N. Appendix

For more information on experimental conditions and specific soil treatments discussed in this text, 16 articles have been organized chronologically and reproduced here. The first 10 items pertain to soil treatments. Items 11-13 refer to systemic herbicides. Items 14-15 refer to use of virgin soil (NRPS). Item 16 provides directions for the validation of these technologies and others if they are to be moved into orchard and vineyard settings.

Proc. First Intl. Res. Conf. Methyl Bromide Alternatives and Emissions Reductions
1994, Orlando, FL

A Discussion of Five Portable Soil Drenching Devices, Three Biocide Injection Methods and Ten Biocide Agents Under Field Conditions

by
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A portable soil drenching device has been developed for delivery of any number of short-residual, water soluble, biocidal materials for pre-plant soil treatment in order to eliminate pests and disease agents. The device includes a series of hoses, each having drip irrigation emitters in place thereon at 30-cm intervals. The hoses may be attached to the underside of a tarp. Each hose is sealed at one end and attached at the other end to a manifold delivery system. The hoses are deployed onto the field which is to be treated, and the manifold is connected to a water supply and material mixing source. The selected materials are mixed with the water and introduced into the hose and manifold system by one of three alternative methods (uniform delivery, wave delivery or stacking) resulting in drenching of the field for elimination of pests and/or disease agents. Alternative embodiments allow for connection to existing linear, wheel line, and center-pivot irrigation systems and for the use of low atomizing sprinklers instead of hoses.

The standard biocides that have now received greatest evaluation have been the MITC-liberators, including Vapam®, Soil Prep® or Metham Sodium®. Nine other biocides evaluated at least once in a field situation include: emulsified 1,3-dichloropropene, carbon bisulfide, Clorox®, chlorine dioxide, calcium hypochlorite plus urea, Acrolein, urea plus sucrose, Furfural and cold water extracts from the stubble of safflower, *Carthamus tinctorius*, marigold, *Tagetes tenuifolia* and Cahaba White Vetch, *Vicia sativa* x *Vicia cordata.*

Treatments with MITC-liberators have repeatedly given consistent performance when applied via the Portable Soil Drenching Device (PSDD). Soil must be properly prepared or have the capability of infiltrating 10 to 15 cm water in 6 to 8 hr, respectively. Control of plant-parasitic nematodes at 98 to 99.9% one year after treatment is possible within the surface 150 cm of soil at 1º to 30º C. At 360 kg ai/ha drenched to the 150-cm depth the MITC-liberators give 100% control of viable tree and vine roots down to 60-cm depth. At double that treatment rate 100% root kill is achievable to 120-cm depth. Soils containing viable roots smaller than pencil-sized do not pose a problem; however at the existing labeled rate of 360 kg ai/ha the MITC-liberators are only mediocre in performance in replant of orchards and vineyards. The increased growth response (IGR) following use of MITC-liberators has not always been as dramatic as it is after use of methyl bromide. Grapes, *Vitis vinifera*, can grow better after MS than methyl bromide, however, walnuts, *Juglans niger* and peach, *Prunus persica*, may not. Efforts are underway to drench IGR-promoting substances into the surface 30 cm of soil during treatments with MS.

Nematode infested fields to be planted to annual-type crops or one-year nursery crops may be successfully treated by using 220 to 360 kg ai/ha in 10 cm water delivered to the surface 90 cm of soil profile. Products delivered to soil via PSDD become locked into the soil profile, thereby greatly reducing their volatilization when properly applied.

In terms of nematode kill in 150 cm of soil, the emulsified 1,3-D treatments can perform slightly better than treatments with MITC-liberators. Relative to the IGR response, there are indications that some materials are better promoters for certain crops but not others.

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Soil Fumigants Provide Multiple Benefits; Alternatives Give Mixed Results

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Since the 1950s growers have routinely used soil fumigants such as methyl bromide (MSr) and 1,3-dichloropropene (1,3-D), before replanting orchards and vineyards. Fumigants double plant growth in the early years after replanting and provide several years of nematode relief when resistant rootstocks are unavailable. However, the recent suspension of 1,3-D and the mandated phase-out of methyl bromide by 2001 have clouded the future of fumigant use. To develop alternatives, we must first document the pest control value and plant growth benefit of fumigation. Over the last decade, we have initiated several 2-year field trials in replant sites in the San Joaquin Valley. Our results quantify fumigation benefits and point to the feasibility of some alternatives, including a portable soil drencher.

Scientists cannot entirely explain the powerful benefit of fumigating soil before replanting perennial crops. The doubling of plant growth in the years that follow is only partly accounted for by the elimination of plant pathogens, nematodes and insect pests. Evidence suggests that myriad detrimental factors commonly present in old orchard sites are remedied by fumigation and soil profile disruption.

However, the future of this widely used technology is in doubt. In 1990, California use of 1,3-D was suspended due to it occurrence in off-site air samples. In addition, MB use in the United States will be phased out by the year 2001 under provisions of the 1990 Clean Air Act.

At present, there are few satisfactory alternatives to the long-standing practice of soil fumigation. Fumigants are capable of destroying most life stages of soil-dwelling organisms as well as the roots of old grapevines which can otherwise remain alive in soil for 10 years after the vine trunk has been ripped out of the ground. Roots of peach, plum, apple and walnut deteriorate faster than those of grape, but viable roots are likely to be present for at least 3 years after tree removal. These woody roots provide a food source for a variety of soilborne plant pathogens and insects. Viruses, bacteria or actinomycetes (rod-shaped, branching bacteria which may be obligatory plant parasites or simply grow in association with the roots) will also persist in soil as long as the old roots remain viable. Fumigation at 250 to 700 lb/ac MB or 1,3-D to potential problems. It kills old roots in the surface 4 to 6 feet of soil profile, and most life stages of soil-borne pathogens and insects, promoting growth and vigor in a replanted orchard.

However, if an orchard is replanted in nonfumigated soil, the result is quite different. This is due to a phenomenon known as the “replant problem,” which occurs to varying degrees worldwide. The replant problem is illustrated when soil is collected from anywhere along an old orchard or vineyard floor and placed in a pot in the greenhouse: Any woody perennial replanted into it will not grow as well as if it were planted to soil that had never been in an orchard or vineyard. Two of the perennials that present the worst replant problems (when followed with any other perennial) are peach and walnut. If a replanted perennial is the same type as the previous one (e.g., grape to grape), the plant growth reductions can be striking. This latter phenomenon is referred to as a "specific replant problem."

There are biological, chemical and physical components of the replant problem and they are not necessarily the same from site to site or region to region. For example, replanting peach to peach in the Sacramento Valley is not as perilous as doing so in the San Joaquin Valley. In some replant sites, all that is needed to correct the problem is deep soil ripping or backhoeing of the planting sites.

The symptoms of a replant problem include poor growth with nutritional deficiencies such as phosphorus and zinc distributed non-uniformly across the field. Nematodes, phytophthora, phylloxera and other soil pests may be abundant along the roots. Plants do not develop adequate root systems and all of this can be visible by mid-summer of the first year. In some situations, these problems will disappear after one or two years. In other cases, especially where a known soil pathogen is present, the plants may become an economic liability to the grower unless a rootstock with resistance to the dominant pest was planted.

The combination of soil profile disruption and proper soil fumigation at the planting sites will stop the general replant problem and greatly minimize the specific replant problem. Soil fumigation will provide 6 months to 6 years of nematode relief, depending on the quality of the treatment. If nematodes have returned to the site within 6 months after planting a susceptible rootstock into a soil conducive to their development; the plants may grow well for the first 2 years and then quickly or gradually decline in vigor. In fumigated and nonfumigated blocks grown side by side, a grower may continue to see the growth difference decades later. The grower can try a number of post-plant treatments to revitalize the poorer growing block, but usually with only mediocre success. For purposes of comparison, 4 years of dry fallowing prior to replanting is generally adequate to avoid most of the replant problem.

In this paper, numerous pre-plant treatments will be compared for their long term nematode control value and the vitality they impart to replanted trees and vines. These studies are the results of cooperative field trials located at sites where human and vehicle traffic could be kept to a minimum to avoid contamination from plot to plot. MB and 1,3-D are examples of "true" soil fumigants. This means that their movement through soil is primarily as a gas. These two biocides are released into soil behind tractor-pulled shanks. The biocides become gaseous and move through soil air spaces (fuming), while dissolving into associated films of soil water. Within the soil water film, soil microbes are contacted and killed.

Although it is a very good biocide, the fumigant metam sodium (MS) actually has poor fuming action. It permeates the soil only if it is moved with water. Several nematicides, including fenamiphos, oxamyl and ethoprop, are not biocides or fumigants but rather nematicides moved best with water. Carbon bisulfide has excellent fuming action, but can be ignited by a spark. However, the formulated product Enzone has limited fuming action, is nonexplosive, and also is moved best through soil by adding it to water.

Marigold (*Tagetes* spp.), which is antagonistic to various nematode species, may be grown as a rotation crop or refuse of its above-ground parts may be added by incorporation as a soil amendment. Extracts of marigold can also be drenched onto soil. Marigold provides an example of a potential nonconventional alternative to soil fumigation.

Soil drenching is a procedure for mixing biocides into irrigation water and delivering the water onto the field surface through basins, sprinklers or large tanks on wheels. A new procedure for drenching involves the use of a portable soil drenching device (PSDD). These devices can deliver a wider variety of biocidal agents with greater uniformity while minimizing fumigant escape (off-gassing); minimal off-gassing was recorded in preliminary measurements by air monitoring instruments. Using the PSDD, a dripper emitter is temporarily located on each square foot of field surface that is drenched. The drencher mixes biocide with water, and distributes the mixture through the soil profile over an 8-hour period. The cost of using the PSDD is estimated at $150 per treated acre plus chemicals, which is similar to that of nontarped methyl bromide applications, the prevalent practice of the tree and vine industry at present.

Materials and Methods

Studies were conducted at eight locations, which are referred to here as Sites A through H (see Table 1). All the locations were in Fresno County, except Site G, which was in Stanislaus County. Sites A, B, C, F and H were near Parlier. Site D was close to Orange Cove, Site E was near Reedley and Site G was close to Ceres.

The overall goal of this research was to establish the benefit of current soil fumigation and investigate the feasibility of alternatives. The specific goal in each trial was to reduce grower costs without losing long-term benefit. Evaluations were conducted on more effective plastic tarpaulin, lower treatment rates, dripper applications with nematicides instead of biocides, natural nematicides, and eventually a number of biocides and nematicides applied through the portable soil drencher.

During the first month or two after each treatment, and before replanting, soil samples were collected at 1-foot increments down to a 5-foot soil depth. These five soil samples were analyzed separately, but to simplify reporting the results have been averaged together and listed under the 1-month sampling column. Once the treated sites were replanted, all subsequent soil samples were collected from the 0- to 2-foot depth of each treated replicate.

Collected soil was extracted for nematodes using a combination Cobb Sieving and 5-day mist extraction. Collected nematodes were placed beneath a microscope for speciation and counting. Nematode counts for the nontreated control are indicated as nematodes/250cm^3 soil. All other data for that site are depicted as percent control across the four to eight replicates for that treatment when compared to the nontreated. Counts for *Paratrichodorus minor* (Stubby Root Nematode) and *Paratylenchus hamatus* (Pin Nematode) were excluded from all data sets.

Plant growth measurements were taken 1 or 2 years after treatment and included plant weight, pruning weight, plant height and trunk circumference.

The soil in Site D was a Porterville clay. All other sites involved a Hanford sandy loam soil. The treatments were as follows.

Site A. The Site A study was designed to determine the value of a new high barrier, greater density tarp (HBF-1) compared to the lower density tarp, which was in common use until the late 1980s.

Site B. The Site B study was conducted to determine if 1,3-D fumigations at low rates (150 lb/ac) plus monthly 1 lb/ac additions of conventional nematicides through an irrigation dripper could be as effective as a conventional pre-plant fumigation with 1,3-D. In one of the 10 treatments, the 1,3-D was followed in a week by a 6-inch deep rotovater with MS (metam sodium) sprayed just before the front tines for incorporation. (The rotovater has moving tines which mix up soil to a depth of several inches.)

Site C. At Site C, dual treatments with MB and 1,3-D were compared to conventional treatments. Dual treatments involve a normal treatment, followed two weeks later by a plowing designed to flip the surface 1 ftoo of soil completely upside-down. The plowing is followed within a day by a second treatment of usually the same fumigant but at a reduced treatment rate. The first comparisons with a Portable Soil Drenching Device (PSDD) began in Site C. It was used to deliver 3 inches of water with various biocides or nematicides to the surface of dry soil after a deep fumigation or 7 inches of water with various biocides to a moist soil. The PSDD delivered the water at the surface with the biocide uniformly metered over a 3- or 9- hour period. When using a PSDD, dripper emitters are placed on each square foot of field surface.

Site D. Site D involved a comparison of 1,3-D with marigold, *Tagetes tenuifolia* c.v. Nemakill as a rotation crop or as a refuse amendment. The fresh weight of the aboveground marigold plant was approximately 15,000 lb/ac as it was incorporated and irrigated in four months before planting of cherry/mazzard.

Sites E through H. At Sites E through H, we performed field tests of PSDD using various biocides.

Site F. In Site F, five each of seven different host crops were grown in each plot after the treatments. MB was applied at 200 lb/ac at a depth of 3 feet, the soil flipped in 7 days and retreated at 100 lb/ac at the 18-inch depth. One set of plants was planted 10 feet away from the old tree rows while all other plants were within 2 feet of the old planted row. At this site, the untreated block was flooded for 40 days and nights with 16 feet of water in an unsuccessful attempt to kill old roots. These flooded treatments can be considered a nontreated control.

