EFFECTS OF METAM SODIUM AND ROOTSTOCK ON PLANT-PARASITIC NEMATODES, TREE GROWTH, YIELD, FRUIT QUALITY, AND LEAF MINERALS IN 'BRAEBURN' APPLE

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ABSTRACT

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Effects of two levels of metam sodium [methyl isothiocyanate (Vapam, 33% a.i., v/v)] and five rootstocks on plant-parasitic nematode populations, trunk cross sectional area (TCSA), yield per tree, yield efficiency (yield per tree/TCSA), fruit weight, color, sunburn, and leaf minerals in 'Braeburn' apple (*Malus domestica* Borkh.) were studied. Metam sodium treatments suppressed different parasitic nematode populations. Trees receiving low or high metam sodium treatments (Vapam at 748 L/ha or 1496 L/ha, respectively) had significantly larger TCSA than those of the un-treated control one year after application. Two and three years after applications, trees from the high metam sodium treated areas had higher TCSA than those with lower metam sodium and trees in both of these treatments had significantly higher TCSA than control trees. Yield efficiency in trees with both rates of metam sodium was similar, and was greater than that of the controls two and three years after planting. Both rates of metam sodium had similar fruit size that was significantly greater than that of controls three years after application. Leaf N in the un-treated control trees was higher than in metam sodium-treated trees two years after application, but no significant differences existed in leaf N three years after application. Metam sodium significantly reduced leaf Mn. Trees on rootstocks M.9 EMLA and M.26 EMLA had significantly lower TCSA than all other rootstocks, but they were significantly more precocious, producing more yield per tree and, therefore, more yield efficiency than all other rootstocks.

Key words: chemical control, crop loss assessment, fumigant, *Malus domestica*, metam sodium, plant parasitic nematodes.

RESUMEN

Fallahi, E., S. L. Hafez, M. M. Colt y M. M. Seyedbagheri. 1998. Efecto del metano de sodio y del pie de injerto, en nematodos fitoparasíticos y en el crecimiento, rendimiento, calidad de la fruta y minerales en la hoja del manzano "Braeburn". Nematropica 28:71-79.

Se estudiaron los efectos de dos niveles de metano de sodio (metiloisotiocianato (Vapam, 33% a.i., v/v) y de cinco pies de injerto, en las poblaciones de nematodos fitoparasíticos, la sección transversal del tronco (TCSA), el rendimiento por arbol, la eficiencia del rendimiento (rendimiento por árbol/TCSA), el peso de la fruta, color, quemaduras de sol y presencia de minerales en la hoja del manzano "Braeburn" (*Malus domestica* Borkh.). Los tratamientos con metano de sodio suprimieron diferentes poblaciones de nematodos parasíticos. Los árboles que recibieron cualesquiera de los tratamientos con metano de sodio, (Vapam a 748 L/ha o 1496 L/ha, respectivamente) tuvieron un TCSA significativamente mayor que los del control sin tratar un año después de la aplicación. Después de dos y tres años de las aplicaciones, los árboles de las areas tratadas con altos niveles de metano de sodio tenían un TCSA mayor que aquellos tratados con bajos niveles, así mismo, los árboles en ambos tratamientos tuvieron un TCSA, significativamente mayor que los árboles control. A los dos y tres años después de plantados, la eficiencia del rendimiento fue similar o mayor en los árboles tratados con metano de sodio, que en los árboles control. El tamaño de fruta fue similar con ambos niveles de metano de sodio y a la vez, significativamente mayor que en los controles, tres años después de la aplicación. El nitrógeno en la hoja de los árboles control no tratados, fue mayor que en los árboles tratados con metano de sodio dos años después de la aplicación, pero no se encontraron diferencias significativas después de tres años. El metano de sodio redujo significativamente el Mn en la hoja. Los árboles en M.9 EMLA y M.26 EMLA tuvieron un TCSA significativamente menor que todos los otros pies de injerto, pero fueron más avanzados y mostraron un mayor rendimiento por árbol y eficiencia de rendimiento que aquellos.

Palabras claves: control químico, diagnóstico de pérdida de cultivos, fumigación, *Malus domestica*, metano de sodio, nematicida, nematodos parasitadores de plantas.

INTRODUCTION

Apple is the major fruit crop in the state of Idaho and the Pacific Northwest region of the U.S.A. Poor growth of young apple trees planted on sites where fruit trees were grown previously is referred to as the apple replant syndrome. No specific leaf symptoms are evident, but roots of affected plants may be weak, sparsely branched, and discolored (Traquair, 1984). The causal agent(s) of replant disease appear to persist in the soil for several years (Utkhede and Thomas, 1988).

