CALIFORNIA FRESH CARROT ADVISORY BOARD
RESEARCH REPORT 2017/18

Project Title: Evaluation of crop protection products against root-knot nematodes suitable for organic and conventional California fresh carrot production

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Introduction & Objectives

Carrots are among the most popular vegetables in the US. California's fresh market carrot production accounts for approximately 80% of the US harvested acres (1). Approximately 14% of fresh market carrots in California are cropped according to organic production guidelines (2, 3, 4); that represents about 11,500 acres. Several root-knot nematodes species (rkn, *Meloidogyne* spp.) are the main cause of plant disease problems in California's carrot production (5, 6). In 1999 production loss was conservatively estimated at 5-8% despite the use of various soil fumigants (7). These nematodes are widespread throughout Central and Southern California and are especially damaging in lighter soil types (8). Root-knot nematodes in carrots lower the quality of the harvested product due to forking and root galling. In addition, galled feeder roots are less able to sustain the demand of the plant for water and nutrients. Consequently, rkn can significantly lower the marketable yield.

In the absence of an effective post-seeding nematicide, management of root-knot nematodes in California has typically relied on the pre-planting use of soil fumigants such as Telone® II (1,3-dichloropropene) and metam-sodium or potassium metam. In conventional production systems, substantial portions of fields need be excluded from fumigation because of buffer zone requirements (9) or because of township restrictions to reduce emissions of volatile organic compounds (VOC) associated with fumigant use.

Many "soft" nematicides are promoted for organic production systems. The "2015 Guide for Organic Carrot Production" (10), lists several nematicides and biocontrol products for use in organic carrots. However, it states that the efficacy of these products is "not reviewed or no research is available".

Several new nematicides and biocontrol or biorational products are under development for use against plant-parasitic nematodes in conventional or organic production systems. The objectives of this project were to determine the efficacy, crop safety and/or application methodology of these novel nematicides and biocontrol products in root-knot nematode-infested carrot field trials at the UC South Coast Research and Extension Center (SCREC), Tustin, and at the UC Kearney Research and Extension Center (KREC), Reedley.

Materials and Methods

The soil at the UC South Coast Research and Extension Center, Tustin, CA was a San Emigdio sandy loam with 18% clay, 62% sand and 20% silt, 0.1% OM, pH 7.5 at the trial site. This field site was infested with the Southern root-knot nematode *M. incognita*. The other field site at UC Kearney REC was infested with *M. javanica*. The soil type was a sandy loam. Both locations have been cropped during spring to fall with at least one rkn-susceptible host (beans or tomato) for the past few years. As a winter cover crop, we grew rkn-susceptible wheat (cv. Yecora Rojo), primarily for agronomical reasons. This year's trials were designed as a randomized complete block with 5 replications. Each individual plot was 10 ft long and 2 ft wide. After setting up the trials, six soil cores were taken from each plot to a depth of 10-12 inches. The soil was pooled, and thoroughly mixed. Subsamples were extracted after 5 days incubation on Baermann funnels at 26˚C. The extraction efficacy with our soil types and analysis method is approximately 35%. Second-stage juveniles of the nematodes were enumerated under 40x magnification.

For crop safety reasons both metam sodium and the mustard seed meal were applied three weeks before seeding (SCREC, July 11, 2017; KREC, July 12, 2017). Metam sodium was applied at 75 gal/acre with a surface drip tubing system (0.53 gallon/hr emitters, one foot apart). Mustard seed meal (*Brassica juncea* cv. Pacific Gold (fine), Farm Fuel Inc) at 2 tons/acre was uniformly spread onto the plots in a 1.65 ft band and rototilled 4-5 inches into the soil before applying one-gallon water on top of the bed. On July 25 (SCREC) Nimitz EC 480 (a.i. fluensulfone) at 5 pt/acre was suspended in one gallon of water, applied with a sprinkler can in a 1.65 ft band and rototilled into the top 4-5 inches. An additional one gallon of water was then sprinkled on top of each plot. At KREC the treatment occurred on July 26. Three days before seeding another gallon of water was applied to each treatment plot at both locations. The additional water was recommended by the manufacturer to mitigate potential crop safety issues that have been encountered with certain seeded crops. All other treatments were applied at SCREC on August 1 and at Kearney on August 2, 2017. Salibro SC 500 (50% a.i. fluazaindolizine, DuPont) was used at 30.7 fl oz/acre, Velum One (40% a.i. fluopyram, Bayer) at 13 fl oz/acre, and Vydate (24% a.i. oxamyl, DuPont). The products were suspended in one-gallon water, applied with a sprinkler can in a 1.65 ft band and rototilled into the top 4-5 inches. An additional one-gallon water was then sprinkled on top of each plot. At SCREC and KREC, non-treated carrot seeds cv. Imperator 58 (Lockhart Seeds Inc., Stockton, CA) were seeded in one row (approximately 0.62 g/10 ft) on August 1 and 2, respectively. Majestene™ (Marrone Bio Innovations, Inc), a new biocontrol product based on fermentation broth of *Burkholderia rinojensis* was used at 4 gal/acre plus Ad-Sorb FC (agricultural soil surfactant, J. R. Simplot Company) at 1 qt/acre. The products were suspended in water and 20 ml/plot were applied in a narrow band (~3 inches wide) onto the seed row. Treatment #9 was an experimental seed coating with Avicta 400 FS (a.i. abamectin) and a mixture of fungicides (Apron XL, Maxim 4FS, Dynasty). Treatment #10 was another experimental carrot seed treatment with a combination of fluopyram and thiram on cultivar Choctaw.