Site G. At Site G young rooted grapevines were planted 1 month after mid-summer treatments including a relatively high rate of carbon bisulfide (Enzone). Vine top weights from 60 vines in each replicate were collected and weighed.

Site H. In Site H a variety of natural or nonconventional biocidal agents were applied via PSDD after killing the old orchard trees with a 2% foliar application of glyphosate. A “uniform delivery” was achieved by mixing the biocide into every drop of water delivered except for the last 30 minutes of delivery. The drenched 1,3-D included a non-emulsified and an emulsified product.

Sites F, G and H are still under investigation at the time of this writing.

Results and Discussion

Field replant sites receiving 250 to 700 lb/ac of properly applied 1,3-D or MB frequently exhibited nematode population reductions of 95% up to 2 years after fumigation (see Table 1). These nematode reductions are accompanied by plant growth benefit. Although the use of marigold as a rotation crop or as a refuse amendment in the year before planting cherry resulted in reduced nematode populations, it significantly reduced plant growth when compared to fallowing for 1 year or the pre-plant use of 1,3-D (site D).

Soil drenching, when used to apply MS (the active ingredient released by metam sodium in soil) with 6 inches of water to properly prepared soil, came very close to being as effective as soil fumigation (Sites C, E, F and G). However, the MS treatments do not kill old tree roots below 2 feet soil depth when applied at 327 lb/ac (100 gal/ac Vapam). At double the treatment rate (654 lb/ac), old roots may be killed down to 4 feet; however, replants placed in the soil 6 months later (Site F) grew poorer than those planted to MB fumigated soil. At the 327 lb/ac rate grapevines planted one month after treatment (Site F) or Nemaguard rootstock planted 3 months after treatment (Site E) did grow as well as the fumigated comparisons (no significant differences).

Compared to the untreated control, replants of black walnut were doubled in size 2 years after a 1,3-D fumigation at conventional rates (Site B). Treatment rates of 150 lb/ac of 1,3-D only gave nematode control in the surface 3 feet of soil profile and did not kill all the old roots in that zone. Knowing this, dripper applied treatments of conventional nematicides at 1 lb/ac were applied monthly to repel intrusion of the root lesion nematode. The dripper treatments were effective in the narrow zone receiving treatment, but not in sites more than 2 feet away from the drip emitter (data not shown). Fenamiphos (Nemacur), when applied in this manner to 2-year-old nursery stock of walnut, reduced plant growth during the first year of treatments but improved walnut growth in the second year (Site B). In Site F, walnut trees planted into MB-fumigated soil that had not previously been planted to walnut were four-fold larger than the nontreated. Compared to MB treatments the growth of walnut trees in soil treated with 654 lb MS/ac (200 gallons/ac Vapam) was reduced although nematode control was excellent. In Site F, the only plants infected with root lesion 1 year after the MS drench or MB fumigation were those adjacent to one edge of the field where a buried concrete pipe line existed.

Nemaguard Peach, NC Black Walnut and Teleki 5C grape were the three rootstocks that showed greatest growth benefit from a pre-plant soil fumigation. These are examples of plants that appear to be more sensitive to the replant problem in general. All three have resistance to root knot nematode, but are susceptible to root lesion nematode. In Site F, high rates of MS reduced growth of the subsequent planting, but it should also be noted that young grape rootings do not always grow well after MB (see Site G), whereas they do grow well after 1,3-D fumigation (not shown). In none of these trials did we make an attempt to correct nutritional deficiencies with fertilization, since such deficiencies are usually a result of the killing of beneficial soil microorganisms such as mycorrhizae. MS applied by PSDD at 327 lb/ac gave control of nutgrass *Cyperus esculentus* similar to that achieved with tarped MB. The microbial-rich surface soil receives high dosage levels during the drenching process (especially at 654 lb/ac rate of MS) and we should anticipate kill of some beneficial organisms at high treatment rates. The relatively high rate of carbon bisulfide used in Site G resulted in visible growth improvement within that treatment compared to MB treated soil. The results are not statistically significant probably because the young vines were only in the ground for two summer months before being weighed.

The lack of root killing power in MS at the 327 lb/ac rate may be more of a problem for old orchard sites than for vineyards where smaller roots are more common. It should be noted that trees and vines irrigated by dripper or mini-sprinkler have a greater number of small-sized roots which would succumb to MS at a lower dosage rate. As recipes and equipment for PSDD have gradually evolved the potential for drenching with existing low volume irrigation systems has also become apparent. After the last harvest, existing irrigation systems can become the vehicle for drenching with MS and other biocides.

Drenching will become one of the methods used to replace soil fumigation. One primary reason is that a fumigant's ability to move well through soil as a gaseous biocide also causes it to appear off-target in ambient air. Unlike fumigations, drenching locks the biocide into soil. If the biocide has been properly selected (e.g. short half-life) it will degrade in place. Drenching also permits the use of less-volatile biocides. In using the PSDD to deliver MS, we have repeatedly observed a reduction in the quantity of biocide volatilized from treatment sites. The odors of Vapam are not detected 100 ft from the treated area. Our early studies indicated that whether soils were 40°F or 80°F, the efficacy of the MS was adequate (data not shown) against nematodes in the surface 4.5 feet of soil. Soils must be in proper condition to receive the drenching. If water will not move through the soil with uniformity, then neither will a biocide having low volatility. In regard to proper soil conditions, there is much less flexibility with MS than with MB.

The timing of 1,3-D and MB treatments has been consistently recommended for the fall months before 2 inches of rainfall. Fumigation has usually been the last cultural event before replanting. Drench treatments have traditionally followed a similar recipe; however, evidence is accumulating to indicate that there may be a waiting period and/or a rotation crop needed between drenching and replanting. Drenches with MS may be more appropriately applied before or just after removal of the old orchard or vineyard. After plant removal and soil profile modification, annual crops that are deep rooting and nonhost to indigenous soil pests may need to be grown for six months or more before replanting of trees and vines. The waiting period would further reduce populations of endoparasitic nematodes, restore beneficial soil microbes and restore soil structure prior to replanting. It will require several years to field-evaluate this change in general procedures.

Although average treatment rates of 400 lb/ac of biocidal agents seem relatively high, the "nonchemical" alternative we have studied most is 15,000 lb/ac of aboveground fresh weight of marigold. A simple water extract of marigold is nematicidal at 10g fresh weight/liter of water. Equivalent nematicidal activity can be attained with MB or 1,3-D at 10 mg/l. Whether we apply the marigold as an extract within a drench or incorporate and add water to the soil, the marigold contains numerous biocidal ingredients that appear to persist in soil unless about 40 inches of rain falls between incorporation and replanting. These biocidal agents do not kill old roots, but they inhibit growth of replanted trees and vines. We are continuing to study marigold drenches followed by 40-inch irrigations, but it is incorrect to assume that because ingredients occur naturally they are safe for the environment.

The soil fumigants have offered growers flexibility and have been relatively easy to apply. There are no examples of MB or 1,3-D as contaminants of groundwater because both fumigants also degrade in soil. Both products are, however, relatively volatile and apparently difficult to maintain below ground once they are applied. Procedures for keeping them below the soil surface include reductions in treatment rates. As treatment rates are reduced, the spectrum of soil-borne pests they control will also be reduced.

Conclusions

For a variety of reasons, soil fumigation has proven to be an economically viable pre-plant treatment. Even "resistant" rootstocks grow poorly their first year or two without such soil treatments. Crop rotations of 1 or 2 years are relatively expensive and, as with marigold in an arid climate, may not yield positive growth benefits. Our more deliberate approach to soil drenching has provided a broader list of potential biocides and treatment combinations, while also indicating how the more volatile biocides may need to be applied to minimize off-gassing. Inches beneath our feet right here on Earth there are microbiological systems and interactions that we know absolutely nothing about. Until this deficiency is corrected, the finding of alternatives to fumigation will be like shooting in the dark.

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Table 1. Data on plant growth and nematode return in the 24 months following various soil treatments

Site A – Vineyard with root knot nematode and dagger nematode replanted to tomato and piper sudan grass						
Treatment and rate	**Nematode control levels***					**Plant growth**
	1 mo	**6 mo**	**12 mo**	**18 mo**	**24 mo**	
lb/ac	%					
MB, tarp (HBF-1) at 300 lb/ac	– –	100.0 a	100.0 a	100.0 a	99.84 a	
MB, tarp (HBF-1) at 200 lb	100.0 a	98.7 abc	100.0 a	99.3 a	99.97 a	
MB, tarp (LDPE) at 300 lb	100.0 a	100.0 a	100.0 a	99.9 a	100.0 a	NO DATA
MB, no tarp at 300 lb	100.0 a	99.7 a	99.9 a	99.8 a	98.3 a	
1,3-D, no tarp at 500 lb	100.0 a	100.0 a	99.9 a	99.7 a	99.84 a	
	Actual nematodes/250 cm³ soil					
Non-treated control	**102.0**	**81.0**	**130.0**	**757.0**	**896.0**	

Site B – Walnut with root lesion nematode replanted to walnut							
Treatment and rate	**Nematode control levels***					**Plant top growth**	
	1 mo	**6 mo**	**12 mo**	**18 mo**	**24 mo**	**1 yr**	**2 yrs**
lb/ac	%					*lb*	
1,3-D at 500 lb/ac	100.0 a	100.0 a	99.9 a	99.1 a	100.0 a	2.6 a	7.3 a
1,3-D at 500 flip 1,3-D at 200 lb	99.9 a	100.0 a	99.93 a	99.9 a	100.0 a	2.2 abc	7.7 a
1,3-D at 500 plus rotovate in 65 lb MS	99.1 a	100.0 a	100.0 a	99.97 a	99.96 a	2.2 abc	7.5 a
1,3-D at 150 lb	99.9 a	99.5 a	99.94 a	100.0 a	88.4 a	2.4 abc	7.0 a
1,3-D at 150 plus monthly aldoxycarb 16 lb	– –	100.0 a	100.0 a	100.0 a	73.1 ab	2.4 abc	7.5 a
1,3-D at 150 plus monthly fenamiphos 16 lb	– –	100.0 a	100.0 a	99.97 a	99.9 a	2.4 abc	7.0 a
1,3-D at 150 plus monthly oxamyl 16 lb	– –	100.0 a	100.0 a	99.99 a	99.3 a	2.6 a	7.7 a
Monthly aldoxycarb totaling 16 lb	– –	32.5 b	44.3 bc	50.3 b	0.0 c	1.8 bcd	3.1 b
Monthly fenamiphos totaling 16 lb	– –	36.6 b	89.6 ab	91.8 a	99.3 a	1.5 cd	3.5 b
Monthly oxamyl totaling 16 lb	– –	5.6 b	72.7 ab	63.9 b	33.6 c	2.2 abc	3.5 b
	Actual nematodes/250 cm³ soil						
Non-treated control	**55.0**	**145.0**	**673.0**	**1053.0**	**921.0**	0.5 d	1.4 b

Site C – Vineyard with root lesion and root knot nematode replanted to strawberry

Treatment and rate	Nematode control levels*					Plant growth
	1 mo	6 mo	12 mo	18 mo	24 mo	
lb/ac	....	....	*%*	....	....	
1,3-D at 125 lb/ac	100.0 a	99.1 a	94.7 a	87.0 a	51.0 b	Good
1,3-D at 500 lb	100.0 a	100.0 a	100.0 a	70.0 ab	37.0 b	Excellent
Cis-1,3-D at 150 flip 50 lb	100.0 a	100.0 a	98.1 a	71.0 ab	61.0 ab	Excellent
Trans-1,3-D at 150 flip 50 lb	100.0 a	98.2 a	88.2 a	67.0 b	56.0 ab	Excellent
MB at 300 flip 150 lb	100.0 a	100.0 a	100.0 a	99.2 a	95.0 a	Excellent
MB at 300 then MS 65 lb via PSDD	100.0 a	100.0 a	99.3 a	100.0 a	83.0 a	Excellent
MB at 300 then ethoprop 20 lb via PSDD	100.0 a	92.6 a	48.5 b	11.0 c	48.0 b	Excellent
MB tarp (LDPE) at 300 lb	100.0 a	100.0 a	100.0 a	99.2 a	41.0 b	Excellent
MB non-tarped at 300 lb	99.5 a	98.2 a	58.1 b	76.0 ab	50.0 b	Excellent
MS PSDD at 300 lb	100.0 a	100.0 a	100.0 a	99.2 a	89.0 a	Excellent
Ethoprop PSDD at 20 lb	75.0 b	0.0 b	58.0 a	0.0 c	0.0 c	Good
	Actual nematodes/250 cm^3 soil					
Non-treated control	**27.0**	**41.0**	**26.0**	**16.0**	**77.0**	Good

Site D – 30-yr-old plum/M2624, with citrus nematodes in clay soil, removed and replanted 2 years later to cherry/mazzard

Treatment and rate	Nematode control levels*					Plant growth Height of cherry/mazzard after 1 yr
	1 mo	6 mo	12 mo	18 mo	24 mo	
lb/ac	....	....	*%*	....	....	.... *in* ....
1,3-D 800 lb/ac	100.0 a	– –	100.0 a	– –	– –	48.2 a
1-yr marigold rotation (incorp. 15,000 lb/ac)	95.0 a	– –	94.0 a	– –	– –	35.9 c
1-yr marigold roots only	92.0 a	– –	98.0 a	– –	– –	34.1 c
Marigold tops only (incorp. 15,000 lb/ac)	85.0 a	– –	94.0 a	– –	– –	36.1 bc
	Actual nematodes/250 cm^3 soil					
Non-treated control	**350.0**	**– –**	**110.0**	**– –**	**– –**	**39.9 b**

Site E – 20-yr-old plum/Nemaguard, with root lesion and ring nematode, removed and replanted to nectarine/Nemaguard

