Area-wide Pest Management Project for Methyl Bromide Alternatives

Project Leadership:
Dan O. Chellemi, Project Coordinator-South Atlantic Component; USDA, ARS, U.S. Horticultural Research Laboratory, 2001 South Rock Road, Fort Pierce, FL 34945 (772) 462-5888, dan.chellemi@ars.usda.gov
Greg T. Browne, Project Coordinator-Pacific Component; USDA, ARS, Crops Pathology and Genetics Research Unit, Department of Plant Pathology, University of California; Davis, CA 95616; (530) 754-9351; gtbrowne@ucdavis.edu
Ken Vick, USDA, ARS, National Program Staff, 5601 Sunnyside Ave., MD 20705, (301) 504-5321, kwv@ars.usda.gov
Sally Schneider, USDA, ARS, National Program Staff, 5601 Sunnyside Ave., MD 20705, (301) 504-6918, sally.schneider@ars.usda.gov
John Lydon, USDA, ARS, National Program Staff, 5601 Sunnyside Ave., MD 20705, (301) 504-6918, john.lydon@ars.usda.gov
EXECUTIVE SUMMARY

Methyl bromide (MB) has been used extensively as a soil fumigant to control nematodes, fungi, insects and weeds on more than 100 crops worldwide. It is considered essential for production of many high-value annual and perennial food, nursery, and ornamental crops. In 1997, 96% of MB use was concentrated in five states including California (45%), Florida (38%), Georgia (4%), North Carolina (5%) and South Carolina (4%) (U.S. Environ. Prot. Agency, 1997).

MB was classified as an Ozone Depleting substance under the Montreal Protocol on Substances that Deplete the Ozone Layer and the United States Clean Air Act. Its use as a soil fumigant has been phased out except for Critical Use Exemptions (CUEs) approved by Parties of the Montreal Protocol after annual review. Under the Protocol, CUEs are limited to crops for which no “technically or economically feasible” alternative is known. The most recent US CUE requests, for 2008 soil fumigation, totaled more than 8.7 million kg MB (including 1.8 million from California and other western states; 6.8 million from Florida and other south Atlantic states; and 0.1 million kg from Michigan). In 2000, combined economic losses for California and Florida using the best alternatives to methyl bromide were estimated at $436 million (VanSickle et. al., 2000) while U.S. losses using the best alternatives were estimated at $479 million (Carpenter et al. 2000, National Center for Food and Agricultural Policy).

Since 2000, extensive research has identified potential technically feasible MB alternatives for some crops. However, widespread industry adoption of these alternatives has not occurred for several reasons, including but not limited to: variability in the effectiveness of the alternatives coupled with incomplete knowledge regarding the sources of variation and the means to manage them; the need to combine many of the alternatives with supplementary herbicides or other inputs for acceptable efficacy; failure to demonstrate the benefits from integrating the MB alternatives into a more comprehensive pest management approach, and, especially in California, regulatory restrictions that limit uses of the alternatives.

This project is designed to foster effective transitions to MB alternatives in key southeastern and western U.S. crop systems. In each cropping system, the project will involve multi-disciplinary teams, working with growers, to conduct large-scale commercial field trials comparing standard treatments with MB to the best available alternatives. The trial sites will be chosen to adequately represent environmental variation found in the production systems, and the alternatives will include fumigants as well as supporting integrated pest management practices. Emission reduction strategies will be tested for the fumigant alternatives. Data from the commercial trials will be used to conduct comprehensive biological, environmental, and economic assessments of the MB alternatives and to identify problems that hinder their adoption. Where feasible, the problems will be addressed with supplementary research. The project will incorporate the data and assessments into regional crop-specific educational programs designed to facilitate transition to integrated MB alternatives. In the targeted production systems, it is expected that the project will provide and demonstrate integrated alternatives to MB that: a) contribute to sustained economic competitiveness, b) result in reduced, acceptable environmental impacts, and c) increase farm worker safety. In production systems beyond those targeted, the project will model effective strategies for management of soilborne pests without MB.
PROBLEM STATEMENT

