Costs of Methyl Iodide Non-Registration: Economic Analysis

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Executive Summary

The objective of this report is to examine the potential costs to California agriculture of the non-registration of methyl iodide (MeI)-based fumigant products. These costs fall into two basic categories: increased production costs, and reduced output of affected crops. Both types of costs can reduce the profitability of California agriculture and its competitiveness with other major producers. The purpose of this report is not to estimate the cost to California agriculture if no fumigants are available; similarly, the purpose of this report is not to estimate the cost to California agriculture of the non-availability of methyl bromide (MBr) per se. The report evaluates the costs of MeI non-registration under the assumption that MBr is no longer available, MeI use would be governed by the use regulations included in the U.S. EPA registration, and other fumigants are available under their current California (and U.S.) use regulations. Time constraints prohibited an investigation of the potential impacts of further restrictions governing the use of other fumigants.

The analysis has three major components: a gross revenue loss analysis that utilizes information from 2011 critical use exemption (CUE) applications approved by EPA and forwarded to the Parties, an examination of the potential interactions between MeI registration and existing 1,3-D township caps, and a discussion of specific problems for selected crops. In the gross revenue analysis, we use estimated yield losses given currently registered alternatives from 2011 CUE applications in order to provide a forward-looking analysis of the impact of the denial of registration of MeI. In this analysis we assume that MeI can compensate fully for these estimated yield losses. Consequently, to the extent that MeI is less efficacious than MBr our analysis will overstate the cost of the non-registration of MeI to California agriculture. In terms of gross revenues, cut flowers sustained the largest estimated losses on a percentage basis. Some nursery crops also demonstrated large percentage losses. Losses increased if prices were assumed to be unaffected by reductions in California production. This would be the case if competing producers elsewhere in the U.S. and in other countries could compensate fully by increasing their output.

Even if MeI is not the most efficacious alternative to MBr, it could serve as an alternative for growers affected by township caps on 1,3-dichloropropene (1,3-D) applications. Crops that utilize pre-plant soil fumigation relatively intensively and have production concentrated in specific townships may be disproportionately affected in those areas by the non-registration of MeI, because it would deny them an alternative to 1,3-D. Strawberries and sweet potatoes are relatively concentrated, and a number of townships could be affected.

The final component of the analysis is a discussion of specific problems for selected crops that potentially could be treated with MeI. This discussion identifies cases where the non-registration of MeI could be particularly costly. It also identifies cases where MeI is noticeably less efficacious than MBr, so that the cost of non-registration would be reduced or even eliminated. It is worth emphasizing that in such cases the loss of MBr may be quite costly; the point of the analysis is that MeI cannot substitute for MBr in these instances, so that the non-availability of MeI is not costly. In such cases, the gross revenue loss analysis overstates the losses due to the non-registration of MeI.

Costs of Methyl Iodide Non-Registration: Economic Analysis

I. Report Objective

The California Department of Pesticide Regulation (DPR) is considering whether or not to approve the registration of pesticide products containing the active ingredient methyl iodide (MeI), also referred to as iodomethane. The objective of this report is to examine the potential costs to California agriculture of the non-registration of MeI-based fumigant products. These costs fall into two basic categories: increased production costs, and reduced output of affected crops. Both types of costs can reduce the profitability of California agriculture and its competitiveness with other major producers. Throughout our analysis, we assume that registration is all-or-nothing, so that either all MeI products are approved or none are approved. We also assume that California's domestic and international competitors do not face these same costs. The objective of this report is not to assess the cost to California agriculture if no fumigants were available.

The remainder of this report is organized as follows: section II discusses the scope of our analysis. Section III provides background on MeI. Sections IV to VI present our analysis of the economic implications of the denial of MeI registration. Section IV is a gross revenue loss analysis that utilizes information from 2011 critical use exemption (CUE) applications approved by EPA and forwarded to the Parties. Section V examines of the potential interactions between MeI registration and existing 1,3-D township caps. Section VI discusses of specific crop-specific problems for selected crops. Section VII concludes.

II. Scope of the Analysis

When assessing the potential costs of the denial of the registration of MeI, there are three types of scenarios to consider. They differ in terms of the availability of methyl bromide (MBr) and the regulations governing the use of MBr and other fumigants, most importantly 1,3-dichloropropene (1,3-D) and chloropicrin (Pic). In the first, short-run scenario, MBr may still be used under CUE (USEPA 2009b-e) allowances. Other fumigants are available to growers under current market and regulatory conditions. Some commodities now use little or no MBr; others, such as nursery and ornamentals, strawberries, and several perennial crops rely on MBr for a significant share of their acreage. For 2011, U.S. producers received a total of eleven critical use exemptions for methyl bromide. Of those eleven, seven include MBr use in California: fruit, nut and flower nursery; forest seedling; orchard replant; ornamentals; strawberry fruit; strawberry nursery; and sweet potato slips.

Government and industry sources anticipate that 2015 will be the last year for which critical use exemptions will be available to U.S. producers. Developing countries have chosen not to pursue CUEs for years following their 2015 implementation of the methyl bromide ban. European regulators have not requested any CUEs for 2009 or later. Consequently, efforts by the U.S. to extend the phase-out period through post-2015 applications for critical use exemptions are unlikely to be viewed favorably internationally.

Given this ending date, we examine a second scenario addressing the potential value of MeI when MBr is no longer available.

Under the second scenario, MBr has been phased out completely. Existing fumigant and non-fumigant alternatives to MBr are available under the market and regulatory conditions that exist currently. While the prices of alternative treatments may change once MBr is no longer available, we do not assess this possibility here.

Current regulations regarding the use of fumigants create scope for the denial of MeI registration to be costly for California agriculture. One limitation on the use of currently available fumigants is DPR's fumigant use regulations, which are designed to reduce volatile organic compounds emissions due to pesticide use in air quality non-attainment areas, most importantly the San Joaquin Valley and Ventura air basins. If MeI is determined to have a substantially lower emission potential than Pic, 1,3-D and other fumigants, then denial of its registration would prevent growers from using it in order to increase fumigation without exceeding emission limits. Denial of MeI registration means that MeI products will not be available to growers constrained by regulations specific to another fumigant. One important fumigant-specific regulation places a spatial-temporal limit on the application of 1,3-D in order to protect human health. California limits the amount of 1,3-D that can be applied within a township in a given year. Only a few townships in the state are affected by the caps currently (1,3-D use is concentrated in strawberries for some of these townships and in sweet potatoes for some others). Even when 1,3-D is the preferred treatment for a given pest or disease problem on a specific crop, township caps may lead to growers applying MeI as a second-best choice. The extent to which this would be the case depends on whether or not MeI is the most attractive option based on efficacy, price, and use regulations. If the registration of MeI is denied, then growers will not have this option. Currently, Pic is subject to its own use regulations, including buffer zones. Some counties restrict the maximum application rate of Pic per acre. The interaction between the costs of the registration denial of MeI and Pic use regulations is less clear, because the MeI products under consideration for registration contain MeI and Pic.

Obviously, changes in economic and regulatory conditions could alter the cost of MeI non-registration to California agriculture. The possibility of regulatory change leads to a third class of scenarios, in which one or more regulations are enacted or altered. Currently, DPR is reviewing the level of 1,3-D township caps. To the extent that these caps are reduced, the cost of not having MeI available as a substitute for 1,3-D increases. Pic is currently undergoing a risk assessment. Because other fumigants are combined with Pic, regulation of Pic has the potential to affect the vast majority of fumigant applications in California. The US EPA now requires buffer zones and other means of reducing human exposure risk for multiple soil fumigants, including 1,3-D, Pic, metam potassium, metam sodium, and MBr. Assuming no price response due to reduced production, Urbanchuk and Kowalski (2009) estimate revenue losses of 7-8.8% for California strawberries due to the buffer zones proposed during the rulemaking process, while Carter et al. (2005) estimate losses equivalent to 3.2% of gross revenues from the buffer zones for methyl bromide implemented by California in 2001. However, MeI is subject to its own buffer zones, so

that any cost due to its non-registration would depend on relative buffer sizes, and, for mixed products, whether the Pic or MeI buffer would apply. Given existing and potential regulations, the denial of the registration of MeI would reduce growers' flexibility by denying them an option that may be better for them technically and economically, given the regulatory environment in which they operate.

In the limit, the combination of these regulatory decisions could be that all fumigants other than MeI would be unavailable to California agriculture. However, this report does not address this scenario, for three reasons. First, projecting future regulatory decisions in the absence of concrete proposals is a speculative exercise. Second, as noted earlier, potential regulatory change does not lead to a single scenario, but rather a large number of scenarios, each with a different set of changes. Finally, the costs of any of these scenarios are not due to the regulatory decision regarding the registration of MeI alone, and there is no natural way to determine the marginal effect of the non-registration of MeI. On the one hand, because MeI is not available as part of the status quo the marginal cost of non-registration is zero, regardless of the set of regulatory changes considered. On the other hand, one could argue that the entire cost of the complete set of regulations regarding other fumigants is due to the non-registration of MeI if one assumes that it would be registered under conditions that would allow it to substitute perfectly for other fumigants (and it's sufficiently efficacious at the price at which it's sold to do so). This analysis does not address the cost to California agriculture of all fumigant use being prohibited.

The latter two scenarios- current regulatory and economic conditions, and various possibilities of regulatory changes- are both subject to the caveat that non-fumigant alternatives, such as soil sterilization through heat and/or steam, may become available for large-scale commercial use. If these alternatives became technically and economically feasible, then the cost of MeI non-registration to California agriculture would be reduced. We do not consider that possibility here. Another possibility we do not consider in our aggregate analysis is that new pest or disease problems may emerge.[1] We do not consider the possibility that pests or diseases controlled previously by MBr may reemerge after repeated use of alternative treatments and affect costs and/or yields to a greater extent than the estimates provided in the 2011 CUE nominations. Such problems may increase the cost of the denial of MeI registration, because MeI would give growers an additional pest control option. Similarly, we do not address that the use of VIF and other techniques for reducing VOC emissions from fumigation may become more economically feasible, thus relaxing a regulatory constraint. As the price premium commanded by VIF relative to HDPE decreases, its economic viability will increase. Another possibility is that global positioning system-guided shank fumigation may reduce application rates, thus relaxing regulatory constraints. Finally, additional chemical treatments are being tested for technical and economic feasibility as MBr alternatives, including dimethyl disulfide, which is undergoing testing in the US and EU.

[1] Our discussion of strawberries in the crop-specific analysis does address problems that have emerged after repeated bed applications of alternative fumigants.

III. Background

Martin (2003) characterized MeI as the MBr alternative that's "closest as a drop-in replacement" because of its broad spectrum of control, its high vapor pressure compared to other alternatives (although still lower than MBr), and the ability to apply it using the same fumigation equipment as MBr. MeI remains in the soil longer than MBr, which provides a greater dose to the soil from a given application rate, but which also requires a longer time period between fumigation and planting (Hutchinson et al. 1999b). MeI has been known to be effective at controlling some insects since the 1930s (Sims et al. 1995). Ruzo (2006) hypothesizes that MeI's higher cost, compared to MBr, and the limited availability of iodine are likely major factors contributing to the delay in MeI's commercial development.

Current registration status

US EPA approved a time-limited one-year registration for MeI in October, 2007. In September, 2008, the EPA converted this registration to a time unlimited conditional registration. The conditions of registration are intended to ensure that all fumigants are regulated similarly when the reregistration process for other fumigants is concluded (USEPA 2009a). Arysta LifeScience North American Corporation is the registrant. Registered trade names included Midas Bronze, Midas Gold, Midas 98:2, Midas 50:50, Midas 33:67, and Midas 25:75. These products differ in terms of the percentages of MeI and Pic, and in terms of whether the product is intended for drip or broadcast fumigation. The EPA registration allows the treatment of field-grown strawberries, peppers, tomatoes, stone fruits, tree nuts, grapevines, ornamentals and turf. It also allows the treatment of certain nursery crops: strawberries, stonefruits, tree nuts, and conifer trees (USEPA 2007). As of September, 2009, MeI products are approved for use in 47 states, excluding California, New York, and Washington. Registration is pending final review of comments received by EPA in Washington, and a registration resubmission is being prepared for New York. MeI is registered in Japan, and its registration is pending in fifteen countries, including Argentina, Australia, Brazil, Chile, Costa Rica, Guatemala, Honduras, Israel, Jordan, Mexico, Morocco, New Zealand, South Africa, Turkey, and Uruguay. An application for registration will be submitted in the EU (Ann Grottveit, Kahn, Soares and Conway, LLP, personal communication 10/2009).