Treatment and rate	Nematode control levels*		2 yr trunk circumference
	12 mo	24 mo	
lb/ac	..........%	..........%	..........*in*..........
1,3-D at 350 lb/ac	96.0	80.0	13.0.
MS at 165 lb/ac by PSDD	80.0	78.0	12.4
MS at 327 lb/ac by PSDD	100.0	90.0	15.3
(No significant differences among nematode counts or growth)			

Site F – 15 yr old peach and plum orchard, with root lesion and citrus nematode, removed and replanted to various plants

Treatment and rate	Nematode control		Pruned plant growth, after one year						
	1 mo	12 mo	Rose/ Dr. Huey	Cherry/ Colt	Peach/ Nemaguard	Plum/ M2624	Walnut/ NC Black	Cab. Sauv.	Cab. Sauv./ Teleki 5C
lb/ac	......%	......%	......*in*	......*in*	......*in*	......*in*	......*in*	......*in*	......*in*
MB, 200 flip 100	100.0	93.0	2.10 a	0.61 a	1.01 a	1.00 a	0.52 a	0.73 a	0.73 a
MS 654 by PSDD	100.0	86.0	1.80 a	0.56 a	0.57 b	0.72 b	0.28 b	0.52 b	0.35 b
Non-treated, 10 ft away	– –	0.0	0.71 b	0.39 b	0.22 c	0.46 c	0.14 b	0.35 bc	0.22 bc
Non-treated, but flooded 40 days/nights	– –	0.0	0.91 b	0.27 b	0.10 c	0.31 c	0.12 b	0.19 c	0.11 c
	Actual nematodes/250 cm^3 soil								
	– –	**436.0**	– –	– –	– –	– –	– –	– –	– –

Site G – Old almond orchard, with root lesion and ring nematode, removed and replanted to various grape varieties

Treatment and rate	Nematode control levels* Control 1 mo	Average plant growth from 60 vines after 6 months Chardonnay	110R	Teleki 5C	520A	5BB
lb/ac	.... *%*..........	.... *in.*				
MB, 300 lb/ac tarped (HBF-1)	98.9	0.51	0.70	0.43	0.38	0.68
MS PSDD 327 lb	88.7	1.09	0.81	0.76	0.69	1.28
Carbon bisulfide, PSDD at 1183 lb	96.3	0.95	1.01	1.12	0.70	1.34
Non-treated control		0.51	0.48	0.35	0.32	0.57
	Actual nematodes/250 cm^3 soil					
	26.6	– –	– –	– –	– –	– –

Site H – 15-yr old peach and plum orchard with root lesion and citrus nematode removed and treated with various drenches

Treatment and rate	Nematode control levels* Root lesion 1 mo	Citrus nematode 1 mo
lb/ac	.... %	....
MS 327 lb/ac delivered uniform via PSDD	96%	99%
Clorox 327 lb delivered uniform	53	82
Urea 654 lb delivered uniform	97	64
Tea from 15,000 lb safflower delivered uniform	25	81
Chlorine dioxide 6.4 lb delivered uniform	71	45
Telone 327 lb emulsified, uniform	100	100
Telone 327 lb non-emulsified, uniform	no control below 2 ft depth for either nematode	
	Actual nematodes/250 cm^3 soil	
	280.0	**250.0**

* Level of nematode population control expressed as percentage of the nontreated check. Numerical values in each column followed by the same letter are not significantly different from each other (*P*=0.05) following an analysis of variance and Duncan's Multiple Range Test.

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FIRST-YEAR EVALUATION OF TREE AND VINE GROWTH AND NEMATODE DEVELOPMENT FOLLOWING 17 PRE-PLANT TREATMENTS

by
Michael McKenry, Tom Buzo, and Stephanie Kaku

In a two hectare plum replant site three separate experiments were conducted. On half the site trees were removed, soil was ripped to 0.7 m depth and a dual application of 366 kg/ha methyl bromide (MB) was compared to 40 days flooding or a 732 kg/ha drench of methyl iso-thiocyanate (MITC). The plot was split with rootings of Nemaguard Peach, Black Walnut, Dr. Huey Rose, Marianna 2624 Plum, and Teleki 5C Grape either replanted in 6 mo. or after 18 mo. of crop rotation involving Barley, Sorghum x Sudan and Cahaba White Vetch.

On the adjacent one hectare the existing plum trees received a foliar spray of 2% glyphosate 60 days before their removal. The field was then planted to barley. After discing under the barley, ripping to 1.3 m and resettling the soil, treatments were drenched into the surface 1.6 m of soil profile. To this half the field all trees and vines were replanted a full 18 mo. after tree removal. Six months after the glyphosate treatment there was 80% kill of old Nemaguard roots and 40% kill of old plum roots. Populations of *Pratylenchus vulnus* nematode were still present within the root systems two full years after the glyphosate treatment. Populations of *Tylenchulus semipenetrans* nematode also remained alive around the plum roots two years after the glyphosate.

Each October after replanting the growth of five reps of each of five plant cultivars was destructively sampled. Plant growth was compared to the nontreated that were replanted 6 mo. after tree removal. For example, several treatments produced plants that were 7 to 11 times larger than the nontreated. The multiple for plant growth improvement was averaged across the five plant cultivars to provide a single value which depicts relative plant growth.

Four treatments provided nematode control one year after treatment that was 99% of the nontreated. These four treatments also provided plant growth 7.0 to 8.5 times better than the nontreated that was planted 6 mo. after tree removal. The four comparable treatments included: 1) MB at 366 kg/ha followed by an 18 mo. crop rotation; 2) MS at 732 kg/ha followed by 18 mo. crop rotation; 3) Glyphosate-treated site followed by a drench of emulsified 1,3-D at 366 kg/ha and 4) MB at 366 kg/ha replanted after 6 mo.

A fifth treatment, glyphosate followed by acrolein drench at 366 kg/ha gave plant growth of 8.3 times the nontreated but after one year the nematode control averaged only 50% among the three most susceptible hosts.

Three treatments that provided plant growth comparable to the above-mentioned but provided no long-lasting nematode relief included: 6) 40 days flooding then 13 mo. sorghum x Sudan and vetch; 7) glyphosate followed by MS drench at 366 kg/ha and 8) glyphosate followed by 18 mo. fallow.

Replanting 3 m away from the old tree row provided 2.6 times more growth in the first year but no nematode relief.

Flooding for 40 days and planting within two months did not provide kill of remnant roots or nematode reductions and plant growth was only 1.4 times the nontreated.

Fallowing or crop rotation for 18 mo. greatly improved growth of replants but didn't provide adequate nematode relief against endoparasitic nematodes which remained in roots.

A drench of urea gave 95% nematode relief in soil but didn't reduce populations of endoparasitic nematodes within roots. A drench of marigold tea plus urea followed in one month by 1 ha-m irrigation gave control of soil-dwelling nematodes without creating a biological vacuum. Plant growth of 4.6 times the nontreated indicated, however, that a phytotoxic residue remained in the soil.

A drench with 366 kg/ha chlorine gave surprising benefit to the growth of peach but nematode control in soil and in remnant roots was inadequate. Drenches are very useful in sites where 15 cm water can be delivered within 8 hr. These drenches were each delivered throughout the surface 1.7 m of soil using a portable soil drenching device.

Table 1. Summary of plant and nematode responses in the two years following various soil treatments.

Treatment Product, Rate and Method					Nematode Control		Plant Growth Compared to Nontreated Planted After 6 mo.	
Biocide	Rate	Kg ai/ha	mg ai/L Water	Injection Method	One Year After Planting	Two Years After Planting	First Year	Second Year
MB then 18 mo. rotation	350 lb/ac	392	Variable	Shank	99%+		7.14 x	
Vapam then 18 mo. rotation	200 gpa	732	490	PSDD-Uniform	99%+		8.54	
Roundup then 1,3-D	33 gpa	366	245	PSDD-Uniform	99%+		7.00	
MB then 6 mo. fallow	350 lb/ac	392	Variable	Shank	99%+	99%	7.28	3.70
Roundup then Acrolein	--	366	980	PSDD-Wave	50%+		8.34	
40 day flood then 13 mo. fallow	--	--	--	--	Poor		7.00	
Roundup then marigold tea	7.5 ton/ac	16,800	27,750	PSDD-Uniform	Poor		4.60	
Vapam then 6 mo. fallow	200 gpa	732	490	PSDD-Uniform	Poor	None	3.28	2.48
Roundup then Vapam, fallow	100 gpa	366	245	PSDD-Uniform	None		8.02	
18 mo. crop rotation (barley, sudan, vetch	--	--	--	--	None		3.56	
Roundup then low bi urea	654 lb/ac	732	490	PSDD-Stacked	None		6.52	
Roundup then chlorine	--	366	980	PSDD-Wave	None		6.56	
Roundup then 18 mo. fallow	--	--	--	--	None		7.06	
Nontreated then plant 10 ft. away after 6 mo.	--	--	--	--	None	None	2.44	1.66
Roundup then fallow 18 mo. then plant 10 ft. away	--	--	--	--	None		3.76	
40 day flood then plant in 2 mo.	--	--	--	--	None	None	1.38	1.24
Nontreated plant after 6 mo.	--	--	--	--	None	None	1.00	1.00

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EVIDENCE FOR THE DEVELOPMENT OF A "BIOLOGICAL VACUUM" IN SOIL FOLLOWING PRE-PLANT SOIL FUMIGATIONS OR DRENCHES

by
Michael McKenry, Stephanie Kaku, and Rulon Ashcroft

Soil sterilization reduces soil microbe populations that are beneficial as well as those that are detrimental to plant growth. Following soil fumigation, plant parasitic nematode species can be reduced to nondetectable levels (1). Subsequently-planted trees or vines respond favorably to the treatment for at least these reasons: 1) The lack of soil pests, 2) The lack of microbes not usually considered as pests or disease incitants, and 3) These plants also exhibit an "increased growth response" (IGR) due to changes in nutrient availability (2). Participants in soil fumigations have occasionally observed a fourth phenomenon in that the first microbes that are reintroduced into fumigated soil develop greater abundance than if they were introduced into nonfumigated soil. These organisms appear to be filling a "biological vacuum" but since the treated vines or trees also grow many times faster than the nontreated it has been difficult to quantify the impact of a biological vacuum. In a separate paper at this conference an example involving Vapam was presented illustrating the importance of remnant roots as a protective habitat for endoparasitic nematodes and the ability of those nematodes to rebuild quickly within treated soil. In conducting those same experiments we inadvertently observed a "biological vacuum" effect in more quantifiable terms.

Six months before various tree and vine crops were replanted a variety of "softer" soil drench treatments were compared. Nematodes in the field included *Pratylenchus vulnus*, *Tylenchulus semipenetrans*, and *Paratylenchus hamatus*. The latter nematode is usually an ectoparasite but in a few crops including Dr. Huey Rose this nematode occurs as an endoparasite. In fact, the bareroot roses we planted to the field were contaminated with a low population level of *P. hamatus* at planting. A drench treatment of 366 kg/ha 1,3-D resulted in no plant parasitic nematodes on six of seven hosts. Six months after planting, however, a population of *P. hamatus* was present at threefold the level present in the nontreated sites when planted to rose. By contrast, the nontreated sites had *P. hamatus, P. vulnus,* and *T. semipenetrans* across all seven crops. This threefold population increase over the nontreated also occurred after drenches of Vapam and Acrolein (see Table 1). By contrast, treatments of marigold tea plus urea resulted in *P. hamatus* populations on rose very similar to those of the nontreated, and very similar to those on the other crops planted. In this experiment the marigold and urea treatment provided tree and vine growth at slightly less than those treated with Acrolein, 1,3-D or Vapam. For tree and vine crops the existence of a biological vacuum carries two significant impacts. First, we should be learning how to add back or stimulate beneficial organisms after soil treatment. Secondly, treatments that might miss specific life stages of soil pests need to be evaluated for at least two growing years after treatment. The MS and Acrolein treatments, for example, can be expected to result in very high populations of *P. vulnus* in the second year.

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Table 1. Plant biomass and nematode populations one full year after planting *P. hamatus* contaminated roses into infested soil that had received three conventional biocides compared to a "softer" treatment of marigold tea plus urea.

	Plant Growth	Nematodes/250 cm^3 soil	
Soil Treatment	(g/plant)	*P. hamatus*	*P. vulnus*
1,3-D	1185 ns	742 a	0 a
MS	1108	802 a	227 a
Acrolein	1068	743 a	81 a
Marigold Tea Plus Urea	779	243 b	295 a
Nontreated Control	969	204 b	1292 b

Variance of the means was analyzed and subjected to a T test. Means in each column followed by a different letter are significantly different from each other ($\underline{P} < 0.05$).

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MITIGATING THE VOLATILIZATION ASSOCIATED WITH TELONE

by
Michael V. McKenry and Tom Buzo

In 1972 this author reported the volatilized amount following a 280 kg/ha shankless, 30 cm deep injection of 1,3-Dichloropropene (1,3-D) in a drying soil to be 2% of the applied. Using shanks the volatilized amount could reach as much as 20% depending on the attention given to filling and compacting of soil behind the delivery shanks (1). Eighty-five percent of the volatilization occurred between day 1 and day 5 with the peak amount on day 3. Excessive volatilization and the subsequent 1990 suspension of 1,3-D use in California prompted the development of new shank delivery designs, maximum treatment rates of 135 kg/ha, and higher soil moisture content at the time of treatment (2). As a consequence, 1,3-D is now permitted for selective use in California. Unfortunately, in old vineyard and orchard sites treatment rates of 400 kg/ha applied to a dried soil are required to kill remnant roots down to 1.5 m depth and provide control of endoparasitic nematodes to 99.5% of the nontreated as much as two years after treatment (3).

