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NATIONAL PROGRAM 308
METHYL BROMIDE ALTERNATIVES

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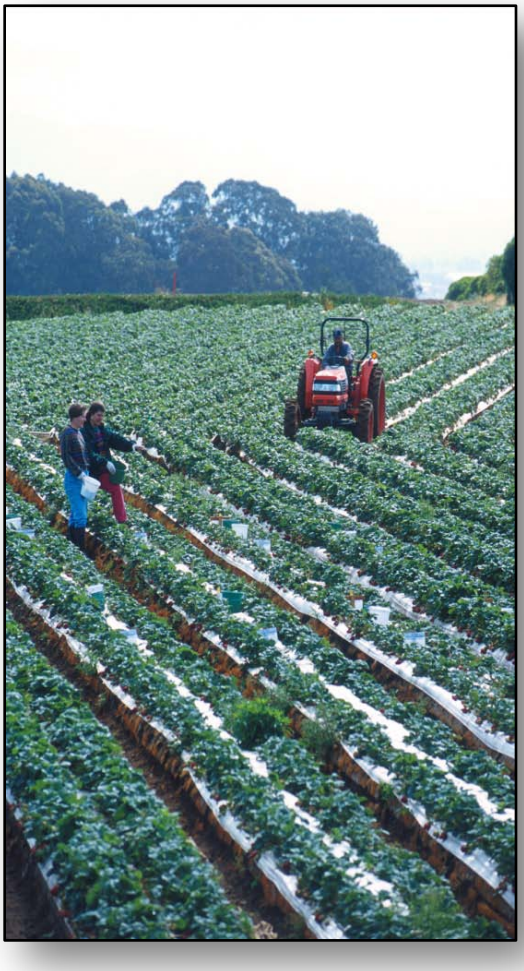

National Program 308 – METHYL BROMIDE ALTERNATIVES
FY 2008 Annual Report

Introduction
The Methyl Bromide Alternatives National Program encompasses research to determine alternatives to methyl bromide, which has been officially phased out as of January 1, 2005. This is the result of indications that it negatively impacts the stratospheric ozone layer. While there are a limited number of exceptions to the phase out, continued use of methyl bromide depends upon securing a Critical Use Exemption by providing economic and production information why currently available alternatives are insufficient for pest problems. Methyl bromide remains an extremely important pesticide in the United States and in the rest of the world. It has been used to rid the soil of pests before crops are planted and on postharvest commodities to kill pests in order to protect product quality. Pre-plant use controls soilborne pathogens, nematodes, insects, and weeds. Postharvest use, which kills insects and other arthropods, also includes quarantine treatment, which prevents accidental introduction of organisms into areas where they did not previously exist.

Appropriate alternatives must be found so that the United States can continue economically viable production systems that permit agriculture to maintain its role in domestic and international trade. Quarantine treatments are currently exempted from the phase out, thus the primary focus of research has been on pre-plant and postharvest uses. In the near term much of the U.S. domestic food production of fruits, nuts, and vegetables will be severely impacted if suitable alternatives are not found. In the long term, systems approaches will be developed using combinations of pest suppressing techniques.

The Methyl Bromide Alternatives National Program (NP 308) is comprised of two components:
- *Pre-Plant Soil Fumigation Alternatives*; and
- *Postharvest Alternatives.*

During fiscal year (FY) 2008 this program produced several important discoveries and advances. Some of these are described below, grouped by program component:

Component 1: Pre-plant Soil Fumigation Alternatives

- *Biofumigation as an alternative to methyl bromide.* Biofumigation with soil-incorporated plant materials has been associated with reduction in soilborne pathogens and diseases. A field experiment was conducted by ARS scientists in Parlier, California, to determine soil-incorporated white mustard as a green manure crop on controlling soilbore pathogens and nematodes. *Fusarium oxysporum* counts were significantly reduced after soil incorporation of white mustard and no control was found for *Pythium* spp. Soil populations of citrus nematodes were reduced and free-living nematode populations increased after soil incorporation of white mustard. The study demonstrated measurable production of volatile methyl sulfide and dimethyl disulfide gases, the beneficial biofumigants for controlling soilborne pathogens and a potential for methyl bromide

alternatives.

