

USDA
AGRICULTURAL RESEARCH SERVICE

NATIONAL PROGRAM 308
METHYL BROMIDE ALTERNATIVES
Action Plan 2007 – 2012



United States Department of Agriculture
Research, Education, and Economics
AGRICULTURAL RESEARCH SERVICE

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ACTION PLAN
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Goal: National Program 308, *Methyl Bromide Alternatives*, supports research in soilborne plant pathology, post-harvest entomology, plant pathology, and plant physiology in a national research program to develop alternatives to the agricultural uses of methyl bromide, a widely used fumigant and known ozone depletor. Methyl bromide is a highly efficacious fumigant that has for a number of decades been used on more than 100 crops, in forest and ornamental nurseries, and on wood products to control insects, nematodes, weeds, and pathogens, and thus, has been critical to important segments of U.S. agriculture. The research has focused on strawberry, pepper, tomato, perennial replant, field-grown propagative material, and ornamental and cut flower cropping systems for pre-plant methyl bromide use, and for processing and storage structures, fresh and durable commodities, and quarantine for post-harvest use. The ultimate goal of this National Program is to make available to the U.S. agriculture community environmentally acceptable, practical, economically feasible, and sustainable alternatives to methyl bromide.

At their November 1992 meeting, the Parties to the Montreal Protocol (Parties) listed methyl bromide as a stratospheric ozone depletor and agreed to freeze production levels for developed countries at 1991 levels in 1995. Except for some post-harvest and quarantine pre-shipment (QPS) uses and Critical Use Exemptions (CUEs) granted on a case-by-case yearly basis, complete phase-out of manufacturing and importation occurred January 1, 2005, in developed countries. Developing countries were given until 2015 to phase out methyl bromide use. No decision was taken to regulate QPS uses, and methyl bromide can still be used for those purposes as needed.

Other uses require a CUE, granted by the Parties when an effective, practical, economical alternative is not available to replace methyl bromide, and significant market disruption would occur if methyl bromide could not be used. Since 1993, considerable Federal, state, and private funds have been spent conducting research on alternatives to allow the phase-out to occur. Consequently, by 2006, there have been significant reductions in methyl bromide use compared to the 1991 baseline, but for some uses and some circumstances adequate alternatives, available and registered, have not been identified, developed, and marketed. CUEs were granted to the United States and other developed countries in 2005-2007 for a variety of commodities, both pre-plant and post-harvest, including tomatoes, strawberries, peppers, eggplant, floriculture, perennial field nurseries, strawberry nurseries, perennial replants, flour mills, bakeries, food processors, traditional ham curing, and historical artifacts. In 2006, additional CUEs are under consideration for calendar year 2008. CUEs, when granted, are often limited to specific small portions of the commodity with particularly difficult circumstances that make available alternatives not usable or ineffective.

In addition to the methyl bromide uses allowed with CUEs under the 2005 ban, ARS conducts research to find alternatives for QPS use of methyl bromide currently not banned by the Montreal Protocol ban. ARS understands that reliance on one particular fumigant for such an

important use is not prudent and is committed to finding methyl bromide alternatives to avoid possible disruption of trade in the future. Effective quarantine treatments are very important to maintaining international trade and preventing spread of quarantine pests that can devastate a country's agricultural and natural resource assets. On the export side, methyl bromide is important to maintaining many markets abroad for U.S.-produced commodities where quarantine issues prevent shipment without methyl bromide fumigation. On the import side, many commodities shipped to the United States enter only after mandatory methyl bromide fumigation (required by regulation). Even when there is no mandatory fumigation, commodities may still be fumigated if inspections reveal quarantined pests. Furthermore, methyl bromide fumigation of solid wood packaging material has become more prevalent to stem the spread of exotic forest pests. Recent international standards mandate use of methyl bromide or heat for solid wood packaging used in international trade.

The U.S. Department of Agriculture (USDA) has vigorously responded to the methyl bromide challenge. It has brought together agricultural and forestry leaders from private industry, academia, state governments, and the federal government to assess the problem, formulate priorities, and implement research directed at providing solutions to the problems predicted by the methyl bromide phase-out. The Agricultural Research Service (ARS) was assigned the lead in this process and has emphasized the importance of research on alternatives to methyl bromide by redirecting funds from other programs to this area, and by implementing new research projects funded by additional Congressional appropriations.