There are at least three approaches that may be used to mitigate 1,3-D volatilization at these higher treatment rates. Sealing the field surface with a poly film tarpaulin doubles the treatment cost but also presents special exposure problems during tarpaulin removal. A second approach involves delivery of 1,3-D at 75 cm depth instead of the usual 30-45 cm depth. With shank traces properly filled and compacted there would be less of the 1,3-D and it would not reach the field surface for 48 hr (1). The use of moveable sprinklers utilized intermittently to produce a surface seal between 36 and 120 hr after treatment should be evaluated.

A third approach, and the one we have studied most, involves drenching of the field with 15 cm-ha water containing 366 kg/ha emulsified 1,3-D uniformly injected into it (3). Two years after making such a treatment it is now apparent that each of seven selected tree and vine crops planted 6 mo after treatment has grown comparable to that achieved following shanked methyl bromide or 1,3-D. Control of root lesion nematode, *Pratylenchus vulnus* and citrus nematode, *Tylenchulus semipenetrans*, one year after treatment was 99.5% of the nontreated.

In two separate drench sites we also monitored 1,3-D volatilization. Both sites involved a dripper emitter located at each 30 cm interval across the field, but in one site they laid on the field surface and in the other they were buried 30 cm deep. Unfortunately, the water infiltration rate for this soil was closer to 15 cm in 10 hr rather than the preferred 15 cm in 8 hr or less. Puddling occurred in the buried-emitter site as well as the on-surface site. Two weeks of continuous air monitoring from a point 15 cm above the field surface revealed that two-thirds of the volatilization from the surface drip occurred in the 12 hr period during application. Volatilization from the buried drip was half of that from the surface drip with peak volatilization occurring in the 12 hr period just after application. These data suggest that by drenching 1,3-D one can reduce volatilization as it becomes locked into the soil profile with water. A reusable poly film tarpaulin may need to become a component of the drenching device when broadcast treatments are made in soils with slower water infiltration.

A fourth approach with 1,3-D is now apparent. Emulsified 1,3-D delivered via existing low-volume irrigation systems can provide kill of tree and vine roots before removal of the planting. Minimal 1,3-D volatilization would occur because 1) less 1,3-D would be used per hectare and 2) puddling of water in that area can be kept to a minimum. Strip treatments such as this would only be applicable where resistance to soil pests is also available.

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IT IS A LONG ROAD FROM THE FINDING OF A NEW ROOTSTOCK TO THE REPLACEMENT OF A SOIL FUMIGANT

by
M. V. McKenry and J. O. Kretsch

Culminating eight years of small plot evaluations we recently reported the finding of three grape rootstocks with "broad nematode resistance." Our first four years were spent identifying the nematode susceptibilities of existing rootstocks (see Table 1). Meanwhile, Dave Ramming of the USDA Plant Breeding Station in Fresno, CA was in possession of more than 500 mature vines that had been collected over decades and occasionally submitted to various screenings. Knowing our specific needs, we set out to find sources of resistance to three very aggressive Meloidogyne populations. Our definition for resistance is a lack or near lack of reproduction by the nematode on the cultivar over a two-year period. Thirteen of the USDA cultivars met our objective so we looked further to identify, one species at a time, the breadth of their resistance to each of the other common nematode species on grape in California.

The notion that these three rootstocks or any others will replace methyl bromide is premature. First, methyl bromide solves the replant problem by killing nematodes and most everything else in soil. Although these rootstocks do not permit nematode reproduction they may not stop nematode feeding. Since remnant grape roots can survive in soil as much as a decade after vine removal, there can be an abundant supply of nematodes and viruses in the proximity of newly planted grape roots.

To answer the question of how well these potential rootstocks replace soil fumigation, at least three additional screenings are needed. First, using four or five different replant soils, how well do the rootstocks grow compared to nonreplant or fumigated soil? This test is now underway. Second, do these rootstocks tolerate nematode feeding? Tolerant rootstocks are the ones that grow as well in the presence of nematode feeding as in their absence. Freedom and Ramsey grape rootstocks, for example, actually grow significantly better (35%+) in the presence of limited nematode feeding. By contrast, cultivars of *V. vinifera* commonly grow significantly less (12-50%) in their first year of exposure to nematode feeding. The third screening should be across a variety of common soil pests including Phylloxera *Daktalosphaeria vitifoliae*, Phytophthora spp. and *Armillaria mellea* as well as their performance in droughty soils, calcareous soils, shallow soils, etc. It has been our experience that field-level rootstock trials can go on in abundance for decades and provide only partial answers to specific soil and pest questions. We need to be more efficient at learning the limitations of rootstocks.

If there is inadequate resistance or tolerance by the rootstock to the replant problem, growers will continue to need either strip or spot treatments of soil fumigant before planting. Or, with broad nematode resistance planted to primarily nematode problem sites we may be able to use "softer" pre-plant treatments. For example, growers with an existing dripper system may be able to apply products at biocidal rates to mitigate some of the replant problem and then rely on broad nematode resistance for the lifetime of the vineyard. One point to be remembered is that resistance to nematodes is a helpful tool once the vineyard is established but there are no examples of it being useful in solving replant problems where vineyards or orchards are removed one year and replanted the next. The second point is that there are no universally acceptable rootstocks, whereas soil fumigants have a history of very broad acceptance among a range of high-value crops.

Table 1. Susceptibility or resistance of various grape cultivars to various nematode populations.

	Populations of *Meloidogyne* spp.									*Xiphinema* spp.				
Rootstock	Mi	Mj	Mm	Ma pt H	Ma pt F	Mc-L	Mc-D	Pv [1]	Ts [2]	Xi	Xa	Xc-1	Xc-2	Cx [3]
Ramsey	R	R	R	HS	HS	S	R	R	S	9	71	-	-	100
Freedom	R	R	R	HS	HS	R	S	SS	S	2	10	S	-	50
Dogridge	R	R	R	HS	HS	-	-	S	S	24	15	-	-	123
1613C	R	R	MR	HS	HS	S	S	SS	S	7	72	-	-	164
Harmony	MR	R	R	HS	HS	S	S	SS	S	24	52	-	-	35
Teleki 5C	SS	MR	S	HS	HS	-	-	S	S	9	72	-	-	65
Oppenheim-4	SS	MR	S	S	-	-	-	S	S	6	43	-	-	65
Schwarz.	S	MR	S	HS	HS	-	-	SS	S	5	13	-	-	42
039-16	S	S	HS	S	S	-	-	S	S	2	5	S	-	-
99R	HS	S	S	S	-	-	-	S	SS	54	28	-	-	71
3309C	HS	S	HS	HS	HS	-	-	SS	S	20	44	-	-	136
Thomp. S.	S	S	HS	HS	S	S	HS	S	S	100	100	100	-	100
Flame S.	S	S	HS	S	S	S	S	S	S	154	32	-	-	185
Rubired	S	S	S	S	-	-	R	S	SS	365	51	-	-	59
K51-32	R	SS	S	S	-	-	-	R	S	2	52	-	-	272
Grenache	-	-	-	-	-	-	-	-	-	-	-	-	-	251
USDA Selections														
6-19B	R	R	R	SS	-	R	MR	R	R	15	2	1	30	12
10-17A	R	R	R	R	-	R	R	R	R	2	-	1	16	24
10-23B	R	R	R	R	-	R	R	R	R	5	-	1	7	19
Ramsey x Schwarzmann Selections														
RS-9	R	R	R	R	R	R	R	-	-	-	-	-	-	-
RS-3	R	R	R	SS	-	-	-	-	-	-	-	-	-	-

Resistant	R = <0.2 nematodes/gr root	
Moderate resistance	MR = 0.21 to 0.6 nematodes/gr root	- = no data
Slightly susceptible	SS = 0.61 to 3.0 nematodes/gr root	
Susceptible	S - 3.1 to 180 nematodes/gr root	
Highly susceptible	HS = 180+ nematodes/gr root	

For ectoparasites population buildup is expressed as a percentage of that level built up on Thompson Seedless. Levels of 100 are normal, levels of 10 or less indicate resistance.

[1] *Pratylenchus vulnus*

[2] *Tylenchulus semipenetrans*

[3] *Criconemella xenoplax*

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METHYL BROMIDE ALTERNATIVES FOR FIELD-GROWN NURSERY STOCK

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INTRODUCTION

It is through the purchase of contaminated nursery stock that new and different soil pests, diseases, nematodes and viruses are most readily and widely distributed to farmers' lands. For California growers the nurseries have provided nematode-free field-grown nursery stock through the combination treatments of fallowing/soil fumigation. Today, California farmlands remain free of reniform nematode and burrowing nematode. The same cannot be said for growers in Florida, Texas or northern Mexico. Of the 300,000 ha of California stone fruits and almonds, some of which have now been replanted three or four times, only 33% are infested with *Pratylenchus vulnus*, the root lesion nematode. As new biotypes of root knot nematodes have broken the resistance mechanisms in Harmony and Freedom grape rootstocks that problem is clearly an in-field occurrence rather than a problem being transported along with nursery stock. The same can be said about biotypes of phylloxera on A x R_1 (syn. *Vitis* Ganzin Number One) rootstock. Additionally, the fallowing/soil fumigation treatment has by its existence reduced the spread of soil pathogens other than nematodes.

The soil fumigants that formed the backbone of the nursery treatment have been methyl bromide and Telone, and alternatives to these two are currently the subject of much investigation. This paper provides an overview of our effort to evaluate potential alternatives and lists the four most practical alternatives which are now ready for fine tuning under field conditions. One should be careful to note that there are soil pests other than nematodes which influence the eventual worth of nursery stock.

FIVE POTENTIAL ALTERNATIVES

The first potential alternative to the current treatment of fallowing/soil fumigation would be to double or triple the length of the fallowing period, thus increasing the land needed by the nurseryman. Certain advocates suggest that a rotation might help to shorten the fallowing period. For example, if one nursery crop has resistance to root lesion while another has resistance to root knot nematode one could still take advantage of the resistance they do have by rotating their planting through the nursery lands. Of course, nursery crops are grown for their demand by farmers, not for their utility as a rotation crop, but a bigger shortcoming is that no nursery crops are resistant to all nematodes and there are more than a dozen nematode species that can occur in California crops. Additionally, acceptance by nurseries of a lengthy clean fallow treatment, which can generate dust, may become a problem as the California PM_{10} requirements evolve. Also, tree and vine roots remaining in soil can survive at least a year after undercutting for harvest and the nematodes without available food should be expected to persist a year and a half beyond as an egg stage. This lengthy fallow approach will have potential until the land once becomes contaminated with endoparasitic nematodes. We recently learned that peach and plum roots that had been dead for 2 full years remain a protective refuge for root lesion eggs within.

A second potential alternative involves the increased use of container-grown plants using steam-treated soils or soil mixes that are nematode-free. This approach has been taken in other areas of the world as well as in California. Factors to consider include the farmer's expectations for a large root system, the need for recycling of potting containers and many additional benefits or constraints associated with container-grown stock.

A third potential alternative involves the use of biocides or nematicides other than methyl bromide (MB). On the top of the list is a shanked Telone application. After 6 years without Telone the current California requirement is that no more than 65 ha/9400 ha of land can receive a Telone treatment each year. Given the size of California nurseries they would need to have a priority for the use of Telone within their township. For a better perspective, California's irrigated farmland is only about 350 townships in size. This California EPA requirement is based on the need for public protection from a Type B carcinogen as it is volatilized above the surface of a treated field.

It is clear that any new technologies which reduce Telone volatilization would be helpful for increasing the total hectares treated with Telone each year. In this regard, we now have data to show that Telone applied as a drench within 15 cm water is just as efficacious against nematodes as the same amount of Telone shank applied (McKenry, 1995). Telone drenches will probably never be applied by sprinkler or as a basin application. A portable drenching device like the one we have built would be necessary but it would also need to be covered by a plastic tarpaulin capable of moving across the field with the dripper lines (McKenry et al., 1994). Water is a very useful tool for reducing biocide volatilization once the biocide is beneath the soil surface.

A fourth potential alternative involves methyl-isothiocyanate (MITC)-liberating compounds such as Vapam or Soil Prep and others. For nursery settings requiring 1 and 2 years of nematode protection (tree or vine crops) MITC-liberating compounds can become an alternative, but we have identified serious shortcomings to the use of the product. First, MS delivery can be effective when uniformly mixed into a solution of 10 to 15 cm of water, but it will not be effective when applied via shank where 99.9% nematode control is a requirement. The reason is that MS is a poor fumigant even when delivery nozzles along each shank are spaced only 12 cm apart. A second problem is that there are many soils which cannot be effectively drenched. Soils having good internal drainage and usually classified as a sand, loamy sand, or coarse sandy loam are suitable for drenching if the 15 cm of water can be delivered with no puddles remaining after 8 h. A third shortcoming of MS is that MS delivered at 500 ppm (200 gal per acre in 15 cm water) can reduce growth of trees or vines planted within 6 months after a treatment. This problem disappears after a full year of clean fallowing. A fourth problem is that MS is a poor penetrant. Roots that are pencil-sized and larger, tubers, corms, or even the nutlets of nutgrass need to be penetrated. A dosage of 250 ppm is adequate only if these plant tissues are all located within the surface 60 cm of soil. There must be no surviving pest-infected roots in the top 120 cm of soil to be planted to tree or vine nurseries. A fifth shortcoming with MS is the need for a well-mixed addition of the MS into the water so that in theory, every drop of water has some MS within. On a positive note, MS deliveries by sprinkler or basin can be effective if they meet the requirement of infiltration of 15 cm water within 8 h.

