MELON RESEARCH BOARD
Research Report
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Project Title: **Project title: Effect of application method on the efficacy of the nematicide Nimitz™ 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, is registered for use on fruiting vegetables - including melon - in California. This non-fumigant nematicide has a CAUTION label and an REI of 0 hr (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. A first field trial with Nimitz™ in melon in 2014 showed that this nematicide also significanlty reduced nematode-caused root-galling compared to the untreated control and to Vydate. In the 2014 trial Nimitz™ was applied pre-plant over the top of the bed followed by shallow incorporation, or applied through shallow buried drip tubing. In this years' trial the efficacy of this product applied through a deep buried drip was evaluated. Another, not yet registered development product (DP) that in previous years also appeared very promising was again included in this years' 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 5/8/2015. Beds (60 inch c-c) were shaped, and treatments were assigned to 35 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: Two Nimitz treatments (trt #3, trt #4 see Table 1) were applied through irrigation tubing (drip emitters 2 l/hr, 1 ft spacing) buried at 12 inches depth in the center of the beds. A "standard" Nimitz treatment (trt #5), pre-plant Vydate (trt #2) and pre-plant DP (trt #6, trt #7) were applied by hand-watering the products over the top of pre-moistened beds using a watering can 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-plant applications of Vydate (trt #2) and DP (trt #6, trt #7) were applied through drip tubing placed on top of the beds. For application through drip tubing (trt #2, trt #3, trt #4, trt #6, trt #7) water was run for 10 minutes to ensure all irrigation tubing was filled before injecting the products,. 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 seven treatments: there were three 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	UTC	Untreated			
2	VYD	Vydate	0 dbs 15 das	5 pt/A	incorporated drip on top
3	NIMinc_l	Nimitz	10 dbs	3.5 pt/A	deep buried drip (12")
4	NIMdrp_h	Nimitz	10 dbs	5 pt/A	deep buried drip (12")
5	NIM_c	Nimitz	10 dbs	5 pt/A	incorporated
6	DP_7		7 dbs 14 & 28 das	30.7 fl oz/A 7.7 fl oz/A	incorporated drip on top
7	DP_0		0 dbs 14 & 28 das	30.7 fl oz/A 7.7 fl oz/A	incorporated drip on top

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]
5/8/2015	18.3	shape beds, stake out plots, bury drip tubing in appropriate plots.	
5/20/2015	19.4	collected soil samples from all plots	
5/22/2015	19.4	applied Nimitz @ 5 pt /A (in 2 gallon water, followed with 2 gallons water, tilled in)	5
		applied Nimitz @ 3.5 pt /A (chemigation, 12" buried drip)	3
		applied Nimitz @ 5 pt /A (chemigation, 12" buried drip)	4
5/28/2015	20.0	applied DP @ 30.7 fl oz/A (in 2 gallon water, followed with 2 gallons water, tilled in)	6
6/4/2015	21.1	applied DP @ 30.7 fl oz/A (in 2 gallon water, followed with 2 gallons water, tilled in)	7
		applied Vydate @ 5 pt/A (in 2 gallon water, followed with 2 gallons water, tilled in)	2
		seeded melon Cantaloupe 'Durango'. 2 seeds/spot, spots at 1 ft intervals. Additional 5 spots off-center for mid-season root indexing.	
6/18/2015	22.8	applied Vydate @ 5 pt/A (chemigation, drip on top).	2
		applied DP @ 7.7 fl oz/A (; chemigation, drip on top).	6,7
		thinned plants to 1 plant per spot.	
7/2/2015	23.3	applied DP @ 7.7 fl oz/A (chemigation, drip on top).	6,7
		Rate vigor of plots	
7/16/2015	25.0	removed 5 'extra' melon plants, index for mid-season root-galling. Weigh shoots.	
		Rate vigor of plots.	
8/20/2015	24.9	collected soil samples from all plots	
		harvested all melon fruits	
		indexed roots of all melon plants 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 6/4/2015. An extra 5 spots (2 seeds/spot) per plot were seeded slightly off-center for mid-season root-galling. On 6/18/2015 seedlings were thinned to 1 plant per spot. Plants were fertigated according to commercial practices.

The vigor of the plots was rated visually on 7/2/2015 and on 7/16/2015 on a scale from 1-5, with 1=worse, 5=best. Vigor included the size of plants, plant color, uniformity, and general appearance. On 7/16/2015 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. The fresh shoot weights of these plants was determined

At harvest (on 8/20/2015), 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. The roots from all melon plants 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 minor differences in vigor between plots on but these differences were not related to treatments (Table 3).

Table 3. Average (n=5) vigor of melon 'Durango' plots during the 2015 growing season in seven treatments. Field located at SCREC, Irvine, CA. Vigor on a scale from 1 to 5, with 1=worse, 5=best (±se)

		Vigor on	
Treatment		7/2/15	7/16/15
1	UTC	2.8 ±0.4	3.0±0.3
2	VYDATE	2.6 ±0.6	3.0 ±0.7
3	NIMITZ DRP_L	3.9 ±0.2	4.0 ±0.3
4	NIMITZ DRP_H	3.7 ±0.2	4.0 ±0.3
5	NIMITZ_C	3.2 ±0.2	3.6 ±0.4
6	DP_7	3.3 ±0.3	3.4 ±0.2
7	DP_0	3.3 ±0.4	4.2 ±0.6
	treatment *P-value*	0.15	0.31

The treatments resulted in highly significant differences in fresh shoot weight of plants removed on 7/16/2015, with the two DP treatments (#6 and #7) and the low rate of drip-tubing applied Nimitz (#3) resulting in higher shoot weights than the untreated control.

