MELON RESEARCH BOARD
Research Report
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Project Title: Evaluating the Efficacy of the Novel Nematicide "Nimitz" to Prevent Root-knot Nematode Damage in Melon

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Introduction

Root-knot nematodes (*Meloidogyne incognita* and *M. javanica*) are economically the most damaging plant-parasitic nematodes of cucurbits, including all types of melons. The nematodes are widespread throughout Central and Southern California and are especially damaging in lighter soil types (Siddiqui et al., 1973). Damage results from the invasion of melon roots by second-stage juveniles (J2) and their subsequent feeding on the cell contents. The roots are modified by the feeding nematodes to produce large numbers of big root galls, typical of root-knot nematode infestation. The damaged root systems are unable to sustain the demand of the plant for water and nutrients, resulting in stunted growth, early wilting and yield loss. Furthermore, root systems affected by the nematodes become more susceptible to further damage by soil borne fungi and bacteria. Few nematodes are needed to cause damage. DiVito et al. (1983) found in microplot trials in Italy that when 100 cc soil contained more than 19 root-knot nematodes at planting time, damage started to occur. In California, Ferris (1985) reported that even 1 nematode per 100 cc at planting time resulted in damage. Similar results were more recently obtained from greenhouse pot experiments and from field trials by Ploeg and Phillips (2001) who estimated damage thresholds for cantaloupe cv. Durango between 3.5 and 0.5 J2 per 100 g soil at planting.

All melons are excellent hosts for root-knot nematodes and there are no resistant cultivars. Although cultural methods can be helpful in reducing pre-plant nematode population levels, management of root-knot nematodes in commercial melon production has relied almost exclusively on the availability of soil fumigants and soil-applied nematicides. The current UC IPM guidelines for cucurbits recommend nematicide treatment of fields whenever root-knot nematodes are detected in pre-season samples (Westerdahl, 2000). However, increasing costs and regulatory restrictions have reduced the number of available options. Methyl bromide, a soil fumigant used against certain soilborne pathogens, plant-parasitic nematodes and weeds, has been implicated in stratospheric ozone depletion and is no longer available for use in the US (Noling and Becker, 1994). Currently, other soil fumigants are being re-evaluated in California, because they have been identified as major contributors to the release of VOC's (volatile organic compounds) into the atmosphere, causing air pollution.

Several new potential nematicides have been tested by us in the last few years and a few appear to be very promising. One of these products, Nimitz™ (a.i. fluensulfone) from ADAMA, has recently received federal EPA registration. This non-fumigant nematicide has a

CAUTION label and an REI of 24hr (http://www.adama.com/us/en/crop-protection/Insecticides/nimitz.html). In previous field trials with tomato and carrots, Nimitz™ consistently and significanlty reduced symptoms of root-knot nematodes on roots of these crops compared to the untreated control, but field trials with melon had not been done. Another, not yet registered development product (DP) that in previous years also appeared very promising was included in this field trial with melon.

Experimental design and set-up

Field location and layout: A field trial was initiated at the South Coast Research and Extension Center located at Irvine, Southern California. The field site was on root-knot nematode (*M. incognita*) infested sandy-loam. The field was prepared on 6/2/2014. Beds (60 inch c-c) were shaped, and treatments were assigned to thirty plots (20 ft long section of bed, 3 ft buffer between plots along the beds) according to a randomized block design.

Soil sampling and nematode analysis: Before the first treatment and at harvest, soil samples were collected from all plots using a sampling tube (diameter 0.5 inch) from between 5-10 inches deep. Ten cores were collected at random from each plot to form one composite sample per plot. Samples were transported to the laboratory and nematodes were extracted from 100 g sub-samples using a Baermann-funnel technique. Numbers of second-stage root-knot nematode juveniles were counted under 40x magnification.