Methyl bromide as a soil fumigant. Methyl bromide (CH$_3$Br) (MB) is an odorless, colorless gas at normal temperatures and pressure. Since its first application in the 1930’s, MB has been extensively used as a soil fumigant to control nematodes, fungi, insects and weeds on more than 100 crops worldwide. Factors contributing to its popularity include a broad spectrum of activity, relatively low cost, ease of application, effectiveness under a wide range of soil conditions and a short plant-back interval due to its ability to diffuse rapidly from the soil into the atmosphere. In the southeast, MB use occurs primarily in high value vegetable, turf, and floriculture production systems characterized by a large and variable pest complex. Management practices that mitigate pest build-up such as cover crops or rotational crops are difficult to employ due to the extended length of the growing season and the limited availability of alternative sites. In the west, pre-plant soil fumigation with MB is used for production of strawberries, deciduous fruits and nuts and grapes; and diverse field nursery and floriculture crops. Each of the western crops presents a unique complex of soil pests, environments, and regulatory concerns.

Description of key pests, South Atlantic Component. Key soilborne pests of solanaceous crops include several species of root-knot nematodes (Meloidogyne spp.), a number of fungal plant pathogens and multiple weed species. On tomato, Fusarium wilt, caused by Fusarium oxysporum f. sp. lycopersici and Fusarium crown rot (Fusarium lycopersici f. sp. radicis-lycopersici) are found throughout the southeast. Verticillium wilt and Corky brown root rot (Pyrenochaeta lycopersici) are unique to the Dade county tomato production area in extreme southern Florida. Damping-off, caused by Pythium spp. and Rhizoctonia spp., during the early stages of growth is a significant problem in both crops. Pythium aphanidermatum, P. myriotylum, P. helicoides, and P. splendens also attack the roots of mature pepper producing symptoms similar to those associated with low fertility, including stunting, chlorosis, and reduced vigor. Southern blight (Athelia rolfsii, sclerotial stage Sclerotium rolfsii) and white mold (Sclerotinia sclerotiorum) can also occur in both crops. Phytophthora blight, caused by Phytophthora capsici is often the most devastating disease impacting pepper. It occurs sporadically throughout the southeast. Weeds are also extremely important in tomato and pepper and represent some of the most difficult to control pests. Nutsedges (Cyperus rotundus and C. esculentus) are consistently problematic throughout the southeast. In addition to nutsedges, pigweeds (Amaranthus spp.), nightshades (Solanum spp.), ragweed (Ambrosia artemisiifolia) and eclipta (Eclipta prostrata) are common problems. In addition to causing significant crop losses due to direct and indirect competition with the crop plants, several of these weeds serve as hosts to a number of pathogens that affect the crops in which they are found.