- *Efficacy of brassicaceous seed meal amendments for apple replant disease suppression dependent on rootstock.* Studies were conducted to assess the interaction between apple rootstock and the capacity of brassicaceous seed meals to provide control of two components of the pathogen complex that incites replant disease; the nematode *Pratylenchus penetrans* and the fungal pathogen *Pythium* spp. ARS scientists in Wenatchee, Washington, discovered that Geneva series rootstocks were less susceptible to root infection by native populations of *Pythium* spp. and supported lower populations of *P. penetrans* than did rootstocks of the Malling or Malling-Merton series. Nematode suppression in response to two of the seed meal amendments, *B. napus* or *S. alba* SM was only observed when used in combination with a tolerant rootstock, while another seed meal amendment, *B. juncea* SM, suppressed lesion nematode root populations irrespective of rootstock. These findings demonstrate that utilization of brassicaceous seed meal amendments for replant disease suppression must employ an appropriate rootstock to achieve optimal disease control.

- *Surfactant production by the biological control agent, Pseudomonas fluorescens SS101, is not required for suppression of complex Pythium spp. populations.* Integrated strategies are needed to suppress apple replant disease in orchards. Rhizobacteria have been shown to control the apple replant disease by production of surfactants, such as massetolide. In studies that employed SS101, which produces the surfactant and a closely related strain that does not produce a surfactant, ARS scientists in Wenatchee, Washington, demonstrated that control of native *Pythium* spp. under "worst case scenarios" was achieved with both strains irrespective of surfactant production. These data demonstrate that surfactant production is one of multiple mechanisms employed by SS101 for suppression of *Pythium* spp., and that this strain has significant potential for use in conjunction with seed meal amendments in an integrated strategy for control of apple replant disease.

- *New chemicals for weed, nematode, and pathogen control.* Laboratory, greenhouse and microplot trials were conducted to evaluate novel, reduced-risk compounds for control of weeds, plant pathogenic fungi and bacteria, and plant parasitic nematodes. ARS scientists in Fort Pierce, Florida, have identified two compounds that have broad-spectrum pest control activity at very low application rates. The use of one of these materials has been expanded to include applications for the control of gastrointestinal parasites of small ruminants. Two invention disclosures have been filed and one provisional and one full patent have been filed on the inventions.

- *Demonstration and assessment of improved plastic mulches.* Plastic mulches are used for conventional strawberry production for horticultural reasons and to improve retention of pre-plant fumigants in soil, thereby improving soilborne pest and pathogen control and reducing atmospheric emissions. Several new plastic mulches offer reduced permeability

to fumigants and increased durability during field applications. Both have large impacts on overall mulch performance, but growers have had little experience with the new products and few data are available to document their performance. ARS scientists in Davis, California, collaboratively tested and demonstrated the performance of the new plastic mulches under California coastal conditions. Several mulches with improved performance were identified and compared to conventional high density polyethylene. A new "totally impermeable film" was found that can be effectively glued as required for broadcast applications. The film is very durable under field conditions, maintaining extremely low permeability to fumigants following field application activities, which can damage some tarps. This accomplishment could lead to reduced atmospheric fumigant emissions and improved fumigant efficacy in the strawberry industry.

- *GPS-controlled shank injection system for spot fumigation in orchards.* Pre-plant spot fumigation using hand-held probes at tree sites can prevent almond replant disease using much less fumigant than strip or broadcast fumigation using conventional shank injection equipment. However, probe treatments involve applicator risk and labor expense. In collaboration with University of California-Davis, a GPS-controlled shank injection system was developed by ARS scientists in Davis, California, which safely and economically fumigates tree sites using less fumigant than conventional strip or broadcast treatments thereby reducing costs and fumigant emissions.