Even prior to the Montreal Protocol decision in 1992, many ARS research projects addressed methyl bromide issues. The banning of ethylene dibromide in the mid-1980's for post-harvest treatments left U.S. agriculture with only two post-harvest fumigants: methyl bromide and phosphine. Methyl bromide is the only fumigant certified for certain quarantine and pre-shipment trade uses. Thus, it was prudent to carry on a continuing program of research that would lead to possible alternatives to the approved fumigants as a critical safeguard for U.S. trade in a number of commodity areas. In some cases, methyl bromide, while effective for quarantine security, caused loss of product quality, such as surface burn on citrus. Some commodities, such as mangoes, papayas, guavas, and other tropical products, could not be marketed in the United States because of quarantine restrictions and unacceptable product damage caused by treatment with methyl bromide. Thus, development of alternative, non-damaging quarantine treatments was on-going. In fiscal year (FY) 1993, about 75 percent of the ARS research program for methyl bromide replacement was targeted to developing alternatives to methyl bromide for post-harvest commodity treatment. This ratio was viewed by ARS as out of balance and was addressed by allocating 75 percent of all new funding allocations and project redirections to pre-plant soil fumigation alternative issues. ARS research now is weighted towards pre-plant needs where most of the CUE-authorized methyl bromide is used. ARS also continues to allocate significant research resources toward QPS uses to support the USDA Animal and Plant Health Inspection Service (APHIS) and U.S. agriculture to facilitate trade and protect the U.S. homeland from exotic pests.

Since 1993, ARS has worked closely with the U.S. Environmental Protection Agency (EPA) to track and facilitate adoption of alternatives to methyl bromide. In 1995, the USDA Secretary and the EPA Administrator formed the Methyl Bromide Alternatives Working Group to assist in

this effort. USDA representatives participate in a variety of significant national and international forums that provide venues for interactions with growers and private industry on issues related to methyl bromide. For example, three USDA employees sit on the Methyl Bromide Technical Options Committee, an international committee that was formed under the auspices of the United Nations Environment Programme. Moreover, the USDA has co-sponsored, with the Crop Protection Coalition and the EPA, annual comprehensive conferences on methyl bromide alternatives and emissions reduction. These conferences provide an opportunity for technical exchange and interactions among USDA, growers, and private industry on significant issues related to methyl bromide research.

While the problem of finding suitable, effective, and environmentally acceptable alternatives to methyl bromide has not been completely solved, progress has been made. Alternative chemistries (iodomethane, propargyl bromide, 1,3-dichloropropene, chloropicrin, phosphonates, iodine-based products, 2-bromoethanol, metam sodium, sodium azide, propylene oxide, furfural, and others) have been evaluated in annual, perennial, and nursery cropping systems. Alternative application technologies (drip fumigation, Yetter Avenger deep placement coultter system, under-bed fumigator, modified power tiller, and others) have been developed. Non-chemical control strategies (biological control, host resistance, cover crops, crop rotation, fallow periods, and solarization) were assessed. ARS research played a significant role in the transition of approximately 50 percentage of California strawberry production from methyl bromide to alternatives by 2006, largely due to improved technologies for drip application of fumigants. However, growers' experience also showed the rates of efficacy on some alternative treatments declined in each successive year, making the need for additional multi-year evaluations of methyl bromide alternatives a necessity.

There have been significant declines in the use of methyl bromide for post-harvest uses over the last few years especially for durable commodities, such as raisins and, in some cases, nuts, where the need for quick treatment is not so important. Significant research needs remain for commodities that are marketed soon after harvest to meet critical holiday markets. Some alternatives are perceived as working too slowly to be acceptable to the industry and other more rapid treatments have regulatory and efficacy issues that preclude full adoption by the industry. A new alternative recently became available for structural fumigation, but industry has been very slow to adopt it because of outstanding efficacy and dosage issues that need to be clarified by additional research. Further research into integrated pest management (IPM) approaches can help reduce reliance on methyl bromide for structural fumigation and augment the efficacy of alternative fumigants. Alternative treatments for quarantine use were developed for a number of commodities that rely on methyl bromide for export clearance. These involve heat and modified atmospheres – alone or in combination, irradiation, cold, and alternative fumigants, but still there is great reliance on methyl bromide as the main tool to clear quarantined commodities for U.S. export to other countries and to treat quarantined commodities being imported into the United States.