The US EPA approved the registration of MeI as being in the public interest based on "the designation of iodomethane as a methyl bromide replacement, agricultural need, and the likely benefits." Unlike MBr, MeI is unlikely to reach the upper atmosphere. It lasts only two to eight days in the atmosphere, degrading quickly in the troposphere due to photolysis. In contrast, MBr may last as long as two years (Zhang et al. 1998).

Efficacy

Like MBr, MeI provides control of a broad spectrum of pests and diseases. Its efficacy against fungi, nematodes, and weeds is equal to or better than that of MBr on an equimolar basis (Duniway 2002). This subsection provides a brief overview of some of the general research regarding MeI's efficacy that is reported in the peer-reviewed scientific literature. Of course, the efficacy of MeI is not constant, but depends on field conditions, soil type, application method, and the crop. We do not address those technical variations.

Weeds. Overall, MeI compares favorably to MBr for weed control. In laboratory experiments, Zhang et al. (1998) found that MeI provided better and more consistent control of the weed species *Abutilon thoephrasti* and *Lolium multiflorum* than MBr did across soil types, moistures and temperatures in laboratory experiments. Hutchinson et al. (2003) evaluated the ability of various fumigants to control *Cyperus esculentus L* (yellow nutsedge) under laboratory conditions. MeI was more effective at controlling yellow nutsedge than MBr or 1,3-D, as effective as Pic, and less effective than metam sodium and propargyl bromide. When combined with 17% Pic, the MeI:Pic and MBr:Pic blends demonstrated comparable efficacy. Based on laboratory bioassays and field experiments, Zhang et al. (1997) concluded that MeI provided equivalent or greater control than MBr for eight weed species, including redroot pigweed.[2] Using a combination of laboratory and field experiments, Ohr et al. (1996a) found that MeI provided control comparable to methyl bromide for five weed species: nutsedge, annual bluegrass, lambsquarters, nettleleaf goosefoot, and London rocket.[3] In turfgrass establishment experiments, Unruh et al. (2002) found that shank injections of MeI at 336 kg/ha, an amount which exceeds the EPA maximum application rate, provided control of purple nutsedge, yellow nutsedge, globe sedge and common bermudagrass equivalent to the control provided by shank injections of 560 kg/ha of MBr (98:2). However, MeI did not control redroot pigweed (in contrast to the results in Zhang et al. 1997), and its control of tall morning glory and sharppod morning glory did not always equal the control provided by MBr. Gilreath and Santos (2004) found that 50:50 formulations of MeI:Pic provided better control of purple nutsedge than 98:2 formulations did. An application of 350 pounds per acre of shank-applied 50:50 MeI:Pic, which is equivalent to the maximum EPA sanctioned application rate, provided purple nutsedge control equivalent to that of 350 pounds per acre of MBr.

Fungi. Stanghellini et al. (2003) found in melon production field trials that MeI and MBr provided equivalent control of *Monosporascus cannonballus*, which causes root rot and vine decline, when the fumigants are applied at a rate of 448.4 kg/ha, a rate more than double the maximum application rate for MeI set by the EPA, using drip irrigation on raised beds. Pic applied at 249.0 kg/ha also provided equivalent control of the fungi. Hutchinson et al. (2000) found that MeI was more efficacious than MBr, on average, in laboratory experiments including nine fungal species. *Fusarium oxysporum* was one of the species examined. Combining MeI with Pic increased its efficacy substantially, as was also the case for MBr. Becker et al. (1998b) found in container trials that MeI was more effective than MBr against *Rhizoctonia solani*. Using laboratory and field trials, Ohr et al.

[2] Zhang et al. (1997) apply MeI at 25, 50, 100, 150, 200, 300, and 350 lbs active ingredient per treated acre (lbs a.i./acre). Of these application rates, only the four lowest are below the EPA specified maximum application rate of 175 lbs a.i./acre.

[3] Ohr et al. (1996a) apply 0.022, 0.045, 0.09, 0.18, and 0.36 moles per meters squared (3, 64, 128, 255, 511 lbs a.i./acre) of iodomethane in field container trials with weeds. Only the lower three applications are below the EPA's maximum application rate. In weed field trials, the author apply iodomethane at 4.8 moles per 9.29 meters squared (approximately 773 lbs a.i./acre). This amount also exceeds the maximum application rate.

(1996a) found that MeI provided control comparable to MBr for four fungi species: *Phytophthora citricola*, *P. cinnamomi*, *P. parasitica*, and *Rhizoctonia solani*.[4]

Nematodes. Using laboratory and field experiments, Hutchinson et al. (1999a) found that MeI provided more efficacious control than MBr for three nematode species: *Meliodognye incognita*, *Heterodera schachtii*, and *Tylenchulus semipenetrans*.[5] Using field trials, Hutchinson et al. (1999b) found that MeI and MBr provided equivalent control of *Meliodognye incognita* in carrot production.[6] Becker et al. (1998b) found in container trials that MeI was more effective than MBr against three plant parasitic nematodes: *Meliodognye incognita*, *Heterodera schachtii*, and *Tylenchulus semipenetrans*. Based on small-scale field plots, the authors concluded that, relative to MBr, MeI is likely to provide comparable control at comparable rates under field conditions.[7] Using laboratory experiments, Ohr et al. (1996a) found that MeI provided control comparable to MBr for *Heterodera schachtii*.

Use regulations and fumigant efficacy. Like fumigant products with other active ingredients, MeI products, registered under the name Midas™, are subject to use regulations in the EPA registration. If registration is approved in California, then the EPA use regulations will apply and additional California-specific use regulations may be added. Use regulations can limit the scope for MeI to serve as a replacement for MBr, or, more broadly, can limit the scope for it to serve as an additional effective pest management tool for growers. Some use regulations, such as limits on application rates, may limit the efficacy of MeI products directly. Others, such as buffer zones, may limit the ability to use MeI on land where fumigant products with other active ingredients cannot be applied.

The EPA registration for Midas products specifies four application methods and permitted application rates: raised bed-shank injection (75-175 pounds active ingredient per treated acre), broadcast/flat fume-shank injection (100-175 pounds active ingredient per treated acre), auger probe-deep injection (0.5 to 2 pounds per injection site), and raised bed-drip application injection (100-175 pounds active ingredient per treated acre) (USEPA 2007). Other use regulations include that drip applications must occur a minimum of ten days prior to planting, and that raised bed and broadcast fumigation applications be covered with a tarp for at least five days, and occur a minimum of seven days prior to planting (USEPA 2007). The EPA sets buffer zones for each product that depend on various factors, including the application method, number of treated acres, and the type of tarp used (USEPA 2007).

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[4] In fungi field trials, Ohr et al. (1996a) applied 1.2, 2.4, and 4.8 moles of MeI per 9.29 meters squared (approximately 183, 367, and 733 lbs a.i./acre), none of which are permissible under the EPA guidelines.

[5] The field experiments in Hutchinson et al. (1999a) apply MeI at 6.7, 21.5, 36.3, 51.1, 65.9, and 80.6 kg a.i./ha. These amounts are all well below the EPA specified maximum application rate.

[6] Hutchinson et al. (1999b) apply 112, 168, 224, and 336 kg/ha. Of these applications, only the two lowest application rates are below the currently specified maximum application rate.

[7] Becker et al. (1998b) apply MeI at 0, 28, 56, 112, 168, and 224 kg/ha. Only the highest application rate, which is equivalent to 200 lbs/acre, violates the maximum EPA application rate. The key results of this paper apply to the lower, legal rates.

Economic Considerations

Efficacy is not the only criterion that must be met in order for the denial of the registration of MeI to be costly for California agriculture. Its use must also be cost-effective. Hueth et al. (2000) uses studies of the economic value of MBr to California agriculture combined with information on the technical efficacy of MeI and existing substitutes to examine the potential demand for MeI. The minimum price per pound they consider is $6 and the maximum is $16. They conclude that depending on its price, whether or not tarping is required, and other factors, MeI could mitigate some of the costs of a methyl bromide ban. If tarping is required, they estimate a range of mitigation benefits of $1 million to $36 million for California agriculture. For our purposes, these correspond to a cost of non-registration of MeI under scenario 2 of $1 million to $36 million. For a price per pound of $10-$12, the corresponding cost of non-registration would be $2.6 million to $19.9 million.

UNEP (2008) addressed the economic feasibility of MeI as a substitute for MBr. Assuming that MeI use results in the same gross revenues as MBr use and that all other costs will remain unchanged, it concludes that MeI may be an alternative that is suitable for many crops and locations. In its analysis, it considered scenarios where MeI was 1.4 to 2.0 times as expensive as MBr per hectare, adjusting dose rates to obtain equal yields. It notes that for crops with sufficiently high gross revenues per hectare the difference in treatment cost between MeI and MBr is a small share of net revenues.

Arysta LifeScience reports tomato trials in the southeastern U.S. for which tomatoes planted in soil treated with Midas had, on average, 11% higher yields than those planted in soil treated with MBr. These higher yields and the ability to reduce application rates by 20-30% without reducing efficacy make Midas products cost-competitive with existing MBr-Pic formulations, even at higher prices per pound of product (Allen 2008). A per-acre treatment cost comparison for strawberry, tomato/pepper, and ornamentals systems in the southeastern U.S. reports that the cost of Midas treatments using VIF ranges from 87% to 136% of the cost of the comparable MBr-Pic treatments, some using VIF and some using standard film (Arysta LifeSciences document provided by Ann Grottveit, Kahn, Soares and Conway LLP, 10/2009). By definition, these calculations are dependent on the production systems considered. In finer soils and/or other production systems higher rates of MeI may be required.

Sydorovych et al. (2008) examine the economic performance of several fumigants and compare them to MBr-Pic for tomato production in North Carolina, using a partial budget approach. Their estimates are based on data from six years of field trials, although Midas was applied in only four of those six years. They find that the use of Midas 50:50 (300 pounds per acre) resulted in $425 less in returns per acre than the use of MBr-Pic 67:33 did. Pic (15 gallons per acre, Chlor-o-pic), Telone-C35 (35 gallons per acre) and drip-applied metam sodium (Vapam, 75 gallons per acre) all resulted in higher returns per acre than MBr-Pic. Additionally, metam sodium (broadcast+till, Vapam, 75 gallons per acre), Pic EC plus metam sodium (200 pounds per acre of TriChlor EC, 75 gallons per acre of Vapam), and Pic resulted in returns that were substantially above those for Midas, although below those for MBr-Pic.

IV. Economic Implications of the Denial of Registration of Methyl Iodide: 2011 CUE Application-based Analysis

Scientific, economic, and regulatory factors determine the cost of non-registration of MeI to California agriculture, and to specific crops. Under the first scenario, when MBr is still available under critical use exemptions, the cost of non-registration of MeI products to California agriculture will depend on the extent to which it is the best alternative to all other treatments, *including* MBr, when technical efficacy, costs, and regulations are considered. If MeI is a sufficiently close substitute for MBr technically, then economic and regulatory considerations will be the most important determinants of the cost of MeI non-registration. Under our second scenario, in contrast, the cost of the non-registration of MeI products is determined by the extent to which it is the best alternative to all other treatments, *excluding* MBr.