- *Plant extracts as potential nematicidal agents.* Methyl bromide (MB) has been an important component of soiborne plant parasitic nematode control. However, due to the ban of MB use, there is a need for developing alternative management strategies. ARS scientists in Beltsville, Maryland, demonstrated that oil of clove (*Syzygium aromaticum*) is inhibitory to egg hatching and J2 larval mobility of root-knot nematode, *Meloidogyne incognita*, both in vitro and in soil. This, in addition to previously reported fungicidal property and discovery of its antibacterial properties, makes clove oil a candidate for control of various soilborne pathogens. This control strategy could also be used in organic production systems.

- *Proper irrigation can reduce fumigant emissions without reducing soil gaseous fumigant concentrations.* Emission reduction is required from soil fumigation to improve air quality and adequate fumigant concentrations are needed for pest control. ARS scientists in Parlier, California, demonstrated that water seals applied to soil columns following fumigant injection significantly reduced emissions for different textured soils (e.g., loamy sand, sandy loam and clay loam) without reducing fumigant concentrations in the soil profile. They also demonstrated that increasing soil water content prior to fumigant injection significantly reduced emission peaks, which would minimize acute human exposure risks to workers and bystanders. Compared to plastic tarps, irrigation is a low-cost technique for reducing fumigant emissions, and it is especially appealing for commodities with low profit margins in meeting environmental regulations on emission reductions.

- *Virtually impermeable film can effectively reduce fumigant emissions in field applications.* There have been uncertainties on whether low permeable tarps such as virtually impermeable film (VIF) can reduce fumigant emissions in large field applications. ARS scientists in Parlier, California, demonstrated that VIF can significantly reduce fumigant emissions when fumigant was drip applied to raised-beds in large strawberry fields. In studies in Gainesville, Florida, ARS scientists showed that VIF consistently decreased emissions to the atmosphere of all of the fumigants that were tested [methyl bromide, 1,3-dichloropropene, chloropicrin, methyl isothiosyanate (from metam sodium)] in raised bed plasticulture conditions. One study showed that use of VIF film could reduce the amount of fumigant required to achieve equal effectiveness compared with use of standard polyethylene films. VIF provides a technology for reducing emissions and offers a feasible method on emission control from fumigation for high-valued crops.

- *Iodomethane as a short-term methyl bromide alternative for the Florida floriculture industry*. ARS scientists in Fort Pierce, Florida, in collaboration with the University of Florida researchers, evaluated the use of soil solarization and fumigants including iodomethane (Midas™ iodomethane:chloropicrin, 50:50, 200 lb/acre) under metalized films as an alternative to methyl bromide for soil fumigation. Four field trials were performed under both commercial and experimental field conditions at three locations in Florida. Pest pressure varied according to location and ranged from high nematode and weed pressure, to low nematode, but high weed pressure. Cut-flower crops evaluated were Celosia (*Celosia argentea*) and snapdragon (*Antirrhinum majus*). Results show that Midas applied under metalized film provided weed control comparable to high rates of methyl bromide (98:2 400 lb/acre) under high density polyethylene film, and lower rates of methyl bromide (98:2 200 lb/acre) under metalized film. Low rates of methyl bromide (67:33 mbr:chloropicrin 200 lb/acre) under metalized film did not provide good weed control. Soil solarization provided better control of white clover (*Trifolium repens*) than any fumigant tested.

- *Nutsedge management can be enhanced through the combination of mulching and the biological control agent, Dactylaria higginsii*. ARS scientists in Fort Pierce, Florida, conducted multiple laboratory, greenhouse, and field trials to evaluate the use of the biological control agent, *Dactylaria higginsii*, combined with multiple types of hay for solid substrate production of inoculum. For mass production of *D. higginsii*, 14 solid substrates in the form of dried, cut shoots of various plants were tested. These were tested alone or with various amendments. Conidial yields were highest when the fungus was grown on purple nutsedge hay without amendments for 4 weeks. Conidia produced on sorghum and cogongrass hays were slightly larger and thicker walled than those produced on other hay media. Conidia produced on sorghum were the most virulent on nutsedge seedlings. Cogongrass hay was most effective for suppression of nutsedge.