The Methyl Bromide Alternatives National Program (NP 308) is comprised of two components:

- Pre-plant Soil Fumigation Alternatives; and
- Post-Harvest Alternatives.

Relationship of This National Program to the ARS Strategic Plan: Outputs of NP 308 research support the "Actionable Strategies" associated with the performance measures shown below from the *ARS Strategic Plan for 2003- 2007*, Objective 5.2: *Provide Science-Based Knowledge and Education to Improve Quality and Management of Soil, Air, and Water Resources.*

Performance Measure 5.2.3: *Develop approaches that mitigate the impact of poor air quality on crop production and provide scientific information and technology to maintain or enhance crop and animal production while controlling emissions that reduce or destroy the ozone layer.*

Component 1: Pre-plant Soil Fumigation Alternatives

Pre-plant soil fumigation with methyl bromide is used to control soilborne pathogens, nematodes, weeds, and diseases of unknown causes for many high-value crops including strawberries, tomatoes, peppers, ornamentals, field-grown propagative materials, grapes, and fruit and nut trees. The phasing out of methyl bromide raises two major issues. The first is to quickly find effective, economically feasible, alternative control strategies. Methyl bromide can be used effectively against a broad spectrum of soil pests over a range of soil types, temperature, and moistures resulting in greater flexibility and less risk of loss than is possible with many other soil management strategies. Most, if not all, potential methyl bromide alternative fumigants have a narrower spectrum of activity and/or a more restricted range of optimal soil conditions. As a result, growers will need to use their experience, soil analyses, crop consultants, or other resources to select an alternative effective against the pest(s) in their fields under the soil conditions found in that field, that is also economically feasible and environmentally acceptable. ARS is addressing this first issue by evaluating new chemicals, host resistance and grafting to resistant rootstocks, soil amendments, biological control agents, mulches, crop rotation, fallow, suppressive soils, and new application technologies to deliver biological and chemical alternatives. The second issue is to increase understanding of the pathogens and soil factors limiting crop production. A long-term, integrated management approach requires a thorough understanding of biological, chemical, and physical soil factors, their interactions, and their spatial variability, and will include chemical, genetic, biological, and cultural management strategies. The short-term solutions to methyl bromide alternatives are stepping stones to the longer term research into integrated management systems without methyl bromide for crops that currently use methyl bromide.

Problem Statement 1A: Development of New Technologies for Alternatives and Integration into Commercial Crop Production Systems Currently Dependent upon Methyl Bromide Soil Fumigation.

Four distinct crop production sectors currently rely on methyl bromide soil fumigation: Plasticsulture annual fruit and vegetable crops; Annual ornamental crops; Perennial crops; and Nursery crops. Each of these sectors has different economic thresholds and different pest complexes to address. For each sector, an integrated production system must consider all the soil biological, physical, and chemical factors and must be tailored to meet the specific needs of each commodity in several different geographical regions. Currently available chemical alternatives have varying degrees of potential for negative environmental impacts related to worker exposure, air and water quality, and long-term exposure of surrounding populations. Potential negative

impacts have already limited the use of some chemicals through buffer zone requirements and township cap regulations. In addition, all of the existing alternative chemicals have limitations in terms of the spectrum of pests and weeds that they control.

New approaches are needed to supplement the currently-registered products as well as to provide alternative tools for the future. New chemistries and new application technologies to optimize efficacy of new and currently available chemicals need to be evaluated under field conditions and over multiple cropping cycles. In addition, non-chemical management strategies need to be developed and evaluated within the framework of existing commercial production systems. Integration of nematode- and pathogen-resistant germplasm into commercially acceptable varieties for all sectors, as well as grafting desirable scions onto pest and pathogen resistant rootstocks, would increase the potential for pest and pathogen control. Development of new biological control agents and improvements in the efficacy and applicability of existing biological agents are needed. A greater understanding of the mechanisms of activity and the genetic basis of control will enhance the usefulness of biological control agents. Cultural practices, such as fallowing, can also be a useful component in an integrated management production system where economics allow. Each of these tactics can be improved through the integration of multiple compatible approaches into long-term, sustainable systems. All new management strategies, whether single tactic or an integration of multiple strategies, need to be evaluated under commercial field conditions with significant pest and pathogen pressure over multiple cropping cycles to determine whether they constitute technically and economically feasible alternatives to methyl bromide.

