To: California Pepper Commission

RE: Research Report for 2017-18

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Project Title: Efficacy of novel nematicides and plant resistance against root-knot nematodes on bell peppers.

Statement of the problem and background.

The Southern root-knot nematode (*Meloidogyne incognita*) has been reported to cause serious damage to peppers. The second-stage nematodes (J2) are worm-shaped, move through the soil, and enter the plant roots. In roots of a host crop, the second-stage juveniles nematodes develop into females, while the root system responds to infection with the formation of galls. The fully developed females can produce up to 400 eggs, that are contained in clusters in a gelatinous material and "glued' to the outside of the roots. From these eggs second-stage juveniles can emerge to repeat the cycle, or eggs can remain in the soil during fallow period to serve as inoculum for the next crop cycle. The duration of the nematode life cycle depends primarily on the species of root-knot nematode and on soil temperature. *Meloidogyne incognita*, the most important species infecting bell-pepper, can complete its' life cycle in less than 4 weeks under an optimum soil temperature of 32C (90F), and become inactive when the soil temperature drops below 17C (62F). In most host crops, root-knot nematode infestation can easily be diagnosed because of obvious galling on the affected roots. Above-ground symptoms are however not specific, and can include chlorosis, wilting under sufficient soil moisture, stunting, and increased susceptibility of plants to fungal or bacterial root pathogens.

In the Coachella Valley of Southern California, approximately 5,000 acres are cropped with bell peppers, representing an estimated gross crop value of $90,000,000. Root-knot nematodes are widespread throughout the Coachella Valley and growers report serious damage. To control nematodes, pepper growers in the Coachella Valley commonly apply fumigant nematicides such as metam-sodium (Vapam) or 1,3-dichloropropene (Telone) as a post-harvest and/or pre-plant soil treatment through the drip tubing.

In our previous studies, also funded by the CPC, we found that root-knot nematodes (M. incognita) were relatively common in pepper fields in the Coachella Valley. Soil and root infestation levels were sometimes very high. In greenhouse pot experiments, using nematode populations isolated from Coachella pepper fields, we found that of two nematode-resistant pepper varieties tested (Charleston Belle and Carolina Wonder), the Carolina Wonder pepper was highly resistant even under high nematode inoculum levels.

In this report we present results from a repeated field trial at two locations where effects of novel nematicides were evaluated in susceptible and resistant bell pepper grown on root-knot nematode infested plots.

Material and Methods 2017 Field Trials.

Identical field trials were done on root-knot nematode (*M. incognita*) infested field sites at two locations: CVARS (Coachella Valley Agricultural Research Station) and SCREC (SouthCoast Research and Experiment Station, Irvine).

Each site had 25 plots. Plots consisted of 20 ft long sections of 60-inch-wide (CVARS) or 40-inch-wide (SCREC) sections of beds. There were five treatments:

1) Untreated control
2) Metam-sodium @ 75 gallon/acre, drench incorporated, 3 wk pre-plant
3) Nimitz @ 5 pt/acre drench incorporated, 1 wk pre-plant
4) Salibro @ 61.4 oz/acre drench incorporated, 1 wk pre-plant
5) Velum One @ 6.5 oz/acre drench incorporated, 1 wk pre-plant

Field was designed according to a latin-square with 5 replicates. Transplants of susceptible pepper 'Baron' and resistant 'Carolina Wonder' were grown in a UCR greenhouse and planted in the plots on 2/15/2017 (CVARS) and 6/21/2017 (SCREC). Plants were planted in two lines (1 resistant. 1 susceptible) per bed, at 16 inch spacing. Watering and fertigation was through buried drip.

Data collected were pre-treatment soil root-knot nematode levels, galling of pepper root systems at harvest, fruit yield (CVARS) or plant fresh shoot weight (SCREC) at harvest, and nematode infestation levels of the roots. Fruits at CVARS were collected four times (5/12, 5/25, 6/9, and 6/21) and graded according to size. The total harvest per plant is reported here. At the SCREC, we had some problems with gopher damage early on in the season, resulting in uneven stands and variation of plants within the plots. Because of this we decided not to harvest the fruits, but at end of the experiment we collected the five largest plants from each plot, and determined shoot weight, root-galling and nematode infestation levels from these 5 plants from each plot.

Results

Pre-treatment root-knot nematode levels (second-stage juveniles/100 g soil) were moderate (CVARS: 16 J2/100 g, SCREC: 5 J2/100g) and not different between the treatments.

Effects of the nematicide treatments on total fruit yield per plant at CVARS were not significant. There was a significant effect of the pepper cultivar on yield, with the resistant 'Carolina Wonder' yielding more than the susceptible 'Baron'. The interactive effect "nematicide *x* cultivar" was not significant, indicating that the nematicide treatments gave similar results for both pepper cultivars.

Table 1. Effect of nematicides and pepper cultivar on total fruit yield (gram/plant). CVARS station, 2017 trial (n=5).

