Field Evaluation of Metam Sodium for Rhizomania and Root Knot Nematode Control in Tulare County, California

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When Telone II was removed from the California market, sugar beet growers were left with no known effective materials for controlling root knot nematodes. In addition, before it was removed from the market, Telone II looked promising in reducing losses from rhizomania. Metam (metam, metam sodium, Vapam, Soil Prep, Sectagon) was registered for use and was known to be an effective nematicide under certain conditions. However, it was unknown if application techniques compatible with current sugarbeet production practices would be effective in placing metam where it needed to be placed. Unlike Telone II which readily fumes and moves through soil, metam does not move more than 4 to 6 inches from the point of application. It was unknown if metam would have any impact on rhizomania. Three trials have been conducted in growers' fields to evaluate metam application methods and impact on yields when rhizomania and/or root knot nematodes were present.

In Tulare County, California, sugar beets are commonly planted November through February, either as single rows on 30-inch beds or double rows on 42-inch beds. Furrow irrigation is used during the season and, when necessary, for germination and emergence. Harvest is usually from mid-August into November.

With the exception of one treatment in one trial, metam was applied using three-tiered, winged, spray blades. These consisted of a shank with three "wings," each with a spray nozzle, placed 4 inches apart vertically. Furrowing shovels placed behind shanks threw soil up into a bed as applications were made. The horizontal area treated per shank was 10 inches wide. On 30-inch beds a single shank/bed treated approximately 1/3 of the area. A broadcast rate of 100 gal/acre on 30-inch beds would indicate 33.3 gallons used per field acre. On 42-inch beds, two shanks were used thereby treating approximately 50% of the total area. A broadcast rate of 100 gal/acre in this case would mean that per field acre 50 gallons were applied.

In one trial a "spray rake" was evaluated. This tool consisted of a horizontal bar from which four bars, at approximately a 45 degree angle arose. Each of these four bars contained four nozzles about 3 inches apart along its length. The rake was pulled so that the bottom horizontal bar cut underneath an already formed bed as soil flowed up and over the angled bars through which metam was sprayed.

Trials were conducted in commercial fields, using normal grower practices. All treatments were made using commercial equipment. Individual plots were large, ranging from 4 to 16 rows wide and from 1000 to 1280 feet in length. The size of harvested area for yield data varied from half the plot (two inside beds in a four row plot) harvested with commercial equipment to small, hand-harvested plots. Sucrose and nitrate analysis were courtesy of Spreckel's Sugar, Mendota, California.

Trial 1, conducted in the 1990/91 season, was located in a field that pre-trial samples indicated had root knot nematodes. By season's end it was suspected, due to mild symptoms, that rhizomania was also in the field. This was confirmed with a soil bioassay conducted at the U.S.D.A. research center at Salinas, California.

The trial was over 8 acres in size. The field was not uniform but the soil was primarily a Chino clay loam. A sand streak was more pronounced in the west half of the trial. Each plot was almost a quarter mile in length (1258 ft) and four beds wide. Beds, 42 inches apart, were planted with two rows of beets per bed. Root knot nematode samples were collected only from the center two beds of each plot. Yield data were collected from the center two beds for the entire length of plots.

Five treatments replicated four times in a randomized complete block design were: an untreated check; metam applied at 50, 75, and 100 gpa (broadcast basis) with winged spray blades; and metam applied at 75 gpa (broadcast basis) with the spray rake. The area treated was estimated to be 50% of the total area for both application methods, resulting in using 25, 37, and 50 gallons of metam per field acre with the spray blades and 37 gallons per acre with the rake. On a broadcast basis, the volume of spray solution applied for spray blade treatments was 200 gallons/acre and for the rake method was 171 gallons/acre.

Treatments were applied on December 13 and 14, 1990. Soil conditions were dry except for the surface which was damp due to a small amount of rain (about 1/3 inch) two weeks prior to treatment. Cotton residue from the previous cotton crop did build up on both types of equipment but was worse with the rake. Several times the tractor had to stop, lift the rakes, back up, shake the rakes clean, and then resume the application. Two days after treatment, approximately 0.2 inches of rain occurred. The field was planted on January 8, 1991, with NB2, a rhizomania susceptible variety.

Soil samples were collected for root knot nematode extraction prior to treatment in December, in April, and again in July. Ten cores, 18 inches deep, were taken at regular distances in each plot. Cores were combined for a single composite sample from each plot. Soil samples were sent to Dr. Westerdahl, Department of Nematology, UC Davis, for nematode extraction.

