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CALIFORNIA ALMOND BOARD FINAL REPORT

Project Title: Methyl Bromide Alternatives and Improvements

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Executive Summary: This report culminates a 5-year multi-commodity study to find the best field-testable methods for using methyl bromide with reduced volatilization and/or identifying alternatives to its use as a pre-plant soil treatment. Roots of trees on Nemaguard rootstock can be 95% killed through application of Roundup systemic herbicide plus diesel oil or MorAct adjuvant applied to the cut cambium soon after a post-harvest irrigation but prior to mid-October. Such a treatment plus waiting 18 months before replanting Nemaguard can eliminate a major portion of the replant problem. This treatment will not give adequate control of root lesion nematode nor several other serious soil pests/diseases that can be present as part of the replant problem. Applied to Lovell rootstock the root kill is less effective but root knot nematode within the Lovell was reduced in population by 95% when sampled 60 days after treatment. Commercial-scale evaluation of this method to relieve a portion of the replant problem is being initiated.

Root kill in the surface 4 to 6 ft of soil is common following 350 lb/acre methyl bromide. Root kill in the surface 4 to 5 ft of soil is common following 350 lb/acre Telone when applied to dried soil. A drench of Vapam at 325 lb MITC in 6 acre inches water (100 gal/acre) can kill roots to 2½ to 3 ft depth. Doubling the Vapam rate provides kill to 4 ft depth but plants do not grow well after such doses unless there is a one year waiting after the drenching. Non-tarped methyl iodide at 325 lb/acre performs as well as methyl bromide but with *Prunus* spp.(Nemaguard and especially Marianna 2624) we have observed phytotoxicity so a range of Prunus rootstocks would have to be screened after various treatment rates to determine its feasibility. Enzone at 300 gal/acre drenched in 6 acre inches water will not kill remnant roots. Clorox solutions, urea, extracts of marigolds or safflower or walnut hulls drenched in 6 acre inches water will not kill old roots nor the nematodes within. Eighteen months of cover cropping involving Sudan grass, vetch or barley will not kill old roots or the nematodes within although they can reduce nematode populations within soil. Forty days of flooding during winter time will not kill old roots.

The delivery of Vapam via an existing drip line at 250 ppm MITC in enough water to uniformly spread product 4 ft deep and 4 ft wide will kill old roots within that zone but provide no more than one year of nematode protection. This treatment in combination with rootstocks having resistance to soil pests present or expected in the new planting is a tactic in need of field testing.

Telone shanked at 35 gal/acre followed in one to two days with a drenching of 250 ppm MITC will produce vine growth and nematode control comparable to methyl bromide while

reducing Telone volatilization. Chloropicrin is a mediocre nematicide at 350 lb/acre but promotes growth of Nemaguard and Lovell when present at 125 lb/acre or more. There needs to be field testing of Telone C-35 at 50 gal/acre.

The use of composts, manures and soil amendments can improve tree growth but do not solve the replant problem nor nematode problems.

Introduction of the Problem Being Addressed: The phase out of methyl bromide is projected for the year 2001. Loss of this product will have dramatic effects on the tree and vine industry. Much of this loss has been underestimated because EPA loss figures are only calculated for one year at a time and growers of perennials do not replant each year. We know that trees and vines that start out slow may never catch up whereas the pest pressures can. Regardless of whether there is or is not a methyl bromide in the future, there must be a reduction in volatilization of fumigants and there must be identification of "softer" alternatives. This 5-year project was begun in 1993 with support of seven different tree and vine commodity groups. It is now terminated with the exception of a text being written by this author which deals with the replant problem and its management. The goal has been to screen a wide variety of replacement strategies and then point the direction for field trials in the future. For the almond industry we are initiating commercial-scale evaluations of the best treatments listed above as well as conducting additional study on Non Replant Problem Soil or "virgin soil".

Objectives of the Project: 1) Find an alternative to methyl bromide soil fumigation. 2) Identify methods that reduce volatilization of fumigants or greatly reduce the treatment rates.

Procedures Used to Meet the Stated Objectives: This work was commonly carried out at the Kearney Agricultural Center to enable full control of the plots. In small plot settings with 5 to 15 replicates of each treatment a variety of chemical treatments, physical treatments, soil additives, composts and botanical extracts were screened for their nematicidal potential. In larger field trials the most promising treatments from the literature, the small plot work, or from previous experiments received full field evaluation. These trials consist of removal of an old vineyard or orchard, characterization of the pest and disease problems present, installation of the treatments using best known methodologies, planting of a host susceptible to the pest pressures, and evaluating pest buildup and plant growth for two full years. During these trials it was essential that equipment followed a traffic pattern; was kept to a minimum and also that flooding across treatment plots did not occur. The tree rootstocks usually involved Nemaguard, Marianna 2624 and occasionally Lovell. Some evaluations of Guardian, S-60, and Hansen's 182 were also made.. These larger field trials involved replanting with and without one year of fallowing as well as the use of virgin soils. There were always at least four replicates in randomized block design.