Under the second scenario, the scope of the potential costs of MeI non-registration increase. We focus our analysis on this scenario. Because MeI, like MBr, has the ability to act against a broad spectrum of pests there is the possibility that it will be able to manage pest and/or disease pressures that are not managed effectively by other MBr alternatives. Information contained in MBr critical use exemption requests for specific crops provide one measure of the potential scope for MeI to benefit California agriculture. However, in some cases direct research regarding the ability of MeI is unavailable, and in other instances it is limited. Here we take two approaches. First, we assume that MeI would substitute perfectly for MBr, both technically and economically, and use yield loss and acreage information from the 2011 CUE requests from the U.S. for specific crops in California to provide an estimate of the cost of the denial of MeI product registration to growers of these crops. Our strategy in this approach is to evaluate the "opportunity cost" to agriculture if the registration of MeI is denied. To the extent that MeI is not as efficacious as MBr in certain applications, the cost of the non-registration of MeI will be overestimated. Second, we focus on crops with 2011 CUE requests approved by the U.S. government, and discuss specific disease and pest problems and the available methods for control. The greater the limitations of currently available alternatives are, the greater is the potential for the non-registration of MeI to be costly for growers of these crops if it is not subject to these limitations.

The costs of the denial of registration for MeI will be affected by the use regulations associated with MeI registration, the use regulations associated with other fumigants, and the prices of MeI products relative to the prices of alternative treatments. For specific disease and pest problems, the cost of not registering MeI will depend on the potential damage caused by that pest/disease if only 1,3-D and Pic are available (and, in some cases, other MBr alternatives), as well as on the cost per acre of using MeI and its efficacy under regulatory constraints. If MeI is applied due to limitations on 1,3-D applications due to township caps, or limitations on the application of other fumigants due to VOC emission restrictions, then its value depends on the returns realized under the next best alternative.

Changes in Gross Revenues Based on 2011 CUE Applications

We use four CUE applications approved by the EPA and forwarded to the Methyl Bromide Technical Options Committee (MBTOC) for approval for 2011, along with information for ten associated crops to obtain the number of acres for which MBr has been requested (http://www.epa.gov/Ozone/mbr/2011_nomination.html).[8] We use 2011 nominations rather than 2009 CUEs in order to provide a forward-looking analysis of the impact of the denial of registration of MeI. As existing stocks of MBr are exhausted, the pattern of its use will change, so that 2009 values are of relatively limited use even for short-term projections.[9] In 2007, the ten crops considered here accounted for $8.5 billion in cash receipts, 23% of California's total cash farm receipts (NASS 2008a; NASS 2008b).[10] We compute the cost of MeI non-registration as failing to mitigate the losses in gross revenues for these ten crops that would be incurred if MBr was not available. This analysis assumes that the technical efficacy is identical for MeI and MBr, yields are identical, the cost per acre of applying the two fumigants is identical, and that the applicable regulations are identical. If MeI is more efficacious, results in higher yields, cheaper, or would be subject to fewer use regulations (if registered), then the cost of non-registration would increase.[11] If MeI is less efficacious, more expensive, or is subject to more regulations, then the costs would decrease. The analysis does not address the possibility that MeI would be preferred to the non-MBr treatments used currently on other acreage, a possibility which in turn is dependent on the relevant prices and regulations. A review of the CUE applications shows that the economic justifications do not show substantial cost increases due to the use of the best alternative to MBr; all but one show constant costs or a minor change of less than three percent. Consequently, we use changes in gross revenues for these ten crops as a measure of the cost of MeI non-registration. Our analysis excludes crops that are using MBr from existing stocks and did not obtain a 2011 CUE application that was approved and forwarded by the EPA. We do, however, examine the case where all acreage of the ten crops we consider is impacted by the denial of the registration of MeI, not just the CUE acreage (Table 2). This case addresses the possibility that current use of existing MBr stocks for these crops means that the 2011 CUE application acreage understates the importance of MBr and the potential losses that would occur if MeI registration was denied.

In order to compute revenue changes, we use own-price elasticities of demand from the existing literature, when available, and the estimated change in total quantity due to the

[8] Two additional California crops had CUE nominations approved by the U.S. EPA: strawberry nursery, with an estimated 2007 value of $48.6 million dollars (CDFA 2008) and sweet potatoes, with a 2007 value of $80.9 million dollars (NASS 2008a).

[9] Across all U.S. uses of MBr, existing stocks are expected to account for less than 10% of total MBr use in 2011.

[10] Consistent with the CUE applications, this value estimate includes two categories of nursery stock: "Nursery, fruit/vine/nut, non-bearing" and "Nursery plants, rose" (NASS 2008b).

[11] Ajwa et al. (2005) find that commercial strawberry yields from two MeI:Pic products, 33/67 and 50/50 applied through shank injection and drip application at a rate of 200 pounds/acre were higher than those from a drip application of methyl bromide –Pic EC at 200 pounds per acre at one experimental site, although not at the other. (Note: drip application of MBr is not permitted for commercial use in California.) All treatments were applied under standard polyethylene tarp. Under clear VIF, yields from the same MeI:Pic formulations had yields that were not significantly different from MBr:Pic (67/33) at 350 pounds per acre (Ajwa et al. 2006)

change in yield on the affected acreage reported in the CUE applications.[12] A good's own-price elasticity of demand is its percentage change in the quantity demanded per percentage change in price. Yield losses are the ones reported in the economic feasibility analysis in each application. We assume that harvested perennial acreage is in full production, and that the share of that acreage subject to yield reductions corresponds to requested CUE acreage as a share of planted acreage.[13] Results are reported in Table 1.

Table 1. Effect of Denial of MeI Registration on Gross Crop Revenues: CUE Acres Only, Yield Loss Estimates from 2011 CUE Applications*

	Yield loss (%)	2007 planted acreage	2007 harvested acreage	2011 CUE acreage	Gross revenues MI available ($ millions)	Gross revenues MI not available ($ millions)	Change (%)
Almond[a]	-4%	21,080	615,000	217	2,154	2,155	0%
Cut flower[b]	-20%	8,126	8,126	716	182	166	-9%
Grape (table)[a]	-10%	2,977	82,000	0	-	-	0%
Grape (raisin)[a]	-10%	906	227,000	106	602	608	1%
Grape (wine)[a]	-10%	9,112	480,000	254	1,854	1,860	0%
Nursery (fruit and nuts)[c]	-100%	0	0	86	165	161	-2%
Nursery (roses)[d]	-100%	0	0	12	36	35	-1%
Stonefruit[a]	-4%	8,913	302,000	1,662	865	869	0%
Strawberry[e]	-15%	35,500	35,500	13,444	1,339	1,305	-2%
Walnuts[a]	-4%	3,185	218,000	274	754	761	1%
TOTAL					7,951	7,920	0%

a. Assumes all acres in full production and affected propoprtionately
b. Acreage from 2007 U.S. Census of Agriculture.
c. 2006 gross revenues from NASS, 2007
d. 2008 gross revenues nursery, rose category from CDFA CAC data 2009
e. Assumes that fresh and processed strawberries revenues proportionate across all acreage

* This analysis does not address the regulatory scenario of fumigants other than MBr being further restricted, or the possibility that new pest and/or disease problems may emerge.

Sources: See appendix.

Cut flowers sustain the largest revenue losses in percentage terms: 9%. This is due to the relatively large (20%) yield decrease reported in the CUE application and the relatively

[12] A commodity's own-price elasticity of demand is the percentage change in the quantity demanded due to a percentage increase in price. For example, a commodity with a demand elasticity of -0.5 would see a 50% decrease in the quantity demanded if price increased by 100%. Own-price demand elasticities were unavailable for cut flowers and nursery crops. We specified perfectly elastic demands for these two crops, so that price remains unchanged when the quantity produced declines. Cut flowers face a substantial amount of competition from imports, suggesting that price is unlikely to increase as the quantity produced in California declines. This pattern is consistent with recent developments in this industry. Very little information is available regarding the demand for nursery crops. Because nursery crops must be certified as nematode-free, infested product has zero value to the producer. Effectively, by specifying that demand is perfectly elastic we are assuming that the share of rose nursery stock that is infested is sufficiently small that it does not increase the price of the remaining rose nursery stock.

[13] Because the CUE analyses suggest comparable internal rates of return for treatment with MBr-Pic and the best available alternatives we do not perform a production cycle analysis for the life of the orchard or vineyard. Although the resulting internal rates of return are comparable, it is worth noting that tree and vine loss increases with the use of some alternatives for some crops.

large share of planted acreage for which a CUE is requested, as well as to the very elastic demand that they are assumed to face. Although the request for fumigation of roses in nurseries indicates only a 1% loss in gross revenues, this is because the requested CUE acreage and associated revenues at risk reported in the CUE application are quite small, relative to total industry revenues. Cut flowers and at least some nursery crops could incur substantial costs if MeI is not registered.

Yield losses for other crops are mostly or completely offset by price increases received for the remaining production. Based on CUE application information regarding yield losses, cost changes, and acreage requiring MBr, the costs of not registering MeI are small for many crops at the aggregate level. However, these estimates are based solely on yield effects reported in the 2011 CUE applications for each crop. It is also important to keep in mind that MeI may not be a perfect substitute for MBr. When this is the case, the cost of the non-registration of MeI is correspondingly reduced. Critically, in such cases the cost of losing MBr itself could be extremely high. This analysis does not address the cost of losing MBr or all fumigants, it simply evaluates the cost of not registering MeI when MBr is no longer available.

In the case of strawberries, our loss estimates reflect the success that the industry has had in identifying alternatives to MBr, which proxy as alternatives to MeI and mitigate the costs of the denial of registration. In the early years of the MBr phaseout, more research was done on the alternatives to methyl bromide in strawberry production than in any other production system (Duniway 2002). Losses to the strawberry industry are noticeably smaller than the projected 6-17% reported in Carter et al. (2005a). This is due largely to that study's assumption that all strawberry acreage would be affected, which is not supported by the more recent information in the CUE application. Similarly, the surplus loss estimates reported in ERS (2000) are much larger, ranging from 15-20% for producers and consumers combined, than the comparable figure is for producers and consumers in our analysis: 7%. In addition to the difference in the acres affected, the ERS estimates were based on a yield loss of 21.5% documented in Carpenter, Giannessi and Lynch (2000).[14]

Comparing the relative magnitudes of planted acreage (when available) and CUE acreage indicates that most of the acreage in these crops is treated currently with an alternative to MBr, suggesting that at least one alternative is feasible for most production. This is consistent with CUE justifications, which focus on the greater efficacy of MBr for nematode control in heavier soils, as well as on regulatory constraints, especially the 1,3-D township caps. Moisture requirements for Pic applications are also noted in the orchard replant request.

[14] Tables A.2 and A.3 in the appendix use the yield losses presented in Carpenter, Gianessi and Lynch (2000) as the basis for two additional estimates of the cost of the denial of MeI registration for the ten crops we examine. The Tables correspond to Tables 1 and 2 in the text. Because the percentage yield losses vary, estimates of gross revenue losses vary. Notably, the more recent yield loss estimate for cut flowers, 20%, is more than twice the 9% reported in Carpenter, Gianessi and Lynch (2000).

Although no acreage request for table grapes is included as part of the orchard replant CUE application, the application uses it for the analysis of the economic effects on grapes, so we include it in Table 1. If acreage had been included in the CUE application, then the behavior of gross revenue changes would be very similar to those for raisin grapes. The orchard replant CUE application provides information regarding the second-best alternative to MBr for table grapes when 1,3-D is not available. Using metam sodium results in an estimated yield loss of 20%. This yield loss does not result in a gross revenue loss, due to the associated price increase for the remaining production.

In addition to direct effects on agriculture, changes in agricultural revenues affect other economic activity. Using IMPLAN multipliers for California, total economic activity would decrease by approximately $55 million and employment would decrease by approximately 820 due to the $31 million reduction in agricultural revenues.

As noted earlier, an important caveat to this analysis is the use of CUE acres; to the extent that users rely on MBr from existing stocks, CUE acreage requests will understate the use of MBr. Assuming that growers use MBr on twice the acreage included in the CUE requests does not have noticeable effects on the changes in gross revenues for perennial crops. Because such a high share of strawberry acreage is included in the CUE request, doubling the MBr-treated acreage increases the gross revenue loss from the non-registration of MeI to 8%. Losses for cut flowers increase from 9% to 18%, losses for fruit and nut nurseries increase from 2% to 5%, and losses for rose nurseries increase from 1% to 3%.