Research Needs

Data regarding efficacy, spectrum of activity, and feasibility of use are needed for new chemicals. Research is needed to enhance the selection of desirable traits among existing biological control agents to improve efficacy and commercial acceptability. New populations of biological agents should be investigated and screened for suitability for use in integrated systems, either as individual isolates or as beneficial populations arising from whole-farm management practices. Additional research on germplasm development and selection can better address hard-to-control pests. Cultural management tools, such as cover crops, soil amendments, crop rotations, and alternative mulches should be evaluated for their potential contributions to multi-component alternative production systems. Characterizing the impact that all of these alternative approaches have on soil biological communities will allow for optimization of systems. A more thorough understanding of how system components work will allow for more effective coupling of pest control measures. Knowledge of each alternative system's efficacy against target pests, ease of implementation, and required modifications to existing practices are necessary. Ultimately, the impact of alternative systems on crop yield and profitability must be compared to methyl bromide or acceptable to the producer. In the case of systems that include crop rotations or double-cropping, this information must be gathered for all crops included in the production plan. On-farm research trials that involve the cooperation of researchers, growers, farm managers, contract fumigators, and county extension agents and specialists are critical for determining the applicability of alternative production systems to individual users of methyl bromide.

Anticipated Products:

- New chemicals controlling targeted pests.
- Additional commercially viable biological control agents.
- New germplasm lines with improved resistance to pests and acceptable horticultural characteristics.
- Multi-component management systems that address current and emerging pest problems to keep production systems viable and avoid the potential for future dependence on any single chemical pesticide.
- Knowledge base containing performance measures for various target pests and cropping system conditions comparing newly developed approaches or integrated systems with methyl bromide soil fumigation.

Potential Benefits:

- Reduction in the number of methyl bromide CUE applications or the total amount of methyl bromide requested under CUEs.
- An over-all reduced need for pre-plant fumigation via implementation of IPM-based systems.
- Integration of new chemicals, improved biological agents, and appropriate cultural management tools will minimize adverse environmental effects associated with the use of methyl bromide and other soil fumigants.
- An integrated approach will allow for the continued profitable production of the high-value crops currently dependent on methyl bromide soil fumigation.
- Growers remain competitive in the global market.
- Improved efficacy of biological control agents.

Problem Statement 1B: Pest Management Systems to Optimize Efficacy of Pesticides and Reduce Harmful Emissions.

Currently registered, chemically based alternative systems face existing and potential problems associated with township use limitations, emission control, and buffer zone restrictions. In addition, although a substantial amount of work has been done with many of the alternative fumigants, the lack of consistent performance across crops, pests, regions, soil types, and soil water content reduces the likelihood of their adoption. Factors impacting efficacy are poorly characterized. New materials that are nearing registration have not been adequately tested in all crops and regions and over multiple cropping cycles.

Research Needs

Performance of alternative fumigants needs to be evaluated in two ways: 1) Under controlled laboratory or small plot conditions where relationships among fumigant concentration, exposure time, environmental conditions, pest species, and growth stage need to be determined; and 2) In the field, where factors such as chemical distribution, pest population density and distribution, pest interactions, and environmental and soil conditions influence efficacy. Knowledge on emission characteristics and efforts to control emissions through fumigant application technology needs to be expanded.

Anticipated Products:

- Improved understanding of the impact of fumigant concentration, movement through soil, pest exposure time, soil temperature, soil moisture, soil type, and pest species on fumigant efficacy.
- Improved fumigant application methods to reduce emissions and enhance efficacy with less potential for negative environmental impacts.

Potential Benefits:

- Reduced use of methyl bromide due to increased adoption of chemical alternatives with improved efficacy gained through a better understanding of the factors affecting fumigant dispersion and performance.
- Reduced use of methyl bromide, as well as alternative fumigants, due to reduced application rates resulting from implementation of emission-reducing technologies and approaches.
- Fewer negative off-site environmental impacts.

Problem Statement 1C: Identification and Mitigation of Emerging Problems.