Key pests of southeastern strawberry production include sting nematode (Belonolaimus longicaudatus) and nutsedge (Cyperus rotunda and C. esculentus). Other weeds that cause economic damage are Carolina geranium (Geranium carolinianum), cut-leaf evening primrose (Onoethera laciniata), and black medic (Medico spp.). The most important soilborne pathogens are Phytophthora crown rot (Phytophthora citricola and P. cactorum), and anthracnose (Colletotrichum spp.).
Key pests of southeastern floriculture crops are listed below.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Pests</th>
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<tbody>
<tr>
<td>Antirrhinum</td>
<td>Nematodes: <em>Belanolaimus longicaudatus</em>, <em>Criconomella</em> spp.,</td>
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<tr>
<td></td>
<td><em>Dolichodorus heterocephalus</em>, <em>Meloidogyne</em> spp.</td>
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<td></td>
<td>Pythium root rot (<em>Pythium irregulare</em>)</td>
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<tr>
<td>Caladium</td>
<td>Nematode: <em>Meloidogyne</em> spp.</td>
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<td></td>
<td>Chalky rot (<em>Fusarium</em> sp.), Pythium root rot (<em>Pythium</em> sp.)</td>
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<tr>
<td>Calla lily</td>
<td>Erwinia soft rot (<em>Erwinia carotovora</em>)</td>
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<tr>
<td></td>
<td>Pythium root rot (<em>Pythium</em> spp.)</td>
</tr>
<tr>
<td>Delphinium</td>
<td>Sclerotinia stem rot (<em>Sclerotinia</em> spp.)</td>
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<tr>
<td>Dianthus</td>
<td>Fusarium wilt (<em>Fusarium oxysporum</em> fsp. <em>Dianthii</em>)</td>
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<tr>
<td>Eustoma</td>
<td>Nematodes: <em>Meloidogyne</em> spp.</td>
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<tr>
<td></td>
<td>Fusarium wilt, root rot, and stem rot (<em>Fusarium oxysporum, F. solani, F. avenaseaum</em>) (Figure 23)</td>
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<tr>
<td>Freesia</td>
<td>Fusarium wilt (<em>Fusarium</em> sp.)</td>
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<tr>
<td>Gladiolus</td>
<td>Fusarium wilt (<em>Fusarium oxysporum</em> fsp. <em>Gladioli</em>), Stromatinia neck rot (<em>Stromatinia gladioli</em>)</td>
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<tr>
<td>Helianthus</td>
<td>Downy mildew (<em>Plasmopara halstedii</em>)</td>
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<tr>
<td>Hypericum</td>
<td>Nematodes: <em>Meloidogyne</em> spp.</td>
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<tr>
<td></td>
<td>Pythium root rot (<em>Pythium</em> spp.)</td>
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<tr>
<td>Iris</td>
<td>Fusarium wilt (<em>Fusarium oxysporum</em> fsp. <em>iridis</em>)</td>
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<tr>
<td>Larkspur</td>
<td>Sclerotinia stem rot (<em>Sclerotinia scleroiorum</em>)</td>
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<tr>
<td>Liatris spicata</td>
<td>Sclerotinia stem rot (<em>Sclerotinia scleroiorum</em>)</td>
</tr>
<tr>
<td>Lilium</td>
<td>Pythium root rot (<em>Pythium</em> spp.)</td>
</tr>
<tr>
<td>Matthiola</td>
<td>Sclerotinia stem rot (<em>Sclerotinia scleroiorum</em>), Xanthomonas leaf spot (<em>Xanthomonas campestris</em> pv. <em>campestris</em>)</td>
</tr>
<tr>
<td>Ranunculus</td>
<td>Pythium root rot (<em>Pythium</em> spp.), Xanthomonas leaf spot (<em>Xanthomonas campestris</em>)</td>
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<tr>
<td>Bulb, tuber, corm crops</td>
<td>Bulbs, tubers, corms from previous season</td>
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<tr>
<td>Celosia argentea (ornamental cockscomb)</td>
<td>nutesedge (<em>Cyperus</em> spp.), <em>Pythium</em> spp., to root-knot nematode</td>
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Methyl bromide and the ozone layer. Methyl bromide was has been classified as a Class 1 stratospheric ozone depleting substance, based upon its ability to destroy ozone (an ozone depletion potential of 0.38) and its ability to remain in the stratosphere (0.7 years) (WMO, 2003). The Vienna Convention on the Protection of the Ozone Layer, signed in 1985, established a legal framework for addressing anthropogenic sources of ozone depleting substances. The Montreal Protocol was established in 1987 to provide guidelines for reducing use of ozone depleting substances. An amendment to the protocol in 1992 identified MB as a substance of concern and established a phase-out program in developed countries. The program was amended in 1997 to allow critical use exemptions (CUEs) and to phase out the production and consumption in steps; starting with the baseline amount of MB used in 1991, countries were to phase out MB in steps of 25%, 50%, 70% and 100% of the 1991 baseline in 1999, 2001, 2003 and 2005, respectively. A separate phase out schedule was developed for countries identified as Article 5 nations under the Protocol.

Critical Use Exemptions. A process for allowing CUE’s was established by The Parties to the Montreal Protocol to prevent significant market disruptions for commodities that lack effective alternatives to MB. The CUEs are considered in a 2-year nomination and review process and are granted only when the following criteria are met:

1. Failure to provide access to MB would result in a significant market disruption;
2. There are no technically and economically feasible alternatives available to an applicant that are acceptable from environmental and human health standpoints;
3. The applicant has taken all feasible steps to minimize use and associated emissions of MB; and
4. Appropriate efforts have been made to evaluate, commercialize and register alternatives to MB for use by the applicant.

The U.S. forwarded CUE requests for 16 crops/uses in 2005 and 2006, including commodity storage, cucurbits, eggplant, food processing, forest tree seedling nursery, ginger, nursery seed bed trays, orchard nursery, orchard replant, ornamental nursery, pepper, strawberry, strawberry nursery, sweet potato, tomato, and turf grass. Similar, yet smaller, CUE requests were submitted by the U.S. for 2007 and 2008 MB use. The U.S. CUE requests for 2005, 2006, and 2007 resulted in the Parties authorizing use of 37.4, 32.0, and 26.4% of the U.S. 1991 baseline amount (ca. 25.5 million kg) MB. The 2008 U.S. CUE nomination includes 15 crops and totals 25% of the 1991 baseline. Approximately 91% of the 2008 nomination total is for preplant soil fumigation and 9% for postharvest fumigation.