A fifth potential alternative to the fallowing/soil fumigation treatment involves the use of reduced rates of fumigants applied deeply followed within days by 4 to 5 cm of 250 ppm MS solution. For example, 224 kg ha^{-1} MB applied at 60 cm soil depth followed by a ring roller and then 24 h after treatment apply 1.2 cm of 250 ppm MS each day for the next 4 days. This would mean the addition of approximately 120 kg ha^{-1} of MS as a sprinkler application. If 325 to 400 kg ha^{-1} Telone is the shanked biocide at 45 cm soil depth; follow at 48 h, 72 h, 96 h and 120 h with 1.2 cm of 250 ppm MS solution. Treatments such as these will greatly reduce volatilization by plugging air pore spaces while delivering biocide to the surface 30 cm of soil where it is needed most.

POTENTIAL ALTERNATIVES THAT HAVE SERIOUS LIMITATIONS

Other suggested alternatives specifically including hot water, steam, solarization or antagonistic rotation crops have serious limitations where endoparasitic nematodes are the pests of concern. Biocides incapable of penetrating roots such as Enzone, Clorox, urea, and plant extracts also have major limitations where endoparasitic nematodes are present.

FOUR ALTERNATIVES HAVING THE GREATEST CHANCE FOR FIELD SUCCESS

Based on the previously listed information, there are four alternatives worthy of field evaluation. Two are for situations where endoparasitic nematodes along with other soil pests (except oak root fungus, *Armillaria mellea*) are known to be present:

Alternative #1. Shank 390 kg ha^{-1} Telone at a 45 cm depth. Connect manifold lines to existing sprinkler pipe and then 48 hours after treatment deliver 3 to 5 cm water containing 250 ppm MS over a protracted period of up to 4 days.

Alternative #2. Drench 500 ppm MS (200 gal per acre) in 15 cm water. Drenching may be by sprinkler or portable soil drenching device (McKenry, 1994) but the soil must take all the 15 cm water in 8 h or less. Then, clean fallow for one full year before planting.

For situations with ectoparasitic nematodes as the only pests present or where remnant roots are fully decayed, two additional alternatives are worthy of field testing:

Alternative #3. Drench 250 ppm MS by some type of portable drenching device in 10 to 15 cm water that infiltrates in 5 to 8 h, respectively. Water may also be delivered by sprinkler if the application is uniform. A basin irrigation may have value in soils that infiltrate the water in 3 h or less.

Alternative #4. Drench 1,000 ppm Enzone in 10 to 15 cm water. Water may be delivered by various means that provide uniformity of treatment.

This is not a final report but actually the first of a 3-year study now underway as we evaluate these four alternatives and many others.

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Nutritional Deficiencies as a Component of the Peach Replant Problem

by
Michael V. McKenry and Tom Buzo

A benefit associated with soil fumigation is the increased growth response (IGR) it provides to the planting that follows. IGRs are demonstrated by their occurrence in the absence of known soil problems and they appear to be a result of improved nitrogen availability or status. In this work we set out to identify alternative methods for providing an IGR, but instead we learned that subtle nutritional deficiencies are a common occurrence when peaches or walnuts are replanted.

In a peach replant site infested with *Pratylenchus vulnus* three preplant soil treatments were imposed in the fall with replanting the next spring. Treatments included: 1) A solution of Vapam® at 500 ppm (mg/l) MS delivered in an 8 hr irrigation using a drip line with 2 l/hr emitters spaced 0.6 m apart; 2) Methyl bromide (MB) applied by injecting 1.12 kg/ha at 0.6 m depth every 3.3 m in distance; and 3) Nontreated check. There were four replicates of each treatment randomly placed down the old tree rows with 30 trees/row spaced 1.3 m apart. Tree rows were 6.6 m apart. Six sub-treatments having the possibility to promote an IGR were then randomly applied to each of five adjacent trees down each row. Enzone® was applied to planting sites 45 days before planting by digging a 0.5 m by 0.6 m deep hole caving in the side walls and then drenching 40 l water containing 1000 ppm CS_2. Other sub-treatments were made on the day of planting and they included: New Era Compost® mixed into planting hole at 0.18 kg/site; 0.36 kg/site steer manure sprayed with 92 ml/site Hinder®; an ammonium soap; Hinder® sprayed alone; complete fertilizer consisting of NPK + Super Micro®, and a nontreated comparison. The fertilizer treatment consisted of solubilizing 100 g 15-15-15 fertilizer into 8 l water adding 8.3 ml Super Micro® to it and drenching it to the selected tree sites. Once planted the dripper tube was also used to deliver monthly fertilizations of 11 kg/ha nitrogen in the form of calcium nitrate to all plants.

Within four weeks of treatment the Enzone® treated trees appeared to be negatively impacted. At six weeks the treatment of NPK + Super Micro® yielded the best appearing trees. At 12 weeks after planting the MB treated trees were visibly better than the more chlorotic and stunted Vapam or nontreated check comparisons. The compost treatment did not appear beneficial until 20 to 25 weeks after planting. In the fall all trees were cut to ground level and weighed. Soil samples were collected, and *P. vulnus* extracted by sieve-misting and then counted.

Results are depicted in Table 1. The strip treatments of MB or MS gave one year of nematode protection. The NPK + Super Micro® treatment was highly beneficial to plant growth regardless of preplant treatment. In this experiment even the nonfumigated trees benefited from NPK + Super Micro®. In other experiments the fertilizer treatment appears to be of benefit even when trees are planted into nonreplant sites and it is as beneficial to walnut trees as to peach but applications need to be made before mid summer of the first year. The cost of NPK + Super

Micro® is 6¢/tree and it corrects a nutritional need experienced by young trees. Its benefit may not be a result of the replant problem. It is not the IGR response we were searching for and it is not nematicidal. However, the benefit it provides is even greater than that from the IGR and any experimentation with MB alternatives for tree and vine crops should include the use of complete fertilizers. Conventional wisdom of fertilizing first-year trees with only a nitrogen source appears to be in error.

This work partially supported by Cling Peach Board, California Almond Board, California Tree Fruit Agreement, and California Table Grape Commission.

Table 1. First-year growth of peach replants and buildup of *P. vulnus* following three preplant treatments and six planting site treatments.

TREATMENT					
Preplant	At Planting Site	Growth in kg/tree		*Pratylenchus vulnus* / 250 cm^3 Soil Sample	
MB	NPK + Super Micro®	2.24	a	0.25	c
MS	NPK + Super Micro®	1.82	a b	23.	c
MB	Compost	1.75	a b c	66.	b c
Nontreated	NPK + Super Micro®	1.64	b c d	316.	c
MB	Hinder®	1.54	b c d e	0.5	c
MB	Enzone®	1.42	b c d e f	0	c
MB	Nontreated	1.25	c d e f	0	c
MB	Manure + Hinder®	1.24	c d e f	0.25	c
MS	Compost	1.20	c d e f	2.	c
Nontreated	Compost	1.17	d e f	688.	a
Nontreated	Hinder®	1.13	d e f	335.	a b c
MS	Hinder®	1.05	e f	1.	c
Nontreated	Nontreated	1.03	e f	450.	a b c
MS	Enzone®	1.02	e f	0.4	c
MS	Nontreated	0.99	e f	18.	c
MS	Manure + Hinder®	0.98	e f	432.	a b c
Nontreated	Manure + Hinder®	0.95	f	552.	a b
Nontreated	Enzone®	0.93	f	88.	b c

Note: Values followed by a different letter are significantly different at P = 0.05

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FIELD COMPARISON OF 20 POTENTIAL METHYL BROMIDE ALTERNATIVES FOR TREE AND VINE NURSERIES

Michael V. McKenry*, Tom Buzo, Stephanie Kaku, and David Dougherty

Fifteen preplant soil treatments of four replicates each were installed into a four-acre field site at Kearney Agricultural Center, Parlier, CA. The site contained nematodes but no replant problem and no remnant woody roots except for those remaining from a one-year nursery crop that had been removed one full year before. This site is typical of a California nursery setting except that *Pratylenchus vulnus*, *Tylenchulus semipenetrans*, and *Paratylenchus hamatus* nematodes were present and they can occur as deep as 2 m.

Ninety days after the preplant treatments each of the plots was sampled for nematodes at 30 cm increments down to 150 cm depth. In March 1997 13 Marianna–2624 Plum and 13 Nemaguard Peach rootings were planted to each plot of 30 m by 3.3 m. At planting time an additional five postplant treatments were installed within the randomized block design in an effort to quantify the value of a preplant treatment compared to monthly dripper-applied treatments made post plant.

Trees will be grown for two full years and sampled for nematodes at six-month intervals. After one year eight of the preplant treatments and one of the postplant treatments were generally effective at nematode reductions of 99% or better with effectiveness down to 150 cm depth.

Three treatments were responsible for visible tree damage. Peach and plum planted 120 days after 360 kg/ha (320 lb/acre) methyl iodide exhibited leaf scorching and necrosis at the margins about 30 days after planting. Leaf scorching was still apparent on the plums 240 days after treatment, however the trees are also nematode free. Trees treated at 30-day intervals with 10 ppm of an MITC-liberating product exhibited reduced growth, and some severe chlorosis of peaches after three such treatments, while not providing adequate nematode control. A single postplant treatment of 700 ppm sodium tetrathio carbonate (Enzone) 30 days after planting resulted in death or extensive necrosis to seven of 104 trees treated. This treatment at 500 ppm will be resumed in September because of the nematode control it did provide.

Trees from two of the treatments have provided a visual growth benefit that surpasses that of methyl bromide. The best looking treatment is 360 kg/ha 1,3-dichloropropene (35 gal/acre) shanked at 45 cm depth followed by a drench of 100 kg/ha (30 gal/acre) Vapam in two acre inches water. Also, trees receiving monthly postplant drenchings of Vydate 4L at 1.12 kg/ha (1 lb/acre rate) exhibit excellent growth and nematode control when soil samplings are only conducted in the treated zone.

One surprisingly good preplant treatment involved the shallow incorporation of 360 kg/ha Basamid granules followed by 15 hours of intermittent irrigation with 15 cm (6 acre inches) of water. This treatment was scheduled for 15 hours to enable better dissolving of the slow-dissolving granules.

This work will continue another 18 months as the nematode populations are allowed to develop on their favored host. It is still premature to list the winning treatments but there are definite losers which included:

1. Peroxyacetic acid at 40 gal/acre plus 40 gal/acre stabilizer drenched either as a pulse or uniformly applied into the six acre inches of water.
2. An attempt to make chloropicrin in the soil using picric acid and calcium hypochlorite.
3. A drench of 20 kg/ha phenamiphos (Nemacur) in six acre inches water.
4. A uniformly delivered preplant drench of 1142 kg/ha sodium tetrathio carbonate plus one liter/ha Tillam during the last hour of an eight hour (six acre inch) drenching.
5. A monthly postplant treatment of peroxyacetic acid plus biological inocula at commercial rates actually raised the nematode population levels.
6. A monthly postplant treatment of MS released at 10 ppm.
7. The nontreated check.

It is critical that California tree and vine nurseries be able to provide nematode-free planting material to local growers.

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NEMATODE BUILDUP AND GROWTH OF NEMAGUARD AND MARIANNA 14 MONTHS AFTER 16 PREPLANT TREATMENTS

Michael V. McKenry

		Plant Growth kg.		
		Nemaguard	Marianna 2624	Control of *P. vulnus* (as % of nontreated)
U.	325 lb Basamid, sprinkled 15 hr.	2.28	1.81	74
S.	PSDD 1,3-D + PIC in 6 in. water.	2.23	2.17	99.2
W.	1,3-D shanked + 250 ppm MS.	2.13	1.65	100
O.	Methyl iodide 325 lb shanked.	2.04	1.14	100
M.	Vapam 325 lb PSDD.	1.97	1.98	99.8
A.	MB 240 lb shanked.	1.96	1.76	92.1
D.	PSDD 1,3-D + MS.	1.78	1.79	100
H.	PSDD Enzone 300 gal/acre + Tillam + one fall postplant Enzone.	1.75	1.82	45.6
K.	PSDD urea at 300 lb N in 6 in. water.	1.70	1.93	22.1
J.	Shanked pre Acrolein.	1.62	1.66	79.5
E.	Picric acid sprinkled over CaOHCl.	1.50	1.73	36.0
P.	PSDD 1,3-D in 6 in. water.	1.49	1.73	99.9
I.	Peroxyacetic 40 gal + monthly 7 times.	1.48	1.58	0
Q.	Untreated water only.	1.29	1.58	(448) actual number
L.	Nemacur 18 lb in 6 in. water.	1.28	1.58	30
V.	Vapam-like at 10 ppm 3t, 20 ppm 2t.	0.76	1.18	77.3

MVM:ls
2/26/98

Table ___. Efficacy of various post-plant nematicides after first year of applications via drip to mixed Nemaguard/Lovell planted spring 1997.

Treatment	Nematodes/250 cc Soil			
	P. vulnus	*P. hamatus*	*P. minor*	Other
1. (Q) Untreated check.	448 c	11	7.0	0
2. (D) Telone/Vapam drench preplant standard.	0 a	0	0	0
3. (G) Vydate 7 treatments 1 lb/acre each.	12 a b	15	0	1 Ring
4. (V) Vapam 10 ppm 3 times, 20 ppm 2 times.	102 b	9	3	0
5. (C) Enzone 700 ppm spring, 500 ppm fall.	203 c	2.5	8.8	0
6. (F) DiTera 3 treatments of 20 lb/acre each.	221 c	13	23	0
7. (I) Oxycom + Inoculum 7 treatments at 2000 ppm each.	649 c	2.3	9.3	12 Citrus
	$P = 0.05$	NS	NS	

Note:

1) Phytotoxicity very apparent in treatments of Vapam and the spring treatment of Enzone (30 days after planting).

2) Soil samples collected only at 0-18 inch depth down the tree row.

3) Treatment means represent antilogs of log transformed data.