- *Rapid assessment of pathogenicity of Verticillium dahliae on lettuce.* Current methods to assess Verticillium wilt of lettuce are time-consuming and labor-intensive, especially for routine assays to examine virulence of *Verticillium* spp. isolates. A technique that takes advantage of an early flowering plant introduction line was thoroughly tested and validated by ARS scientists in Salinas, California. The experiments revealed that the technique is suitable for the rapid analysis of virulence of *V. dahliae* isolates and thus has an impact in reducing the time required for analyses of the *V. dahliae*-lettuce interaction. Because resistant lettuce provides the most cost-effective control strategy alternative to the use of methyl bromide and soil fumigation in general, comparative tests also were conducted with additional lettuce cultivars. These comparative experiments revealed that the method is not suitable to screen lettuce for resistance to *V. dahliae*.

- *Bacterial Blight in Arugula.* Bacterial diseases of vegetables can significantly limit yield as well as their usefulness in crop rotations. In collaboration with Washington State University, ARS scientists in Salinas, California, examined the etiology of bacterial pathogens. It was determined that the pathogen causing Bacterial Blight, which has recently been found in arugula in Nevada from organic and conventional production fields, is *Pseudomonas syringae* pv. alisalensis. This was the first report of bacterial blight on arugula in Nevada; thus, eliminating them as potential rotational crops for previously diseased fields.

- *Molecular diagnostics for Phytophthora ramorum.* There are several different molecular methods that have been used to identify *Phytophthora ramorum*, the pathogen responsible for Sudden Oak Death. Three are currently used by USDA-APHIS to identify the pathogen in plant samples; but, widespread testing of this method using a broad range of isolates and species of the genus has not been done. Likewise, similar testing has not been done for the other detection methods. In an effort to assist APHIS in evaluating these molecular diagnostic techniques, an ARS scientist in Salinas, California, has initiated and is coordinating with a researcher at the University of California-Riverside a blind test of 11 diagnostic methods by 7 labs that have developed them. The results have been provided to APHIS-PPQ-CPHST to assist them in deciding on additional assays to include in their analysis. The results of this work will help regulatory agencies make decisions on additional diagnostic markers they can use to identify this important quarantine pathogen.

- *Mitochondrial haplotype determination for Phytophthora ramorum. Phytophthora ramorum* causes sudden Oak death and is a pathogen under strict quarantine restrictions. The mitochondrial genomes for 2 isolates of *P. ramorum* were sequenced by ARS scientists in Salinas, California, and will be useful for monitoring spread of specific pathogen genotypes. PCR primers for haplotype determinations were developed and published with additional details of the work forwarded to USDA-APHIS with an offer to assist them in evaluating the utility of the technique with field samples. The results of

this work will help regulatory agencies make decisions on additional diagnostic markers they can use to identify this important quarantine pathogen.

- *Web site to support Phytophthora research.* The genus *Phytophthora* has approximately 80 species and is responsible for a wide range of diseases on a worldwide basis; but due to similarities in morphological features identification to a species level can be a challenge. In an effort to enhance an understanding of the genus, simplify identification, and stimulate research, a collaborative project was initiated by ARS scientists in Salinas, California, with researchers at Penn State University, University of California at Riverside, North Carolina State University, and an ARS researcher in Peoria, Illinois, to develop a Web-based database for the genus. The database includes complete morphological descriptions, information on host range and geographical distribution, and a comprehensive molecular phylogeny using at least five nuclear genes (mitochondrial genes will be added when the sequence analysis described above is completed). The molecular database is fully searchable and designed in a way to facilitate molecular identification of unknown isolates with a section on molecular markers added in the near future. It is expected that this database will serve as a resource for researchers working on the genus as well as a repository for future work to keep the information presented current.

- *Assessing soil microbial populations and activity following the use of polyglycerol polyricinoleate (PGPR)-based inoculants: effects on nematode suppression*. ARS scientists in Fort Pierce, Florida, in cooperation with Auburn University researchers, used commercial biological inoculants to study changes in rhizosphere microbial activity and its relation to root-knot nematode suppression in field and greenhouse trials. Two inoculants, BioYield and FZB42, induced significant reductions in nematode population and galls per plant. Additionally, increases in total culturable bacteria and heat-tolerant bacteria in the tomato rhizosphere were detected in plants treated with BioYield and FZB42.