Of the 2008 U.S. CUE nomination for pre-plant soil fumigation, ca. 78% is for crops in southeastern states, ca. 21% is for crops in the west (mainly California), and ca. 1% was for crops in other regions (mainly Michigan). In the southeast, MB CUE requests were greatest for tomatoes and peppers (ca. 82% of southeastern CUE), followed by cucurbits (ca. 9%), strawberry fruit (5%), and various nursery crops and ornamentals/flowers (2%), eggplant (1%) and turf (<1%). The western CUE requests were greatest for strawberries (ca. 69%), followed by deciduous tree crops (19%), various nursery and floriculture crops (8%), and grapes (3%). Although the CUE requests were limited to crops of relatively high economic value per unit of MB, their relative CUE amounts are a reflection of technical as well as economic factors and therefore are not adequate indicators of crop value that would be lost without MB.
Potential impact from the loss of MB. Initial estimates of the economic losses to U.S. producers resulting from a ban on the agricultural use of MB for soil fumigation ranged from $1.0 to $1.1 billion per year (NAPIAP, 1993). A more recent economic assessment published in 2000 projected annual loss of $479 million in the U.S. resulting from banning soil fumigation with MB (Carpenter et al. 2000). Fresh market strawberry and tomato would suffer the most, with a combined annual losses projected at $189 million. Other commodities with major losses were almonds ($45 million), grapes ($75 million) and sod ($56 million). Other commodities suffering economic losses in the millions include stone fruits, walnuts, caladiums, cut flowers, sod, plant nurseries, watermelons, cucumbers, squash, peppers and eggplant.

Alternatives to MB with demonstrated potential. Four excellent reviews documenting the status of alternatives to MB for soil fumigation have been published since 2003 (Ajwa et al., 2003; Martin, 2003; Roskopf et al., 2005; Schneider et al., 2003). They describe chemical fumigant alternatives to MB identified in research trials as providing effective broad spectrum control of key soilborne weeds, plant parasitic nematodes and fungal diseases of strawberry, fresh market tomato and pepper production systems using plastic mulched beds. The fumigant alternatives include combinations of 1,3-dichloropropene (1,3-D) and chloropicrin (Pic) marketed under the trade names Telone C-35 and InLine (Dow AgroSciences, Indianapolis, IN), methyl isothiocyanate (MITC) generators marketed under the trade names Vapam and Kapam (AMVAC Chemical Corp., Los Angeles, CA) and a combination of methyl iodide and Pic marketed under the trade name Midas (Arysta LifeScience North American Corp., Cary, NC).

Large-scale demonstration trials conducted on commercial pepper, strawberry and tomato production farms in the southeastern U.S. have evaluated the technical and economic feasibility of fumigant alternatives to MB. The alternatives often required supplementary chemicals including herbicides and/or modifications to the application equipment, application methods and type of plastic mulch used. Despite their general efficacy, the alternatives variability in pest control when compared to MB has been observed. Together, these factors have contributed to the lack of adoption by the agricultural industry on an area-wide basis.

Soil solarization is a nonchemical alternative to MB with demonstrated potential in fresh market tomato production in the southeastern US when used within an IPM approach (Chellemi et. al., 1997). Although demonstrated to be technically feasible in the southeastern U.S. its application potential is limited to the fall production season and requires growers to prepare their planting beds 6 weeks in advance. Thus, it has not been embraced by the conventional tomato production industry. Several nonchemical pest management practices have been used to target specific soilborne pests of some methyl bromide dependent crops (Chellemi, 2000). Most notably, crop rotation has been documented to mitigate the impact of some key soilborne pests. However, damage from pests not controlled by the rotational crop must still be accomplished, and the limited availability of land suitable for rotation in some production regions has limited adoption by growers.