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NEMATICIDAL VALUE OF EIGHTEEN PREPLANT TREATMENTS ONE YEAR AFTER REPLANTING SUSCEPTIBLE AND RESISTANT PEACH ROOTSTOCKS

M. V. McKenry*, B. Hutmacher, T. Trout

A 15-year-old orchard on Lovell peach rootstock was removed in 1996. Root knot nematode, *Meloidogyne incognita,* was present across the sandy loam soil of this orchard but observable tree damage was only associated with a diagonal strip across 10% of the land which had a sandy subsurface. Pin nematode, *Paratylenchus hamatus,* also occurred across the orchard and provided a useful bioassay for nematicide efficacy.

Eighteen preplant treatments were installed during fall and winter 1996 within 3.3 m-wide strips down each old planting row. The MS (Vapam® was sprayed on the soil surface with a microsprayer at each planting site (140 and 280 g ai./tree). The 1,3-D was drenched onto a 2 in diameter area at each planting site with drip hose (140 g ai./tree). The 1,3-D plus chloropicrin (Telone C35EC®) was applied through four lines of subsurface drip tape down each tree row (140 g 1,3-D/tree. In spring 1997 Nemaguard and Lovell seedlings were replanted into each treated row alternating three Nemaguard and three Lovell with 24 total trees per treatment plot and four replicates of each treatment in a randomized block design.

Seventeen of 18 preplant treatments that were replanted to Nemaguard and 16 of 18 treatments replanted to Lovell provided significant (P = 0.05) reductions in nematode populations one year after replanting. Seven of the Nemaguard replanted treatments (a, b, c, d, e, f, g) and two of the Lovell replanted treatments (a, b) provided nematode control comparable to that provided by methyl bromide (97% + reduction in nematode population one year later).

Compared to the nontreated check, three Nemaguard replanted treatments (a, d, o) provided significant (P = 0.05) improvements in plant growth; whereas only one of the Lovell replanted treatments (o) exhibited significant improvement in first-year tree growth. The best treatment for plant growth was chloropicrin shanked to the 20 inch depth at 350 lb/acre rate (treatment o). This treatment and the second-best treatment (d), which also included chloropicrin, did not provide adequate nematode control. These two treatments would be useful where nematodes are absent or not problematic or the replanted rootstock provides resistance to their presence. The third-best treatment for plant growth (a) also gave the best nematode control. Properly applied, this treatment of 280 ppm 1,3-D delivered via subsurface drip lines and MS to the surface via microsprinklers or drippers has the potential to replace methyl bromide in those soils that are drenchable. Soil profile modifications in the form of backhoeing to increase drenchability did not enhance viability of the treatment. For products such as MS there may not be adequate exposure time if macropores are too abundant. These drench treatments were applied in late November during a time when 1 to 2 inches rainfall was also occurring. As a consequence, the targeted total water application of 6 inches was reduced to 4 inches but delivered at higher than our normal treatment rates (280 and 320 ppm instead of the usual 250 ppm). It is notable that treatment rates of 640 ppm MS (treatments g, h) did not provide nematode control nor enhance plant growth.

Additions of ½ yard NRPS (non replant problem soil or “virgin soil”) provided observable benefit in plant growth during the third and fourth month after planting (not shown) but this benefit was lost by midsummer. The NRPS soil was the same we had used in other experiments (1) and it has consistently proven to be of only short-term value when placed into soil previously treated with MS.

Trunk treatments of Garlon, Roundup and fosthiazate two months prior to stump removal to kill tree roots did not improve overall nematode control one year later although fosthiazate plus Roundup reduced nematodes/gram of root by 95% when sampled 60 days after the treatment (data not shown). Plant growth benefits following treatments of Roundup or Garlon do not occur unless replanting is 18 months after such root-killing treatments (2).

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Table 1. Control of pin nematode and root knot nematode one year after 18 preplant treatments.

	Preplant Treatments	**Control Expressed as a % of Nontreated**	
	Products Drenched to Ripped Soil	Nemaguard Replants	Lovell Replants
a	Rip, drench 280 ppm 1,3-D then 280 ppm MS.	99.5 %	99.9%
b	Rip, drench 320 ppm MS.	99.5	98.0
c	Rip, drench 280 ppm 1,3-D.	99.9	94.0
d	Rip, drench 320 ppm 1,3-D + chloropicrin.	99.99	89.0
e	Rip, drench 320 ppm MS, add ½ yard NRPS.	99.0	93.0
f	Roundup to trunk, rip, drench 320 ppm MS.	99.0	91.0
g	Rip, drench 640 ppm MS.	98.7	92.0
h	Rip, drench 640 ppm MS, add ½ yard NRPS.	94.0	94.0
	Products Drenched to Backhoed Planting Sites	Nemaguard Replants	Lovell Replants
bb	Backhoed, drench 320 ppm MS.	95.0%	92.0%
ee	Backhoed, drench 320 ppm MS, add ½ yard NRPS.	83.0	85.0
ff	Roundup to trunk, backhoed, drench 320 ppm MS.	97.5	87.0
jj	Fosthiazate + Roundup to trunk, backhoed, drench 320 ppm MS.	90.0	80.0
kk	Garlon to trunk, backhoed, drench 320 ppm MS.	93.0	62.0
ll	Roundup to trunk, backhoed, drench 212° F water.	89.0	63.0
mm	Roundup to trunk, backhoed, naphthalene to side walls, drench 212° F water.	83.0	36.0
	Products Shanked to Ripped Soil	Nemaguard Replants	Lovell Replants
n	Rip, shank 350 lb/acre methyl bromide, nontarped.	99.5%	97.0%
o	Rip, shank 350 lb/acre chloropicrin, nontarped.	88.0	85.0
	Nontreated Check	Nemaguard Replants	Lovell Replants
p	Rip, nontreated.	(405/250 cc soil)	(571/250 cc soil)

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PERFORMANCE OF METHYL BROMIDE, METHAM SODIUM, AND GLYPHOSATE IN ELIMINATING VIABLE PRUNUS ROOTS AND ASSOCIATED NEMATODE POPULATIONS

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INTRODUCTION AND OBJECTIVE

Viable roots left over from a previous orchard will harbor parasitic nematodes for a long period of time after tree removal. These parasitic nematodes cause considerable damage to small trees in a replant situation if left untreated. Currently, the only preplant fumigant used commercially to control these pests in a wide variety of agricultural crops is methyl bromide (MB). The objective of this experiment was to search for comparably effective compounds that kill roots culminating in an absence of a food source for plant parasitic nematodes.

METHODOLOGY

Three different compounds with various application methods were used in an attempt to eliminate viable prunus roots on 5-16 year old prunus trees at the Kearney Agricultural Center (Table 1). The trees had established infections of *Pratylenchus vulnus* (root lesion nematode), *Paratylenchus hamatus* (pin nematode), and *Criconemella xenoplax* (ring nematode).

Table 1. Listing of method and rate of various root killing treatments.

ID #	TREE ID	TREATMENT
1	L-1	Methyl isothiocyanate soil drench at 2.42 l ai/tree, 200 gpa metham sodium (MS) 2x rate
2	L-5	MS soil drench at 1.21 l ai/tree (100 gpa rate), normal rate
3	L-6	MS wick at 76.8 ml ai/tree
4	RC-VW	MS wick at 76.8 ml ai/tree
5	L-7	MS drilled to trunk at 80 ml ai/tree
6	RC-VD	MS drilled to trunk at 192 ml ai/tree
7	L-2	Methyl bromide (MB) at 686 g/tree site delivered at 1 m depth (1.5 lb/tree)
8	L-3	.41% glyphosate wick, 34.2 ml ai/tree delivered over 7 days
9	RC-RW	.41% glyphosate wick, 31.4 ml ai/tree delivered over 4 days
10	RC-RS2	.41% glyphosate spray at 31 ml ai/tree in a.m.
11	RC-RS4	.41% glyphosate spray at 31 ml ai/tree in a.m. and again in p.m.
12	L-4	.41% glyphosate spray at 31 ml ai/tree in a.m. and again in p.m.
13	L-8	Girdled control
14	RC-G	Girdled control

The treatments consisted of: 1) methyl bromide; 2) metham sodium (MS); and, 3) glyphosate, 41% by weight in Roundup. Methyl bromide was applied from a 1.5 pound, pressurized can, three feet deep at the base of the tree. The applications of metham sodium were as follows: A) absorbed into the cambium layer of the tree through a cotton wick wrapped around a 1/2-inch girdled area; B) poured into 3/4-inch holes that were drilled diagonally into the base of the tree and sealed with a cork; and C) applied at rates of 200 gpa and 100 gpa with a soil drenching device which delivered chemical through emitters spaced over every square foot in a 400 square foot area around the tree. The compound was metered in with six acre inches of water.

The applications of glyphosate were as follows: A) absorbed into the cambium layer of the tree trunk through a cotton wick wrapped around a 1/2-inch girdled area; B) sprayed once with 2 gallons of .41% glyphosate solution over the entire leaf surface of the tree; and C) sprayed twice, once in the morning and once in the afternoon, with 2 gallons of .41% glyphosate solution (a total of 4 gallons) over the leaf surface of the tree.

The treatments were monitored for twenty days, then the most promising treatments were selected to be examined more closely. Twenty to thirty days after treatment, soil samples were collected from three, six, and nine feet from the trunk at one-foot depth increments down to five feet, for a total of 45 samples per selected tree. The counts from each of the three replications at each depth were averaged to indicate the effect of each treatment on general soil microbe populations (Fig. 1).

A 10-foot long x 3-foot wide x 6-foot deep trench was dug 4-feet from a random side of each tree. The roots were exposed by washing the soil from that side of the tree into the trench. The excess water was pumped from the trench into a furrow alongside the tree row. The roots were completely exposed to a depth of five feet. The root system was then marked, cut, and bagged using a two dimensional grid. Then, root samples from each were cut lengthwise and into cross-sections, placed on the grid board, and tested for viability using a tetrazolium chloride (TTC) test. The tetrazolium test is a biochemical method in which viability is determined by the red color appearing when viable plant materials are soaked in a 2,3,5-tryphenyltetrazolium chloride solution (Plant Propagation Principles by Hartman, Kester, and Davies).

RESULTS

I. Plant Parasitic Vermiform Nematode Counts: Nematode populations were averaged together to display the average number of live nematodes found at each distance and depth on the soil grid after treatment. Nematode counts provide a bioassay to indicate the depth to which the compounds reached. The nematode populations were reduced following 100 gpa and 200 gpa metham treatments, and the MB treatment. As expected, the nematode populations in the glyphosate treatments did not differ from the non-treated control since glyphosate is not a nematicide and was not moving through soil.

Table 2. Populations of vermiform nematodes at various distances and soil depths from the tree trunk 20 to 30 days after the root killing treatments.

TREATMENT 13: GIRDLED CONTROL
Vermiform Nematodes/250cm^3 Soil Samples

	Distance		
Depth	3'	6'	9'
1'	971	181	27
2'	369	43	3
3'	143	208	15.5
4'	110	269	40
5'	164	58	58

TREATMENT 1: 2X RATE MS
Vermiform Nematodes/250cm^3 Soil Samples

	Distance		
Depth	3'	6'	9'
1'	0	0	0
2'	0	0	0
3'	0	0	0
4'	0.3	4.9	0
5'	0	2.7	3

TREATMENT 2: NORMAL RATE MS
Vermiform Nematodes/250cm^3 Soil Samples

	Distance		
Depth	3'	6'	9'
1'	0	0.3	0
2'	0.33	4.0	0
3'	0.33	6.33	0
4'	5.3	24	.5
5'	8.5	50.9	0

TREATMENT 7: METHYL BROMIDE
Vermiform Nematodes/250cm^3 Soil Samples

	Distance		
Depth	3'	6'	9'
1'	4.3	27	11.5
2'	10.7	89.5	2.5
3'	0	7.7	0.5
4'	5.3	0.7	0
5'	0.7	1.3	0.5

TREATMENT 8: GLYPHOSATE WICK
Vermiform Nematodes/250cm^3 Soil Samples

	Distance		
Depth	3'	6'	9'
1'	95.3	29.3	37
2'	158	88.9	11
3'	39.7	11.9	8
4'	42	122.7	3.5
5'	82.3	5.3	6

TREATMENT 12: GLYPHOSATE SPRAY (am & pm)
Vermiform Nematodes/250cm^3 Soil Samples

	Distance		
Depth	3'	6'	9'
1'	794.9	153.3	162.5
2'	559.6	22.33	27.5
3'	497.3	65.3	22.5
4'	55.3	34.3	45
5'	87.7	12	39

II. Root Viability Test Results: The root viability test showed that all wick treatments were ineffective for root kill, although they were highly effective at killing the tops of trees. The 2x rate MS, methyl bromide 1.5 lb, and the glyphosate spray (am and pm) were almost totally effective for root kill to depths of five feet. The 100 gpa rate MS was only effective to a depth of two feet, below that all large roots tested positive.

Table 3. Root viability as live (+) or dead (-) based on a tetrazolium color change to roots collected at various depths and distances from the soil trunk interface.