Application of products: Pre-seeding "incorporated" applications were done by hand-watering the products over the top of pre-moistened beds using a watering can. Products were applied in an 18-inch-wide band over the center of the beds in 2 gallons water per plot. This was followed with an additional 2 gallons of water only, and incorporating into the top 5 inches of soil using a roto-tiller (UTC plots were also tilled). Post-seeding applications were applied through irrigation tubing (drip emitters 2 l/hr, 1 ft spacing) either buried at 4 inches depth through the center of the beds (trt 1, 4, 5) or on top of the beds (trt 6, 7). Prior to injecting the products, water was run for 10 minutes to ensure all irrigation tubing was filled. Products were dissolved in 3 gallons (11.3 l) water, and pumps were adjusted to deliver 22 l/hr. to result in a 30-minute chemigation period. The suspension was continuously agitated during the 30-minute chemigation period. Chemigation was followed by a 10-minute irrigation period (water-only) to flush the lines.

Treatments and rates: There were eight treatments: there were four Nimitz treatments, two DP treatments, a Vydate treatment, and a non-treated control.

Table1. Treatments and application schedule.

TRT #	TRT code	PRODUCT	TIMING	RATE	METHOD
1	VYD	Vydate	0 dbs	5 pt/A	incorporated
			15 das	5 pt/A	buried drip
2	NIMinc_l	Nimitz	14 dbs	3.5 pt/A	incorporated
3	NIMinc_h	Nimitz	14 dbs	5 pt/A	incorporated
4	NIMdrp_l	Nimitz	14 dbs	3.5 pt/A	buried drip
5	NIMdrp_h	Nimitz	14 dbs	5 pt/A	buried drip
6	DP_l		0 dbs	15.4 fl oz/A	incorporated
			28 das	7.7 fl oz/A	drip on top
7	DP_h		7 dbs	30.7 fl oz/A	incorporated
			28 das	7.7 fl oz/A	drip on top
8	UTC	Untreated			

Treatments and rates were applied as shown in Table 2.

Table 2. Dates, soil temperatures, treatments[1], rates[2], and field activities.

Date	Soil temp (C)	Activity	Treatment number[1]
6/2/2014	21.2	shape beds, stake out plots, bury drip tubing in appropriate plots.	
6/9/2014	22.0	collected soil samples from all plots	
		applied Nimitz @ 3.5 pt /A (in 2 gallon water, followed with 2 gallons water, tilled in)	2
		applied Nimitz @ 5 pt /A (in 2 gallon water, followed with 2 gallons water, tilled in)	3
		applied Nimitz @ 3.5 pt /A (chemigation, buried drip)	4
		applied Nimitz @ 5 pt /A (chemigation, buried drip)	5
6/18/2014	22.3	applied DP @ 30.7 fl oz/A (in 2 gallon water, followed with 2 gallons water, tilled in)	7
6/24/2011	22.5	applied DP @ 15.4 fl oz/A (in 2 gallon water, followed with 2 gallons water, tilled in)	6
		applied Vydate @ 5 pt/A (in 2 gallon water, followed with 2 gallons water, tilled in)	1
		seeded melon Cantaloupe 'Durango'. 2 seeds/spot, spots at 1 ft intervals. Additional 5 spots off-center for mid-season root indexing.	
7/8/2014	23.6	applied Vydate @ 5 pt/A (chemigation, buried drip). thinned plants to 1 plant per spot.	1
7/22/2014	23.4	applied DP @ 7.7 fl oz/A (trts 6[1], 7[1]; chemigation, drip on top).	6,7
7/31/2014	24.2	removed 5 'extra' melon plants, index for mid-season root-galling. Rate vigor of plots.	
9/9/2014	24.2	collected soil samples from all plots harvested all melon fruits indexed roots of five melon plants per plot for galling	

[1]treatment numbers as shown in Table 1.
[2]Actual amounts applied were calculated according to: bed surface=20 ft long x 18 inches width of bed =30 sq ft/plot=0.00069 acre. Thus, amount per plot = 0.00069 x rate/acre.