Table 2 allows us to examine the effect of the specified share of planted acreage affected by the denial of registration on the estimated costs. It assumes that the yield losses reported in the 2011 CUE nominations apply to all harvested acreage. Consequently, the analysis reported in Table 2 enables us to place an upper bound on the potential cost of MeI non-registration due to additional acreage of these crops using MBr from existing stocks. Table 2 assumes that MeI is the best available alternative fumigant for all acreage in the absence of MBr, given technical properties, prices, and applicable regulations. Comparing Tables 1 and 2 allows us to isolate the effect of restricting acreage impacted by the denial of MeI registration to the 2011 CUE acreage. Due to inelastic demand, almonds, raisin grapes, winegrapes, stonefruit and walnuts are not impacted adversely. Losses for strawberries increase to 7%. Because of the assumed perfectly elastic demand, cut flower losses are 20%. Because a 100% yield loss is assumed for nursery crops due to the nematode-free certification requirement, losses equal 100%. Because some acreage in each of these crops is using MBr alternatives, these estimates will exceed the likely actual cost of MeI non-registration under current regulations. It is important to note that the estimates in Table 2 should not be interpreted as estimates of the cost to these commodities of eliminating all fumigant use. The yield losses in the 2011 CUE nominations do not represent this scenario. In the absence of fumigant use, higher yield losses would be predicted. Similarly, rates of tree loss would be anticipated to be higher.

Table 2. Effect of Denial of MeI Registration on Gross Crop Revenues: All Acreage Impacted, Yield Loss Estimates from 2011 CUE Applications *

	Yield loss (%)	2007 harvested acreage	Gross revenues MI available ($ millions)	Gross revenues MI not available ($ millions)	Change (%)
Almond[a]	-4%	615,000	2,154	2,168	1%
Cut flower[b]	-20%	8,126	182	146	-20%
Grape (table)[a]	-10%	82,000	623	617	-1%
Grape (raisin)[a]	-10%	227,000	602	648	8%
Grape (wine)[a]	-10%	480,000	1,854	2,003	8%
Nursery (fruit and nuts)[c]	-100%	0	165	-	-100%
Nursery (roses)[d]	-100%	0	36	-	-100%
Stonefruit[a]	-4%	302,000	865	882	2%
Strawberry[e]	-15%	35,500	1,339	1,239	-7%
Walnuts[a]	-4%	218,000	754	833	10%
TOTAL			8,573	8,535	0%

a. Assumes all acres in full production and affected propoprtionately
b. Acreage from 2007 U.S. Census of Agriculture.
c. 2006 gross revenues from NASS, 2007
d. 2008 gross revenues nursery, rose category from CDFA CAC data 2009
e. Assumes that fresh and processed strawberries revenues proportionate across all acreage

* This analysis does not address the regulatory scenario of fumigants other than MBr being further restricted or the possibility that new pest and/or disease problems may emerge.

Sources: See appendix.

Total revenues for these ten crops decline by $38 million. In addition to direct effects on agriculture, changes in agricultural revenues affect other economic activity. Total income would decrease by approximately $67 million, and employment would decrease by approximately 1,005.

Tables 1 and 2 use demand elasticity estimates from the existing literature. Table 3 presents gross revenue losses if demand for all of the commodities addressed was perfectly elastic; that is, regardless of the change in California's production of the commodity in question the price received by growers would not change. This would be the case if, for example, competing domestic and international producers could replace completely any decline in California's production. Given that cut flowers were specified to have a perfectly elastic demand in Table 1, losses are unchanged at 9% of gross revenues. Changes in gross revenues for most crops are not altered substantially, due mostly to the relatively small share of planted acreage for which a CUE exemption was requested. The exception to this pattern is strawberries, which requested an exemption for a much larger share of planted acreage than any of the other crops and show a correspondingly larger increase in losses, from 2% of gross revenues to 6%.

Table 3. Effect of Denial of MeI Registration on Gross Crop Revenues: CUE Acres Only, Yield Loss Estimates from 2011 CUE Applications, Perfectly Elastic Demand*

	Yield loss (%)	2007 planted acreage	2007 harvested acreage	2011 CUE acreage	Gross revenues MI available ($ millions)	Gross revenues MI not available ($ millions)	Change (%)
Almond[a]	-4%	21,080	615,000	217	2,154	2,153	0%
Cut flower[b]	-20%	8,126	8,126	716	182	166	-9%
Grape (table)[a]	-10%	2,977	82,000	0	-	-	0%
Grape (raisin)[a]	-10%	906	227,000	106	602	595	-1%
Grape (wine)[a]	-10%	9,112	480,000	254	1,854	1,849	0%
Nursery (fruit and nuts)[c]	-100%	0	0	86	165	161	-2%
Nursery (roses)[d]	-100%	0	0	12	36	35	-1%
Stonefruit[a]	-4%	8,913	302,000	1,662	865	859	-1%
Strawberry[e]	-15%	35,500	35,500	13,444	1,339	1,263	-6%
Walnuts[a]	-4%	3,185	218,000	274	754	751	0%
TOTAL					7,951	7,832	-1%

a. Assumes all acres in full production and affected propoprtionately
b. Acreage from 2007 U.S. Census of Agriculture.
c. 2006 gross revenues from NASS, 2007
d. 2008 gross revenues nursery, rose category from CDFA CAC data 2009
e. Assumes that fresh and processed strawberries revenues proportionate across all acreage

* This analysis does not address the regulatory scenario of fumigants other than MBr being further restricted or the possibility that new pest and/or disease problems may emerge.

Sources: See appendix.

Total revenues for these ten crops decline by $119 million. In addition to direct effects on agriculture, changes in agricultural revenues affect other economic activity. Total income would decrease by approximately $211 million, and employment would decrease by approximately 3,146.

Constructing the equivalent of Table 3 for the scenario examined in Table 2 simply involves specifying gross revenue losses that are proportional to yield losses on all crop acreage. Doing so requires imposing worst-case assumptions regarding both demand and yield losses for estimating the cost of the denial of MeI registration. Table 4 reports these estimates. These estimates are unlikely to represent the actual cost of the denial of MeI registration under current regulatory conditions, due to the availability of other fumigants which can be used to treat at least some acreage. On the other hand, the estimates do not correspond to the losses to these crops that would be incurred if no fumigants were available; yield losses would be expected to be larger, sometimes substantially so.

Total revenues for these ten crops decline by $896 million. In addition to direct effects on agriculture, changes in agricultural revenues affect other economic activity. Total income would decrease by approximately $1,586 million, and employment would decrease by approximately 23,690.

Table 4. Effect of Denial of MeI Registration on Gross Crop Revenues: All Acreage Impacted, Yield Loss Estimates from 2011 CUE Applications, Perfectly Elastic Demand*

	Yield loss (%)	2007 harvested acreage	Gross revenues MI available ($ millions)	Gross revenues MI not available ($ millions)	Change (%)
Almond[a]	-4%	615,000	2,154	2,068	-4%
Cut flower[b]	-20%	8,126	182	146	-20%
Grape (table)[a]	-10%	82,000	623	560	-10%
Grape (raisin)[a]	-10%	227,000	602	542	-10%
Grape (wine)[a]	-10%	480,000	1,854	1,669	-10%
Nursery (fruit and nuts)[c]	-100%	0	165	-	-100%
Nursery (roses)[d]	-100%	0	36	-	-100%
Stonefruit[a]	-4%	302,000	865	830	-4%
Strawberry[e]	-15%	35,500	1,339	1,138	-15%
Walnuts[a]	-4%	218,000	754	723	-4%
TOTAL			8,573	7,677	-10%

a. Assumes all acres in full production and affected propoprtionately
b. Acreage from 2007 U.S. Census of Agriculture.
c. 2006 gross revenues from NASS, 2007
d. 2008 gross revenues nursery, rose category from CDFA CAC data 2009
e. Assumes that fresh and processed strawberries revenues proportionate across all acreage

* This analysis does not address the regulatory scenario of fumigants other than MBr being further restricted or the possibility that new pest and/or disease problems may emerge.

Sources: See appendix.

There are a number of factors that suggest that this case of zero price response reported in Tables 3 and 4 is unlikely to hold across the board. For example, buyers may be willing to pay a premium for California products, perhaps due to advertising by California commodity groups or food safety considerations. For some fresh products seasonality may limit the ability of competing producers to replace California production. In the case of Chile, for example, while grapes account for just over a third of U.S. agricultural imports from Chile, the majority of Chilean grapes arrive between December and April, while U.S. grapes are harvested mostly from May to December (Adcock and Rosson 2004).

For other competitors, the ability to meet sanitary and phytosanitary (SPS) requirements may limit their ability to increase exports, at least in the intermediate run. For example, after its accession to the WTO in 2001, China was expected to increase its production and exports of labor-intensive agricultural products, such as fruits and vegetables. However, due to its inability to meet SPS standards, its exports were constrained. An estimated 90% of China's agricultural exports were affected by technical standards, and China lost an estimated $9 billion in export value in 2002, compared to a realized value of agricultural exports of $14.5 billion (Dong and Jensen 2004).

Some observers predict that China's agriculture will face increasing resource constraints as its population grows and its average income increases. This will limit its ability to increase exports, and as its population becomes richer it will demand more fruits, vegetables, meat, as well as higher-quality items within each category, which may increase imports (Gale and Huang 2007). In 2002, China's agricultural imports of $16.1 billion exceeded its exports (Dong and Jensen 2004).

Overall, the results of this analysis of the role of price responses should be interpreted with caution. Competition from other producers is commodity-specific, and the degree to which this scenario's pricing assumption reflects potential future competitive conditions will vary by commodity as well.

V. Economic Implications of the Denial of Registration of Methyl Iodide: Role of Binding 1,3-D Township Caps

Another type of cost imposed by the non-registration of MeI is that it is not available as an alternative for growers who cannot use 1,3-D due to binding township caps. The caps limit total applications of 1,3-D adjusted for application method to 90,250 adjusted pounds per year. Carpenter, Lynch and Trout (2001) estimate that demand for 1,3-D would increase to 16 million pounds after the methyl bromide ban, but that due to township caps only 10 million pounds could be applied. They predict that the caps will be binding for 47 townships, primarily in strawberry-producing areas along the coast but also in the San Joaquin Valley in areas producing sweet potatoes, almonds, peaches and nursery crops. In total, they estimate that growers will be unable to treat 26,879 acres with 1,3-D due to the township caps, but do not provide a dollar estimate of the cost. In related work, Trout (2003) estimates that due to the township caps 30% of the acreage fumigated with Telone (1,3-D product), MBr, or Pic alone could not be fumigated if growers could only use 1,3-D-based products.

In this subsection, we assume that 1,3-D township caps are binding, and that MBr is growers' best alternative to 1,3-D. If MBr is not available, then we assume that MeI is growers' best alternative to 1,3-D. In this case, the cost of the non-registration of MeI is the loss of an alternative to 1,3-D. Unlike previous work, we do not examine adjusted pounds of 1,3-D. Rather we use unadjusted pounds from DPR's Pesticide Use Reports (PUR) data. As such, our analysis is very much an approximation of the potential impacts that depends on the extent to which the adjustments reduce or increase effective applications of 1,3-D. We also do not address the possibility that township caps may be increased if growers use lower emission application methods. Given these caveats, we evaluate the cost of the denial of registration of MeI products by assessing the extent to which township caps would prevent growers from substituting 1,3-D for MBr once the MBr ban is in effect.

Table 5 reports the acres treated with 1,3-D and with MBr "production" applications in townships that exceeded the 90,250 pound cap for 1,3-D, in terms of unadjusted pounds. Once MBr is no longer available, we assume that growers would replace MBr with either

MeI or 1,3-D. Because of the township caps, in these townships growers would be unable to increase their use of 1,3-D and would use MeI, if available. In fact, many of these townships are using more than the permitted annual cap, by also using available application pounds from previous years. Thus, over time growers would need to utilize 1,3-D less. Denial of MeI registration would eliminate an option for growers.