TREATMENT 13: GIRDLED CONTROL

Depth	Distance 1'	Distance 2'	Distance 3'
1'	+	+	+
2'	+	+	+
3'	+	-	+
4'	+	+	+
5'	+	-	+

TREATMENT 1: 2X RATE MS

Depth	Distance 1'	Distance 2'	Distance 3'
1'	-	-	-
2'	-	-	-
3'	-	-	-
4'	-	-	-
5'	+	-	-

TREATMENT 2: NORMAL RATE MS

Depth	Distance 1'	Distance 2'	Distance 3'
1'	-	-	-
2'	-	-	-
3'	+	+	+
4'	+	+	+
5'	+	+	+

TREATMENT 7: METHYL BROMIDE

Depth	Distance 1'	Distance 2'	Distance 3'
1'	-	-	-
2'	-	-	-
3'	-	-	-
4'	-	-	-
5'	-	-	-

TREATMENT 8: GLYPHOSATE WICK

Depth	Distance 1'	Distance 2'	Distance 3'
1'	+	+	+
2'	+	+	+
3'	+	+	+
4'	+	+	+
5'	+	+	+

TREATMENT 12: GLYPHOSATE SPRAY AM & PM

Depth	Distance 1'	Distance 2'	Distance 3'
1'	-	-	-
2'	-	-	-
3'	-	-	-
4'	-	-	-
5'	-	-	-

TREATMENT 3: MS WICK

Depth	Distance 1'	Distance 2'	Distance 3'
1'	+	+	+
2'	+	+	+
3'	+	+	+
4'	+	+	+
5'	+	+	+

DISCUSSION

It is apparent that metham sodium applied at a 200 gpa rate using the soil drenching device described above does effectively kill live roots to a depth of five feet. All roots collected from the subject looked and tested dead except for one piece of tap root located five feet deep directly below the tree. The root was located below a compacted silt layer. This suggests that metham sodium may not penetrate deep enough in soils having shallow compacted silt layers. Metham sodium 200 gpa rate was also the most effective treatment for controlling plant parasitic nematodes. The results from this screening are promising. However, as a broadcast treatment the cost could be approximately $1,000/acre. More work will be done to evaluate this treatment in a completely randomized design.[1]

Metham sodium applied at a lesser rate of 100 gpa was not effective at root kill in large roots below the depth of two feet. However, roots less than 1 centimeter in diameter were affected as deep as four feet. Nematode counts from the treated soil were low, especially in the top three feet of soil, which agrees with earlier studies (McKenry, 1987, unpublished).

Methyl bromide, the industry standard, was effective against roots in the top five feet and laterally depending upon their distance from the point source application. Nematode counts from this treatment indicated the treatment was effective considering the point injection method by which the fumigant was applied. In a commercial application the counts would be more consistent and low at various distances away from the trunk.

All of the wick treatments, metham sodium or glyphosate, were ineffective against roots. However, this method of application was effective in killing the tops of all three specimens. It was surprising that this method did not effect the roots of the trees.

The glyphosate spray treatment (am & pm) was completely effective against roots in the top five feet of soil. This was surprising and may relate to time of year of treatment or other factors. As expected the nematode population in the glyphosate treatment did not differ from the non-treated control since glyphosate is not a nematicide moving through soil. Glyphosate should be tested in combination with 1) soil applied nematicides, 2) 14 months dry fallowing or, 3) 14 months non-host rotation crops such as Sudan Grass or Barley.

CONCLUSIONS

The compounds which were comparably effective to the industry standard, methyl bromide, at root kill in this experiment are Treatment 1, metham sodium (200 gpa rate) and Treatment 12, glyphosate sprayed am and pm.

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[1] This preliminary experiment set the standard for a pair of bonified replicated and randomized experiments involving the best performing treatments from this experiment, metham sodium 200 gpa rate and glyphosate spray (am & pm).

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A Novel Approach to Provide Partial Relief from the Walnut Replant Problem

by Michael V. McKenry and Tom Buzo

Remnants of woody roots and associated rhizosphere microbes can survive a number of years after tree or vine trunks have been removed. Live roots of *Prunus* spp. may survive for two years, *Juglans* spp. for more than three years and *Vitis* spp. for more than eight years. Soil fumigations involving methyl bromide or 1,3-dichloropropene have historically provided a method for complete and quick kill of remnant roots within the surface 1.5 to 2 m depth. Kill of these roots results in rhizosphere changes that provide partial relief from the replant problem. In a recent study foliar-applied glyphosate herbicide resulted in 85 to 95% root kill to a peach orchard six months after treatment. Unfortunately, the eggs of *Pratylenchus vulnus* survived within killed roots for two years after treatment.

Two hundred trees of the two major walnut rootstocks, *J. hindsii* and *J. hindsii* x *J. regia*, were planted in 1989 in a 0.5 acre planting site near Parlier, CA. In October 1994 each of five trees of each rootstock received a 10 g ai herbicide treatment applied either to the foliage or to the cut trunk surface. Over the next year above- and below-ground assessments of tree viability were made. Foliar sprays of Envy®, Garlon® or Roundup® were compared with trunk-paint treatments with or without the addition of diesel oil. Trunk applications involved chain saw removal of the 10 to 25 cm diameter trunks followed by the forming of a concave surface on the cut trunk. Into each newly-formed trunk cup was painted 10 g ai of each herbicide with or without a smaller quantity of diesel oil. One year after treatment a backhoe was used to visually rate root viability down to 2 m depth. At that time roots were collected, rinsed free of soil and the *P. vulnus* were mist-extracted from a known root mass and counted.

Foliar applications of the herbicides were generally ineffective as indicated by new growth above ground and the abundance of live roots present one year later (see Table 1). However, there was also a significant reduction in the count of *P. vulnus* from roots of trees receiving some of the foliar herbicides.

Applications of the herbicides to cut trunks provided greater root destruction, and in many cases no regrowth aboveground the following year. The addition of diesel oil to the painting solution improved root kill. The rootstock choice did not influence root kill so the data sets in Table 1 are compiled across the two rootstocks. Root kill of 97% plus reductions in the *P. vulnus* populations by 98% resulted from a trunk treatment of Garlon 3A® plus diesel oil. Unlike our previous work with peach, the roots of *Juglans* spp. degenerate into a moistened, sloughing surface when killed by systemic herbicides. The leaking of tannins and phenolic compounds throughout the root cortex is likely important in the reduction in *P. vulnus* populations surviving there. Ninety-eight percent reductions in *P. vulnus* will not protect the new trees beyond one year so an additional soil treatment will need to be coupled into the replanting strategy.

This work partially supported by California Walnut Board.

Table 1. Root viability and *Pratylenchus vulnus* populations in walnut roots one year after various systemic herbicide treatments.

Foliar Applications	Surviving Tree Tops	Surviving Roots	Surviving *P. vulnus*/g root
Nontreated	100 %	99.5 a	258 a
3% Envy®	100	86 a b	10 b c
3% Garlon®	Trunks only	72 b	54 b c
3% Roundup®	100 %	87 a b	34 a b c
Applications to Cut Trunk	(Trunk Cup Method using 10 g ai herbicide)		
Nontreated		100 a	150 a b c
22 ml Envy®		85 a b	150 a b
27 ml Garlon®		30 c	0 c
27 ml Roundup®		95 a	9 b c
22 ml Envy® + 11 ml diesel		35 c	1.5 c
27 ml Garlon® + 13.5 ml diesel		3 d	3 c
27 ml Roundup® + 13.5 ml diesel		72 b	27 b c

Note: Values followed by a different letter are significantly different ($P = 0.05$) based on ANOVA and Duncan’s Multiple Range Test.

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FAILURE OF LATE-NOVEMBER SYSTEMIC HERBICIDE TREATMENTS TO CONTROL THE REPLANT PROBLEM

Michael V. McKenry* and Tom Buzo

From November 21 to 28, 1995 a three-acre, 15-year-old planting consisting of almond, prune or nectarine scions all grafted onto Nemaguard rootstock received a variety of systemic herbicide treatments in an attempt to kill remnant roots (1). The purpose of the experiment was to improve herbicide effectiveness through plant manipulations prior to treatment. Because there had not been a killing frost all trees had a full canopy of leaves at time of treatment. The orchard had been irrigated a week prior to the treatments. All herbicide treatments were made within minutes of the sawing of the tree trunks. The main plot consisted of three trunk removal treatments randomized across the different scions. These included: 1) a cut trunk with no scaffolds remaining; 2) a cut trunk with one scaffold remaining; 3) a cut trunk with one scaffold and a thin strip of phloem tissue removed from it using a 1/8" girdling device.

To these main plot treatments we applied by paint brush the following sub plot treatments to the cut trunk:

1) 50 ml Garlon 4E plus 25 ml diesel fuel.
2) 50 ml Garlon 4E plus 25 ml Mor Act.
3) 50 ml Roundup plus 25 ml diesel fuel.
4) 50 ml Roundup plus 25 ml Mor Act.
5) Nontreated check.

The trees were eventually pulled in late January 1996 and half the field replanted to Mission cultivar of almond/Nemaguard in April 1996 and the other half fallowed for one year and then replanted to Mission almond/Nemaguard in March 1997.

In June, August, and October 1996 the remnant roots were randomly examined to 150 cm depth. No treatment produced greater than 25% visually dead roots. Our conclusion is that November applications of systemic herbicides are too late to provide adequate translocation and eventual root kill. Trees replanted in 1997 after one full year of fallowing exhibited extensive replant problem regardless of the treatment. Aboveground portions of the trees are killed with most of these treatments, but adequate root death may not be possible with fall treatments.

Literature Cited:

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Growth Benefit Of Adding "Virgin Soil" When Replanting An Orchard

by
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Virgin soil, or a better term "non replant problem soil" (NRPS), is a soil that has not supported a perennial crop for 10 to 15 or more years and does not harbor soil pests or chemical residues that might limit the growth of subsequent perennial crops. Replant problem soil (RPS), by contrast, is the soil that can be collected from anywhere near the roots of established trees or vines and when as little as 2 or 3 pounds is added to a young tree or vine at planting the first year plant growth is markedly reduced even when no known soil pests are present.

For the field tests reported here NRPS was collected from the center of an 80-foot-wide zone located between an old orchard and an old vineyard. This NRPS zone had received occasional tillage but had not supported perennial plants for 15 years. The NRPS was collected by the use of a Vermeer Tree Spade that dug a hole 50 inches square at the surface and tapering down to a point 36 inches in depth. This ½ yard volume of soil was transported to the orchard and inserted into a tree site where the same equipment had previously dug a hole. On April 12, 1996 almond trees on nemaguard rootstock were planted into sites having complete NRPS, complete RPS, ½ yard NRPS surrounded by RPS, and ½ yard RPS surrounded by NRPS. For comparison two additional treatments included RPS but were backhoed before planting and RPS backhoed and treated with 1 lb/tree site of methyl bromide (MB).

Four weeks after replanting the NRPS soil supported almond/nemaguard trees with two times more top growth than those trees planted into replant soil (RPS). At 8 weeks after replanting the trees replanted to NRPS or ½ yard NRPS were similar in size and four times larger than those of any other treatment. By mid-July or 12 weeks after replanting those trees planted into ½ yard NRPS began to slow their growth as their roots invaded the surrounding RPS soil. Also the trees in MB treated sites were by this time half the size of the NRPS trees although they were much more rank in appearance and slightly yellower. By mid-September the trees growing in RPS or backhoed RPS were beginning to grow well so that by mid-October they appeared to have grown past the replant problem. Trees planted in complete NRPS never slowed their growth while trees planted to ½ yard NRPS had not yet resumed their growth by mid-October. The final 1996 trunk circumferences for each treatment are detailed in Table 1. This site was selected because it contained the replant problem without pathogenic nematodes present. These data show that methyl bromide does not solve the complete replant problem.

In this orchard site that did not have a nematode component, the replant problem still occurred. I refer to this major and most visible component of the replant problem as the rejection component. The new trees had overcome the rejection phenomena six warm months after they encountered it. We know that the rejection phenomena can be transported by physically transporting RPS but within soil it does not appear to be mobile. Rather, it is an entity that the roots can encounter and then adjust to. This rejection phenomena can slow even the most vigorous of root systems. This field trial will continue for two more years.

Table 1. First-year growth of almond/nemaguard replanted 4 months following removal of an almond/nemaguard orchard that did not have a nematode problem.

Treatment	Trunk Circumference (cm)
Complete NRPS (= virgin soil)	3.62 a
½ yard NRPS surrounded by RPS	3.54 a
RPS backhoed + 1 lb MB	2.98 b
RPS nontreated	2.41 c
½ yard RPS surrounded by NRPS	2.35 c
RPS backhoed only	2.27 c

Numbers followed by the same letter are not significantly different from one another (P = 0.01). RPS is replant soil.

This work partially funded by the California Almond Board, California Cling Peach Board, California Tree Fruit Agreement, and a cooperative agreement with the USDA.

Table 1. Growth of Mission Almond on Nemaguard Peach in a 4.0 acre site without nematode problems but having a replant problem present.

No.	Treatment	Fallow Period	Reps	Trunk Diam. (cm) 1st leaf	Trunk Diam. (cm) 2nd leaf	1st to 2nd year Diff.
1.	NRPS site	NA	2	3.62 a	8.34 a	4.72
2.	½ yd RPS within NRPS site	4 mo	2	2.35 c	6.54 c	4.19
3.	½ yd NRPS within RPS site	4 mo	5	3.54 a	7.48 b	3.94
4.	RPS site backhoed + 1 lb MB	4 mo	5	2.98 b	7.56 b	4.58
5.	RPS site backhoed only	4 mo	5	2.27 c	6.31 c	4.04
6.	RPS site untreated	4 mo	5	2.41 c	6.47 c	4.06
				(*P*=0.01)	(*P*=0.05)	
7.	½ yd NRPS within RPS site	15 mo	4	3.67 a	–	
8.	RPS site backhoed + 1 lb MB	15 mo	4	3.19 b	–	
9.	RPS site backhoed + MS @ 250 ppm + ½ yd NRPS	15 mo	4	3.29 b	–	
10.	RPS site untreated	15 mo	4	2.90 c	–	
				(*P*=0.01)		

Note: These Nemaguard trees were 0.95 cm diameter at planting time.

- NRPS = non replant problem soil or “virgin soil” that had not grown trees/vines for 15 years.
- RPS = replant problem soil due to removal of 15-year-old almond/Nemaguard orchard.
- Backhoed = digging to 5-6 ft depth by backhoe than caving in side walls and refilling.