Table 4. Average (n=5) fresh shoot weight (g ±se) of melon 'Durango' plants removed on 7/16/2015 during the 2015 growing season in seven treatments. Field located at SCREC, Irvine, CA. Different letters in shoot weight column represent significant differences at the 95% confidence level.

Treatment		shoot weight (g)
1	UTC	67.1 ±27.7 b
2	VYDATE	52.9 ±18.3 b
3	NIMITZ DRP_L	173.1 ±52.4 a
4	NIMITZ DRP_H	133.0 ±43.3 ab
5	NIMITZ_C	44.4 ±7.4 b
6	DP_7	195.8 ±26.3 a
7	DP_0	208.2 ±45.7 a
	treatment *P-value*	0.005

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). Although the average fruit yields (kr per plant, nr. fruit per plant) were about 1.5 times higher in the DP treatments compared to the untreated control, these differences were not statistically significant (Table 5).

Table 5. Average (n=5) fruit yield of melon 'Durango' plots during the 2015 growing season in seven treatments (±se). Field located at SCREC, Irvine, CA.

Treatment		kg fruit per plant	nr. fruit per plant	% marketable fruit
1	UTC	1.00 ±0.32	1.05 ±0.21	17.8 ±10.5
2	VYDATE	1.13 ±0.33	1.23 ±0.20	10.3 ±6.2
3	NIMITZ DRP_L	1.01 ±0.08	1.17 ±0.08	12.5 ±4.6
4	NIMITZ DRP_H	0.74 ±0.15	0.88 ±0.14	13.8 ±6.1
5	NIMITZ_C	0.92 ±0.30	1.08 ±0.23	6.9 ±3.5
6	DP_7	1.57 ±0.34	1.53 ±0.18	24.6 ±13.2
7	DP_0	1.26 ±0.09	1.48 ±0.06	9.3 ±2.5
treatment *P-value*		0.44	0.17	0.58[1]

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

Soil nematode levels: Initial root-knot nematode (*M. incognita*) levels were moderately low, with an average of 23 J2/100g soil. Prior to applying the treatments, there were no significant differences in soil root-knot nematode levels (Table 6). At harvest, nematode levels had increased in all treatments, but none of the treatments resulted in significant differences with the untreated control (Table 6)

Table 6. Average (n=5) root-knot nematode levels in melon 'Durango' plots during the 2015 growing season in seven treatments. Field located at SCREC, Irvine, CA. Number of second-stage root-knot nematodes (*M. incognita*) per 100g soil.

Treatment		RKN level	
		initial (Pi)	harvest (Pf)[1]
1	UTC	19 ±12	352 ±74 ab
2	VYDATE	20 ±9	268 ±81 b
3	NIMITZ DRP_L	35 ±21	424 ±45 ab
4	NIMITZ DRP_H	22±10	580 ±129 a
5	NIMITZ_C	36 ±12	456 ±96 ab
6	DP_7	15 ±3	230 ±44 b
7	DP_0	16 ±8	274 ±33 ab
	treatment *P-value*[2]	0.38	0.05

[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.

Root-galling: The severity of root-galling was indexed at mid-season (7/16/2015) and at harvest (8/20/2015). At mid-season, average root galling was already high and ranged between 2.9 in the DP_7 treatment and 6.2 in the low rate drip-applied Nimitz and the untreated control. At this time, galling in the two DP treatments (#6, #7) was significantly lower than in the untreated control (at the 90%, but NOT at the 95% confidence level). At harvest, galling was very high in all treatments and there were no significant differences (Table 7).

Table 7. Average (n=5) galling on melon 'Durango' roots at mid-season and at harvest during the 2015 growing season in seven treatments. Field located at SCREC, Irvine, CA. Galling on a scale from 0=no galls, to 10=100% of roots galled.

Treatment		Galling index	
		Mid-season	At harvest
1	UTC	6.2 ±1.2 a	8.9 ±0.5
2	VYDATE	5.5 ±1.1 ab	8.3 ±0.6
3	NIMITZ DRP_L	6.2 ±0.6 a	9.3 ±0.1
4	NIMITZ DRP_H	5.3±0.7 ab	9.4 ±0.3
5	NIMITZ_C	4.1 ±0.7 ab	8.6 ±0.3
6	DP_7	2.9 ±0.9 b	8.2 ±0.5
7	DP_0	3.0 ±0.8 b	8.4 ±0.5
	treatment *P-value*	0.09	0.38

[1]different letters in a column indicate significant differences at the 90% confidence level.

Conclusions

This year, none of three Nimitz™ treatments were significantly different from the untreated control with respect to plant vigor, melon yields, root-galling, or soil nematode levels.

Last year in a similar trial, Nimitz™ treatments did reduce the root galling on melon. In our trials this year with tomato and carrot the efficacy of Nimitz™ was also less than what we expected based on previous years' results. Our initial theory that the batch of Nimitz that was used in this year's trials was for some reason less effective, however does not correspond with results from our 2015 sweetpotato trial at the SCREC, Irvine location, where Nimitz™ showed good efficacy.

As in our 2014 trial, the two DP treatments were the most promising: mid-season galling was reduced (at 90% confidence level), and mid-season shoot weight was higher. Although the DP treatments again had the highest yields (kg fruit per plant, nr fruit per plant) these effects were not statistically significant. There was no indication that any of the treatments had a season-long lasting effect on root-knot nematode levels in the soil.