Table 5 examines a subset of townships likely to be affected greatly by the non-registration of MeI. Figures 1 to 6 address a wider set of townships also likely to be affected. These townships are identified by having total pounds of 1,3-D plus MBr at least as large as the 1,3-D township cap. Because unlike Trout (2003) and Carpenter, Lynch and Trout (2001) we do not examine specific application rates by crop, this selection criterion assumes that a grower choosing between a 1,3-D-based fumigant and a MBr-based fumigant will choose products with the same percentage of those active ingredients. The corresponding analysis by township identifies 35 (2008), 29 (2007), and 22 (2006) townships affected by the caps, compared to the 47 townships identified by Carpenter, Lynch, and Trout.

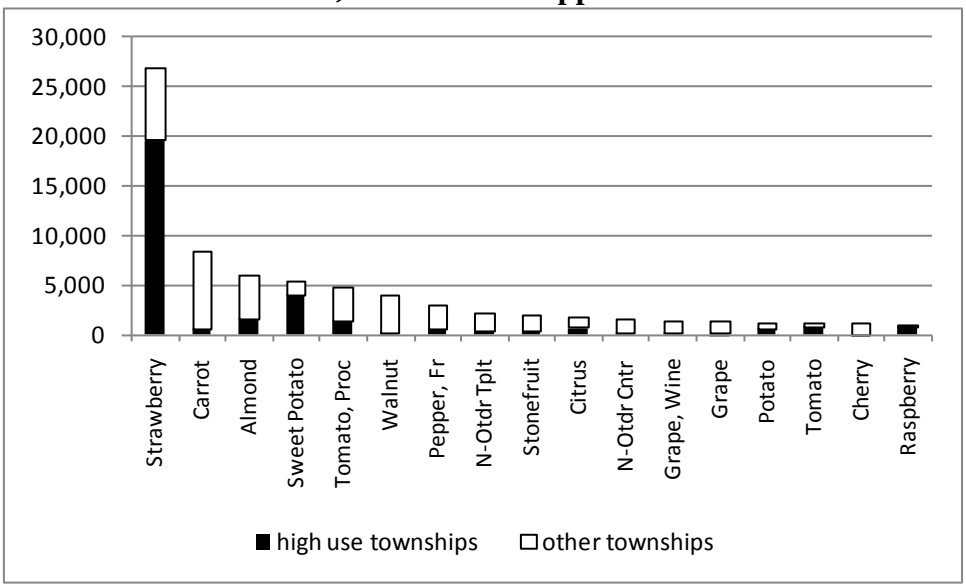
Table 5. I,3-D and MBr application acres in townships applying at least 90,250 unadjusted pounds of 1,3-D: 2006-2008

	Year		
	2006	**2007**	**2008**
Number townships	17	14	18
Acres treated with 1,3-D	16,278	13,262	15,291
Acres treated with MBr	10,798	11,673	7,211

Source: Authors' calculations using PUR data, various years.

Figure 1 plots total California fumigated acreage in 2008 for the seventeen crops reporting over 1,000 acres fumigated with products containing either 1,3-D or MBr. Pre-plant soil fumigation for an unspecified crop, the second-largest acreage category, is omitted because the crops are unknown, so assessing the share of total acreage within high fumigant use townships has no natural interpretation. Total fumigated acreage is divided into acreage in townships with high 1,3-D and MBr use, versus acreage in townships with less than 90,250 pounds of 1,3-D and MBr. Strawberries accounted for over 2.5 times as many fumigated acres as carrots, the crop with the second largest number of total fumigated acres. Of the largest half-dozen crops, strawberries and sweet potatoes were the ones with the largest shares of fumigated acreage in townships with high total use of 1,3-D and MBr. This suggests that the denial of MeI registration has the potential to be most costly for the strawberry industry, in terms of its total fumigated acreage and the potential for MeI to replace MBr in townships where the 1,3-D cap is binding. Among the remaining crops, tomatoes and raspberries had high shares of total fumigant use in townships with relatively high total 1,3-D and MBr use.

Figure 1. Total Fumigated Acreage and Share in Townships with More than 90,250 Pounds of 1,3-D and MBr Applications: 2008

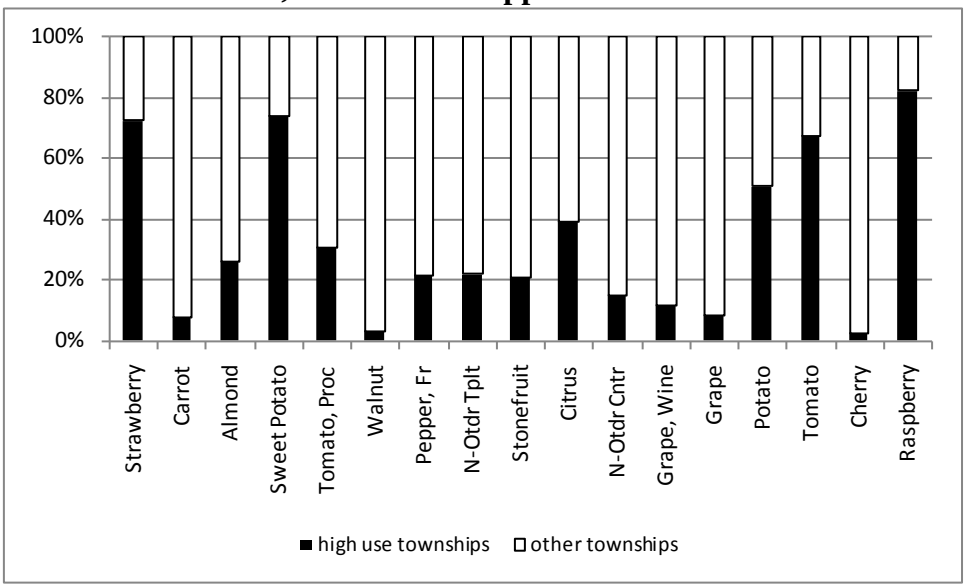


Source: Authors' calculations using PUR data.

However, offsetting these apparent ordinal impacts, perennial crops are subject to special dynamic considerations. As perennial crops, almonds, walnuts, stonefruit, citrus, winegrapes, grapes, cherries, and raspberries have fumigant use statistics that are governed by replant rates. If total acreage is not constant over time, then the use of fumigation will vary with the trend in planted acreage. Because application rates are relatively high for perennial replant, demand in specific years can exceed the township cap, even if average annual demand is within it. Another caveat regarding perennials is that the loss of MBr may alter the effective lifetime of a planting. If the economic life of an orchard, grove or vineyard would be reduced when pre-plant fumigation with currently registered MBr alternatives is used, but pre-plant fumigation with MeI would eliminate this reduction, then reduced lifespans for perennials would be an additional cost of the denial of the registration of MeI.

Figure 2 reports the share of total fumigated acreage in townships with high total use of 1,3-D and MBr in 2008. Unlike Figure 1, Figure 2 reports these shares as straight percentages, and does not scale for total acreage. While Figure 1 summarizes total potential acreage impacts, Figure 2 addresses the relative potential importance of township caps for individual crops. Figure 2 identifies crops with small total acreage that are likely to be more severely affected. This analysis suggests that on a percentage basis there is substantial potential for MeI to mitigate the cost of the MBr ban for not only strawberries, but also sweet potatoes, potatoes, tomatoes, and raspberries. If the registration of MeI is denied, then growers will not have it available as a fumigation option, which would be most costly to growers with land in townships where fumigant use is high currently.

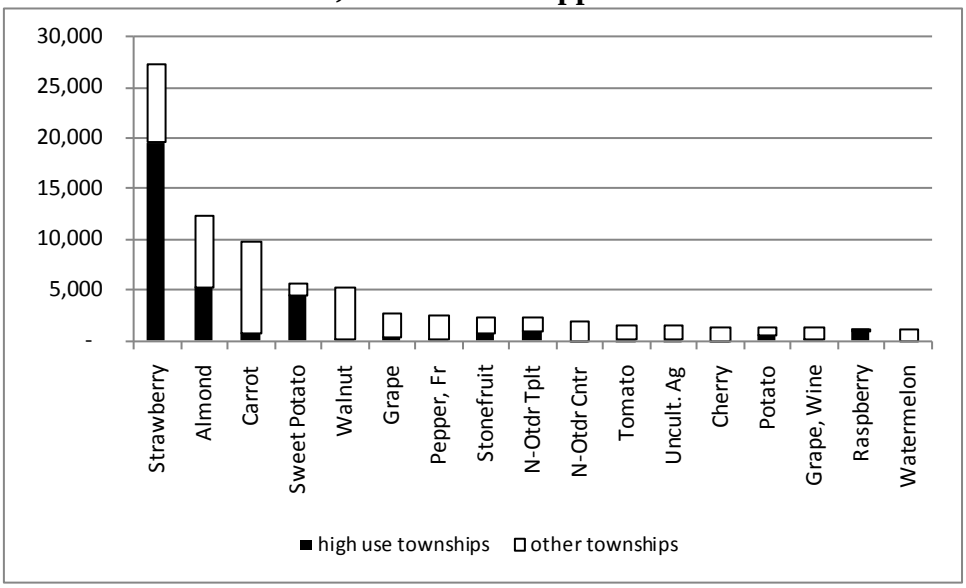
Figure 2. Share of 1,3-D and MBr Use in Townships with More than 90,250 Pounds of 1,3-D and MBr Applications: 2008



Source: Authors' calculations using PUR data.

Figure 3 plots total fumigated acreage in 2007 for the seventeen crops reporting over 1,000 acres fumigated with products containing either 1,3-D or MBr statewide. Pre-plant soil fumigation for an unspecified crop, the third-largest acreage category, is omitted, as was the case for 2008. Consistent with perennials' demand for fumigation being "lumpy" due to replant decisions, almonds' total fumigated acreage was more than double its level in 2008. While perennial acreage decisions altered some of the total acreage rankings, the same patterns regarding the share of fumigant use in townships with relatively high total fumigated acreage were mostly apparent. As in 2008, sweet potatoes, raspberries and strawberries were highly concentrated in high fumigant use townships. Tomato fumigant use, however, was mostly outside high fumigant use townships, and total fumigation was much lower.

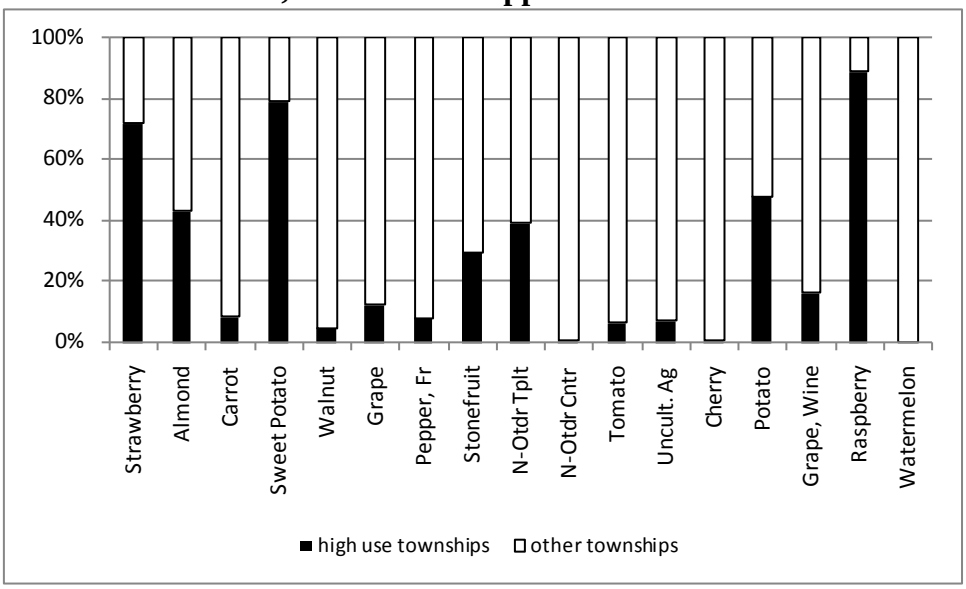
Figure 3. Total Fumigated Acreage and Share in Townships with More than 90,250 Pounds of 1,3-D and MBr Applications: 2007



Source: Authors' calculations using PUR data.