Methods Used to Carry Out Experiments: In order to optimally deliver any chemical treatments they were applied through a drenching device (not commercially available) that consists of one dripper emitter every foot of distance used to deliver 6 acre inches of water with the product uniformly injected within. Cover crops were fully incorporated into soil and water applied after incorporation. All treatments received complete micronutrient fertilization within 6 weeks of planting. Within 30 to 60 days after any soil treatments samples were collected from each replicate at 1 ft increments down to 5 ft depth and analyzed for nematode presence. Samples

were again collected at 6 mo., 12 mo., 18 mo. and 24 mo. after the treatments but only from the surface to 18-inch depth in the vicinity of the growing plant. Where appropriate, root samples were also collected but usually only during the final two-year sampling. Plant growth measurements were collected by cutting off tops down to six inches at the end of each year and then weighing total biomass.

Results and Conclusions: There will be a text written on the results of these field evaluations because we have developed a new hypothesis as to what the replant problem is and therefore better methods to manage it. Until then it is important that the industry and other researchers know which treatments have the greatest potential as replacements for methyl bromide, because their evaluation in diverse commercial settings is essential.

1. Telone at 35 gal/acre shanked at 18 inch depth to dried soil that has not yet received more that two inches rainfall followed in one to two days with a one to two inch sprinkling or drenching of water containing Vapam at 250 ppm MITC. This treatment does not offer as much flexibility as MB relative to soil conditions but trees and vines can outgrow those planted to MB and nematode control after two years can be as good as those following MB. (not registered)
2. Telone C35 at 50 gal/acre shanked at 18 inch depth to dried soil that has not yet received more than two inches rainfall. Nemaguard, Marianna 2624 and Lovell seedlings grow well after such treatments but some manner of reducing volatilization associated with this treatment needs implementation. The current Telone label provides that water be applied prior to treatment but such irrigations can work to the disadvantage of efficacy. (not registered)
3. Vapam at 500 ppm MITC or 200 gal/acre in 6 acre inches water uniformly delivered can provide plant growth and nematode control comparable to MB but there must be a full year of waiting or non-host cover crops between treatment and replanting. (not registered and may never be)
4. Vapam at 250 ppm MITC or 100 gal/acre in 6 inches water uniformly delivered can provide vine growth and nematode control comparable to MB but only if the pest problems are all ectoparasitic, such as ring nematode. A one year waiting period after this treatment is not necessary. (Registrations available but adequate delivery methods are generally lacking)
5. Vapam at 250 ppm MITC via one or two dripper or microsprinkler lines installed down the old or new planting row in enough water to spread product at least 4 feet deep and 4 feet wide will provide partial relief from the replant problem but soil pests will return at the end of a year. This treatment is feasible where no soil pests are identified or resistance to them is available and dependable. (Registrations available, and treatment rates approximate 15 to 30 gal/acre but do not overtreat)

6. Enzone at 300 gal/acre rate or more has potential if endoparasites or root-borne viruses are not the problem. Generally, this product does not penetrate roots well enough, trees should not be replanted within 45 days of a wintertime treatment, summertime treatments can produce increased growth responses. (Expensive treatments unless pest pressure is low, strictly for ectoparasites, and a strip treatment is involved but registrations available)
7. The field evaluations of systemic herbicides need to be continued to determine their limitations. There will have to be an 18 month wait before replanting but this treatment needs

field testing where no known soil pests/pathogens are known to exist, soil is not concucive to their development or rootstocks with durable and adequate breadth of resistance are available. (Registration of these treatments is unclear except that diesel oil is listed among the proposition 65 materials.)

Literature Cited:

McKenry, M. V. March 30, 1998. Compilation of 17 Research Reports on Methyl Bromide Alternatives. Presented to Participants of California Nematology Workshop, Kearney Agricultural Center, Parlier, CA.

Methyl Bromide Alternatives and Improvements – Year Five

Michael V. McKenry

November 7, 1997

Abstract:

As of this reporting there are six months remaining in our five-year generic study of methyl bromide alternatives and improvements. Our final report will be presented on March 30, 1998 as a written text entitled the "Replant Problem and Its Management." On that date there will also be an open tour of our existing field trials at Kearney Agricultural Center. These five years have altered our understanding of the replant problem. We have separated out at least four components of the replant problem. The most visible component I refer to as the rejection component. It is managed by killing the old tree/vine root system and waiting for 18 months. Several other components including soil pests and chemical or physical layers in the soil must also be managed, pre-plant. However, unless these components are in very high numbers or concentration they are usually not the major components that result in reduced first-year growth. These latter components are responsible for the long-lasting plant growth problems that remain after the rejection component subsides. The rejection component for peach subsides in six months to a year after replanting but is longer lasting in grape.