Nearly half of California’s strawberry acreage has transitioned to MB alternatives of drip-applied InLine or Pic or shank-applied Telone C35, each used in combination with a preemergence herbicide or metam sodium (D. Legard, personal communication). Although these treatment programs generally have been effective, further transition to the alternatives is complicated by regulatory limitations focused on fumigant emissions (1,3-D use caps, large buffer requirements, general concerns of fumigant use in the increasingly urban state), hilly terrain not amenable to drip applications of the alternatives, and concerns over long-term buildup
of pest and disease problems where the alternatives are used in successive years. Shank fumigation with Telone C35 or Pic, when combined with use of basamid for weed control, proved effective in commercial strawberry nurseries (Kabir et al., 2005)

Preplant fumigation in California’s orchards has shifted towards increased use of 1,3-D and, more recently, Pic. Pic is more effective than MB for control of Prunus replant disease (Browne et al. 2006); however, Pic typically is less effective than MB for management of plant parasitic nematodes. MB is still a fumigant of choice for walnut, orchard crops in fine-textured soils, and deciduous nurseries. The superior potential of MB to diffuse through soil, compared to that of 1,3-D and Pic, facilitates control of nematode populations for deep-rooted orchard crops, especially on fine-textured soils. Preliminary work in California indicates that short-term crop rotations can contributevaluably to integrated management of Prunus replant disease.

Although 1,3-D has been used effectively by nurseries on sandy loam soils, it is not approved for production of certified stock on clay loam soil. Achieving adequate weed control with MB alternatives has been a major problem for nurseries, including those producing fruit and nut trees, grapevines, garden roses for planting, and other field floriculture crops.

**JUSTIFICATION**

For both the South Atlantic and Pacific Components, a multi-faceted regional approach is needed to facilitate the transition of growers and production systems to MB alternatives. The transition involves diverse pest complexes, climates, soils and environmental and regulatory constraints. The diversity calls for crop-system-specific approaches, in which chemical, cultural and biological alternatives to MB are integrated into technically and economically feasible pest management programs. MB alternatives need additional scrutiny and further optimization in commercial production operations to encourage wide-scale adoption by growers; critical data are lacking to describe the specific conditions and management practices required to consistently obtain maximum and acceptable efficacy.

The general approach used in AW pest management projects is well-suited to the objectives of this project. The characteristic use of comprehensive, inter-disciplinary teamwork that involves scientists, extension educators, and grower and regulatory stakeholders will help to insure that effective transitions to MB alternatives will be fostered. Also in keeping with the AW approach, this project will emphasize IPM practices where appropriate, and this will contribute invaluably to the effectiveness and durability of MB alternatives. The provision for supporting research in AW projects will be essential to the success of this plan; for example, adoption of reduced fumigant emissions technologies and IPM strategies will require supporting experimentation for optimization. Finally, industry benefit from the concepts and technology developed in this project will be maximized by an integral AW educational program.
OBJECTIVES

1. Demonstrate alternatives to MB in key crop systems and regions dependent upon MB. This will be accomplished by conducting replicated, large-scale field trials that will compare standard treatments with MB to the best available, industry-appropriate alternatives. The alternatives will include substitute fumigants and supporting integrated pest management (IPM) practices. The trials will be conducted in partnership with commercial growers at sites adequately representing the biological and environmental diversity of the production systems.

2. Conduct comprehensive assessments of the performance of alternatives to MB in key crop systems and regions dependent upon MB. This will be accomplished by multi-disciplinary collection and analysis of biological, environmental, and economic data from the trials described above.

3. Identify key variables and their critical values responsible for consistent and effective pest control and crop productivity with MB alternatives and demonstrate prescriptive use of the variables to optimize performance of MB alternatives. This will occur in conjunction with the trials described above.

4. Improve IPM strategies and fumigant emissions reduction technologies in support of fumigant alternatives to MB alternatives. This will occur primarily in conjunction with trials described above, but is anticipated to require additional supporting research.

5. Conduct multi-regional education programs that instruct growers, farm workers, and associated members of the agricultural community on optimized, IPM-supported use of MB alternatives.