- *Low application rate of manure can not significantly reduce fumigant emissions.* Organic material amendment to soil has shown effectiveness in fumigant degradation and reducing their emissions in lab studies. ARS scientists in Parlier, California, determined under field conditions that soil amendment with composted manure with normal application rates is unlikely to be effective to reduce emissions. Much higher organic amendment rates may be required to achieve significant emission reductions in field applications. The conclusion was made based on one field trial data. The results provided information for developing other effective and practical field methods for controlling fumigant emissions.

- *Herbicide efficacy and crop safety.* Evaluation of emerging new herbicides for weed control requires knowledge and information on potential phytotoxicity on crops. Field trials were carried out by ARS scientists in Parlier, California, to evaluate herbicide

efficacy and crop safety. Unlabeled herbicide dithiopyr provided weed control in perennial crop field nurseries equal to or better than oryzalin with similar crop safety. Pre-emergence rimsulfuron and flumioxazin were safer on prunus rootstock planted as hardwood cuttings compared to seeded rootstock cultivars. The research findings contribute to the overall effort on methyl bromide alternatives for weed control in field nurseries.

Component 2. Post-Harvest Alternatives

- *Persistence of beta cyfluthrin, bifenthrin, and methoxyfenozide in almonds and pistachios.* Greater knowledge is needed regarding the persistence of insecticides used to control of navel orangeworm in pistachios and almonds. An ARS entomologist in Parlier, California, demonstrated that methoxyfenozide persisted for 30 days in pistachios, bifentrhin persisted in almonds for 30 days, and beta cyfluthrin persisted in pistachios for 21 days in Madera County. These findings will improve control of navel orangeworm by increasing the flexibility of insecticide application and provide additional insight for optimal treatment times.

- *Effect of a phosphine and carbon dioxide gas mixture on Hessian fly puparia.* Regulatory agencies require a chemical treatment of hay exported to China to prevent accidental introductions of insect pests. ARS scientists in Parlier, California, conducted tests that showed a phosphine and carbon dioxide gas mixture provides a high level of control of Hessian fly puparia at low temperatures, and may be efficacious for a general sanitation treatment. A general proposal was presented to China to consider this treatment in partial fulfillment of import requirements. This research could lead to greater U.S hay exports.

- *Characterized navel orangeworm damage patterns in almonds.* The navel orangeworm is an important pest of almonds, a crop worth over $2 billion annually. Its abundance can vary greatly between and among tree nut crops. ARS scientists in Parlier, California, in cooperation with Paramount Farming Company and the Almond Board of California, found that damage declined greatly within the first 200-400 feet of 160-acre almond blocks and was homogeneous in the remaining interior parts. These results assure growers that they can control navel orangeworm populations in the interior portion of their blocks and at the same time demonstrate possible benefits of cooperative management of regional navel orangeworm populations.

- *Assessment of emergence of overwintering navel orangeworm.* Numbers of overwintering navel orangeworm strongly affect the infestation level of this pest in new season pistachios, yet no assessment techniques are available to estimate overwintering populations. ARS entomologists in Parlier, California, found that degree day emergence curves for navel orangeworm from lab-incubated, winter-collected pistachio mummies matched degree day trap capture curves in pheromone-baited traps during spring

emergence. Because trapping is expected to be less expensive and tedious than lab incubation of mummies, trapping will form a basis for in-season control decisions for improved navel orangeworm management, leading to a reduction in production costs for the grower.

- *Effect of product moisture on efficacy of vacuum treatments.* Non-chemical alternatives to methyl bromide and other fumigants are needed for postharvest insect disinfestation of California tree nuts. Vacuum treatment is one such potential treatment. ARS scientists in Parlier, California, showed that at 25 and 30C high moisture (9 percent), walnuts require longer vacuum treatment times than low moisture (6 percent) walnuts to completely disinfest product of Indianmeal moth, and that diapausing (overwintering stage) Indianmeal moth required longer treatment times than non-diapausing larvae. This information will be used to develop more effective treatment schedules and improve the adoption of vacuum treatments as a non-chemical alternative, thereby reducing industry reliance on environmentally harmful chemical fumigants.

