; Ploeg, A. T., and Stapleton, J. J. 2001; Potter et al., 1999; Smolinska and Horbowicz, 1999; Stapleton and Gamliel, 1994).

Materials and Methods:

A field trial was conducted at the UC South Coast Research and Extension Center in Orange County in a field infested with root-knot nematode (*Meloidogyne javanica).* The field location had a loam soil (66 percent sand, 21 percent silt, 13 percent clay and

0.6 percent stable organic matter) with a pH of 7.6 and a CEC of 0.68 milimhos/cm. The experiment was conducted in a randomized complete block design with 4 replications per treatment.

In the trial area, a crop of broccoli (*cv.* Marathon) was grown and harvested. The remaining leaves and stocks were chopped, transferred to appropriate treatment plots, and rototilled to a depth of 6 inches. Treatments were: 1) untreated (no broccoli soil amendment, although roots of previous broccoli crop remained in place), 2) untreated with tarp), 3) 1x broccoli, 4) 1x broccoli plus tarp, 5) 2x broccoli, and 6) 2x broccoli plus tarp. To create the untreated and 2x treatments, broccoli stocks were moved from the untreated plots to the 2x plots. Two treatments were covered with a 2 mil polyethylene tarp, because in traditional fumigation the fumigant typically diffuses out of the soil into the air too rapidly to control nematodes in the top 2 to 3 inches of soil. Addition of a tarp slows down the rate of diffusion and improves control in the surface soil. Tarps were left in place for three weeks and then removed. A longer period of tarping might improve efficacy via solarization in the top few inches of soil, however, that is not the focus of this proposal. Carrots, a fast growing nematode indicator crop was grown to maturity.

Depth of control was monitored by the use of citrus nematode (*Tylenchulus semipenetrans*) bioassay bags buried in plots at depths of 2, 6, and 12 inches and by evaluation of root-knot nematode in soil samples. Soil samples for nematodes consisted of a composite of 12, 1-inch-diameter cores taken to a depth of one foot in the treatment areas. Nematodes were extracted via elutriation and sugar centrifugation. Citrus nematode survival was evaluated via Baermann funnel extraction.

Each replicate in the trial was 9 feet wide (3 rows) by 20 feet long. Harvest data was taken from the center 10 feet of the middle row of each replicate, leaving sufficient buffers on all sides of each replicate to avoid edge effects and effects caused by soil movement during tillage. Harvested carrots were graded into 4 categories: 1) without nematode damage, 2) with nematode damage only on lateral roots that would normally be removed prior to eating, 3) not typically edible because of nematode damage, and 4) not typically edible without nematode damage. Carrots in each category were counted and weighed. For data analysis, categories 1 and 2 were combined to determine typically acceptable numbers and weights of carrots. Data were analyzed with Analysis of Variance (ANOVA) followed by Fisher's Least Significant Difference Test. Percent values were arcsin transformed prior to analysis.

Results and Discussion:

Carrots were used as the final demonstration crop because they are a very sensitive root-knot nematode bioindicator crop. Results from carrots can be extended to other root-knot sensitive crops such as heirloom varieties of tomatoes, beans, potatoes, sweet potatoes, cucumbers, peppers, squash, and melons.

The PF/PI (final over initial population) of nematodes indicated statistically significant nematode reductions for the 2x broccoli with a tarp (figure 1), and yield increases for the 2x rate of broccoli (figure 2) with and without a tarp. The citrus nematode bioindicators did not demonstrate the depth of control achieved (figure 3).

Conslusions:

This proposal clearly demonstrated the benefits of biofumigation. However, it appears that to be effective, a 2X rate of broccoli should be used, and that effectiveness could be increased by tarping. Not all home gardeners have problems with plant parasitic nematodes, but for those who do, we have little to offer in terms of nematode management. Biofumigation, trap cropping, or combinations of the two could allow the growing of highly susceptible root-knot nematode sensitive crops such as carrots, heirloom varieties of tomatoes, beans, potatoes, sweet potatoes, cucumbers, peppers, squash, and melons.