Figure 4 reports the share of total fumigated acreage in townships with high total use of 1,3-D and MBr in 2007. As was the case for 2008 (Figure 2), on a percentage basis there is substantial potential for MeI to mitigate the cost of the MBr ban for strawberries, sweet potatoes, potatoes, and raspberries.

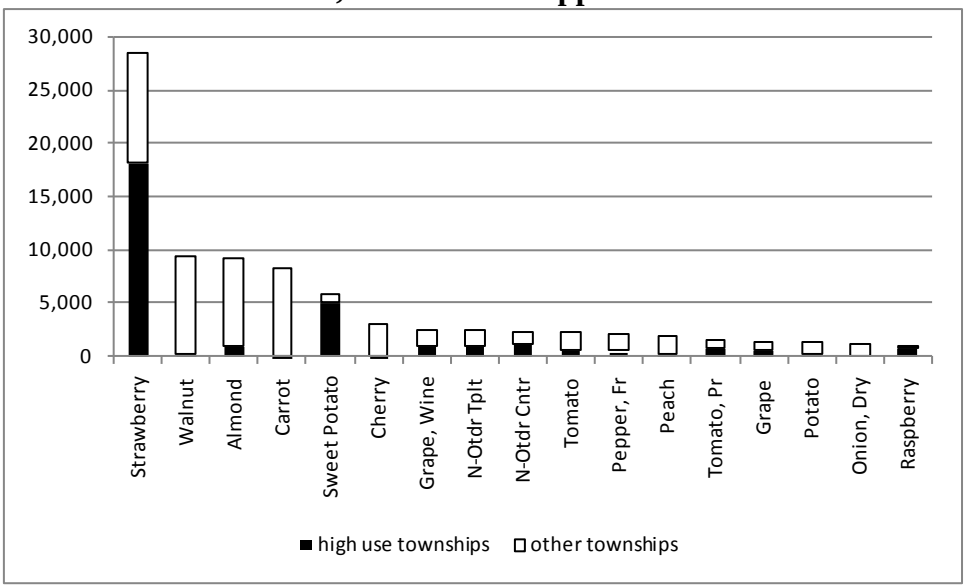
Figure 4. Share of 1,3-D and MBr Use in Townships with More than 90,250 Pounds of 1,3-D and MBr Applications: 2007



Source: Authors' calculations using PUR data.

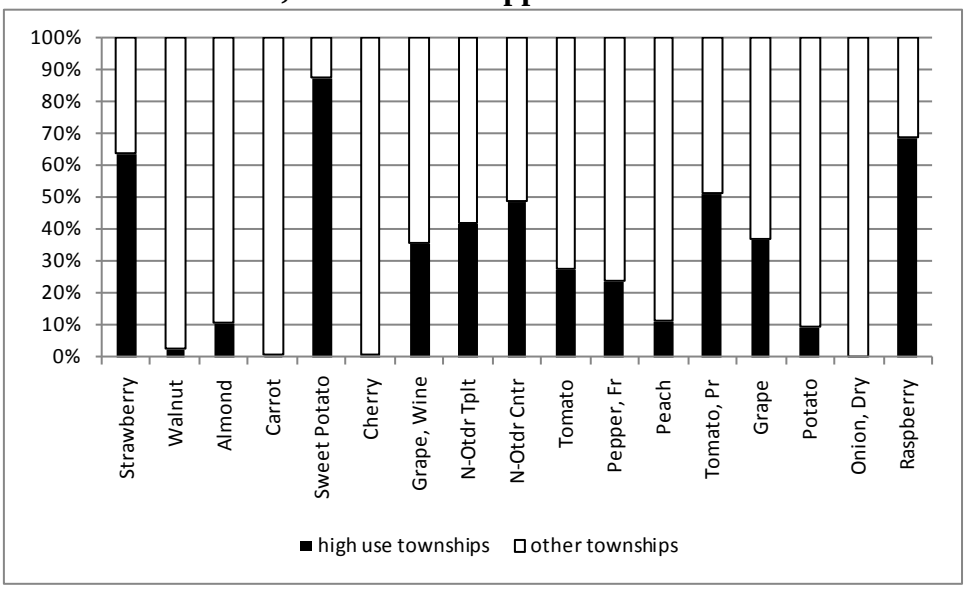
Figures 5 and 6 report the information for 2006 that was presented in Figures 1 and 2 for 2008 and Figures 3 and 4 for 2007. Overall the patterns are consistent with those of the other two years; the primary difference is the relatively greater concentration of nursery fumigation in affected townships in 2006.

Figure 5. Total Fumigated Acreage and Share in Townships with More than 90,250 Pounds of 1,3-D and MBr Applications: 2006



Source: Authors' calculations using PUR data.

Figure 6. Share of 1,3-D and MBr Use in Townships with More than 90,250 Pounds of 1,3-D and MBr Applications: 2006



Source: Authors' calculations using PUR data.

VI. Economic Implications of the Denial of Registration of Methyl Iodide: Specific Pest/Disease-Crop Considerations

The above analysis uses information specified in the 2011 CUE applications to provide a sense of the magnitude of the potential cost to producers of these ten crops if MeI registration was denied, assuming that MeI was a perfect substitute for MBr in terms of technical and economic viability, holding all else constant. In this subsection we discuss briefly specific pest/disease considerations for these crops where MeI would be an additional pest management tool based on efficacy and, possibly, differences in use regulations between it and other fumigants. As noted in the previous discussion, to the extent that MeI is not an efficacious replacement for MBr the cost of its non-registration is reduced for California agriculture. If it is not effective, or if it is not effective at permitted application rates, then there are no benefits to its use.

Almonds and Stonefruit: Peach Replant Disorder and Armillaria Root Rot

Peach replant disorder (PRD) afflicts new almond and stonefruit orchards planted on ground previously in those crops. It results in reduced yields and delayed production. The cause or causes of orchard replant disorder are not all known, and may vary across sites. Many factors have been identified as contributors or possible contributors, including soil characteristics, roots remaining from the previous crop, and various microorganisms, including parasitic nematodes (Bent et al. 2009). Browne et al. (2002) find that the incidence of *Fusarium* and *Cylindrocarpon* is associated with the presence of PRD symptoms. In spite of not knowing the cause of the disorder, producers have been able to use pre-plant soil fumigation with methyl bromide-Pic blends to control this problem (Messenger and Braun 2000).

The presence of roots from the previous planting is associated with the incidence of PRD. One benefit of fumigation with methyl bromide or 1,3-D (Telone) is that they kill roots in the top 1.6 meters of soil (McKenry 1994). In contrast, *methyl isothiocyanate liberators* (MeIT), including metam sodium products, have relatively little ability to kill woody roots (McKenry 1994). Eayre et al. (2000) demonstrated that MeI provided control of the early stages of peach replant disorder equivalent to that provided by MBr for peach trees on Nemaguard rootstock. 0.5% Pic was added to the MBr application, while MeI was applied alone. Two application rates were used in the study, 448 kg/ha, and 392.4 kg/ha, both of which exceed the maximum application rate specified by the EPA. The authors note that additional testing is required to determine the lowest effective application rates. Browne et al. (2009) found that three-year cumulative yields for almonds planted in soil receiving a pre-plant treatment of Mi:Pic 50:50 were not significantly different for those planted in soil receiving a preplant treatment of MBr for either flat fumigation or strip fumigation. Application rates were 400 lbs/treated acre for both treatments.

Alternatives to MBr and MeI include fumigation with 1,3-D-Pic or Pic alone, fallowing, and heat. Trout et al. (2001) found that fallowing for two to three years reduced the severity of PRD and that each additional year further reduced its effects. However, three years of fallowing is not as effective as fumigation. Browne, Connell and Schneider (2006) found that Pic alone provided at least as much control of PRD as MBr did when plant

parasitic nematodes were not present. Duncan, McKenry and Scow (2003) found that peach trees in a replanted orchard grew more rapidly and had larger yields when the orchard had been fumigated prior to planting with MBr-Pic 98:2 than with 1,3-D (Telone II™) or with metam sodium (Vapam™). Browne et al. (2009) found that other fumigants resulted in three-year cumulative almond yields that were not significantly different from MBr and Mi:Pic 50:50, Telone II (340 lbs.treated acre), Telone C25 (535 lbs/treated acre) and chloropicrin (400 lbs/acre). Treating only strips of the field results in treated acres accounting for only 38% of total planted acres, so that realized application rates are noticeably lower than the per treated acre rates. Browne et al. (2004) found that short-term fallowing from April to November had no significant effect on the severity of PRD, although wheat and Sudan grass rotations improved peach seedling growth in a PRD-affected orchard. There is evidence that heating of the soil to fifty degrees Celsius also alleviates the symptoms of PRD (Browne and Kluepfel 2004). Tanner, Reighard and Wells (2006) found that soil solarization leads to peach tree growth that was statistically equivalent to peach trees planted after fumigation with MBr, while tree growth under both treatments was significantly greater than for the untreated control. The use of resistant rootstock is a common tool when managing soil-borne diseases; however, no rootstock appears to be particularly resistant to PRD. Browne, Connell and Schneider (2006) find that the Marianna 2624 rootstock is particularly susceptible.

The pathogen *Armillaria mellea,* which causes Armillaria root rot (also known as oak root fungus) is a soil-borne pathogen that can be controlled using fumigation with MBr-Pic. The pathogen can survive underground for many years on diseased plant material. UC IPM pest management guidelines state that the only treatment is fumigation, with either methyl bromide or sodium tetrathiocarbonate (UC IPM 2009a). "Deep fumigation of almond growers for root rot in the USA" was one of the few specific situations that MBTOC recognized as one for which MBr use did not have an alternative in 2001 (Miller 2001, p. 19). Fumigation may not provide complete eradication. If almonds are planted in infected soil, UC IPM guidelines specify that while all stonefruit rootstocks are susceptible, Marianna 2624 (a plum rootstock) is the most resistant and is the only feasible alternative. (As noted above, however, it may be more susceptible to PRD.)

In Europe, a number of treatments are used commercially as alternatives to MBr for orchard replant (EU 2009b). When nematodes, soilborne fungi and weeds are present, 1,3-D, metam sodium, and dazomet, when registered, are used commercially. Other treatments used commercially include steam, resistant varieties, and grafted plants. Pest-specific treatments, such as fungicides, or herbicides and mulches, are used when not all pests are present.

Cut Flowers: Weed Management in Short Production Cycles with Diverse Crops

Cut flowers and ornamental greens grown in the U.S. include hundreds of species and thousands of varieties (Schneider et al. 2003). These crops are susceptible to a variety of pathogens and differ in their sensitivities to each one. Because so many different crops are grown successively (and in close proximity concurrently), the phytotoxicity of alternative pesticides is also a critical concern. Some flowers are grown on very short production cycles, so that herbicides may carry over into the next cycle and damage the crop.

Preplant fumigation with methyl bromide between crops can provide weed control, including the elimination of volunteer plants from the previous harvest. Given these considerations, a broad spectrum pest and pathogen control agent, such as MBr, is very valuable to flower growers. It provides control without adverse effects on the following crop.