- *Identification of a box design to optimize the commercial heat treatment of stone fruit.* Heat treatment of stone fruit is a viable alternative to fumigation for the fruit export market; however, heat treatment of boxed stone fruit that are stacked tightly together onto shipping pallets is hindered by poor airflow through the boxes. ARS researchers in Parlier, California, tested a variety of different box configurations and venting options and determined that a commercial single layer box with side venting provided the fastest and most uniform heating. This information will help in the development of a non-chemical, commercially viable treatment for the California stone fruit industry that will serve as a replacement for methyl bromide.

- *Biological Control of Olive Fruit Fly.* Economical methods are needed to control olive fruit fly in California to protect the U.S. domestic supply of canned olives and olive oil. A parasitoid was produced in mass numbers in the USDA-APHIS-PPQ Moscamed facilities in Guatemala and shipped to California for release by ARS scientists in Parlier, California, in areas infested with olive fruit fly. Laboratory and field tests showed that the parasitoid reduced numbers of olive fruit fly during the olive growing season. Development of biological control methods for olive fruit fly supports the California olive industry, valued at $75 million annually.

- *Control of Black Widow Spiders in Table Grapes.* Black widow spiders are a problem when grapes are field packed and shipped to European countries, especially Britain. Tests performed by ARS scientists in Parlier, California, using ozone in a chamber indicated that black widow spiders could be completely killed by a 1-hour exposure to 10,000 ppm at reduced pressure. This treatment alleviates the reluctance of countries to import U.S. table grapes and increase the demand for this product. In addition, ARS scientists in Salinas, California, developed an ultralow oxygen treatment for controlling black widow spiders in table grapes, as they were found to be very susceptible to oxygen

deficiency. A 1-day exposure to atmosphere with 0.5 percent oxygen or lower at low temperature was found to be adequate for successful control of the spiders. The treatment was safe for grapes and did not affect quality. Because of short treatment time, low temperature, and easily attainable oxygen level, the treatment has a good potential of being used commercially.

- *Cold Temperature Fumigation of Perishable Commodities with Phosphine.* Imported and exported perishable commodities often must be treated with methyl bromide, which often causes damage to these products and shortens shelf-life. ARS scientists in Parlier, California, have tested a new application of applying phosphine at cold temperature as an alternative to methyl bromide treatment. Results show that the new treatment has no phytotoxic effects on artichokes, white-flesh peaches, and white-flesh nectarines. These results will lead to further testing of the applications to establish efficacy to killing target pests, and if successful in showing efficacy, will lead to the opening of imports of artichokes from Chile and the export of peaches and nectarines to foreign countries.

- *Pallet scale ultralow oxygen treatment for control of western flower thrips on head lettuce.* Western flower thrip is a quarantined pest in Taiwan. Exported lettuce to Taiwan often harbors western flower thrips and therefore requires quarantine treatments. In pallet tests conducted by ARS scientists in Salinas, California, complete control of thrips was achieved and pre-treatment storage also prevented injury to lettuce heart leaves. The large scale pallet tests further demonstrated efficacy and safety of the storage-ULO treatment combination for controlling western flower thrips on head lettuce. The protocols developed for the pallet tests may also be applicable to industry development of ULO treatment and controlled atmosphere storage of fresh commodities. The ultralow oxygen treatments have good potential to be developed into a safer and effective alternative to traditional fumigation for control of quarantined pests on fresh commodities and are also compatible with organic products.

- *Pure phosphine fumigation at low temperature for control of western flower thrips on lettuce, broccoli, asparagus, and strawberries.* Western flower thrip is a quarantined pest n Taiwan. Exported produce to Taiwan often harbors western flower thrips and therefore requires quarantine treatments. ARS scientists in Salinas, California, in collaboration with industry conducted a commercial-scale fumigation trial using pure phosphine in a reefer container. Pure phosphine fumigation was demonstrated to be effective in controlling western flower thrips and safe on all of the commodities tested. This research provides an effective solution to western flower thrips control on exported fresh commodities to Taiwan and benefits U.S. agriculture.

