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Methyl bromide alternatives for strawberry and tomato pre-plant uses: A meta-analysis

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ABSTRACT

This paper reports the results of a meta-analytic synthesis of information from a large number of horticultural experiments that evaluated the technical feasibility of methyl bromide alternatives as soil fumigants in strawberry (*Fragaria ananassa*) cultivation in California, Florida, and Spain, and in tomato (*Solanum lycopersicum*) cultivation in Florida. A technically feasible alternative is defined as a treatment that provides pest control and crop yields similar to methyl bromide standard fumigation. We selected papers using five criteria, which jointly ensured inclusion of field experiments that contained usable information on at least three treatments—(1) an untreated control, (2) a methyl bromide treatment, and (3) a treatment that is an alternative to methyl bromide treatment. Because of the differences in regional cropping environments, we performed separate meta-analyses for four crop/region combinations. To explore the potential effects of missing information on past fumigation history and pest pressure on the results, we performed two sensitivity analyses, in which the set of usable field experiments included only those experiments in which the improvement of the methyl bromide treatment yield over the control yield was either 15% or 50%. Finally, the definition of several potential alternative chemical treatments took into account differences in formulations and application rates. The results we obtained do not support the technical superiority of methyl bromide over its alternatives. We found several potential alternatives for which we could not reject the hypothesis of technical feasibility, based on the experimental data for strawberries in California and Spain. In particular, the results on strawberry field experiments in California indicate that the estimated effect size of the treatment using 1,3-dichloropropene/chloropicrin 65:35 formulation (applied at the standard rate) was close to the estimated effect size for methyl bromide. The results from strawberry and tomato field experiments in Florida were inconclusive. However, this does not establish that methyl bromide is technically superior to its alternatives. Given the data-related limitations of the analysis, standard protocols are necessary for conducting and reporting the experiments to allow for more meaningful synthesis of the experimental data.

1. Introduction

Methyl bromide is a versatile compound primarily used as a fumigant against insects, weeds, nematodes, and soil-borne pathogens. It has played an important role in U.S. agriculture as a pre-plant soil sterilant. However, in 1992, methyl bromide was listed as an ozone-depleting substance under the Montreal Protocol—an international treaty to protect the ozone layer (UNEP, 2006).

Consequently, pursuant to the obligations under the Montreal Protocol, the production and import of methyl bromide was phased out in the United States starting in January 1, 2005, with some exemptions for critical uses (USEPA, 2011a). A specific use of methyl bromide is deemed critical if two conditions are satisfied. First, a significant market disruption in the absence of methyl bromide is likely. Second, there are no technically and economically feasible alternatives to methyl bromide.

In this paper we define a *technically feasible alternative* as a treatment that provides control for pests similar to methyl bromide

Abbreviations: DP, 1,3-Dichloropropene; FIFRA, Federal Insecticide, Fungicide, and Rodenticide Act; MBTOC, Methyl Bromide Technical Options Committee; MeBr, Methyl bromide; MeI, Methyl iodide; Pic, Chloropicrin; USEPA, United States Environmental Protection Agency; WLS, Weighted Least Squares.

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treatment, resulting in average yields that are at least comparable to yields under methyl bromide treatment. This is the necessary condition for considering an alternative to be technically feasible. Note that additional conditions for establishing technical feasibility also include verification of comparability in other yield attributes, such as fruit quality or variation in yields. This paper compares the average yield magnitudes, which is the only yield attribute for which data are available. Other considerations such as the environmental and public health impact of the alternatives are beyond the scope of this analysis.

In anticipation of the methyl bromide phase-out and to support requests for critical use exemptions, various researchers conducted experimental studies to assess the technical efficacy of the available alternatives in the United States and other countries. As a result there is a large volume of published and unpublished papers that examine the efficacy of methyl bromide alternatives, particularly in tomato (*Solanum lycopersicum*) and strawberry (*Fragaria ananassa*) production. These two crops accounted for the largest share of methyl bromide use in U.S. agriculture before the phase-out (USDA, 2000). After an independent technical and economic review of this literature and critical use exemption requests from producers, the United States Environmental Protection Agency (USEPA) determined that some uses of methyl bromide in pre-plant crops are critical—notably, methyl bromide use in strawberry and tomato production. Since 2006, USEPA has recommended methyl bromide use for strawberries and tomatoes for critical use exemption from the phase-out according to the framework for allocating these exemptions (USEPA, 2011b).