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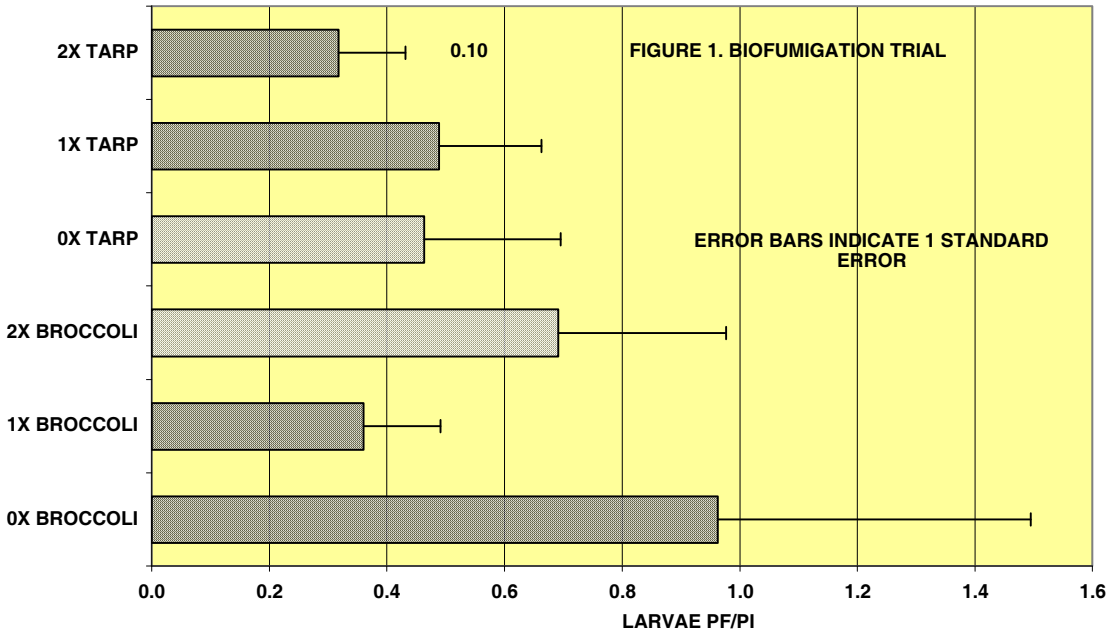
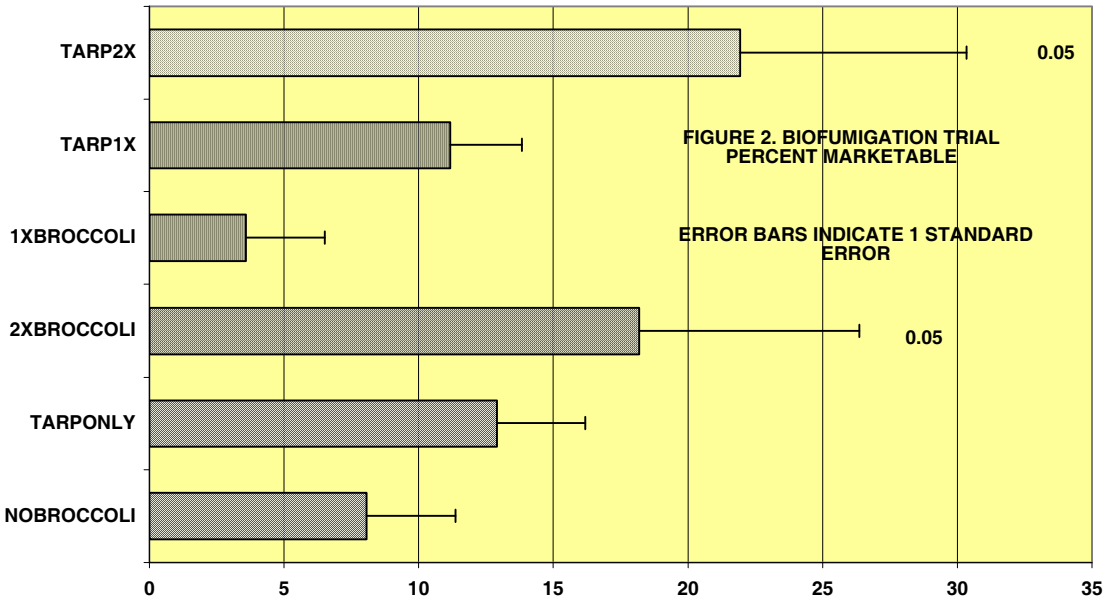
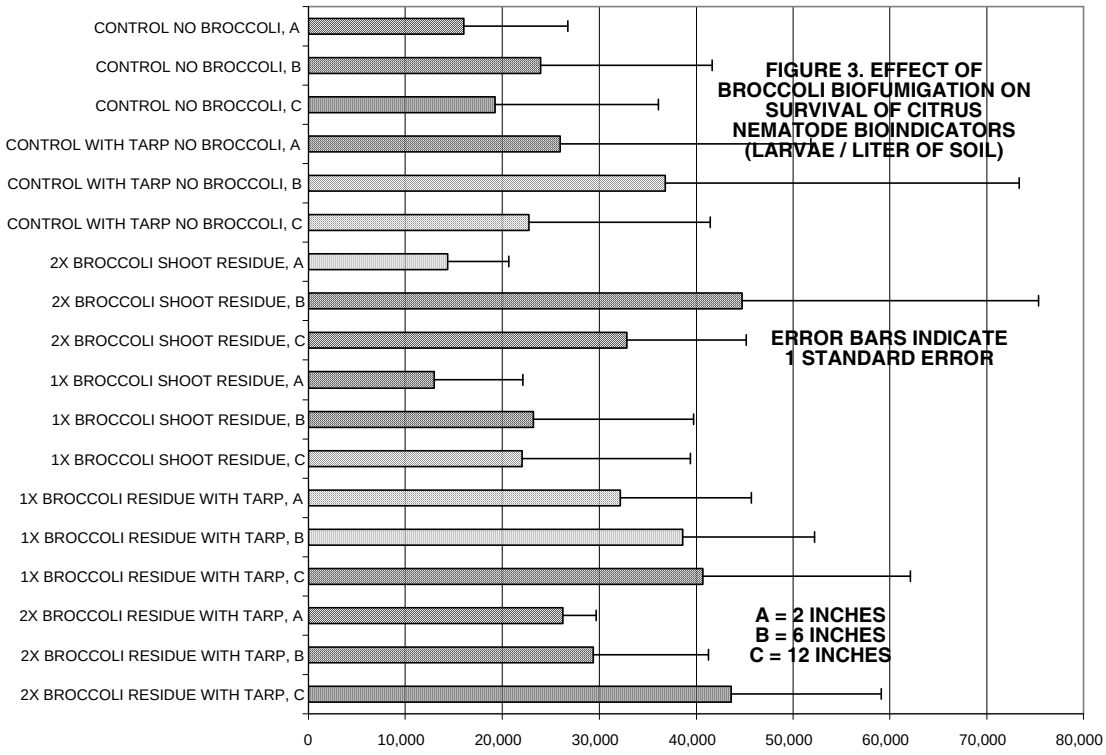