- *New approaches to host status evaluation.* A literature review was completed and data set analyzed for evaluating grapefruit as a host for *Anastrepha obliqua*, the West Indian fruit fly. ARS scientists in Weslaco, Texas, developed a new approach that uses analysis of life tables to evaluate survival of the stages of development of eggs and larvae of the

fly in the peel and pulp tissues. Results showed that egg mortality, due to inability of the females to oviposit below the oil glands, and most larval mortality occurred in the albedo tissue of the peel. Larvae that burrowed into the pulp had high survival to produce pupae and adults. Results from those species and the Mexican fruit fly showed that in Texas, grapefruit are very poor hosts, with eggs and larvae having nearly 100 percent mortality before February 15, but after April 1, Mexican fruit fly readily utilizes the fruit.

- *Sex pheromone of the sapote fruit fly*. The sapote fruit fly (*Anastrepha serpentina*) presents an increasing threat to fruit production, including citrus in Texas where it is periodically trapped and in other regions of the United States where its introduction and survival is possible. Existing fruit fly attractants are only marginally effective against this fly. ARS scientists in Weslaco, Texas, identified chemicals produced by males that are attractive to females and tested these chemicals for attractiveness in laboratory assays. The study was conducted through a diverse collaboration with several ARS laboratories, the Instituto de Ecologia (Xalapa, Veracruz, Mexico), and the Universita degli Studi di Firenze, (Florence, Italy). Results indicate the pheromone probably will not be useful as a lure.

- *Improvement of synthetic lure mixtures containing ammonia for fruit fly trapping*. Anastrepha fruit fly attractants are food based and include volatiles from protein decomposition. Studies by ARS scientists in Weslaco, Texas, show that the emission rate of ammonia is critical, in that above a threshold level, the ammonia becomes repellent. Also, there is an interaction between the artificial lures and the propylene glycol in the capture liquid used to preserve the catch. The research demonstrated and confirmed that there is a synergy when the materials are used in combination. Effective lure-trap combinations are needed for pest survey and detection programs to protect American agriculture from invasive species of fruit flies. Further tests are ongoing in Mexico comparing different delivery systems of the lure components Ammonium Acetate and putrescine using packets versus plugs. One set of tests against *Anastrepha ludens* has been completed. Another test deployed against *Anastrepha obliqua* is under way.

- *Laboratory tests to develop baits for bait stations*. Preparations incorporating grape juice products into the standard spinosad-based bait were completed by ARS scientists in Weslaco, Texas. Optimal compositions of thickeners, adjuvants, humectants, and other additives to produce baits that remains edible and rain-fast were developed and shown in the laboratory to kill more than 95 percent of caged flies in less than 24 hours.

- *Cadaverine in a food-based synthetic attractant for pest tephritid fruit flies*. Putrescine, which is used in combination with ammonium acetate in traps for attracting pest fruit flies, is difficult to analyze chemically, and attraction to this compound may be due to impurities in the formulation. In research by ARS scientists in Miami, Florida, response of the Caribbean fruit fly to a series of related homologous terminal diamines showed that cadaverine elicited both electroantennography (EAG) and behavioral responses

comparable to that of putrescine. Use of cadaverine in place of putrescine would provide improved chemical stability and thus a longer lasting lure for action agencies that use these lures to detect new invasions of pest fruit flies that threaten U.S. agriculture.

- *Efficacy of entomopathogenic nematodes applied by chemigation evaluated.* Entomopathogenic nematodes are expensive to use and a spray application method is needed that will make their use competitive with chemical alternatives. Over the course of 3 years, nematode application through microsprinklers (chemigation) was evaluated by ARS researchers in Parlier, California, in test plots in Madera and Tulare counties. The efficacy of nematodes delivered by this method was demonstrated and the environmental parameters necessary for success determined. This research demonstrated that nematodes can be successfully applied during winter for a negligible labor cost. This research provides pistachio growers in Madera, Fresno, Tulare and Kings counties with a new tool that can be used to reduce overwintering populations of navel orangeworm and thereby reduce the need to use insecticides.