Although no overall conclusions can be drawn for such a diverse industry, a number of studies have examined the efficacy of MeI and other MBr alternatives for various commercial species. Klose and Ajwa (2007) examine the ability of alternative fumigants to reduce weed and fungal populations, improve plant and bulb health, and increase bulb yield in *Ranunculus* and Calla lily production systems. In *Ranunculus* production, the authors conclude that shank injections of Midas 50:50 at 300 lbs/acre manage weeds and pathogens as effectively as MBr plus Pic (67:33) at 350 lbs/acre, while drip applied MBr alternatives (Midas 33:67, Pic, and Inline at 200 lbs/acre) do not. Though shank applied Midas 50:50 does no worse than MBr plus Pic in providing weed and pathogen control in Calla lily production, the authors conclude that drip applications of Midas 33:67 at 200 lbs/acre and InLine at 300 lbs/acre are the most effective MBr alternatives.[15] In trials in ornamental cockscomb production in Florida, Rosskopf et al. (2006) found no significant difference in yields, Fusarium and Pythium forming units, weed counts, or weed weights between MeI:Pic 50/50 and MBr:Pic 98/2 each applied at 200 pounds per acre under metallic film.[16] Studies applying MeI at rates above the maximum permitted under the US registration found that in a carnation production system MeI shank injections provide better weed and pathogen control, in particular with respect to *Fusarium* wilt for which methyl bromide is utilized, than shank injections of MBr (MacDonald and Tjosvold 1997; Ohr et al. 1996b).[17] MacDonald and Tjosvold (1997) also find that ohmic heating of the soil to 50 degrees Celsius provides no worse control of *Fusarium oxysporum*, which are the cause of *Fusarium* wilt, than MeI injections, while Basamid granules (1.22 lb/100 square feet) provide inferior protection. Shank application of MeI appears to be a strong alternative to MBr shank applications in some flower production systems.

In two trials of *Liatris spicata* production, Gerik (2005) evaluates weed and pathogen management, and the resulting plant health and yield, of several drip-applied MBr alternatives.[18] In this study, no alternative provides adequate weed control in terms of the

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[15] The shank injection of Midas (50:50) at 300 lbs/acre is below the maximum application rate specified by the EPA, while the drip application of Midas (33:67) is below the minimum EPA recommended application rate for drip applied Iodomethide of 100 lbs a.i./acre (USEPA 2007).

[16] The 200 lbs/acre application rate of MeI/Pic 50:50 by Rosskpof et al. (2006) is below the maximum application rate.

[17] MacDonald and Tjosvold (1997) apply MBr at 1 lb/100 square feet, MeI at 1 and 1.5 lbs/100 square feet, and Basamid at 1.22 lbs/100 square feet. Ohr et al. (1996b) compared MBr and MeI on a molar equivalent basis as implied by MBr applied at 1 lb/100 square feet (435 lbs/acre).

[18] In a 2002 trial, Gerik (2005) applied the following treatments in addition to a control: Midas with the breakdown of iodomethane (128 kg/ha) plus Pic (337 kg/ha), Pic (337 kg/ha), Inline (369/ha), SEP-100 (112 kg/ha), Vapam (478 kg/ha), Multiguard (454 kg/ha) plus allyl isothiocyanate (152 kg/ha), and Multiguard (337 kg/ha). In a 2003 trial, Gerik (2005) applied the following treatments in addition to a control: iodomethane (213 kg/ha) plus Pic (213 kg/ha), Vapam (356 kg/ha), Pic (355 kg/ha) followed by metam-sodium (356 kg/ha), 1,3-D (153 kg/ha) plus CP (83.6 kg/ha),), 1,3-D (153 kg/ha) plus CP (83.6 kg/ha) followed by Vapam (178 kg/ha), SEP-100 (112 kg/ha), Multiguard (674 kg/ha), Multiguard (337

economic viability of production, and most provide inconsistent management of *F. oxysporum*. The 2003 trial, which includes a treatment of dimethyl disulfide (DMDS) alone at 473 kg/ha and a treatment of DMDS (273 kg/ha) with Pic (237 kg/ha), finds that neither DMDS treatment significantly reduces *Pythium ultimum* nor does DMDS alone significantly increase average plant height from the control. Metam sodium provides better control of stem rot than the other MBr alternatives, though IM and Pic provide significantly better protection than the control. This is unexpected in that Elmore et al. (2007) state that iodomethane provides very good control of fungi, excellent control of nematodes, and excellent control of weeds. Though most fumigants alone provide less effective control of nematodes, fungi, and weeds than MeI, the currently registered alternatives to MBr of drip applied 1,3-D, Pic, and metam-sodium are applied in combination to overcome their individual weaknesses. Iodomethane can also be applied with Pic and metam-sodium (Elmore et al. 2007). Rosskopf et al. (2009) report the results of two studies comparing MeI-Pic 50:50, MeI-Pic 98-2 and DMDS-Pic 79:21 to MBr-Pic 98:2 for delphinium and caladium. In the delphinium trial, there were no significant differences in weeding times, total cuts, or cuts per plant for the season as a whole. In the caladium trial, there were no significant differences across treatments for the total number of weeds per acre, the total number of rogues per acre, or the total weeding time per acre. However, MBr-Pic was the only profitable treatment.

In the EU, cut flowers were one of the six major CUEs for 2006/2007. By the end of 2007, commercial flower production phased out MBr use completely (EU 2009a). Based on historical rates of adoption, about two-thirds of production is treated with steam, on average. Most of the remainder is treated with alternative fumigants, including 1,3-D, Pic, metam sodium and dazomet. A limited amount of production is grown in substrate (EU 2009a). Available treatments vary by country. 1,3-D, Pic, and dazomet are not registered in the Netherlands, for example. Steam, substrates, and metam sodium are used commercially. In Belgium, 1,3-D, metam sodium, and Pic are registered (Pic for open fields only) and used commercially. Dazomet is registered, but not used commercially. Although alternative fumigants are available and are used, about half of Belgian cut flower production uses steam for soil disinfestation (EU 2005).

Grapes: Vineyard Replant Disorder and Oak Root Fungus

Vineyard replant disorder, loosely speaking, refers to a loss of vigor in vines planted to fields previously in vineyards, compared to vines planted in fields with a different previous crop. While the precise cause (or causes) of vineyard replant disorder are unknown, growers have used methyl bromide successfully to control it. One factor often, but not always, associated with vineyard replant disorder is high nematode populations. Schneider, Ajwa and Trout (2006) examined the ability of alternative fumigants to control plant parasitic nematode populations and evaluate vine growth associated with the use of each product in sandy loam soils. The authors conclude that 1,3-D plus Pic, MeI plus Pic, and propargyl bromide are good alternatives to MBr plus Pic for nematode control, but did not control all factors contributing to vineyard replant disorder, as indicated by lower vine

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kg/ha) plus metam sodium (337 kg/ha), DMDS (473 kg/ha), and DMDS (273 kg/ha) plus Pic (237 kg/ha). The amount of iodomethane applied in the 2003 trial is 15 lbs/acre (13 kg/ha) over the maximum application rate of 175 lbs a.i./acre.

growth.[19] In a different trial, Schneider et al. (2003) concluded that MeI, and 1,3-D (Telone II) followed by metam sodium (Vapam) were good alternatives to MBr for managing vineyard replant disease when root-knot nematode and citrus nematode are present, based on the first three years of study after vineyard establishment.[20] The scope for MeI to add additional value will depend on regulatory and economic factors, as well as site-specific variables, such as soil type.

The pathogen *Armillaria mellea*, which causes Armillaria root rot (also known as oak root fungus) is a soil-borne pathogen that can be controlled using fumigation with MBr-Pic. The pathogen can survive underground for many years on diseased plant material. UC IPM pest management guidelines for grapes state that "Preplant chemical fumigation of the soil is the only control for oak root fungus" (UC IPM 2008). Methyl bromide, sodium tetrathiocarbonate, and metam sodium are listed as treatment alternatives. Because grapevine roots are established deep in the soil, a critical requirement for fumigant efficacy is its ability to penetrate deeply and evenly into the field. Water-based applications may have uneven efficacy. Efficacy can be improved by drying the soil prior to fumigation by growing a cover crop, withholding irrigation, or deep tilling. When the fungus is present, diseased or potentially diseased plant materials should be removed from the field prior to fumigation.

Nursery: Nematode-free certification

Like the cut flower industry, the broader nursery industry has a diverse set of products. Consistent with the rest of the analysis, here we focus on the products that qualified for a CUE nomination from the US EPA for 2011. Nursery stock for on-farm use, such as trees and vines intended for transplanting for commercial fruit and nut production, is required under California law to be free of economically important nematodes. Fumigation with MBr is the conventional nursery treatment used to attain nematode-free certification. In some cases, depending on the crop, soil type, and previous history of nematode infestation, 1,3-D products may also be used (CDFA 2009). 1,3-D is efficacious in sandy loam soils, but does not control nematodes to the required five feet in finer soils. A two-year trial examining the efficacy of MeI as a replacement for MBr in producing nematode-free nursery stock in clay loam soil found that 263 kilograms per hectare of MI (at 40-50 centimeters) plus 280-392 kilograms per hectare of Pic (at 60 to 75 centimeters) was required to provide performance equivalent to 448 kilograms of methyl bromide per hectare (McKenry 2005). This MeI application rate exceeds the maximum rate permitted under the US EPA registration. Further research is required in order to identify conditions under which MeI application rates no greater than the registered maximum can provide nematode-free nursery stock.

Rose nursery production was included with fruit and nut nursery in a single CUE application for nursery production. Becker et al. (1998a) found that MeI was able to

[19] Schneider, Ajwa and Trout (2006) conducted trials in 2001 and 2003. The 2001 trial utilizes Midas 50:50 at 448 and 515 kg/ha, which are application rates that exceed the maximum level specified by the EPA. The 2003 trial utilizes Midas 50:50 at 268 and 336 kg/ha, which are levels below this maximum rate.

[20] Schneider et al. (2003) apply iodomethane at 448 kg a.i./ha, which is more than double the maximum application rate, on a vineyard replant field.

control plant parasitic nematodes on rose root tissue remaining in the soil. They conclude that the efficacy of MeI was "consistently superior" to that of MBr. However, their test was conducted at a depth of less than one foot, far shallower than the depths required for California nursery certification.

In the EU, in order to manage plantings affected by nematodes, soilborne fungi and weeds in tree nurseries, growers use dazomet and metam sodium. Mulches and herbicides are also used for weed suppression. Dimethyl disulfide is not currently registered in the U.S. and Europe, but is under consideration (UNEP 2009; ARK 2009). In addition to Europe and the United States, Morocco, Turkey, Israel, South Africa, Argentina, and Mexico are conducting experiments to evaluate it (ALTB 2008; McKown 2008).

Strawberries: Macrophomina phaseolina and Fusarium oxysporum

The 2011 CUE application for strawberries (fruit, open field) cites the reemergence of two soil-borne pathogens as one reason for a critical use exemption, along with use regulations for 1,3-D and Pic. *Macrophomina phaseolina* and *Fusarium oxysporum* are responsible for charcoal rot and Fusarium wilt, respectively.

The pathogens have emerged in fields that have been treated with drip-applied bed fumigation using alternatives to methyl bromide for multiple years. Their emergence does not appear to be fumigant-specific: the treatments have included Inline (1,3-D plus Pic), Inline plus a sequential treatment of Pic, and Inline plus a sequential treatment of metam sodium (Dan Legard, California Strawberry Commission, personal communication 2009). Similarly, recent experiments found that tested fumigant treatments, both shank- and drip-applied, resulted in roughly equivalent plant loss rates (Koike et al. 2009). The prevailing hypothesis among researchers is that the bed-only drip applications allow pathogens to persist in the untreated furrows. Currently experiments with barrier film in a bed-drip fumigation system are being conducted, but the film will not address the role of the furrow as a pathogen reservoir (Dan Legard, California Strawberry Commission, personal communication 2009).

At the present time, potentially efficacious solutions to the management of these pathogens include long-term rotations of infected ground out of strawberries into non-host crops, and flat fumigation. Flat fumigation treats all of the soil in the field, rather than the beds alone. The 2011 CUE application for strawberries proposes an alternative management plan where a field is flat fumigated one year out of three, in order to control pathogens, and bed fumigated the other two years. Ongoing tests suggest that MeI has been as effective as MBr against these pathogens when applied at a sufficiently high rate (Oleg Daugovish, University of California, personal communication, 2009). Due to township caps for 1,3-D and rate restrictions for Pic, the ability of growers to flat fumigate with them at sufficiently high rates for pathogen control is limited in many areas. Non-registration of MeI eliminates an alternative treatment. Ajwa et al. (2001) conclude that at least 300 pounds per acre of MeI:Pic 50/50 are required for strawberry production. MeI:Pic 50/50 applied at 300 lbs/acre is equivalent to 150 lbs of MeI per acre, which is less than the maximum MeI application rate of 175 lbs a.i./acre set by the EPA.