As growers move away from the traditional methyl bromide:chloropicrin soil fumigation treatments, shifts in soil biological communities will occur, as well as changes in soil physical and chemical characteristics. These shifts have the potential to be either beneficial or detrimental. Pests and weeds not previously of concern are likely to emerge as problems. Systems that encourage more diverse microbial communities that are resilient to disturbance could lead to the suppression of some soilborne pests. The implications of shifts in pest populations and emergence of new pest problems will need to be anticipated, identified, and evaluated quickly. The potential impact of existing and emerging pests and weeds on crop production will need to be quantified for all crops in production systems using rotations, cover crops, double crop strategies, pesticides with a narrower spectrum of activity than methyl bromide, and/or resistant germplasm.

Research Needs

The impact of alternative systems on beneficial and detrimental soilborne communities will need to be assessed. Increased knowledge of soil biology, particularly in suppressive systems, will be required. New methods for the identification of current and emerging pests need to be developed. The identification of emerging issues will rely on continued enhancement of our understanding of microbial taxonomic classifications as supported by research in National Program 303 – Plant Diseases, and other related National Programs. Pest population thresholds that impact crop production will need to be quantified. Rapid identification of emerging pest problems will allow for modifications in component pest management system development.

Anticipated Products:

- New diagnostic and detection tools.
- Timely identification of emerging pest problems.
- Quantification of pest impacts on crop production.

Potential Benefits:

- Accurate detection and diagnostic tools for current and emerging pests will foster optimal management decisions.
- Quantification of pest impacts will allow for more cost-effective crop management decision-making.
- Profitable continuation of high-value cropping systems in the face of emerging pests without dependence on methyl bromide

Problem statement 1D: Lack of Commercial Scale Demonstrations of the Technical and Economic Feasibility of Currently Available Alternatives.

Over the past 10 years, extensive research conducted by ARS and other USDA agencies, land grant universities, and private industry produced several technically feasible methyl bromide alternatives for some crops. However, widespread industry adoption of these alternatives has not occurred for several reasons, including, but not limited to: Variability in performance of the alternatives coupled with incomplete knowledge on sources of the variation and means to manage it; The need to combine many of the alternatives with supplementary herbicides or other inputs for acceptable efficacy; Inadequate regionally coordinated efforts to transfer the alternative technologies expeditiously, and; Regulatory restrictions, especially in California, that limit uses of the alternatives. Establishment by ARS of an Area-wide Pest Management Project for methyl bromide alternatives that addresses specific constraints hindering adoption in the Pacific West and South Atlantic areas will address this problem.

Research Needs

Establishment of large-scale, replicated field trials containing paired comparisons of methyl bromide to currently available alternatives will provide commercial growers with the knowledge and experience to successfully use methyl bromide alternatives. Data are needed over a range of biological, environmental, chemical, physical, operational, and economic variables associated with implementation of methyl bromide alternatives. Key variables and their critical values responsible for consistent and effective pest control with methyl bromide alternatives are not known for all management strategies, especially combinations of strategies. New technologies need to be validated under commercial conditions to facilitate acceptance of methyl bromide alternatives. Regional technology transfer programs are needed to provide growers and the supporting agricultural industry with the information and experience necessary for the successful implementation of methyl bromide alternatives.

Anticipated Products:

- Commercial-scale economic information comparing the various alternatives to methyl bromide.
- New pest management systems that have been field validated under the range of biological and edaphic conditions that typify large geographic regions.
- Optimized pest management systems using methyl bromide alternatives.
- Technology transfer program to deliver concepts, assessments, and technologies needed for adoption of methyl bromide alternatives.
- A list of the sources of variability that affect the performance of methyl bromide alternatives.

- A knowledge base of the relationships between pest complexes and methyl bromide alternatives.
- Model for area-wide management of soilborne pests that can be utilized beyond initially targeted locations and commodities.

Potential Benefits:

- Growers remain competitive in the global market using strategies for practical, long-term management of soilborne pests in systems while reducing use of methyl bromide.
- Lower production costs.
- Increased farm worker safety.
- Reduced environmental impacts.