PLAN OF WORK (South Atlantic Component)

The structure of the South Atlantic Area-Wide Pest Management Project for MB alternatives is depicted in Figure 1. A core advisory team (CT) will provide the overall supervision for the project. The team will include scientific and/or industry representation from each major agricultural sector highly dependent on MB use for pre-plant soil fumigation. Specifically, the team’s charge will be to initiate, oversee, and review the operational, assessment, and extension components including, but not limited to:

• Defining specific criteria for field trial sites and treatments.
• Reviewing and refining policies for demonstration trial activities (e.g., grower and scientist responsibilities, cost sharing, methods of applying treatments, variables measured, methods of assessment, and reporting methods).
• Reviewing, approving, and initiating specific field projects and treatments.
• Refining and prioritizing research objectives and launching research projects that will facilitate adoption and continued success of MB alternatives.
• Refining and prioritizing environmental and economic assessment priorities, facilitating and participating in assessments.
• Reviewing and refining educational priorities and methods; facilitating educational outreach; and participating in educational assessments.
CORE ADVISORY COMMITTEE
South Atlantic Area-wide Pest Management Project for Alternatives to Methyl Bromide

Dan O Chellemi, Project Manager, USDA, ARS, Horticultural Research Laboratory, 2001 South Rock Road, Fort Pierce, FL 34945 (772) 462-5888, dan.chellemi@ars.usda.gov
Dan Botts, Florida Fruit & Vegetable Assoc., P.O. Box 948153, Maitland, FL 32794, (321)214-5222, Daniel.botts@ffva.com
Reggie Brown, Florida Tomato Exchange, 800 Trafalgar Court, Suite 300, Maitland, FL 32751, (407) 660-1949, reggie@floridatomatoes.org
Stanley Culpepper, University of Georgia, Crop and Soil Science Department, P.O. Box 1209, Tifton, GA, 31793 (229-386-3328), stanley@uga.edu
Frank Louws, North Carolina State University, Plant Pathology Department, P.O. Box 7616, Raleigh, NC 27695; (919-515-6689), frank_louws@ncsu.edu
Joseph Noling, University of Florida-IFAS, Citrus Research and Education Center, 700 Experiment Station Rd., Lake Alfred, FL 33850 (863-956-1151), jwnoling@mail.ifas.ufl.edu
Eugene McAvoy, University of Florida-IFAS, Multi-County Extension (Vegetables), P.O. Box 68, Labelle, FL; 33975-0068 (863-674-4092), gmcavoy@mail.ifas.ufl.edu
Ken Vick, USDA, ARS, National Program Staff, 5601 Sunnyside Ave., Room 4-2216, Beltsville, MD 20705, (301) 504-5321, kwv@ars.usda.gov
Sally Schneider, USDA, ARS, National Program Staff, 5601 Sunnyside Ave., MD 20705, (301) 504-6918, sally.schneider@ars.usda.gov
Erin Rosskopf, USDA, ARS, Horticultural Research Laboratory, 2001 South Rock Road, Fort Pierce, FL 34945 (772) 462-5887, erin.rosskopf@ars.usda.gov
Nancy, K. Burelle, USDA, ARS, Horticultural Research Laboratory, 2001 South Rock Road, Fort Pierce, FL 34945 (772) 462-5861, nancy.burelle@ars.usda.gov
Bryan, Unruh, University of Florida, West Florida Research & Education Center, Milton, FL, 32583, (850) 995-3720 ext 108, jbu@ufl.edu
Scott Enebak, Auburn University, Forest Nursery Management Cooperative, 3301 Forestry & Wildlife Sciences, Auburn, AL, (334) 844-1208, eebasa@auburn.edu
Tom Starkey, Auburn University, Forest Nursery Management Cooperative, 3301 Forestry & Wildlife Sciences, Auburn, AL, (334) 844-8069, starkte@auburn.edu
Andrew MacRae, University of Florida, Gulf Coast Research & Education Center, Winauma, FL, 33598, awmacrae@ufl.edu
Wesley Roan, Six L’s, Inc., 11900 Six L’s Farm Road, Naples, FL (239) 774-6936, wes.roan@lipmanproduce.com
John Stickles, Florida Pacific Farms, LLC 3922 Moores Lakes Road, Dover, FL 33527 (813) 659-3913, jstickles@berry.net
Eric Nissen, Sunshinge State Carnations, Inc. P.O. Box 573, Hobe Sound, FL, 33475, (772) 546-3000, sunshinecuts@bellsouth.net
Dean McRaw, MaCraw Energy, P.O. Box 60741, Savannah,GA 31420, (912) 596-8624, dean.mccraw@mccrawenergy.com
Victor Lilley, Manager, Triest Ag Group, Inc. 3002 W. Main St. Williamston, NC 27892, (252) 792-1613, vlilley@tiestag.com
Greg Browne Research Plant Pathologist, USDA-ARS, CPGRU Department of Plant Pathology, University of California, Davis, CA 95616; (530) 754-9351, gtbrown@ucdavis.edu
Richard Kegwin, Jr. Director, Biological and Economic Assessment Division, USEPA, Areil Rios Building, 1200 Pennsylvania Ave., Washington, D.C. 20460, (703) 308-8200, keigwin.richard@epa.gov