	Pepper Cultivar		
Treatment	Carolina Wonder (R)	Baron (S)	average
UTC	482.8	377.6	430.2
Metam-sodium	543.8	437.4	490.6
Nimitz	487.7	368.7	428.2
Salibro	486.3	388.7	437.5
Velum	562.7	402.9	482.8
average	*512.7 a*	*395.1 b*	453.9

Different letters within the same row indicate significant differences at the 95% confidence level.

At SCREC, average plant shoot weights at harvest were not significantly different between treatments of the two cultivars.

Table 2. Effect of nematicides and pepper cultivar on shoot weight (kg/plant). SCREC station, 2017 trial (n=5).

	Pepper Cultivar		
Treatment	Carolina Wonder (R)	Baron (S)	average
UTC	2.0	2.5	2.2
Metam-sodium	2.5	2.5	2.5
Nimitz	2.8	2.0	2.4
Salibro	2.2	2.4	2.3
Velum	2.6	2.6	2.6
average	2.4	2.4	2.4

Effects of the nematicide treatments and the pepper cultivar on root galling and on infestation of roots with root-knot nematodes were highly significant at CVARS. Of the nematicide treatments, Salibro resulted in the lowest galling as well as the lowest infestation of the roots with nematodes. However, none of the nematicide treatments was significantly better than the untreated control. As expected, root-galling and nematode infestation was significantly lower on the resistant cultivar. However, there was still considerable galling and a high level of nematode infestation even on the resistant roots (Table 3).

Table 3. Effect of nematicides and pepper cultivar on root-galling (scale 0-10) and root infestation levels (number eggs/g root). CVARS station, 2017 trial (n=5).

	Pepper Cultivar			
Treatment	Carolina Wonder (R)	Baron (S)	average	
root-galling				
UTC	1.9	3.0	*2.4*	*bc*
Metam-sodium	2.6	5.0	*3.8*	*a*
Nimitz	2.7	5.2	*4.0*	*a*
Salibro	0.8	2.0	*1.4*	*c*
Velum	2.7	4.5	*3.6*	*ab*
average	*2.1b*	*3.9a*		
eggs/g root				
UTC	20,144	32,058	*26,101*	*ab*
Metam-sodium	22,954	49,066	*36,010*	*a*
Nimitz	21,295	48,624	*34,959*	*a*
Salibro	9,412	31,773	*20,592*	*b*
Velum	24,938	42,123	*33,530*	*a*
average	*19,749b*	*40,729a*		

Different letters within the same column or row indicate significant differences at the 95% confidence level.

At the SCREC station, the nematicide treatments did not affect root galling or infestation levels of the roots with nematodes. The effect of cultivar was highly significant: The resistant cultivar remained free of root-galling, and nematode infestation of the resistant roots was also very low (Table 4). As a comparison, nematode root infestation at SCREC in the resistant cultivar was reduced by >99% compared to the susceptible pepper, whereas at CVARS this reduction was only about 50%.

Table 4. Effect of nematicides and pepper cultivar on root-galling (scale 0-10) and root infestation levels (number eggs/g root). SCREC station, 2017 trial (n=5).

	Pepper Cultivar		
Treatment	Carolina Wonder (R)	Baron (S)	average
root-galling			
UTC	0.0	2.3	1.2
Metam-sodium	0.0	2.8	1.4
Nimitz	0.0	2.2	1.1
Salibro	0.0	2.5	1.3
Velum	0.0	2.4	1.2
average	*0.0b*	*2.4a*	
eggs/g root			
UTC	25	7,974	3,999
Metam-sodium	33	7,847	3,940
Nimitz	2	5,938	2,970
Salibro	34	8,497	4,266
Velum	18	6,759	3,388
average	*23b*	*7,403a*	3,713

Different letters within the same row indicate significant differences at the 95% confidence level.

Discussion & Conclusion

Three novel nematicides were applied as an incorporated soil drench to pepper beds, 1 week before transplanting nematode susceptible and nematode resistant peppers, at two field locations. The effects of these products on fruit yield or plant growth were not significant, and similar to the untreated control. At the CVARS location, the yield of the resistant pepper cultivar was higher than of the susceptible cultivar. At the SCREC location, plant growth was not different between the cultivars. The nematode infestation of the susceptible peppers was high at both locations (40,729 and 7,403 eggs per gram root at CVARS and SCREC respectively), but the nematicide treatments did not significantly reduce the infestation level. The effectiveness of resistant cultivar was very different between the two locations: at SCREC, the resistant cultivar remained virtually free of nematodes, whereas at CVARS the resistant cultivar still had high levels of nematode infection (19,749 eggs per g root). We speculate that this difference in the level of resistance between the two locations is related to differences in soil temperatures at the two locations. It is known that in nematode resistant tomato, high soil temperatures can lead to resistance breaking, but this has not been reported for field-grown resistant pepper. For example, in a field study in Florida where soil temperatures remained close to or above 30C (86F) throughout the growing season, there were no indications that resistance was compromised. For 2018, we propose to repeat the field trials with novel nematicides, and to determine if resistance-

breaking of pepper ‘Carolina Wonder’ will again occur at CVARS. We will determine both in a field study and in greenhouse pot trials if this is related to (high) soil temperatures.