METHODS TO REDUCE SOIL FUMIGANT USE IN CALIFORNIA: A META-ANALYSIS OF EFFICACY

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I. The quest for effective methods which reduce the use of fumigants

- Methyl bromide has been largely replaced worldwide by the first 4 "Fumigant controls" listed in Table 1.
- Growers and regulators around the world are facing the same issues with these 4 fumigants—mainly their toxicity and accidental exposure of field workers and the public.
- In the past decade, a global research effort has focused on methods ("Primary non-fumigant methods" in Table 1) which reduce the use of the 4 replacement fumigants.
- Globally, hundreds of studies have tested these methods on California's highest fumigant use crops ("Key CA crops" in Table 1).

II. But do these methods (e.g., soil solarization) work in California?

The ability of these methods to reduce pest/disease pressure and maintain yields comparable to fumigant controls, is highly variable among reported studies.

This variability makes it tough to know, for example, whether solarization would effectively protect grapes transplanted in El Dorado County compared to the much hotter San Joaquin County.

Meta-analysis is a statistically-robust method for quantifying the effects of experimental variables on measured outcomes **and** sources of variation between studies which use the same methodology.

III. Meta-analysis: A powerful tool, when used properly

Meta-analysis has been used extensively for decades to overcome two of the main limitations inherent in experimental systems in the fields of medicine and psychology (which also apply to agricultural field studies):

- The lack of complete experimental control over experimental subjects
- The limited scope of individual experiments, both temporally and geographically, due to costs and logistical considerations.

Table 2 lists main advantages and disadvantages of meta-analysis versus running more experiments; and **Table 3** lists advantages of meta-analysis over a textual literature review.

Meta-analysis is increasingly being applied to agro-ecological systems (1). A meta-analysis of methyl bromide alternatives in 2006 (2), focused on the 4 replacement fumigants since very few studies on the non-fumigant methods to be analyzed here were done before 2005.

IV. Steps in performing a meta-analysis in general, and current status of our meta-analysis of the efficacy of fumigant use reducing methods

1. Determine criteria for including studies in the meta-analysis
    a. for our meta-analysis, see Table 4.
2. Literature search and, to minimize publication bias (see Table 3 footnote), survey of researchers for relevant unpublished studies.
    a. For our meta-analysis, very broad queries of CAB Abstracts, BIOSIS Previews, Web of Science, Google Scholar, past MeBr Alternative Conference proceedings (of course), and many other sources **have yielded 683 candidate publications for the meta-analysis** out of over 5000 retrieved database records.
    b. We are very interested in obtaining unpublished data sets from researchers studying the efficacy of anaerobic soil disinfestation, soil solarization, steam/heat treatment, soil-less culture, crop rotation, biological control or other non-fumigant methods in strawberries, tomatoes or other crops listed in Table 1. If you have such data, please contact: **mgrien@ucdavis.edu**
3. Design a data entry sheet
4. Screen for study quality, rejecting studies which lack important details in methodology or data presentation, and noting those which report data from the same study (to avoid counting the same data twice)
5. Data entry—the most time-consuming step (10,000s of data points!)
    a. **We are currently processing the 683 candidate publications through steps 4 and 5 simultaneously.**
6. Determine which experimental datasets can be combined based on similarities in experimental design and experimental conditions
7. Meta-analysis of data—explained in greater detail on the poster

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References

(1) Porter, I.J.; et al. (2006) Validating the yield performance of alternatives to methyl bromide for pre-plant fumigation. UNEP: Nairobi. 97 pp.

(2) Koricheva, J. et al. (eds) (2013) Handbook of Meta-Analysis in Ecology and Evolution. Princeton University Press. 498 pp.

(3) Berman, N.G.; Parker, R.A. (2002) Meta-analysis: Neither quick nor easy. BMC Medical Research Methodology 2: 10

Table 1. Parameters of studies to include in the meta-analysis.

Fumigant controls	Primary non-fumigant methods	Key CA crops
Chloropicrin	Anaerobic soil disinfestation	Strawberries
1,3-Dichloropropene	Soil solarization/biofumigation	Tomatoes
Metam sodium	Non-fumigant chemicals	Potatoes
Metam potassium	Steam/heat treatment	Carrots
Methyl bromide	Soil-less culture	Grapes
Methyl iodide (MeI)*	Crop rotation	Almonds
	Resistant varietals	Walnuts
	Biological control agents	

*While off the market, MeI is a positive control in some studies.

Table 2. Main advantages and disadvantages of meta-analysis compared with experimental systems (adapted from Jay Rosenheim's list of comparisons between experimental systems & ecoinformatics—slides 5-6 of: http://agis.ucdavis.edu/pur/pdf/2013/PUR%20workgroup%202013%20Rosenheim.pdf)

Features	Experimental	Meta-analysis
Proof of causality	√	
Flexibility of design	√	
Between-replicate variation	√	
Data uniformity, completeness	√	
Data insensitivity	√	
Spatial and temporal scales		√
Results applicable to broad range of farming situations		√
Ability to evaluate many variables at once		√
Ability to translate results into broadly applicable recommendations		√
Statistical power		√
Ability to resolve controversial issues[1]		√

√ indicates which system is strongest for the feature

[1]For example, dozens of published studies may provide conflicting conclusions on the efficacy of a particular predator/ pest/crop system (e.g., coccinellid beetles and aphids on tomatoes). Performing one more (yet another) field study of this system is unlikely to resolve the issue by negating all the existing conflicting data. However, a meta-analysis of dozens of studies can include those from different climate types, for example, to study the effect of climatic variables on reported success rates.

Table 3. Advantages of meta-analysis over a textual literature review.

Textual literature review	Meta-analysis
Subjective selection of studies to include (may bias conclusions in favor of one position)	Objective, systematic, and inclusive selection of studies
Often influenced by publication bias[1] since typically include only published studies	Minimizes publication bias (as much as possible) by considering as many relevant unpublished studies as possible
Data analysis typically qualitative ("vote counting")	Statistically rigorous, quantitative data analysis
Yields no new data, only interprets existing data	Yields original data—statistically combines data across studies w/ similar experimental design to obtain universal effect sizes and variance
Variation between studies dealt with only qualitatively	Modeling variation between studies may reveal the sensitivity of effect size to individual experimental parameters
Tends to focus on "Results" and considers the weight of evidence by "vote counting"	Tends to focus on "Methods" as much as "Results" and considers the weight of evidence statistically

[1]"Publication bias" is the tendency of journals to publish only "positive results." It leads to an over-estimation of true effect sizes because experiments with negligible or no effect are seldom published, and therefore not included in narrative literature reviews. However, such studies often make it to the "conference presentation" or "thesis" stage. One goal of meta-analysis is to include such "unpublished" studies by contacting authors to obtain datasets.

Table 4. Criteria for including articles in our meta-analysis.

1. Published in 2003-2013
2. Field or greenhouse study
3. Includes a fumigant control
4. Compares yield or pest/pathogen suppression data obtained with one of the methods listed in Table 1 column "Primary non-fumigant methods" to that obtained with a fumigant control under the same conditions
5. Makes the above comparison using one of the crops listed in Table 1, column "Key CA crops" or one of the major pests/pathogens of those crops which are currently targeted by fumigants in California
6. Reports comparison data as either yield or some measure of pest/pathogen suppression