Root knot nematode counts for the three sampling dates are shown in Table 1. Population numbers refer to juvenile root knot nematodes per liter of soil. Counts from samples taken prior to treatment indicate that there was no difference among treatments in initial nematode populations. Although populations decreased for all treatments including the untreated check between early December and April, the reduction in metam plots was much more than the reduction in check plots. By late July, nematode populations in all plots treated with metam were still quite low while the population in the check had increased substantially.

Table 1. Root knot nematode counts from 1990/91 sugarbeet trial, Tulare County[1]

	Number of Root Knot Nematodes/Liter Soil[2] Date Sampled		
Treatment[3]	12/8/90	4/8/91	7/25/91
Untreated check	700	288	1012
Metam, 50 gpa, broadcast[3], spray blades	750	0	0
Metam, 75 gpa, broadcast[3], spray blades	612	0	12
Metam, 100 gpa, broadcast[3], spray blades	388	0	0
Metam, 75 gpa, broadcast[3], rake	312	25	75
$LSD_{.05}$	NS[4]		

[1]Values represent means of 4 replications. The field was treated on December 13-14, 1990, planted on January 8, 1991, and harvested on August 19, 1991.

[2]Each sample consisted of 10 cores/plot. Cores were collected 0-18 inches deep.

[3]Actual area treated was 50% of total for all treatments. Volume of spray solution (water + metam) for the spray blade application was 200 gpa. The spray volume for the rake application was 171 gpa on a broadcast basis. Applications were December 13-14, 1990.

[4]Only data from the first sampling date was analyzed. Initial counts were not significantly (NS) different among treatments.

Yield Results: Yield results are presented in Table 2. Plots treated with metam produced significantly higher clean root yields than the untreated check ($P<.001$). Root tonnage from the highest rate of metam, 25 T/A, was more than twice the tonnage produced in the untreated check. Root yield increased with increasing rates of metam applied with spray blades. Sucrose percent was extremely low for all treatments, but metam treated plots were significantly higher in sucrose than the check ($P=.03$). There was a slight but significant linear trend for sucrose to increase as metam rates increased. In gross sugar per acre, the check was significantly lower than all treatments ($P<.001$). Gross sugar increased in a linear manner with the increase in metam rate. Root nitrates did not differ significantly among treatments but overall were low with the average ranging from 31 to 47 parts per million (ppm).

Table 2. Root yield, sucrose, sugar yield, and nitrate results from 1990/91 sugarbeet trial, Tulare County[1]

Treatments[2]	Clean root weight (T/A)	Sucrose (%)	Gross sugar (T/A)	Nitrate (PPM)
Untreated check	11.6 a	9.0 a	1.05 a	31
Metam, 50 gpa, broadcast[2], 3-tiered spray blade	19.8 b	9.1 a	1.82 b	47
Metam, 75 gpa, broadcast[2], 3-tiered spray blade	22.4 bc	9.7 ab	2.19 cd	38
Metam, 100 gpa, broadcast[2], 3-tiered spray blade	24.5 c	10.0 b	2.49 d	31
Metam, 75 gpa, broadcast[2], rake	19.8 b	10.0 b	2.00 bc	36
$LSD_{.05}$	2.8	0.8	0.36	NS
CV %	8.9	5.3	11.9	46.0

[1]Values are means of 4 replications with missing values for 2 plots. Within a column, values followed by a common letter do not differ significantly using LSD at the 5% level of probability. Treatments were applied December 13-14, 1990. The field was planted January 8, 1991, and harvested August 19, 1991.

[2]Actual area treated was 50% of total for all treatment. Volume of spray solution (water + metam) for the spray blade application was 200 gpa. The spray volume for the rake application was 171 gpa on a broadcast basis. Applications were December 13-14, 1990.

Discussion: All metam treatments significantly reduced root knot nematode populations and resulted in increased yields. In addition, there was a significant linear trend for tonnage, sucrose, and sugar to increase as rates of metam increased. Because nematode counts indicated good control with metam, the yield response to metam probably was due in large part to nematode control. It is harder to assess if, or how much, metam "controlled" rhizomania. Also, an interaction between root knot nematodes and rhizomania infected roots is possible.

There was no advantage to using the rake in comparison to using three-tiered winged spray blades on shanks. Although effective, the application with the rake performed no better than the equivalent rate applied with spray blades. In addition, cotton residue tended to get hung up more on the rake than on the spray blades.

It was somewhat surprising that metam treatments were so effective in this trial. The soil condition at the time of treatment was much drier than desired for metam to be effective. The high spray volume (200 and 171 gpa broadcast for spray blades and rakes, respectively) and the multiple nozzles which helped with placement and distribution probably contributed to the positive results obtained. In addition, because the soil was dry it collapsed into the grooves behind the shanks as they were pulled through the beds and flowed smoothly (except for the cotton trash) over the rake, helping to seal metam in the soil. The seal was further enhanced by the bedshaping operation which followed soon after each treatment was applied.