Plants and plant data collected: Cantaloupe melon (*Cucumis melo*) were direct-seeded (2 seeds per spot) by hand in the center of the beds at 1-ft intervals on 6/24/2014. An extra 5 spots (2 seeds/spot) per plot were seeded slightly off-center for mid-season root-galling. On 7/8/2014 seedlings were thinned to 1 plant per spot. Plants were fertigated according to commercial practices.

The vigor of the plots was rated visually on 7/31/2014. on a scale from 0-10, with 0=worse, 10=best. Vigor included the size of plants, plant color, uniformity, and general appearance. On the same day (7/31/2014) the 5 'extra' plants that had been planted slightly off center, were dug from each plot and the severity of root galling on these plants was visually rated (scale 0-10; 0=no galls, 10=100% of roots galled). The average of the galling on these five plants was used to give a galling index for each plot.

At harvest (on 9/9/2014), soil samples were collected and processed for nematode extraction as described before, and the number of plants per plot at harvest was counted. All melon fruits larger than 'golf ball' size were picked, and weighed individually. Five plants were dug randomly from each plot, and the roots were indexed for galling as described before.

Statistical analysis: Data were analyzed using SAS statistical software. Data were subjected to ANOVA procedures. If treatment effects were significant, their means were further separated using Fishers' protected LSD test, at the 95% level of confidence. Nematode soil counts were log-transformed prior to data analysis. Percentage marketable fruits were arcsin-transformed before statistical analysis.

Results

Plant vigor: Germination was good, and no obvious differences were observed. There were some differences in vigor between plots on 7/31/2014 but these differences were not related to treatments (Table 3).

Table 3. Average (n=5) vigor of melon 'Durango' plots during the 2014 growing season in eight treatments. Field located at SCREC, Irvine, CA. Vigor on a scale from 0-10, with 0=worse, 10=best (±se)

Treatment	Vigor
VYDATE	6.9 ±1.1
NIMITZ INC_L	6.3 ±1.1
NIMITZ INC_H	6.7 ±0.6
NIMITZ DRP_L	7.8 ±0.3
NIMITZ DRP_H	7.0 ±0.8
DP_LOW	8.5 ±0.9
DP_HIGH	7.9 ±0.6
UTC	6.5 ±1.2
treatment *P-value*	0.47

Fruit Yield: Fruits were counted and weighed individually, and the total fruit weight per plot was divided by the number of plants per plot to give the weight and number of fruit per plant for each plot. Fruits were assigned a commercial size (based on nr. of fruits needed to fill a 40 lb box) according to: 'cull' = <720 g, 'size 23' = 720-853 g, 'size 18' = 854-1056 g, 'size15' = 1057-1293 g, and 'size 12' = >1293 g. Marketable fruits included all fruits in sizes

15 and larger (>1057 g). There were no significant differences (*P≤0.05*) between treatments in the fruit yield (kg fruit per plant), number of fruits per plant, or marketable fruit (Table 4).

Table 4. Average (n=5) fruit yield of melon 'Durango' plots during the 2014 growing season in eight treatments (±se). Field located at SCREC, Irvine, CA.

Treatment	kg fruit per plant	nr. fruit per plant	% marketable fruit
VYDATE	1.84 ±0.38	1.82 ±0.22	37.3 ±8.7
NIMITZ INC_L	2.05 ±0.24	1.94 ±0.16	49.1 ±7.1
NIMITZ INC_H	2.27 ±0.34	2.14 ±0.25	43.7 ±5.5
NIMITZ DRP_L	1.86 ±0.12	1.70 ±0.11	50.4 ±2.4
NIMITZ DRP_H	1.89 ±0.14	1.69 ±0.10	48.3 ±3.4
DP_LOW	2.84 ±0.34	2.37 ±0.22	63.8 ±4.6
DP_HIGH	2.79 ±0.47	2.39 ±0.32	59.1 ±6.0
UTC	2.51 ±0.50	2.18 ±0.33	50.6 ±10.1
treatment *P-value*	0.277	0.248	0.207[1]

[1]*P-value* of arcsin-transformed data, non-transformed data are shown.