The trials were immediately irrigated with approximately 0.25 inch/acre via overhead sprinklers. The next day Ridomil Gold®SL (a.i. mefenoxam) at 1 pt/acre was sprayed on top of the beds to mitigate potential *Pythium* damping-off and cavity spot incidence. The following day, Lorox DF was applied at 3 lb/ac and Prowl H2O was used at 2 pt/ac for weed control. The soil surface was kept moist until emergence. The SCREC trial was fertilized with 20lb/acre of 15-15-15 on August 26. No other disease or pest control treatments were necessary throughout the season. However, the Kearney the trial was reseeded on August 29 because of poor emergence due to a period of extreme heat. The treatments at both locations were evaluated for vigor approximately 6 weeks after seeding (scale 0-10, 10 best).

On October 6 at SCREC and on October 12 at KREC, five randomly chosen carrot seedlings per replication were carefully removed, rinsed with water and evaluated for rkn disease symptoms (scale 0-10, best-worst, Fig. 1).

The carrots were harvested on November 7 at SCREC and on November 28 at KREC. At each location, ten randomly selected carrots from each plot were collected in plastic bags for transport to the UCR Nematology facilities. The soil was rinsed off and the roots were rated for rkn disease symptoms (0-10, best-worst, Fig. 1). Total and marketable weights were noted. We considered carrots within a disease rating 0-3 as marketable. Plant vigor and disease ratings were arcsine-transformed and nematode population data were $\log_{10}$ (x+1)-transformed to normalize variances before statistical analysis. If significant, mean separation was used with Fisher's Protected LSD (P = 0.05) (SuperANOVA, Abacus, Berkeley, CA). The trial results with back-transformed data are summarized in Tab. 1 and 2.

Results and Discussion

The general conditions for both trials were less than satisfactory. The temperatures during seeding and several weeks after emergence at both locations were very hot. Consequently, the emergence and early growth of the carrots were not as uniform as typically expected.

The rkn population in the SCREC trial area was uniformly distributed at an average level of 29 J2 per 100-cm^3 soil (Tab. 2) and at KREC at 13.6 (Tab. 3). This is typically sufficient for considerable crop damage. In Southern California, the damage threshold for rkn (*M. incognita*) in carrots is about one J2/100 cm^3 (11).

Vigor ratings at SCREC 6 weeks after seeding did not differ significantly among the treatments. At KREC one of the seed treatments (#9) had the overall best score followed by the mustard seed meal.

The mid-season disease rating data from SCREC showed no differences (Tab. 1) while at KREC all treatments but Majestene caused significant reductions in root damage (Tab. 2). Six weeks later, at harvest, none of the treatments differed significantly from the control. The marketable weight was quite variable within the replications and among the treatments (Tab. 2). At SCREC, all but Vydate, Velum One and Majestene reduced rkn disease ratings (Tab. 1). Quite remarkable was the disease control provided by the seed treatments, particularly the fluopyram/thiram combination. However, the carrot cultivar in treatment #10 was different than in the rest of the trial, so that the results cannot be directly compared. The mustard seed amendment was as effective as some of the newer synthetic nematicides (Tab.2).

Overall the results need to be viewed with the unusual temperatures in mind. The extreme temperatures certainly influenced the early growth phase of the carrot seedling. Furthermore, it is possible that the heat diminished the efficacy of some of the treatments.

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Figures and Tables

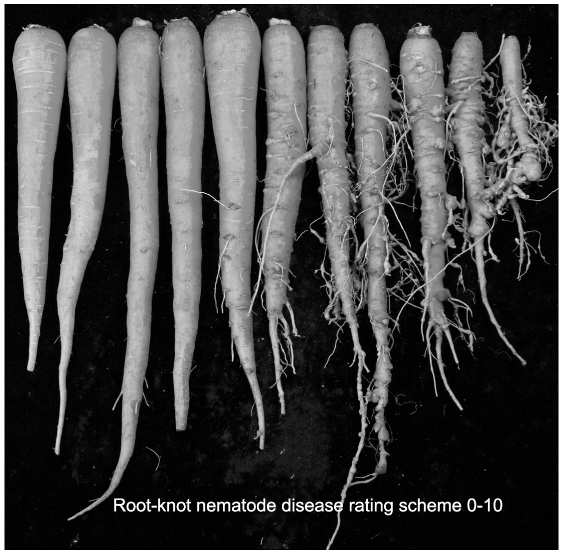

Fig. 1 Root-knot nematode (*M. incognita*) disease rating scheme (cv. Imperator 58).