2X TARP
1X TARP
0X TARP
2X BROCCOLI
1X BROCCOLI
0X BROCCOLI
0.10
FIGURE 1. BIOFUMIGATION TRIAL
ERROR BARS INDICATE 1 STANDARD ERROR
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
LARVAE PF/PI


TARP2X
TARP1X
1XBROCCOLI
2XBROCCOLI
TARPONLY
NOBROCCOLI
0.05
0.05
FIGURE 2. BIOFUMIGATION TRIAL
PERCENT MARKETABLE
ERROR BARS INDICATE 1 STANDARD ERROR
0
5
10
15
20
25
30
35


CONTROL NO BROCCOLI, A
CONTROL NO BROCCOLI, B
CONTROL NO BROCCOLI, C
CONTROL WITH TARP NO BROCCOLI, A
CONTROL WITH TARP NO BROCCOLI, B
CONTROL WITH TARP NO BROCCOLI, C
2X BROCCOLI SHOOT RESIDUE, A
2X BROCCOLI SHOOT RESIDUE, B
2X BROCCOLI SHOOT RESIDUE, C
1X BROCCOLI SHOOT RESIDUE, A
1X BROCCOLI SHOOT RESIDUE, B
1X BROCCOLI SHOOT RESIDUE, C
1X BROCCOLI RESIDUE WITH TARP, A
1X BROCCOLI RESIDUE WITH TARP, B
1X BROCCOLI RESIDUE WITH TARP, C
2X BROCCOLI RESIDUE WITH TARP, A
2X BROCCOLI RESIDUE WITH TARP, B
2X BROCCOLI RESIDUE WITH TARP, C
FIGURE 3. EFFECT OF BROCCOLI BIOFUMIGATION ON SURVIVAL OF CITRUS NEMATODE BIOINDICATORS (LARVAE / LITER OF SOIL)
ERROR BARS INDICATE 1 STANDARD ERROR
A = 2 INCHES
B = 6 INCHES
C = 12 INCHES
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000