Plant-parasitic nematodes are the most important, but not the only components in nonspecific replant disease (Bird *et al.*, 1968; Koch *et al.*, 1980; Traquair, 1984). Numerous plant parasitic nematodes have been identified from samples of soil and roots of fruit tree orchards (Wallace and MacDonald, 1979). Root-knot (*Meloidogyne hapla*), root-lesion (*Pratylenchus* spp.), dagger (*Xiphinema* spp.), ring (*Criconemella* spp.), and stubby-root (*Trichodorus* spp.) nematodes are the most widely distributed in orchards, and their pathogenicity and economic importance on apple are well documented.

Pre-plant control of nematodes with fumigants is an effective treatment. Arnesen and Mai (1976) reported favorable results when orchards were treated with fumigants such as DD or 1,3-D. Even ten years after treatment, there was no indication that the untreated trees were beginning to recover to the level of trees in fumigated plots. Gur *et al.* (1991) indicated that the use of general biocides is probably more effective against the apple replant problem because they destroy nematodes as well as other microorganisms. Growers are increasingly utilizing metam sodium as a preplant fumigant on old apple orchard sites. Therefore, the goal of this study was to investigate the effects of two rates of metam sodium (Vapam) and five rootstocks on plant-parasitic nematode population density, tree growth, fruit yield and quality, and leaf minerals of 'Braeburn' apple.

MATERIALS AND METHODS

The experimental site was located near Weiser, Idaho. During winter of 1992-93, a block of 30-year-old 'Law Rome Beauty' apple was removed. The soil in this orchard had high levels of parasitic nematodes. The adjacent blocks in this area always had severe problems, when new apple trees were planted on previous apple orchard sites. After removing trees, the ground was cultivated and remaining tree roots were removed. The experimental design was a randomized complete block split-plot design with two levels of metam sodium and un-treated control as main plots, and five size-controlling rootstocks as sub-plots. There were six blocks in this experiment. For each rootstock in each sub-plot, two adjacent trees were planted, totaling 12 trees per rootstock per each level of fumigation and 60 trees per each level of fumigation. Metam sodium was applied at two rates (748 L/ha or 1496 L/ha) to rectangular shape blocks, which had 2.1×4.2 m (8.8 m^2) dimensions, on May 6, 1993. The un-treated control blocks received only water application. Uniform 'Braeburn' apple trees (1.09-cm diam.) on five rootstocks were obtained from C & O Nursery, Wenatchee, Washington. Metam sodium solution was sprinkled with a watering can. Treated and control blocks were watered with a sprinkler system immediately after application. Rootstocks were M.9 EMLA, M.26 EMLA, M.7 EMLA, MM.106 EMLA, and MM.111 EMLA. Trees were planted at 2.1×5.4 m spacing on 21 May 1993 (15 days after metam sodium application). At planting, 340 g of 11-52-0 (N-P-K) fertilizer was applied to each planting hole and mixed with soil. Other than the use of mixed rootstocks and fumigation, all cultural practices in this orchard were similar to those of other commercial orchards.

Soil samples for assessment of nematode populations were taken before planting rootstocks, after planting, and one year later. One composite sample from each planting hole, consisting of 10 sub-samples from soil removed with an auger from a depth between 40 and 61 cm, was collected before planting. After planting and one year later, 10 soil cores/tree were collected with 2.22 cm-diam. soil probes to a depth of 50 cm. Cores of soil were collected in a circular pattern approximately 40-45 cm within the tree drip line (within root zones) and bulked for each split plot. Nematodes were extracted from soil using standard procedures involving wet-sieving and sucrose-gradient centrifugation. Nematodes were identified and enumerated using light microscopy.

Leaf samples were taken in August, and trunk cross sectional area (TCSA) was measured at the end of each of the three growing seasons. Yield was recorded and yield efficiency was calculated as yield per tree (kg) divided by TCSA (cm^2) every year. When possible, a sub-sample was taken and fruit weight, fruit color, and the rate of fruit sunburn were measured. Leaf mineral analyses and fruit quality was measured by methods similar to those described by Fallahi and Simmons (1993).

Analyses of variance were conducted and means were separated with least significant differences (LSD) at 0.05 level, using the SAS statistical program.

RESULTS AND DISCUSSION

Effects of Metam Sodium: The lesion nematode, *Pratylenchus vulnus* Allen and Jensen, was detected in soil samples from the orchard. Other plant parasitic nematodes were identified to genus and included root knot (*Meloidogyne* sp.), stubby root (*Paratrichodorus* sp.), dagger (*Xiphinema* sp.) and ring (*Criconemoides* sp.). In general, root-knot, lesion, and ring nematodes were more abundant in the soil than other nematodes. Compared to the control, metam sodium applications at both rates suppressed populations of most plant-parasitic nematodes (Table 1). Regardless of metam sodium rate, there was a natural drop in the populations of root-knot, lesion, and dagger nematodes between 14 April 1993 and 21 May 1993. The magnitude of this drop in the metam sodium-treated soils was greater than untreated sites.