Trial 2 was conducted in 1991/92 in a field that soil sampling indicated had a very low level of root knot nematodes. However, by the trial's end, there was no evidence or root knot nematodes on roots. However, rhizomania was evident in the field by mid-season.

On December 19, 1991, metam was applied with three-tiered winged spray blades and two shanks per 42-inch bed. Broadcast rates of metam were 50, 75, and 100 gallons per acre in 200 gpa of solution. An untreated control brought the number of treatments to four. Plots were four beds wide and extended the length of the field, approximately a quarter mile. There were four replications in a randomized complete block design.

At the time of treatment, soil was dry and fairly cloddy. Four beds were treated at a time, but the tractor was not as powerful as needed. It would have been desirable to travel slightly faster in order to throw more soil over the top nozzle and on top of the bed. Ambient air temperatures that day were in the 40's and 50's (F). A strong north wind was blowing, causing some concern about sealing and leading to two different sealing operations. The 50 and 100 gallon rates were first rolled immediately after treatment and then furrowed out to build the beds back up; the 75 gallon rate was simply furrowed out, to throw more dirt on the bed for sealing.

Beds were mulched and then planted on February 3, 1992. The field was irrigated on February 8, 1992. The trial area was planted to a mixture of SS LS2, a rhizomania susceptible variety, and SS 463R, a variety with some resistance to rhizomania.

On August 9 and 10, 1992, 50 feet of both rows from the center two beds of each plot were hand harvested from the sandiest area of the trial area.

Yield results are tabulated in Table 3. The 75 gpa rate of metam produced roots lower in nitrate than the 50 and 100 gpa rates, but it is not obvious why that occurred. There was no significant difference in sucrose percent among treatments. There was, however, a very definite response to metam fumigation in tons of roots and in sugar produced per acre. In comparing different rates of metam, there was no advantage to applying rates higher than 50 gpa (on a broadcast basis) as higher rates did not result in significantly higher yields. Averaged together, metam treated plots produced 27.78 tons of roots per acre, which was 4.8 tons higher than untreated plots. Fumigation resulted in an increase of 0.62 tons of sugar per acre compared to the untreated check.

Table 3. Yield results from metam trial in sugarbeets, Tula Vista Farms, Tulare County, 1991/92[1]

	Broadcast rate[2] (gpa)	NO_3 (ppm)	Clean roots (tons/A)	Sucrose (%)	Sugar (tons/A)
Untreated	--	15.9 ab	22.96 a	13.9	3.19 a
Metam	50	18.6 b	28.61 b	13.7	3.91 b
Metam	75	9.1 a	27.00 b	13.8	3.71 b
Metam	100	16.3 b	27.74 b	13.7	3.81 b
LSD		6.9	1.80	NSD	0.27
CV %		28.64	4.22	2.5	4.61

[1]Fumigated on December 19, 1991, using two 3-tiered spray blades per 42-inch bed. Two rows per bed were planted on February 8, 1992. Values are means of four replications. Values within a column followed by a common letter do not differ significantly at the 5% level of probability using least significant difference.

[2]Approximately 50% of the area was treated (2 shanks on 42-inch beds) so that on a per actual acreage basis the amount of metam applied would be half of that stated as the broadcast rate. All rates were applied in a volume of 200 gallons per acre on a broadcast basis.

Trial 3 was established in a field that did not have root knot nematodes. It was thought that rhizomania might be present at very low levels but by season's end there was no evidence of this disease at harvest.

Main plots were 16 beds wide and 1000 feet in length. Fumigated and non-fumigated strips were replicated four times. Single rows of six varieties were planted within each main plot:

SS LS2	SS 462R
Beta 4581	SS 287R
Rhizosen	SSH 89781

The trial was planted with an 8-row planter February 5, 1992. The placement of each variety in the planter was not randomized between plots resulting in the identical order of varieties in each plot. This lack of randomization is not accounted for in the statistical analysis, and it should be remembered when evaluating results.

Curly Top (CT) was very prevalent in Tulare County in the 1992 season. One hundred plants of each variety in each plot were visually assessed at season's end to provide a count on the number of CT infected plants.

On July 23, 1992, 200 feet of one row of every variety in each plot was harvested using Spreckel's mechanized small plot harvester. Four samples from each plot were analyzed for root nitrate and percent sucrose.

Disease counts and yield results are presented in Table 4. There were no significant differences due to fumigation for any of the parameters measured. This is not very surprising as hindsight showed the field did not have any detectable levels of either nematodes or rhizomania.