Component 1 Resources:

Nine (9) ARS projects that are coded to NP 308 address the research needs identified under Component 1. ARS scientists who are assigned to these projects include:

<u>Location:</u>	<u>Lead Scientists:</u>
Parlier, California	Ayars, James (acting)
Salinas, California	Martin, Frank N.
Washington, D.C.	Lakshman, Dilip K.
Fort Pierce, Florida	Chellemi, Daniel O.; Bausher, Michael G.
Gainesville, Florida	Allen, Leon H. Jr.
Beltsville, Maryland	Roberts, Daniel P.; Fravel, Deborah R.
Wenatchee, Washington	Mazzola, Mark

The following ARS projects, while not primarily coded to NP 308, have key elements which contribute significantly to the Methyl Bromide Alternatives program in Component 1.

<u>Location</u>	<u>Lead Scientist</u>	<u>Primary NP</u>
Parlier, California	Ledbetter, Craig A.	NP 301
Davis, California	Kluepfel, Daniel A.	NP 303
Riverside, California	Yates, Scott R.	NP 203
Byron, Georgia	Nyczepir, Andrew P.	NP 303
Tifton, Georgia	Johnson, Wiley C.	NP 304
Stoneville, Mississippi	Boyette, Clyde D.	NP 304
Corvallis, Oregon	Linderman, Robert G.	NP 303
Charleston, South Carolina	Thies, Judy A.	NP 303

Additional resources are under consideration that could enhance the programmatic function of the research.

Component 2. Post-Harvest Alternatives

Methyl bromide is used as a post-harvest fumigant to disinfect agricultural processing and storage structures, to preserve the quality of both perishable and durable commodities by killing pests, and as a quarantine treatment to prevent the undesirable movement of insects, pathogens, and nematodes that could be transported with commodities and wood packing material. CUEs

have been granted in post-harvest for a number of commodities and structures where alternatives are perceived to be too expensive, lacking in efficacy, too slow acting when fast turn-around is needed, or too corrosive, or when regulatory issues prevent its use. Quarantine use of methyl bromide is currently exempted from the phase out under the Montreal Protocol. It is in many cases the only approved quarantine treatment to allow movement of a commodity in international trade, and its loss would mean the potential loss of hundreds of millions of dollars in imports and exports of fruit, vegetables, and nuts. ARS research projects under this component are working to reduce the need to fumigate and are developing potential chemical and non-chemical replacement treatments for post-harvest use of methyl bromide.

Problem Statement 2A: Developing Alternatives to Methyl Bromide for Disinfestation of Post-Harvest Food Processing Facilities.

Structures where food is processed and stored, such as flour mills and warehouses, need to be maintained in a manner that minimizes the risk of the food becoming adulterated with insects because of both regulatory and consumer demands. Stored-product pests can inhabit hidden and hard-to-reach areas in buildings, and move from these areas to infest food products; thus, there is a need for a management tool, such as a fumigant, that can penetrate into these areas. Structural fumigation with methyl bromide was typically conducted on a calendar basis during normal holiday plant closings because of the need to shut down production during fumigation. As a response to the phase-out of methyl bromide, those responsible for pest management in these facilities are relying more heavily on monitoring insect populations to determine when to fumigate rather than calendar-based fumigation, adopting other management tactics to reduce the need for fumigations, and exploring other alternative structural treatments.

Alternative structural treatments, including alternative fumigants, are available for the management of stored product insect infestations of food facilities, but how effective these alternatives are compared to methyl bromide is not well understood. Phosphine is a widely used fumigant for bulk-stored products, but its use in food facilities is limited because it causes corrosion to electronic circuits. The fumigant sulfuryl fluoride has been registered for use in structural facilities, but efficacy studies are still needed to optimize its use in different types of facilities and to determine its economic feasibility. No other fumigants are currently registered for post-harvest structural treatments. Research to define the efficacy and environmental effects on that efficacy will be investigated to gain a better knowledge of the important parameters involved and the basic efficacy of alternatives.

A variety of management tactics can be used to delay the need for fumigation, including sanitation and structural modification, heat treatments, spot treatments with insecticides, and aerosol foggings. An important question is how best to integrate these tactics into an integrated or systems approach that can reduce the need for whole structure treatments.