<u>Soil nematode levels:</u> Initial root-knot nematode (*M. incognita*) levels were moderately low, with an average of 12.4 J2/100g soil. Prior to applying the treatments, there were no significant differences in soil root-knot nematode levels (Table 5). At harvest, nematode levels had increased in all treatments, but the at-harvest population levels were not significantly different between the treatments (Table 5)

Table 5. Average (n=5) root-knot nematode levels in melon 'Durango' plots during the 2014 growing season in eight treatments. Field located at SCREC, Irvine, CA. Number of second-stage root-knot nematodes (*M. incognita*) per 100g soil.

Treatment	Initial RKN level (Pi)	RKN level at harvest (Pf)
VYDATE	7±2.0	320±96
NIMITZ INC_L	21±14	255±73
NIMITZ INC_H	6±2.9	158±73
NIMITZ DRP_L	20±2.0	135±36
NIMITZ DRP_H	13±3.3	100±40
DP_LOW	8±2.8	45±24
DP_HIGH	12±3.1	190±80
UTC	12±3.7	205±69
treatment *P-value*	0.50[2]	0.06[2]

[1]different letters in a column indicate significant differences at the 95% confidence level.
[2]*P-value* of Log(x+1)-transformed data, non-transformed data are shown.

<u>Root-galling:</u> The severity of root-galling was indexed at mid-season (7/31/2014) and at harvest (9/9/2014). At mid-season, average root galling ranged between 0.6 in the high rate of DP and 3.4 in the untreated control. At this time, the two incorporated Nimitz™ treatments lowered root-galling compared to the untreated control as well as compared to Vydate. At

harvest, galling in the high rate of DP had not increased (0.6), but was severe both in the untreated control (8.6) and the Vydate treatment (7.7). Both test products (DP and Nimitz™) resulted in significant reductions in melon root-galling at harvest time compared to untreated control and to the Vydate treatment (Table 6).

Table 6. Average (n=5) galling on melon 'Durango' roots at mid-season and at harvest during the 2014 growing season in eight treatments. Field located at SCREC, Irvine, CA. Galling on a scale from 0=no galls, to 10=100% of roots galled.

Treatment	Mid-season		At harvest	
VYDATE	2.9±0.5	ab[1]	7.7±0.6	a
NIMITZ INC_L	1.4±0.1	cd	4.9±0.7	b
NIMITZ INC_H	1.7±0.3	c	2.8±0.3	cd
NIMITZ DRP_L	2.5±0.3	abc	4.6±0.9	b
NIMITZ DRP_H	2.3±0.3	bc	4.2±1.0	bc
DP_LOW	1.8±0.6	c	1.7±0.5	de
DP_HIGH	0.6±0.3	d	0.6±0.2	e
UTC	3.4±0.5	a	8.6±0.4	a
treatment *P-value*	0.0005[2]		0.0001[2]	

[1]different letters in a column indicate significant differences at the 95% confidence level.

Conclusions

There were highly significant differences between the treatments in the severity of galling on the melon roots, both at mid-season at and harvest. The two DP treatments dramatically reduced galling throughout the entire growing season. Although the DP treatments had the highest yields (kg fruit per plant, nr fruit per plant, % marketable fruit) these effects were not statistically significant. The Nimitz™ treatments also significanlty reduced nematode symptoms on the melon roots. There were no indications that the method of Nimitz™ application (incorporated vs. chemigation) affected the efficacy. A season-lasting nematicidal effect of Nimitz™ or DP was not observed: Although the low rate of DP had the lowest root-knot nematode population at harvest, the high rate of DP resulted in at-harvest nematode levels that were very similar to the untreated control.

It appears that Nimitz™ is a viable option for root-knot nematode management in melons, when applied as a pre-plant incorporated drench or pre-plant chemigation through shallow buried drip. Currently it is not known how it will perform when applied pre-plant through deeper (10-12 inches) buried drip (as is common in several vegetable growing systems).