Tab. 1   2017 carrot trial results at UC South Coast Research and Extension Center

		7/13/17		9/13/17		10/6/17	
		initial J2/50 cm3		vigor (0-10, 10 best)		mid-season galling (0-10)	
trmt #	trmt ‡	Mean*	Std. Error	Mean	Std. Error	Mean	Std. Error
1	nt control	11.3	1.69	7.2	0.97	1.9	0.19
2	Nimitz 3.5 pt/ac	13.8	1.92	5.4	1.03	1.8	0.34
3	Salibro 30.7 fl oz/ac	10.8	2.06	6.4	1.40	1.6	0.54
4	Velum One 13 fl oz/ac + Ad-Sorb	12.0	3.85	6.4	0.98	2.4	0.55
5	Vydate L 1 gal/ac	14.0	2.63	6.4	1.17	2.6	0.48
6	mustard seed 2 tons/ac	24.5	3.71	6.0	1.10	2.1	0.29
7	metam sodium 75 gal/acre	24.8	5.34	5.4	0.60	2.0	0.47
8	Majestene 4 gal/ac	13.5	3.92	8.4	0.60	3.5	0.27
9	A1 seed treatment	8.25	1.58	8.2	0.66	1.9	0.46
10	B1 seed treatment	12.5	4.07	8.8	0.37	1.6	0.32

		11/7/17		11/7/17	
		harvest galling (0-10, 0 best)		% marketable weight	
trmt #	trmt ‡	Mean*	Std. Error	Mean	Std. Error
1	nt control	4.7 d	0.38	33.8 a	9.07
2	Nimitz 3.5 pt/ac	3.2 ab	0.22	47.5 ab	8.42
3	Salibro 30.7 fl oz/ac	3.5 abc	0.47	60.3 bc	12.13
4	Velum One 13 fl oz/ac + Ad-Sorb	4.3 cd	0.50	42.0 ab	8.63
5	Vydate L 1 gal/ac	4.0 bcd	0.39	45.1 ab	11.65
6	mustard seed 2 tons/ac	3.2 ab	0.45	64.6 bc	10.86
7	metam sodium 75 gal/acre	2.8 a	0.40	66.7 bc	11.93
8	Majestene 4 gal/ac	4.8 d	0.36	41.9 ab	8.11
9	A1 seed treatment	3.7 abc	0.34	54.5 abc	8.46
10	B1 seed treatment	2.9 a	0.19	80.0 c	2.81

‡ #2-6 applied as 1.6 ft band, incorporated; #7 surface drip applied, #8 applied as 3 inch band on top of seeds

*means with the same letter in a column or in a column without letters are not significantly different (P=0.05)

Tab. 2 2017 carrot trial results at UC Kearney Research and Extension Center

		7/14/17		10/12/17		10/12/17	
		initial J2/50 cm3		vigor (0-10, 10 best)		mid-season gall rating	
trmt #	trmt ‡	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
1	nt control	11.2	2.84	3.4 a	0.40	4.7 c	0.17
2	Nimitz 3.5 pt/ac	3.4	1.50	3.6 ab	1.08	2.9 ab	0.22
3	Salibro 30.7 fl oz/ac	8.6	1.86	3.0 a	0.95	2.4 a	0.40
4	Velum One 13 fl oz/ac + Ad-Sor	10.0	2.21	4.4 abc	0.87	3.1 ab	0.17
5	Vydate L 1 gal/ac	4.4	1.78	4.2 ab	0.80	3.3 ab	0.48
6	mustard seed 2 tons/ac	5.4	1.33	5.6 bc	1.12	3.8 bc	0.52
7	metam sodium 75 gal/acre	7.8	2.69	4.6 abc	0.68	3.0 ab	0.50
8	Majestene 4 gal/ac	4.6	0.93	2.8 a	0.73	4.8 c	0.17
9	A1 seed treatment	7.4	1.96	6.4 c	1.17	2.6 a	0.10
10	B1 seed treatment	7.0	1.41	4.8 abc	0.37	2.6 a	0.50

		11/28/17		11/28/17	
		harvest gall rating (0-10)		% marketable weight	
trmt #	trmt ‡	Mean	Std. Error	Mean	Std. Error
1	nt control	4.8	0.36	20.0	10.51
2	Nimitz 3.5 pt/ac	4.4	0.38	22.1	6.72
3	Salibro 30.7 fl oz/ac	4.0	0.63	42.9	12.24
4	Velum One 13 fl oz/ac + Ad-Sor	4.5	0.30	31.2	8.06
5	Vydate L 1 gal/ac	4.3	0.40	34.2	9.05
6	mustard seed 2 tons/ac	4.7	0.31	26.0	5.40
7	metam sodium 75 gal/acre	3.9	0.28	45.6	8.71
8	Majestene 4 gal/ac	4.3	0.57	33.1	7.38
9	A1 seed treatment	3.9	0.44	38.1	13.51
10	B1 seed treatment	3.1	0.39	66.4	11.75

‡ #2-6 applied as 1.6 ft band, incorporated; #7 surface drip applied, #8 applied as 3 inch band on top of seeds

*Means with the same letter in a column or in a column without letters are not significantly different (P=0.05).