APPENDIX H

Process Used to Select Tools for Use in the Light Brown Apple Moth Eradication Program

Process Used to Select Tools for Use in the Light Brown Apple Moth Eradication Program

Robert V. Dowell, Ph.D.
Director
Light Brown Apple Moth Eradication Program
April 5, 2009

Abstract

This analysis examines all available tools for their use in the light brown apple moth eradication program. The primary criteria used to select the tools were: known to be effective against light brown apple moth or related leafrollers, legally available for use in California, and the most environmentally sound tool if several equally effective tools were available. The tools selected were: pheromone mating disruption, release of *Trichogramma* wasps, ground sprays of organic formulations of *Bacillus thuringiensis* or spinosad, male moth attractant treatments and the release of sterile moths.

The goal of the Light Brown Apple Moth (LBAM) Eradication Program is the elimination of breeding populations of the moth from California. This is fundamentally different than controlling the pest. In control programs the goal is to protect a specified area such as a crop from the damage caused by the moth. Only a portion of the pest population is treated; that which threatens the area to be protected. The control measures are applied to the area to be protected and it is assumed that some damage is acceptable. Control measures are generally not applied outside the area to be protected. Thus, if an exotic pest becomes permanently established in California, control measures will be needed forever.

Eradication programs treat the entire pest population with the goal of eliminating it. If successful, the pest is gone and additional, permanent control measures are no longer needed.

LBAM has never been the target of a previous eradication program. Therefore there are no successful model programs for this program to follow. In these circumstances the California Department of Food and Agriculture (CDFA) and United States Department of Agriculture (USDA) have relied on the use of successful control measures to eradicate the pest. The difference is that instead of simply lowering the pest population in a selected portion of its population (control) we treat the entire population to elimination (eradication).

The CDFA used a step-wise process to evaluate a number of potential tools for use in the LBAM Eradication Program. The process involved an initial screen to determine which tools merited further evaluation and then a second evaluation to determine which tools will actually be used in the program. The following is a description of each potential tool, its known or likely effectiveness in an LBAM eradication program, and any operational constraints on its use. This information was used to select the tools to be evaluated further for use in the eradication program.

I. Initial Evaluation

A. Integrated Pest Management

Integrated Pest Management (IPM) is not a tool but an approach to controlling pests. "Integrated Pest Management (IPM) is an approach which first assesses the pest situation, evaluates the merits of pest management options and then implements a system of complementary management actions within a defined area. The goal of IPM is to mitigate pest damage while protecting human health, the environment and economic viability." (Ciborowski 2007). The components of an IPM program include setting action thresholds, monitoring and detection, proper identification, and action/implementation (Ciborowski 2007). The tools used in an IPM program include biological control, cultural controls such as clean culture and habitat manipulation, chemical controls including insect pheromones, pesticides and biologically produced toxins, genetic control with resistant plants and quarantines (University of California IPM Program 2008, Ciborowski 2007).

All CDFA insect eradication programs represent an integrated approach in which action thresholds are set; detection and monitoring programs are established; target organisms are properly identified, available tools are identified and evaluated for their effectiveness and environmental impacts, and the program is then implemented. For LBAM, the action threshold has changed from the detection of a single moth to the detection of two or more moths within three miles of each other within a time period equal to a single lifecycle. Detection and monitoring is done using over 40,000 traps statewide baited with LBAM pheromone. Suspect LBAM are sent to a CDFA expert for identification. The first LBAM detected in each county is sent to USDA Systematic Entomology Laboratory for confirmation.

The following sections explain the process used by the program to evaluate the potential tools to be used in the LBAM eradication program and to select those tools to be used by the program. Like IPM programs, the program evaluated all available tools including insecticides for possible inclusion in the LBAM eradication program.

The main difference between classical IPM and our eradication programs is the desired end point. For IPM programs, the goal is to use one or more control measures to lower the pest populations within the defined area below economically damaging levels. It is assumed that some damage can be tolerated and that these measures will be needed into the foreseeable future. For our eradication programs, the goal is the elimination of the pest so that control measures will not be needed at all.

IPM, as a control strategy, was not evaluated further in the process to determine which tools would be used in the LBAM Eradication Program. IPM as an approach to pest eradication provides the framework in which individual tools were evaluated.