In 1994 (one year after application), trees receiving low and high metam sodium treatments had larger ($P = 0.05$) TCSA than those of un-treated control

Table 1. Effects of two metam sodium rates on populations of plant-parasitic nematodes in apple replant soil.

		Nematode populations[y]				
Treatment	Date	Root knot	Lesion	Stubby	Dagger	Ring
No Metam Sodium (Control)	April 14, 1993	508.2 a	159.0 a	5.8 a	61.8 a	389.6 a
	May 21, 1993	50.2 b	107.8 a	1.0 a	5.0 b	54.8 b
	June 28, 1994	45.2 b	116.6 a	10.2 a	12.8 b	427.0 a
Low Metam Sodium[z]	April 14, 1993	163.6 a	117.0 a	2.8 a	31.8 a	185.4 a
	May 21, 1993	2.6 b	15.4 b	1.6 a	0.0 b	1.4 b
	June 28, 1994	0.4 b	7.4 b	0.0 b	0.0 b	13.6 b
High Metam Sodium[z]	April 14, 1993	147.6 a	181.4 a	14.4 a	11.0 a	242.0 a
	May 21, 1993	1.0 b	18.2 b	0.0 b	0.0 b	2.6 c
	June 28, 1994	2.4 b	16.6 b	1.0 a	4.0 a	30.0 b

[y]Mean separation within columns of each application rate by LSD at $P = 0.05$.
[z]Low Metam Sodium = Vapam at 748 L/ha; High Metam Sodium = Vapam at 1496 L/ha.

plots (Table 2). However, two and three years after applications, trees treated with the higher rate of metam sodium had greater TCSA than those with treated at the lower rate. Trees in both of these treatments had greater TCSA ($P = 0.05$) than those in un-treated control plots.

Yields per tree and yield efficiency with both rates of metam sodium were greater than those of controls in 1995 and 1996 (Table 2). Trees with both rates of metam sodium had similar yield efficiency in both 1995 and 1996, although yield per tree in the high metam sodium treatment was greater than trees with low metam sodium in 1995.

Fruit size in trees with the two rates of metam sodium was similar in both 1995 and 1996 (Table 2). In 1996, trees with both rates of metam sodium had significantly larger fruit than control trees. Higher yield is usually associated with smaller fruit size (Fallahi and Simons, 1993). In this experiment however, higher metam sodium application resulted in both higher yield and fruit size because of the production of more vigorous and healthier trees.

Fruit color and sunburn were not affected by metam sodium. Leaf N in the un-treated control trees was higher than metam sodium-treated trees in 1995, but no significant differences existed in 1996. Compared to controls, leaf Mn concentration in the trees from metam sodium treated areas was significantly lower in both 1995 and 1996 (Table 2). It is possible that metam sodium reduced or eliminated soil microorganisms responsible for nitrification, resulting in a lower leaf N. However, more vigorous tree growth in the treated areas could be due to improved root growth. Therefore, it is important to understand that fumigation with metam sodium may lead to N and Mn deficiency, particularly when these elements are marginal in the soil. Metam sodium application did not affect concentrations of leaf K, Ca, Mg, Fe, Cu, or Zn (data not shown).

Table 2. Effects of different rates of metam sodium on tree growth, yield, fruit weight and color and leaf N and Mn in 1995-96.

	Trunk cross sectional area (cm^2)			Yield (kg/tree)		Yield efficiency (kg/cm^2)		Fruit weight (g)		Color[w] (1-5)		Leaf N (% dwt)		Leaf Mn (ppm)		Sunburn[x] (1-5)
Treatment	1994	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1996
Control	1.18 b[y]	3.57 c	6.99 c	0.6 c	1.8 b	0.16 b	0.27 b	212.9 a	174.4 b	3.24 a	2.83 a	2.58 a	2.41 a	385 a	359 a	3.2 a
Low Metam Sodium[z]	1.79 a	5.86 b	10.87 b	1.5 b	3.8 a	0.30 a	0.39 a	211.4 a	185.2 a	3.10 a	2.85 a	2.47 b	2.40 a	328 b	290 b	3.6 a
High Metam Sodium[z]	1.90 a	6.83 a	12.00 a	1.9 a	4.1 a	0.33 a	0.38 a	215.3 a	189.3 a	3.38 a	2.83 a	2.43 b	2.43 a	312 b	263 b	3.3 a

[w]Fruit skin color rating: 1 = green progressively to 5 = red.
[x]Sunburn rating: 0 = no sunburn progressively to 5 = severe sunburn.
[y]Mean separation within columns by LSD at $P = 0.05$.
[z]Low Metam Sodium = Vapam at 748 L/ha; High Metam Sodium = Vapam at 1496 L/ha.

Table 3. Effects of different rootstock on tree growth, yield, fruit weight and color in 1995-96.