Research Needs:

Knowledge about how alternative fumigants compared to methyl bromide needs to be expanded in terms of efficacy and impact on commodity quality. Efficacy needs to be understood under both controlled laboratory conditions, where the relationships among fumigant concentration, time, environmental conditions, pest species, and stage need to be determined, and in the field, where factors such as gas distribution, pest population

density and distribution, and environmental and structural conditions influence efficacy. Systems approaches or IPM strategies have the potential to reduce the need for structural fumigations, but how best to implement these approaches needs to be determined.

Anticipated Products:

- Efficacy matrix including, for example, fumigant concentration, exposure time, temperature, pest species, and life stage that compares methyl bromide with alternative fumigants in laboratory tests.
- A knowledge base of field validation data of alternative fumigants and assessment of factors influencing efficacy.
- An evaluation of the impact of different systems approach/IPM techniques at reducing the need for structural fumigations.

Potential Benefits:

- Reduction in the number of methyl bromide CUEs requested, or in the amount of methyl bromide requested.
- Alternative treatments will be available for structural applications.
- Reduce need for post-harvest structural fumigations via implementation of systems/IPM approaches.
- Processors remain competitive in the global market.

Problem Statement 2B: Develop Alternatives to Methyl Bromide for Disinfestations of Post-Harvest Durable Commodities.

For many years, methyl bromide has been used for the treatment of durable commodities, such as dried fruits, tree nuts, dried beans, and others, to disinfest field and storage pests before marketing domestically and abroad. Because these commodities often remain in storage for months or even years before reaching consumers, multiple treatments may be necessary, creating a need for quick, effective, inexpensive treatments and management practices that reduce the frequency of treatments. For some commodities, rapid disinfestation treatments must be used to allow the product to reach time-sensitive markets. In the walnut industry, for example, it has been widely used to eliminate insects from shipments of in-shell nuts going to the United Kingdom and Japan for the November and December holiday season. Nuts harvested in September and October are quickly processed to meet this need, and these nuts are a significant share of the total worldwide market for walnuts. The great variety of processing and storage methods used for these diverse commodities suggests that a variety of alternatives must be developed.

For durable commodities such as dried fruit and nuts, chemical treatments being investigated include new chemicals such as Profume (sulfuryl fluoride), propylene oxide, and new techniques using phosphine at cold temperature. Non-chemical alternatives for durable commodities that will be researched include infrared heating, cold, a new CATTs (hot air plus controlled atmosphere) treatment of fresh fruit, and compression combined with phosphine for treatment of hay going to Japan. Other technologies are in various stages of research and may add to the growing list of potential treatments. In addition to chemical and physical treatments, IPM methods that eliminate pests in the field before they infest fruit or nuts are being investigated

Research Needs:

Knowledge about how alternative fumigants compare to methyl bromide in terms of efficacy and impact on product quality will be extended to durable commodities. For alternative fumigants, the relationships among concentration, time, environmental conditions, pest species, and stage need to be determined, as well as how factors such as gas distribution, pest population density and distribution, and environmental and structural conditions influence efficacy. The efficacy of physical treatments, such as heat treatments, cold storage, vacuum, and irradiation, will be evaluated as alternatives for potential applications. IPM strategies and biorational control methods for controlling field pests of phytosanitary concern have great potential for reducing the need for commodity fumigation, but implementation of these techniques requires greater knowledge of insect behavior and population biology.

Anticipated Products:

- Efficacy matrix including, for example, fumigant concentration, exposure time, temperature, pest species, and life stage that compares methyl bromide with alternative fumigants in laboratory tests.
- A knowledge base of field validation data of alternative fumigants and assessment of factors influencing efficacy.
- Physical treatment parameters for the most tolerant target pests with efficacy of the most promising physical treatments under commercial conditions.
- Models for predicting field pest population growth and evaluating the effect of management practices on pest pressure.
- More effective monitoring methods, including improved pheromone lures, for use by the models.
- IPM strategies which include biorational control methods, such as mating disruption, natural enemies, and pathogens.
- Enhanced methodologies to capture methyl bromide being used under CUEs or QPS Exemptions.

Potential Benefits:

- Reduction in the number of methyl bromide critical use exemptions or reduction in the amount of material requested for durable commodities.
- Chemical and non-chemical alternative treatments available for use on durable commodities.
- Reduction in the need for post-harvest treatments for durable commodities through IPM strategies in the field.
- U.S. industries remain competitive in the global market.