B. Host Removal-In field

This involves the removal of host plants from within a field. The removal may deny the pest a place to build-up numbers before moving onto the crop. For LBAM, several publications recommend weed control as a way to reduce LBAM numbers, especially in the spring (Williams 2008, Cooperative Research Centre for Viticulture 2006, Mo 2006, Rapley and Sowditch 2006, Loch 2007). Implicit in this tool is that the pest feeds on a range of plants not just the crop. There is no evidence that in-field host removal alone will control LBAM. The use of host removal for a pest like LBAM that eats thousands of different plants, (highly polyphageous pest) especially in urban or natural environments, is undesirable as it would require reducing the environment to a waste land devoid of vegetation. In addition, LBAM females would leave an area denuded of host plants thus increasing the size of the eradication area.

Selective host removal could be used to concentrate LBAM larvae on the hosts left behind. The LBAM larvae on these hosts could be treated with an insecticide to kill them. This option would require the elimination of virtually all plants except those to be left behind; a likely unacceptable option in urban or natural settings. In addition, LBAM females would leave an area with very few of host plants thus increasing the size of the eradication area.

Host removal is not limited in action to just LBAM It may also eliminate the host plants of other insects and mites and the natural enemies of the pests attacking the crop. This goes against many IPM practices that encourage the growth of other plants as a way to conserve natural enemies of pest insects and mites (Master Garden Products 2008, Sustainable Agriculture Research and Education 2009).

Localized host removal is not viewed as effective in an LBAM eradication because of the highly polyphageous nature of LBAM and the likelihood that it would increase spread of the pest; an unacceptable outcome in a program that it designed to limit the pest’s spread. Host removal was not evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

C. Host Removal-Large Scale

The elimination of host plants outside fields can be an effective tool for pests with a limited host plant range. For example, a ¼ mile host free buffer can reduce or eliminate apple maggot invasion of apple orchards or Caribbean fruit fly from grapefruit orchards (Weaver accessed on-line November 5, 2008, Weems et al. accessed on-line November 5, 2008). To work with a highly polyphageous pest like LBAM, the area would need to be essentially denuded of vegetation. There are no data indicating that large scale host removal is effective at controlling LBAM.

The large scale use of host removal for a highly polyphageous pest like LBAM, especially in an urban environment is undesirable as it would require reducing the environment to a waste land devoid of vegetation. In addition, LBAM females would leave an area denuded of host plants thus increasing the size of the eradication area.

Large scale host removal is not limited in action to just LBAM. It may also eliminate the host plants of other insects and mites and the natural enemies of the pests attacking the crop. This goes against many IPM practices that encourage the growth of other plants as a way to conserve natural enemies of pest insects and mites(Master Garden Products 2008, Sustainable Agriculture Research and Education 2009).

Large scale host removal is not viewed as effective in an LBAM eradication because of the highly polyphageous nature of LBAM and the likelihood that it would increase spread of the pest; an unacceptable outcome in a program that it designed to limit the pest’s spread. Host removal was not evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

D. Trap Plants

Trap plants can be used to control the damage of polyphageous pests. The trap plant is planted near the plants to be protected. The trap plant is more attractive to the pest than the plants to be protected. As the pest concentrates in the trap plant, they can be killed by applying insecticides to just the trap plants. Trap plants of alfalfa can be used to protect cotton from leafhoppers (Fouche et al. 2000).

To be effective, the trap plant must be much more attractive to the pest than the plants to be protected. To date, we know of no data indicating that there are a few plants that are vastly more attractive to LBAM than all the other plants in the environment. In addition, if such plants were found, there are obvious logistical problems in planting large numbers of them in urban and natural settings and then periodically treating the trap crops with insecticides.

There are no data on the effectiveness of trap plants against LBAM. Trap crops were not evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

E. Repellents- Feeding

Feeding repellents like neem extracts can be used to protect plants from insects (Charleston no year accessed November 7, 2008). Their activity is limited to the treated plants only after the pest has invaded the field. LBAM larvae are not killed by the repellent. Thus larvae on treated foliage will crawl off looking for untreated foliage on which to feed. To be most effective, the feeding repellents must cover all susceptible potions of the plant. For a highly polyphageous pest like LBAM, this means full coverage of virtually all the plants in the environment; a difficult task in urban and natural settings.

Feeding repellents tend to be non-specific in their action. This is a benefit when applied to a crop but a drawback when used in urban and especially natural settings. The large scale use of feeding repellents in natural settings would impact virtually all plant feeding insects with chewing mouth parts like including butterfly and moth caterpillars, beetle and some plant feeding wasp larvae.

There are no data on the effectiveness of feeding repellents against LBAM.