Olkin and Shaw (1995) were the first to propose the use of meta-analysis as an approach to synthesize the results from a large number of individual horticultural field experiments that examine the same question. To date, several meta-analytic studies have examined the efficacy of methyl bromide alternatives (Shaw and Larson, 1999; Larson and Shaw, 2000; Porter et al., 2006).

In one meta-analysis, Shaw and Larson (1999) examined the technical efficacy of chloropicrin; 1,3-dichloropropene; 1,3-dichloropropene/chloropicrin formulation; and metam sodium as possible alternatives to methyl bromide for strawberry production in California. The authors concluded that none of these four treatments was a substitute for methyl bromide in this growing environment. In a related research synthesis, Larson and Shaw (2000) studied the comparative efficacy of methyl bromide; chloropicrin; and 1,3-dichloropropene treatments in strawberry runner plant production. They found that the methyl bromide standard formulation was more effective than chloropicrin alone and that one 1,3-dichloropropene/chloropicrin formulation was as effective as methyl bromide. However, the results of these nursery field experiments are not directly relevant to the current analysis, because this analysis focuses on assessing the impact of fumigants on strawberry yields, which nursery field experiments do not measure.

Results of a more recent meta-analysis of a large number of trials by the Methyl Bromide Technical Options Committee (MBTOC), which is the technical body advising parties to the Montreal Protocol, indicated that there were technical alternatives to methyl bromide for strawberry and tomato production in regions applying for critical use exemptions; namely, Europe, North America, and Australasia (Porter et al., 2006). Specifically, the MBTOC identified chloropicrin, a 1,3-dichloropropene/chloropicrin formulation alone and its combination with metam sodium, as well as a methyl iodide/chloropicrin formulation, as potential technical substitutes for methyl bromide in strawberry production. In tomato production, the MBTOC proposed chloropicrin combined with metam sodium, a 1,3-dichloropropene/chloropicrin formulation in combination with a range of herbicides, and a methyl iodide/chloropicrin formulation as technical substitutes for methyl bromide.

The MBTOC meta-analysis relied on an assumption that researchers in all examined studies used “effective dosage rates for alternatives” as well as “applied treatments using best practice” and did not have a selection criterion that ensured that field experiments used appropriate application rates (Porter et al., 2006, pp. 13–14). Consequently, it is possible that this meta-analysis included data from a number of unreliable experiments with inappropriate application rates. In addition, the results were not specific to a particular growing environment (e.g., California), which makes it difficult to ascertain whether the MBTOC conclusions were appropriate in the context of U.S. agriculture.

This paper extends the existing literature on the technical efficacy of potential methyl bromide alternatives for strawberry and tomato production in several important ways:

(1) Similar to the MBTOC study (Porter et al., 2006), we used meta-analytic methods to synthesize a large number of horticultural field experiments designed to evaluate the technical feasibility of methyl bromide alternatives for tomato and strawberry production in several regions where these crops are important. Because of differences in regional cropping environments, we performed separate meta-analyses by region for this paper.
(2) Given that detailed information about the experimental environment was unknown for most studies (e.g., pest pressure and past methyl bromide fumigation history), we carried out two sensitivity analyses on field experiments for which the improvement in methyl bromide treatment yield over the untreated control was above two thresholds: 15% and 50%.
(3) The definition of several potential alternative chemical treatments took into account differences in both formulations and application rates. We did this for two reasons. First, we analyzed different formulations of chemical treatments separately because they are distinct products designed for specific growing environments (particularly, different pest pressure). Second, these formulations have different U.S. product labels and corresponding application rates. Treatment application at rates above the maximum rate (on a product label) is not permitted in the United States, whereas treatment application at rates below the minimum rate may be ineffective.

Our results do not provide overwhelming evidence to support the claim of methyl bromide’s technical superiority, because we found several potential alternatives for which we could not reject the hypothesis of technical feasibility.

2. Material and methods

The literature search for this meta-analysis encompassed all studies on the efficacy (measured by changes in yield) of methyl bromide and any of its alternatives in tomato and strawberry production, without limiting the year or country of origin of the study.

We collected both published and unpublished studies from a number of sources that included proceedings of two methyl bromide alternatives conferences (the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions and the International Conference on Alternatives to Methyl Bromide); working papers from the University of Florida and the University of California system; California Strawberry Commission pink sheets; unpublished papers compiled by SciReg Inc.; and electronic databases of peer-reviewed journals (EBSCO, Agricola, and Sciencedirect). This literature search yielded 491 relevant studies. Fig. 1 shows the flow diagram of the study selection process. There were 116 studies that satisfied the selection criteria. Of these, 78 studies were ultimately used in the analysis. They included 14 journal publications, 6 proceedings papers, 24 conference papers, 1