Problem Statement 2C: Develop Alternatives to Methyl Bromide for Disinfestation of Post-Harvest Perishable Commodities.

Even though quarantine/preshipment uses of methyl bromide are presently exempted from the provisions of the Montreal Protocol, research is needed to guard against the loss in trade that would result if methyl bromide were lost. Alternative treatments that can be used in place of methyl bromide will include new chemical and non-chemical methods. For perishable commodities such as fresh fruits and vegetables, a number of approaches will be investigated

including radiation treatments, cold, heat, combined heat/controlled atmosphere, and systems approaches. Research to better define the effects of alternative treatments on commodity quality is needed to aid in the development of treatments that do not diminish commodity quality. Systems approaches combine several components to reduce risk of infestation and pest survival to acceptable levels. Research on pest behavior and biology is needed to allow establishment of pest-free zones or reduced-risk zones for species that have demonstration of poor host status for certain pest-commodity combinations such as Caribbean fruit fly infesting citrus and Mexican fruit fly attacking avocados. Low prevalence pest zones have been developed using various technologies such as mating disruption and sterile insect release, but further research is needed because of the large volume and the biology of their pests have been major barriers to post-harvest treatment development.

Research Needs:

Alternative fumigants, such as ethanedinitrile and methyl iodide, will be evaluated for efficacy and commodity quality. Pest management application techniques, including system approaches, will be addressed to replace fumigation requirements. Physical methods will be examined, including alterations to temperatures, atmospheric compositions, irradiation, and changes in pressure. All approaches will be evaluated for cost effectiveness.

Anticipated Products:

- List of the most effective fumigation parameters (time/temperature matrices, dosages, and concentration-times time products) for each promising material for the least susceptible life stage of the targeted species.
- Knowledge of the quality of fumigated commodities using the most effective fumigation.
- Pest monitoring, population suppression by mass trapping and mating disruption, host acceptability, new and more effective methods for pest inspection throughout the system, physical controls, application of pest-free or low-pest prevalence zone and their combinations, and predictive models along with validation tests of those models.
- New management strategies utilizing sterile insect release technologies and biocontrol with parasitic beneficial insects.
- Additional non-chemical control measures (temperature, pressure, controlled atmospheres, combined treatments, and irradiation) for the least susceptible life stage of the target species, along with the impacts of these techniques on commodity quality.
- Enhanced methodologies to capture methyl bromide used under CUEs or QPS Exemptions.
- Multiple, cost-effective treatments incorporating novel approaches that are safe and provide competitive products in international trade.

Potential Benefits:

- Reduction or elimination of methyl bromide fumigations for perishable commodities.

- Increased use of specific treatments using alternative fumigants or physical methods, such as heat.
- Continual development of related methods for similar commodities based on the consequence of suitable, successful procedures.
- Availability of cultural and biological control procedures that reduce the risk of infestation by indigenous and regulated pests in domestic and exported commodities and that maintain zero tolerance or quarantine security levels without methyl bromide fumigation.
- Multiple, cost-effective treatments that incorporate novel approaches that are safe and provide competitive products in international trade.
- “Pest-free zones” that will allow for a systems approach program for export.
- Reduced dependence on methyl bromide for quarantine purposes.
- Growers remain competitive in the global market.

Component 2 Resources:

Six (6) ARS projects coded to NP 308 address the research needs identified under Component 2. ARS scientists who are assigned to these projects include:

<u>Location:</u>	<u>Lead Scientists:</u>
Parlier, California	Obenland, David M.; Leesch, James G.
Salinas, California	Liu, Yong Biao
Gainesville, Florida	Allen, Hartwell
Miami, Florida	Epsky, Nancy D.
Manhattan, Kansas	Throne, James
Weslaco, Texas	Mangan, Robert L.

The following ARS projects, while not primarily coded to NP 308, have key elements which contribute significantly to the Methyl Bromide Alternatives program in Component 2.

<u>Location</u>	<u>Lead Scientist</u>	<u>Primary NP</u>
Hilo, Hawaii	McInnis, Donald O.	NP 304
	Vargas, Roger I.	NP 304
	Armstrong, John W.	NP 304
Manhattan, Kansas	Arthur, Franklin H.	NP 304
Weslaco, Texas	Lester, Gene E.	NP 306
Wapato, Washington	Hansen, James D.	NP 304