Apart from these pathogens, growers must have effective ways of managing other pests and maintaining yields. Among alternative fumigants, only MeI is as effective as MBr at controlling nutsedge. Other treatments do not prevent population buildup and eventual production losses (Oleg Daugovish, University of California, personal communication, 2009). Daugovish, Mochizuki and Fennimore (2009) found that 300 lbs/acre of broadcast shank-injected MeI-Pic 50:50 controlled yellow nutsedge. Preplant application of S-metolachlor (Dual Magnum™) also provided control. Bed-applied steam and physical barriers (combined with an application of Pic for pathogen control) also provided varying degrees of yellow nutsedge control. However, barriers and steam are quite expensive at this point in time. Thus, while these alternative treatments show some long-term promise, there are no immediate feasible substitutes for MBr for control of yellow nutsedge in strawberries if MeI is not registered in California.

Ultimately, strawberry yields are in part due to the efficacy of pest management techniques. Othman et al. (2009) report strawberry yields from trials in the Watsonville and Salinas areas. The purpose of the trials was to compare the performance of alternative fumigants under retentive tarps to that of a standard MBr-Pic treatment. The preliminary results indicated that a reduced rate of MeI-Pic 33:67 under retentive tarps can provide equivalent yields. Sequential treatments of drip-applied 1,3-D-Pic 62:33 (Inline) and metam potassium (K-Pam) can do so as well. Large-scale grower field trials in Florida found that drip-applied 1,3-D provided yields slightly greater than MBr-Pic 50:50, while MeI-Pic 50:50 resulted in yields equivalent to those with MBr-Pic 50:50. Vapam and PicChlor 60 resulted in lower yields (Noling 2009).

An additional consideration for the California commercial strawberry industry is the effect of the non-registration of MeI on the California strawberry nursery industry. Pathogens can be transferred from the nursery to commercial fields. In the absence of MBr, MeI may be the most efficacious treatment for managing pathogens and disease in a nursery setting. Fennimore et al. (2008) reported that a MeI-Pic treatment produced runner plant yields and weed control equivalent to MBr-Pic, as well as equivalent commercial fruit yields from those transplanted plants, although additional research is required to optimize nursery treatment with MeI-Pic.

In the EU, strawberries were one of the six major CUEs for 2006/2007. By the end of 2006, commercial strawberry production phased out MBr use completely (EU 2009a). Based on historical adoption rates, the majority of production is now grown in soil treated with alternative fumigants, including 1,3-D, Pic, metam sodium, and dazomet. Some is grown in substrate (EU 2009a; EU 2009b). A number of EU states grow strawberries in substrate and do not have registered fumigant alternatives (EU 2005), including Germany, which accounted for at least 10% of EU strawberry production in 2007, and Poland, which accounted for 16% (Figurska and Fritz 2008).

Walnuts: Armillaria Root Rot and nematodes

The pathogen *Armillaria mellea*, which causes Armillaria root rot (also known as oak root fungus) is a soil-borne pathogen that can be controlled using fumigation with MBr-Pic. The pathogen can survive underground for many years on diseased plant material. UC

IPM pest management guidelines for walnuts recommend not planting in infected sites. When planting an infected site, choosing a less susceptible rootstock is recommended, as is fumigating the site before planting. Methyl bromide is the only recommended fumigant in the UC IPM guidelines (UCIPM 2009b).

Nematode control is an important consideration in walnut replant. 1,3-D does not work as effectively as MBr in finer soils, which are often the soil types in which walnuts are planted. Application rate restrictions prevent the use of enough 1,3-D to compensate for its lower efficacy. Given these restrictions and the use of currently available rootstock, yields will be 21% lower for trees planted after a treatment of 1,3-D than after a treatment of MBr, based on studies in which the root lesion nematode was present prior to treatment. However, as is the case for other perennials the replant problem is more complex than a nematode infestation, and many walnut trees fail to produce if replanted in non-fumigated soil (Michael McKenry, University of California, personal communication 2009). This loss estimate is notably higher than the 4% yield loss reported in the 2011 CUE request for orchard replant in open fields. Substituting this estimate into our calculations of changes in gross revenues, assuming perfectly elastic demand for walnuts results in a 2% revenue decrease. This decrease is still relatively small because the requested CUE acreage was a small share of acreage planted in 2007. Given the small acreage request, and because the estimated demand for walnuts is quite inelastic, in the base scenario losses are still not observed due to the non-registration of MeI. Notably, the requested acreage in the 2011 CUE application appears relatively small, given the difficulties of managing nematodes in the finer-textured soils in which a majority of California walnuts are grown. This divergence may be due to the relatively high cost of MBr per acre given current and projected market conditions (Michael McKenry, University of California, personal communication March 2010).

VII. Conclusions and Caveats

The analysis focused on the costs of the denial of MeI registration given *current* regulatory conditions. One important caveat is that we do not address how the cost of the denial of registration would be altered by changes in the regulations governing the use of fumigants other than MBr. There are a large number of possible cases. As a consequence, we do not address one aspect of the potential cost of non-registration: the loss of flexibility to growers by excluding MeI from their set of pest management options in cases where the product that would generally be their preferred alternative would be unavailable due to new regulations, supply problems, or other factors unknown at the present time.

The cost of the denial of registration of MeI products to California agriculture is dependent upon a number of factors. First, MeI may not be as effective as MBr or as other MBr alternatives for specific production systems. In such cases the cost of non-registration is lower, because the use of MeI provides fewer benefits. Technical efficacy is a prerequisite, but it is not the only consideration. The prices of MeI and its substitutes will matter, as will regulations governing their use. Looking forward, it is clear that the cost of non-registration of MeI would be highly dependent on the effects of the 1,3-D

township caps, and on the extent to which crops with CUE applications for 2011 would be able to transition to fumigants other than MeI once the MBr ban is complete. Losses would also depend on demand conditions. If new competitors emerge, then for any reduction in the quantity produced there will be a smaller price response, so that losses in total revenues increase.

Specific crops face certain pest problems that have been challenging to manage without MBr. In many cases MeI has the potential to dominate other alternatives to MBr, although in most of these instances more research is desirable. One exception is the use of MeI to control nematodes for fruit and nut nursery in heavy soils. At the maximum application rate allowed by the EPA, MeI products do not provide sufficient control.

Appendix

Table A1. Data Sources for Gross Revenue Analysis

Data	Crops	Source
2007 California price	All excluding nursery and Cut Flowers	National Agricultural Statistics Service, 2008a
2007 California yield	All excluding nursery and Cut Flowers	National Agricultural Statistics Service, 2008a
2007 California harvested acreage	All excluding nursery and Cut Flowers	National Agricultural Statistics Service, 2008a
	Cut flowers	Census of Agriculture, 2007b
2007 California value of production	Cut flowers	National Agricultural Statistics Service, 2008g
2007 California quantity sold	Cut flowers	National Agricultural Statistics Service, 2008g
2007 planted acreage	Grapes	National Agricultural Statistics Service, 2008d
	Almonds	National Agricultural Statistics Service, 2008c
2007 non-bearing acreage	Stone fruit	Census of Agriculture, 2007a
2007 planted acreage	Dried plums	National Agricultural Statistics Service, 2008e
	Walnuts	National Agricultural Statistics Service, 2008f
start date for harvesting	Fresh plums	Day et al, 2004c
	Peaches	Day et al, 2004a; Hasey et al 2004
	Nectarines	Day et al, 2004b
2011 CUE requested acreage	All excluding nursery, cut flowers, and nursery	USEPA, 2009c
	Cut flower	USEPA, 2009d
	Nursery	USEPA, 2009b
	Strawberries	USEPA, 2009e
Own-price elasticity of demand	Almonds	Green, 1999
	Grapes: raisin and wine	Nuckton (1978)
	Peaches and Nectarines	Henneberry, Piewthongngam, and Qiang (1999)
	Fresh Plums	Lichtenberg, Parker, and Zilberman (1988)
	Dried Plums	Alston, J.M., H.F. Carman, J.A. Chalfant, J.M. Crespi, R.J. Sexton, and R.J. Venner, 1998; Green, 1999
	Fresh Strawberries	Carter, Chalfant and Goodhue, 2004
	Processing Strawberries	Han, 2003
	Walnuts	Russo, Green, and Howitt, 2008

Table A.2 Effect of Denial of MeI Registration on Gross Crop Revenues: CUE Acreage, Estimated Yield Losses from Carpenter, Gianessi and Lynch (2000)

	Yield loss (%)	2007 planted acreage	2007 harvested acreage	2011 CUE acreage	Gross revenues MI available ($ millions)	Gross revenues MI not available ($ millions)	Change (%)
Almond[a]	-14%	21,080	615,000	217	2,154	2,155	0%
Cut flower[b]	-8%	8,126	8,126	716	182	166	-9%
Grape (table)[a]	-7%	2,977	82,000	0	-	-	0%
Grape (raisin)[a]	-7%	906	227,000	106	602	606	1%
Grape (wine)[a]	-15%	9,112	480,000	254	1,854	1,862	0%
Nursery (fruit and nuts)[c]	-15%	0	0	86	165	161	-2%
Nursery (roses)[d]	-18%	0	0	12	36	35	-1%
Stonefruit[a]	-8%	8,913	302,000	1,662	865	872	1%
Strawberry[e]	-22%	35,500	35,500	13,444	1,339	1,289	-4%
Walnuts[a]	-6%	3,185	218,000	274	754	765	2%
TOTAL					7,951	7,912	0%

a. Assumes all acres in full production and affected propoprtionately

b. Acreage from 2007 U.S. Census of Agriculture.

c. 2006 gross revenues from NASS, 2007

d. 2008 gross revenues nursery, rose category from CDFA CAC data 2009

e. Assumes that fresh and processed strawberries revenues proportionate across all acreage

* This analysis does not address the regulatory scenario of fumigants other than MBr being further restricted or the possibility that new pest and/or disease problems may emerge.

Sources: Yield losses from Carpenter, Gianessi and Lynch (2000). See Table A.1 for other sources.

Table A.3. Effect of Denial of MeI Registration on Gross Crop Revenues: All Acreage Impacted Estimated Yield Losses from Carpenter, Gianessi and Lynch (2000)

	Yield loss (%)	2007 harvested acreage	Gross revenues MI available ($ millions)	Gross revenues MI not available ($ millions)	Change (%)
Almond[a]	-14%	615,000	2,154	2,166	1%
Cut flower[b]	-8%	8,126	182	169	-7%
Grape (table)[a]	-7%	82,000	623	619	-1%
Grape (raisin)[a]	-7%	227,000	602	661	10%
Grape (wine)[a]	-15%	480,000	1,854	2,748	48%
Nursery (fruit and nuts)[c]	-15%	0	165	-	-100%
Nursery (roses)[d]	-18%	0	36	-	-100%
Stonefruit[a]	-8%	302,000	865	894	3%
Strawberry[e]	-22%	35,500	1,339	1,185	-11%
Walnuts[a]	-6%	218,000	754	876	16%
TOTAL			8,573	9,318	9%

a. Assumes all acres in full production and affected propoprtionately

b. Acreage from 2007 U.S. Census of Agriculture.

c. 2006 gross revenues from NASS, 2007

d. 2008 gross revenues nursery, rose category from CDFA CAC data 2009

e. Assumes that fresh and processed strawberries revenues proportionate across all acreage

* This analysis does not address the regulatory scenario of fumigants other than MBr being further restricted or the possibility that new pest and/or disease problems may emerge.

Sources: Yield losses from Carpenter, Gianessi and Lynch (2000). See Table A.1 for other sources.

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