Dennis Howard, Chief, Bureau of Pesticides, Florida Department of Agriculture and Consumer Services, 3125 Conner Blvd, Doyle Conner Bldg., Room 171, Tallahassee, FL 32399, (805) 487-0532, howardd@doacs.state.fl.us
Operational component. The operational component involves participation from scientists, extension agents, and professionals from private industry who have experience in the development and application of soil disinfestation programs in commercial agriculture. Participants include individuals from each of the main production areas in the south Atlantic region. Key technical support scientists were hired specifically for the South Atlantic MB Alternative Area-Wide Project to facilitate communication among stakeholders, participants in the demonstration trials and members of the Core Advisory and Technical Advisory Teams and to ensure the consistent and accurate application of alternative strategies, assessment of pest control and crop performance, and collection of environmental and biological data. Baseline information including cropping history, soilborne pest complex and severity, cropping practices, prior MB use, fumigant application technology, familiarity with MB alternatives, soil type, marketing and labor constraints were collected prior to initiating demonstration trials.

Assessment component. Assessment of demonstration trials was conducted by extension agents, extension specialists, commercial pest management consultants, scientists and technicians from USDA, ARS and land grant institutions with expertise in each of the three major pest categories (weeds, diseases, and nematodes) and economists. Training on correct procedures for pest identification and collection of economic data was provided by scientists on the Technical Advisory Team. Assessment procedures was standardized within the South Atlantic Area-Wide project. Coordination of assessments for pest control was provided by the AW support scientists and members of the Technical Advisory Team. Disease incidence surveys and weed density counts were made at monthly intervals. Nematode density and root gall estimates were made at first harvest and again prior to crop destruction. Procedures to collect yield and pack-out data were conducted by the grower operator with financial support from the Area-Wide project. The AW support scientists and local participants selected by the Technical Advisory Team will monitor harvests to ensure that the data is collected. Summaries and reports on pest control and yield effects are written and distributed to all Area-Wide Project members by the AW support scientists. Team members ensure that both positive and negative results from the demonstrations trials will be characterized.

Research component. The purpose of the research component is to increase the knowledge base as it pertains to: 1) improving the efficacy and consistency of commercially available MB alternatives that have been shown to be technically feasible, 2) reducing the environmental impacts of MB alternatives, and 3) lowering the risks of worker exposure to alternative fumigants. Participants in the Research Component will include scientists from a broad range of disciplines including but not limited to: agricultural engineering, chemical engineering, horticulture, nematology, microbiology, plant pathology, soil science and weed science. The Technical and Core Advisory Teams are charged with identifying the key variables and their critical values responsible for consistent and effective pest control with MB alternatives. Critical variables to be examined will include the fate of fumigants in the soil following application, atmospheric emission of fumigants, relative permeability of plastic films, dynamics of soil water potential prior to and following chemical applications and the impacts of MB alternatives on soil microbiology. The Technical Advisory Team will integrate variables with assessments in pest control and marketable yield to establish ranges critical for optimizing MB performance, minimizing environmental disruption and mitigating worker exposure to pesticides.
**Educational component.** The purpose of the educational component is to ensure continued and broad adoption MB alternatives beyond the local demonstration sites and to facilitate technical training, communication, and support targeted to growers who depend upon MB and members from private industry working in the management of soilborne pests. An Extension Advisory Team comprised of county extension agents, regional extension specialists and private consultants will be assembled to insure that all major production regions are represented. The educational component will consist of four major parts: (1) direct training programs such as field days, short courses and seminars; (2) training materials including hard copy manuals and a website containing training modules; (3) communication using newsletters and articles in trade publications; and (4) an educational assessment measuring the adoption rates, program benefits and opportunities for improvement.
Figure 1. Organizational structure of the Pacific and South Atlantic Components of the Area-Wide Pest Management Project for Methyl Bromide Alternatives.
Literature Cited