In 1996 and 1997 our focus has been fourfold. First, encourage and establish field trials in commercial settings. Second, learn how to fill the biological vacuum that occurs following "softer" biocides, such as Vapam. Third, learn how to work with non replant problem soil (= virgin soil) and even how to make such soils. Fourth, write a text that pulls together our understanding of the replant problem. This text will show the plant growth and nematode control data for the first one to two years following more than 120 potential MB alternatives, including chemicals, rotation crops, flooding, heating, use of rootstocks and other methods.

Methyl Bromide Alternatives and Improvements – Year Five

Michael V. McKenry

November 7, 1997

Results of Studies from 1996-97:

1. Establishment of field trials in commercial settings.

   Although most of our work has been in field settings, much of it has been at a field station. We must now financially encourage farm advisors and others to take the best, most practical methods developed here and elsewhere into grower settings. For a given test site there will need to be a nontreated check, and a methyl bromide treatment compared to 1-3 of our potential alternatives specifically tailored to the pest/disease problem present in the test site. Underway we have one site being initiated in grapes, two in peaches and none currently with almonds or walnuts. More trials are needed.

2. Filling the biological vacuum.

   Following 350 to 400 lb/acre MB or 40 to 80 gal/acre 1,3-D one achieves 99.9% reductions in pest populations. A biological vacuum is created but few nematodes remain to fill it. With a limit of 35 gal/acre 1,3-D there can be greater pest survival (99.5%) specifically on soils with moisture or those being of finer texture. If only 98% reductions in soil pest populations are achieved but a biological vacuum is also created, nematodes can overrun the planting within 1-2 years. A special weakness of Vapam is its inability to penetrate deeply into remnant roots where endoparasitic nematodes occur. We are continuing to evaluate methods of filling a biological vacuum, however this year's testing was highly revealing. Into sites drenched with Vapam we added singly or in combination seaweed, compost, and manure, and then challenged the sites by adding nematodes at various monthly intervals. In these sites ruby seedless grapes were the test plant. Our data will be coming in for another year but there is one striking result. The grapes that grew the best all involved the use of "virgin soil" at planting and addition of amendments was unimportant. A second, larger field trial involves these same amendments following methyl bromide.

3. Understanding how to make, use, or not use NRPS (= virgin soil).

   We now have partial results from a trial comparing growth of Mission Almond/Nemaguard Peach following use of MB, ½ yard NRPS, and ½ yard NRPS placed within a Vapam-treated site. This site was chosen because it manifests the rejection component of the replant problem without the presence of a nematode pest component (see Table 1). At the end of the first leaf, trees grew just as well in ½ yard NRPS as they did in a field site only containing NRPS. Both these treatments provided trunk diameter significantly larger than where MB was used. By the end of the second year the ½ yard NRPS treatments were

significantly smaller than those growing in an entire site with NRPS but identical in growth to those treated with MB. Essentially, the planting of trees in ½ yard NRPS gave trees comparable to those treated with MB but a third and fourth year of study will be necessary. Last year we asked the logical next question and came up with a surprising result. Can one treat a site or strip with 100 gpa Vapam, then place ½ yard NRPS soil at the planting site and mitigate the growth slowdown as the roots move from NRPS soil into RPS soil? The answer is yes they grow as well in the first year as those treated with MB but they did not grow as well as those with ½ yard NRPS placed directly into an RPS field fallowed 15 months. After searching for errors in our methodology and finding none, our conclusion is that the microbiology following a Vapam treatment may not be compatible with the existing microbiology within NRPS or RPS. There are obvious shortcomings to our work with NRPS. First, there isn't much available and second it is expensive to move. However, dramatic plant growth achievable following its use and our ignorance about how to make it and then use it point the direction for new research.

4. Summarizing of five years' work.

My compilation of the many results from various field trials will show that there are some MB alternatives available for some situations. We will need to better characterize the fields to be replanted. Killing of remnant roots is a must to solving the rejection component of the replant problem. There must be pre-plant, at-plant, or post-plant nematode control to accompany these treatments. There will also be sites where there is no replacement for methyl bromide. Commodities such as walnuts with 85% of their acreage having root lesion nematode pose a more serious need for MB or alternatives than do those commodities with only 1/3 or 1/2 of their acreages nematode infested. Tree and vine crops for which there are registered, reliable post-plant nematicides will bode better than those with no reliable resistance or post-plant nematicides available.

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 (P=0.01)	6.47 c (P=0.05)	4.06
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 + MIT @ 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.