In theory, complete coverage of all host plants in a large area would result in the starvation of the LBAM larvae and all other affected insects in the area. Such spot treatments might be useful against small, outlier populations of LBAM with limited access to host plants. Feeding repellents were evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

F. Repellents-Egg Laying

It is possible to apply materials like kaolin clay to crops to protect them from egg laying by pest insects (Dufour 2001, Appropriate Technology Transfer for Rural Areas). These repellents drive off the pests rather than killing them. For highly polyphageous pests like LBAM, this means that the females simply fly to the nearest untreated plants and start laying their eggs. This tends to disperse the LBAM into a larger area; an undesirable outcome in an eradication program.

Like feeding repellents, full coverage of the plants to be protected is required. This is difficult in urban and natural settings.

There are no data on the effectiveness of egg laying repellents against LBAM.

Given that egg laying repellents tend to disperse the target pest, their use in large scale eradication programs is counter productive. Egg laying repellents were not evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

G. Insecticides

Insecticides are widely recommended for use in controlling LBAM by Australian and New Zealand officials (Rural Industries Research and Development Corporation 2000, Natural Resources and Environment Victoria 2003, Sutton et al. 2003, Baker 2005, Cooperative Research Centre for Viticulture 2006, Mo 2006, Loch 2007). They can be fast acting materials that kill LBAM larvae and adults. They can be used alone or in conjunction with pheromones.

There are no commercial insecticides available that are specific to LBAM but there are materials whose activity is limited to specific groups of insects. Insecticides have been used successfully by the CDFA in other exotic moth eradication programs. To be most effective against LBAM larvae, any insecticide must be applied to all available hosts in an area. This raises some operational difficulties in urban and natural settings for highly polyphageous pests like LBAM. In addition, LBAM larvae hide and feed in leafrolls which afford them additional protection from insecticides.

Insecticides were evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

H. Pheromone Mating Disruption

Many moths, including LBAM, use pheromones to attract their mates. The pheromone is an airborne perfume-like chemical that is emitted by one sex to draw the other sex to it. Pheromones are used by receptive LBAM females to attract LBAM males. Pheromone disruption is used to control a number of moth pests including codling moth (Femenia-Ferrer et al. 2006, Marti et al. 2006, Stelinski et al. 2006, Welter and Cave 2006).

It is possible to disrupt this attraction by flooding an area with the pheromone of the target moth. The male moths are then unable to discern the pheromone plumes of the female moths from the general background level of pheromone and mating is diminished. Pheromone mating disruption has been demonstrated for LBAM and it is recommended for use against the pest by Australian and New Zealand officials (Code of Environmental Best Practice for Viticulture-Sunraysia Region, Suckling et al. 1994, Rural Industries Research and Development Corporation 2000, Mo 2006, Loch 2007).

LBAM pheromones are not specific to the pest but their activity is limited to LBAM and a small number of closely related moths (Dowell 2007). Pheromone disruption does not kill the LBAM adults. Pheromone disruption has not been used to eradicate any moth population. It is used to slow the spread of gypsy moth in the eastern United States (Cloyd 2003, Cremers 2006).

Given its efficacy against LBAM and its limited range of activity against non-target species, pheromone mating disruption was evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

I. Classical Biological Control

Classical biological control is the use of the natural enemies of a pest to control its numbers below economically damaging levels. Typically this involves an exotic pest that has invaded a new area without its complement of natural enemies. The natural enemies of the pest are introduced into the newly invaded area to establish equilibrium with the pest (Hawkins 2008). Classical biological control has a long and successful history in California with recent success against the ash whitefly and pink hibiscus mealybug (Pickett et al. 1996, Pickett and Wall 2003, Roltsch, no year accessed November 7, 2008). When successful, classical biological control requires only inoculative releases of the natural enemies to achieve permanent control.

A basic assumption in classical biological control is that the natural enemies of the pest are capable of reducing pest numbers below damaging levels and then keeping them at these non-damaging levels.

Classical biological control involves looking for the natural enemies of the pest in their native area, importing the natural enemies, rearing them in culture, screening them to determine how specific they are, releasing those deemed as acceptable and then monitoring their effectiveness. This is a multi-year process regulated by the USDA and CDFA. Natural enemies may not be brought into California without a permit from the USDA Animal and Plant Health Inspection Service (APHIS). The release of any natural enemy also requires a permit from the USDA APHIS.