	Trunk cross sectional area (cm^2)			Yield (kg/tree)		Yield efficiency (kg/cm^2)		Fruit weight (g)		Color[x] (1-5)		Sunburn[y] (1-5)
Rootstock	1994	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1996
M.9 EMLA	1.50 b[z]	4.66 b	7.19 b	2.8 a	5.0 a	0.57 a	0.62 a	220.9 ab	186.1 ab	3.62 a	3.15 a	4.6 a
M.26 EMLA	1.48 b	4.54 b	7.38 b	2.4 a	3.9 b	0.53 a	0.50 b	227.4 a	194.2 a	3.71 a	3.18 a	4.5 a
M.7 EMLA	1.83 a	6.24 a	11.61 a	0.6 bc	2.1 c	0.08 b	0.19 d	192.8 c	175.9 b	2.33 c	2.25 c	2.8 b
MM.106 EMLA	1.79 a	6.10 a	12.35 a	0.7 b	4.0 b	0.10 b	0.33 c	213.8 abc	179.3 b	3.29 ab	2.84 ab	3.2 b
MM.111 EMLA	1.50 b	5.97 a	11.94 a	0.3 c	1.7 c	0.04 b	0.13 d	203.4 bc	181.3 b	3.00 b	2.78 b	1.7 c

[z]Mean separation within columns by LSD at $P = 0.05$.
[x]Fruit skin color rating: 1 = green progressively to 5 = red.
[y]Sunburn rating: 0 = no sunburn progressively to 5 = severe sunburn.

Table 4. Effects of different rootstock on leaf mineral concentrations in 1995-96.

	Leaf N (% dwt)		Leaf Ca (% dwt)		Leaf Mg (% dwt)		Leaf Cu (ppm)		Leaf Mn (ppm)	
Rootstock	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996
M.9 EMLA	2.44 c[z]	2.47 a	0.97 a	1.03 a	0.28 bc	0.31 ab	7.8 ab	5.8 b	300 b	314 ab
M.26 EMLA	2.47 bc	2.38 c	0.89 b	0.86 b	0.32 a	0.33 a	7.7 ab	5.1 cd	390 a	343 a
M.7 EMLA	2.58 a	2.44 ab	0.85 bc	0.78 c	0.31 ab	0.31 ab	8.0 a	6.8 a	297 b	247 c
MM.106 EMLA	2.43 c	3.37 c	0.81 c	0.79 bc	0.27 c	0.29 b	7.1 ab	5.7 bc	388 a	319 ab
MM.111 EMLA	2.52 ab	3.39 bc	0.78 c	0.71 d	0.30 ab	0.33 a	6.8 b	5.0 d	331 b	392 b

[z]Mean separation within columns by LSD at 0.05.

Effects of Rootstock: During the first two years of the experiment, rootstock did not influence nematode populations in the soil (data not shown). Trees on M.9 EMLA and M.26 EMLA had significantly lower TCSA than those on MM106 and M.7 EMLA in 1994 and than all other rootstocks in 1995 and 1996 (Table 3). Trees on M.9 EMLA and M.26 EMLA also were more precocious and had more yield per tree and yield efficiency than all other rootstocks in 1995 and 1996.

Fruit from trees on M.9 EMLA and M.26 EMLA were generally larger and had better color than those on other rootstocks (Table 3). These fruits, however, had higher percentages of sunburn because of the smaller size of tree canopies on these two rootstocks. Trees on M.7 EMLA had the poorest color, and the smallest fruit, which was smaller than that on trees of M.26 EMLA in both 1995 and 1996 (Table 3).

Leaf N, Ca, Mg, Cu, and Mn concentrations were affected by rootstock (Table 4). Trees on M.7 EMLA had higher leaf N, while those on M.26 EMLA and MM.106 EMLA had lower leaf N than many other rootstocks in both 1995 and 1996, although differences were not always significant (Table 4). Trees on M.9 EMLA had low leaf N in 1995 but high leaf N in 1996. Trees on this rootstock had significantly higher leaf Ca than trees on other rootstocks in both 1995 and 1996. Trees on M.26 EMLA appeared to have higher leaf Mg and Mn in both 1995 and 1996, which is consistent with previous findings for 'Starkspur Golden Delicious' apple grafted to this rootstock (Fallahi *et al.* 1984). Trees on M.7 EMLA tended to have higher leaf Cu than those on other rootstocks, particularly in 1996. Metam sodium-rootstock interactions were mostly insignificant.

Pre-plant application of metam sodium to old orchard sites, where apples were previously planted, is beneficial. Metam sodium reduces parasitic nematode populations and improves tree growth and yield efficiency. However, trees planted on the metam sodium-treated sites exhibited reduced leaf N and Mn. Rootstock has a major impact on precocity, tree growth, yield, fruit quality and leaf mineral nutrient content.

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