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GROWTH AND YIELD BENEFIT OF REPLANTING INTO "TRANSPORTED NON REPLANT PROBLEM SOIL"

Michael McKenry*, Tom Buzo, and David Dougherty

For the purpose of this study "Virgin Soil," or a better term "Non Replant Problem Soil" (NRPS), is soil that had received occasional tillage for weed control but no irrigation and had not supported any crop for 15 or more years and did not harbor soil pests or chemical residues that might limit growth of subsequent perennial crops. "Replant Problem Soil" (RPS), by contrast is soil that can be collected from anywhere near the roots of established trees or vines. In this test the RPS site was a four acre field located directly adjacent to the NRPS site where nemaguard peach rootstock had been grown for 15 years.

Planting occurred within six months after a fall removal of nemaguard peach rootstock. Backhoeing treatments consisted of digging a hole with a tractor-mounted backhoe to 6 ft depth, caving in the four side walls and replacing the spoil pile back to the top of the planting site. All references to ½ yd soil refer to planting sites where a Vermeer tree spade had dug a hole 50 inches in circumference at the ground surface which tapered as a cone down to a point 36 inches in depth. Holes were dug and then either ½ yd NRPS or RPS was transported to each hole where either a NRPS or RPS cropping history existed. Nursery-grown, 0.95 cm.-diameter almond trees on nemaguard peach were planted to each site with six trees per replicate laid out in a randomized complete block design. Trees were fertilized and irrigated uniformly and pruned according to their vigor for the next three years.

One year after planting the trunk diameters of trees started in complete NRPS or ½ yard NRPS were statistically similar (P=0.01) in size at 3.62 and 3.54 cm, respectively. Trees planted to backhoed RPS sites that had received 1 lb. treatment methyl bromide were significantly smaller, measuring 2.98 cm. in diameter. Trees replanted into the RPS field history without backhoeing, with backhoeing, or into sites that had received ½ yard RPS surrounded by NRPS grew diameters that were 2.41 cm., 2.27cm. and 2.35 cm., respectively.

To the observer, replanted trees grew extremely well for three to four months when replanted into ½ yd. NRPS. As their roots extended into the surrounding RPS their above-ground growth visibly slowed. In their second year these trees gradually adjusted to the surrounding RPS condition and resumed their faster growth rate and greener coloration. Four of five replicates were growing well by the beginning of the third year but all trees in one of the replicates were still showing chlorotic leaves and poor growth throughout the second and third year. The poor growth associated with roots present in RPS followed by an apparent recovery from the problem leads the senior author to refer to this phenomena as the rejection component of the replant problem.

Trees replanted into methyl bromide treated sites did not grow fast for the first four months. Growth accelerated after that producing longer bud internodes and taller trees that were never quite as green as those started out in NRPS.

Growth of trees started out in RPS was always less, leaves were more chlorotic, and roots produced fewer feeder roots than those listed above until they reached into a zone of NRPS where feeder root development was stimulated.

At the end of the second year trunk diameters of trees grown completely surrounded by NRPS was 8.34 cm. This value was significantly (P=0.05) greater than the growth from trees in methyl bromide treated soil or those started out in ½ yard NRPS soil, which was similar at 7.56 cm and 7.48 cm, respectively. Trees started out in non fumigated RPS were similar in growth and significantly poorer than the groupings above. The treatment of ½ yard RPS surrounded by NRPS, RPS untreated, and RPS backhoed produced tree diameters of 6.54 cm., 6.47 cm, and 6.31 cm., respectively. During the third year almond yields were collected. These results are displayed in Table 1. These data indicate that methyl bromide treatments to backhoed sites did not completely rid the soil of the replant problem. Best plant growth and yield was obtained when trees were planted into virgin soil (NRPS).

Starting trees out in ½ yard NRPS in a manner that permits no RPS to mix into the ½ yard produces trees at least equivalent in growth to those treated with methyl bromide four times out of five. We have no explanation as to why the one complete replicate of ½ yard NRPS failed to perform equivalent to the other four, but we believe it was something in the soil rather than an error in our methods. The one poor replicate involved an edge row of the four acre trial. For these reasons we do not expect to repeat our success with ½ yard NRPS in all other locations. There appears to be a biological phenomena involving organisms other than known pathogens which is at work in RPS and the result is a six to 12 month rejection of new root development. This problem disappears as quickly as it appears.

The use of ½ yard NRPS is adequate to overcome much of RPS or at least give three to four months of exceptional root growth enabling a stronger response as roots encounter the RPS condition and then grow past it or in some manner develop a compatibility with it. Our conical shaped ½ yard of soil may not be the best design for this problem. We estimate that 1 or 2 yards NRPS would provide even better growth but there must be economy inserted into the technique. The authors are unclear about the practicality of transporting NRPS though it does have application where there are fewer than 100 plants per acre. Using the current farm gate price of $5.00 per kg of fruit the ½ yd NRPS treatment would have provided $10.00 per tree in the third year whereas the RPS untreated treatment produced $4.80 per tree. The cost of transporting ½ yd soil in this experiment was approximately $7.00 per tree site.

Regardless of the practical implications of these findings the authors are more interested in the academic question of what is RPS and NRPS and why does the replant problem frequently disappear six months after replanting but remain a problem as much as four years to confront a new replant? Note also that tree roots started out in RPS and entering into NRPS within six months did not stimulate a sudden increase in plant growth.

Table 1. Mean weight and fruit numbers per tree in the third year after planting Mission Almond/Nemaguard Peach into six preplant scenarios.

Treatment	Kg Fruit/Tree	Number Fruits/Tree
NRPS	2.09 a	172. a
½ yd NRPS into RPS	1.96 a	184. a
RPS treated with MB	1.85 a	169. a
½ yd RPS into NRPS	0.58 b	50. b
RPS backhoed only	0.66 b	62. b
RPS untreated	0.84 b	79. b
	(*P*=0.01)	(*P*=0.05)

Means followed by a different letter are significantly different based on an analysis of variance and separation of differences by a Duncan's Multiple Range Test.

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TECHNOLOGY TRANSFER AMONG TREE AND VINE CROPS

Michael McKenry

I recall the first time I saw a tractor injecting methyl bromide (MB) and then laying a polyethylene film onto the field surface. It was in the mid 1960s. Plant debris and soil clods were poking and rubbing holes right through the tarp. The treatment costs seemed enormous. It was easy for me to surmise that this was a technology going nowhere. With advances in glue technology and additional years of field testing, treatments shifted from individual rows to solid fields of plastic film. It was the 1980s before this technology was effectively transferred from California to Florida, Texas, and eventually Mexico. Many areas in the world still don't have this technology. Technology transfer to agriculture is a slow and dynamic process and usually involves people from varied sectors. MB use has reached the level it is today because it provides consistent and observable plant growth benefit. More recently the 1984 banning of ethylene dibromide and the 1990 suspension of 1,3-dichloropropene (1,3-D) further fueled its rise in popularity.

There exists in California two million acres of tree and vine crops. Compared to annual crops the long-term benefit of a pre-plant fumigation to perennial crops and the existence of the replant problem add a unique dimension. A further complication for the tree and vine grouping is the fact that the needs and treatment methods of citrus growers, for example, will be different from those of walnut or grape growers. The broad spectrum value of soil fumigation has bridged across these unique differences making specific crop distinctions almost invisible until one tries to replace fumigants.

There are at least forty UC cooperative extension personnel located across California who have a specific focus on the transfer of new technologies to one or more specific perennial crops. Whether the soil-borne malady is nutrient depletion, phytophthora, ring nematode, or phylloxera the solution to pest and disease problems has been pre-plant fumigation with either 1,3-dichloropropene (1,3-D) or methyl bromide (MB). These advisors generally view the benefits of MB as important but the crop is their main responsibility with or without MB. The pending loss of MB and the current use restrictions on 1,3-D will expose a huge gap in our agricultural technology relative to soil and rhizosphere ecosystems. This information gap will affect growers economically but will also fall square in the lap of these UC farm advisors. These people will be among the first to diagnose and characterize the evolving problems and they are already besieged by the wild claims of numerous alternative treatments. It is time for these advisors to be sitting at the discussion tables and becoming involved with problem identification and solutions for their specific crop and locale. The reality is, however, that these people don't have the funds to even attend a meeting such as this nor the funds to put on a field trial. Unless the alternative to MB is available in a well-labeled bottle, has wheels attached and carries a guarantee of 95% effectiveness; the need for tree and vine farm advisor involvement is now. Since 1993 this author has made a special effort to keep growers and their associated cadre of farm advisors fully advised of research progress relative to a replacement for pre-plant fumigation. Their most frequent question has been: What alternatives are there besides 1,3-D and by the way, can we be sure that 1,3-D will work properly under the current use restrictions?

The prevailing restriction of 35 gallons/acre 1,3-D is adequate only if the soil is adequately dry. The requirement of high surface moisture at time of treatment will negate 1,3-D as an alternative except for the sandier soils. Township caps, and moisture requirements must be recognized as impediments to effectiveness of 1,3-D in California. This is an example where technology needs to be transferred to regulators, manufacturers and applicators. In 1996 this author proposed that the best alternative for tree and vine growers involved a deep shanking of 1,3-D to dry soil followed in 1 to 2 days with a drenching or sprinkling of 250 ppm MS as a means of reducing 1,3-D volatilization. Such a procedure was recently registered in Washington State. If sprinkling equipment of correct orifice size were more prevalent among California tree and vine growers and if the manufacturers and regulators could develop solutions relative to re-entry times, etc., this technology could quickly be transferred using commercial-sized demonstration plots.

In 1985 we built a prototype “portable soil drenching device” capable of delivering lethal doses of Vapam with uniformity and consistency. We were soon able to demonstrate consistent nematode control and plant growth as long as no old roots were present deep in the soil profile. UC was notified of this development in 1991 and the work was published in 1994. This procedure has its limitations and advantages. A few growers have now learned how to follow our procedures by manually moving drip lines or existing sprinklers. Large scale development of this process is protected by two patents largely because so many detractors said it would never work. This technology is slowly being transferred but only because smaller growers are becoming familiar with use of dripper lines.

A door of opportunity swung open when we demonstrated in 1995 that killing of the old root system plus fallowing a full year could give relief from a major component of the replant problem. This finding plus our finding of several implicit limitations of the method must now receive commercial evaluation. We also need research into additional specific methodologies that will kill roots across a variety of rootstocks and field situations. With grapes we have found only a single method for root kill and that involves delivery of MS and/or 1,3-D via an existing or temporary dripper line. Since the MS treatment does not control endoparasitic nematodes within roots below 75 cm depth this treatment must be coupled with the use of rootstocks having broad nematode resistance. Even these rootstocks are a new finding (1993) and will need 20 years of field evaluation. Two commercial field trials are currently underway exploring this possibility and both are supervised by farm advisors. A third farm advisor is currently involved with Roundup herbicide applications to cut tree stumps in two different commercial settings. With peach we have no rootstocks with resistance to ring nematode or root lesion nematode so there are limitations to our technology but not to transfer of technology we do have. For walnuts we have a treatment ready for field evaluation but no trials and thus no technology transfer. Except for the use of MS, we have not even studied methods of killing roots of kiwifruit, figs, olives, apple, pecan, citrus, pistachio, persimmon, cherry, plum, prune, bush berries or avocado so we have little information to transfer to these very important crops.

As reported elsewhere at this meeting , it is possible to start trees out in NRPS or "virgin soil" and 80% of the time come very close to the performance of MB as long as there is resistance to the pests present or pests are absent. Although there are obvious limitations some of this information is ready for transfer to smaller growers. Funding for the first commercial evaluation has been sought and a farm advisor is involved in that project. This test site will involve the presence of ring nematode and a serious Bacterial Canker problem and will require five years of evaluation.

The approach we have taken with alternatives for trees and vines has involved extensive small and large plot testing of more than 125 potential replacements to MB. Our list has included hot water, steam, compost, manures, cover cropping, fallowing, ozone, hydrogen peroxide, carbon bisulfide, acrolein, enzone, Clorox, urea, methyl iodide, walnut hulls, backhoeing, rootstocks, fertilizers, flooding, grafting, solarization, several biocontrol agents, use of post-plant nematicides and many additional treatments that have been touted as having potential. Our list of treatments worthy of transfer is much smaller now. Take a minute to contrast work I have presented here with the work presented in the USEPA's 30 case studies of MB alternatives. Our direction of study is clearly biased towards eventual technology delivery, but based on results of replicated field evaluations with a check and a MB comparison. The USEPA chose to hire unbiased but unknowing individuals to collect information towards their specific agenda. Solarization is one of the better USEPA suggestions but has never been tried adjacent to MB in any setting that involved perennial crops. However, it has been evaluated in a two year study involving peaches and in that case root knot nematodes preferred the plastic mulching ten to one. Grafting with resistant rootstocks, another worthy MB alternative cited by USEPA, already occurs on at least 1.5 million acres of California orchard and vineyard land and these are the same growers who need MB or its alternative. The final resting place for this divisive, USEPA information was the internet. Meanwhile, there exists among the vineyards and orchards of California a mechanism for problem identification and technology transfer if funding is available and potential technologies have received primary evaluations.

The Vineyard

by Kayla McKenry
April 26, 1999

Buzzzzzzz the noisy bee swishes
through the vines. The sunny day was shining
its way through the grapes. The farmers
look up from the vines to see the visiting
guests. Guests come here only to see,
believe, and taste the wine. They look at the
vineyard not believing how the vines spread.
The vines spread for miles and miles
from hill to hill covered in grapes.
The birds fly from tree to tree or though
it seems. Children play hide and seek
through the vines. No one knows why
the vineyards are such mysteries. They seem
to hide the smallest detailed thing,
such as how they grow so magnificent
damp, smooth grapes. It seems as though
the fruity vines are all but as small as a bee
but as large as the sky.