Table 4. Disease ratings and yield results for metam trial in sugarbeets, Nichols Farms, Tulare County, 1991/92[1]

	Curly Top (%)		NO_3 (ppm)	Roots (tons/A)		Sucrose (%)		Sugar (tons/A)	
Treatments									
Not Fumigated	39.9		54.0	36.4		12.83		4.7	
Metam @ 100 gpa Broadcast[2]	40.0		63.2	37.4		12.65		4.7	
LSD	NS		NS	NS		NS		NS	
Varieties									
SS LS2	28.4	c	54	33.28	c	13.3	a	4.44	c
Beta 4581	50.9	b	72	34.86	c	12.7	b	4.43	c
Rhizosen	73.0	a	61	34.99	c	12.9	b	4.50	c
SS 462R	23.6	c	45	37.20	b	12.5	b	4.67	bc
SS 287R	51.2	b	61	37.60	ab	12.8	b	4.83	ab
SSH 89781	29.6	c	59	39.43	a	12.7	b	4.99	a
LSD	9.917		NS	1.876		0.374		0.2904	
CV %	24.5		27.2	5.0		2.9		6.1	

[1]Plots were fumigated on December 18, 1991, using one 3-tiered spray blade per 30-inch bed. Planting occurred on February 5, 1992; harvest was on July 23, 1992. Values are means of 4 replications.

[2]100 gpa broadcast rate was equivalent to 33.3 gallons per field acre as approximately one third of the area was treated using a single shank per 30-inch bed.

There were several differences among varieties. This was a bad year for Curly Top. Rhizosen, which is known to be CT susceptible, had an average of 73% infected plants. SS LS2, SS 462R, and SSH 89781 displayed the least amount of Curly Top symptom but still 20-30% of the plants showed symptoms.

Varieties did not differ in nitrates but did differ in sucrose percent. At 13.3%, SS LS2 had the highest sucrose percent. Other varieties did not differ from each other. SSH 89781 produced the most roots per acre and the most sugar. SS 287R was not far behind. SS LS2, Beta 4581, and Rhizosen produced the least tonnage and sugar per acre. The high incidence of Curly Top probably contributed to reduced yields of Rhizosen.

Results from this trial confirm the obvious: Unless there is a problem and distinct reason to fumigate, increased yields should not be expected.

Summary and Discussion

The ultimate goal is that growers need to know the expected return on their investment for their field situation and their levels of inoculum. Relative returns, based on yield results from these trials and assuming that all other costs all equal, are shown in Table 5. In Trial 1 all rates were cost effective, with the highest rate providing the most return. In the 1992 trial that had rhizomania but no root knot nematodes, only the lowest rate of metam returned a profit to the grower. In a situation, such as Trial 3, where no problem with root knot nematodes or rhizomania exists, it is obvious that fumigation is a luxury that farmers cannot afford.

Table 5. Cost effectiveness of metam treatments in 1990/91 sugarbeet trial, Tulare County

Treatment[1]	Cost of metam[2] material + application/A	Root yield increase compared to check, T/A	Value of increase[3] minus cost of treatment/A
<u>Trial 1</u>			
Metam, 50 gpa, broadcast	$118.00	8.2	$128.00
Metam, 75 gpa, broadcast	165.50	10.8	158.50
Metam, 100 gpa, broadcast	213.00	12.9	174.00
<u>Trial 2</u>			
Metam, 50 gpa, broadcast	$118.00	5.6	$ 50.00
Metam, 75 gpa, broadcast	165.50	4.0	- 45.50
Metam, 100 gpa, broadcast	213.00	4.8	- 69.00
<u>Trial 3</u>			
Metam, 100 gpa, broadcast	$149.54	1.0	- $119.54

[1]Metam used on a field acre basis would be half of the amount listed for each treatment because only 50% of the area was treated in trial 1 and trial 2. In trial 3, only a third of the area was treated so the broadcast rate is divided by 3 to determine gallons per field acre.

[2]Cost of each metam treatment was based on metam at $3.80/gal and an application cost of $23.00/acre.

[3]For this example, a price of $30/ton was used for the price received by the grower.

There are many factors that could be involved in why the response to metam fumigation in the first trial was much larger than the second. The first trial had both rhizomania and root knot nematodes while the second had only rhizomania. The second trial did have a mix of varieties, one of which has substantial resistance to rhizomania. Then of course there are numerous factors involving the application itself: soil type, soil moisture, soil texture, soil temperature, weather conditons at application and following application.

Results from these trials indicate that metam can be effective on shanks in reducing losses to root knot nematodes and rhizomania. Three-tiered winged spray blades appear to be an effective tool for placing metam in the top 12-14 inches of the soil profile. More trials, both in growers' fields and under more controlled conditions, are needed to test the consistency of positive results from metam fumigation with rhizomania and root knot nematodes alone and in combination.