Classical biological control is not always successful at lowering the numbers of the target pest below economically damaging levels. Natural enemies of the LBAM are important in lowering the numbers of the pest in Australian and New Zealand crops (Williams 2008, Baker 2005, Mo 2006, Rapley and Sowditch 2006, Loch 2007), but they alone are not always effective at preventing the moth from achieving damaging levels in the field (Harder and Rosendale 2008).

Classical biological control is not eradicative and thus not a useful tool in this eradication program. The CDFA and USDA in collaboration with the University of California have begun an effort to locate, acquire and test the specificity of LBAM natural enemies from Australia. This effort will take several years, if successful, and will be implemented should eradication of the pest prove possible and if acceptable natural enemies have been found.

This classical biological control effort is focusing on parasites of the LBAM and not on predators of the moth. In general, parasites of pests tend to be more specific in their choice of prey than the predators. Both the USDA and CDFA strongly prefer not to permit the importation and release of generalist predators or parasites. Generalist predators will eat any prey items they contact. As the target prey become more scarce, generalist predators will switch to the more common prey allowing the numbers of the target prey to increase. This limits the over-all effectiveness of generalist predators like lacewings, big-eyed bugs, ladybird beetles (ladybugs) and such.

Generalist moth parasites are more limited in their scope of acceptable prey items than generalist predators. For LBAM, it is likely that the generalist parasites will attack a range of other leafroller caterpillars and perhaps other caterpillars of about the same size they encounter in the environment. Classical biological control was not evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

J. Inundative Releases of Parasites

Inundative releases of parasites differ considerably from their use in classical biological control. In classical biological control the goal is a permanent reduction in pest numbers below economically damaging levels without further releases of the parasites. The system is self-perpetuating. Inundative releases are not self-perpetuating or stable. Thus control requires the periodic release of the parasites to achieve control which is lost in later generations of the pest. Inundative releases of parasites require a continuous source of the parasites.

Inundative releases of LBAM egg parasites in the genus *Trichogramma* are recommended for LBAM control in Australia and New Zealand (Code of Environmental Best Practice for Viticulture-Sunraysia Region, Bugs for Bugs a,b accessed on-line November 5, 2008, Rural Industries Research and Development Corporation 2000, Williams 2008, Oag 2001, Baker 2005, Cooperative Research Centre for Viticulture 2006, Mo 2006, Rapley and Sowditch 2006, Loch 2007, Wine Grapes Marketing Board 2007, Domeney 2008, Williams 2008). These releases are designed to lower LBAM numbers to acceptable levels for short periods of time. The recommended parasite *Trichogramma carnivore* is not available in this country. However, research done by CDFA and USDA scientists has found that two *Trichogramma* species (*Trichogramma platerni* and *Trichogramma pretiosum*) commercially available in California and one other species, *Trichogramma fasciatum* will attack and kill LBAM eggs. *Trichogramma* do not attack any life stage of their host except the eggs.

These three parasites are not specific to LBAM and they will attack and kill a wide range of butterfly and moth eggs. Thus they are not acceptable for wide scale use in natural environments. They will be of use in targeted releases in urban environments where their impact on non-target butterfly and moths will be less severe. The inundative release of parasites was evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

K. Inundative Releases of Predators

Commercially available predators can be used in the same manner as commercially available parasites. These predators are generalists and thus have the same limitations described above for those used in classical biological control. They will attack any life stage of their prey that they contact.

Given the drawbacks to the use of predators discussed above and their indiscriminate selection of prey, the inundative release of predators was not evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

L. Sterile Moth Releases

Large numbers of mass reared sterile insects can be used to control or eradicate a target pest. The sterile insects mate with the wild ones resulting in the laying of sterile eggs. Sterile insect technique (SIT) is used by the CDFA to eradicate populations of the Mediterranean and Mexican fruit flies and the pink bollworm. Other targeted pests include tsetse flies in Africa, and screwworm and codling moth in North America (Dowell, 1988, Dowell et al. 1999, Bloem and Bloem 2000, Dowell et al. 2000, Grant et al. 2000, IAEA 2000, Masangi et al. 2000, Bloem et al. 2005, Grefenstette et al. 2007, Hendricks accessed on-line November 5, 2008).

LBAM SIT requires a continuous supply of sterile moths. These mass reared moths are released in numbers greater than those of the wild moths to flood the area with sterile moths and thus greatly increase the probability of the wild moths mating with a sterile moth. This over-flooding is required because the mass reared male moths are typically not as competitive as wild male moths at mating with the wild females. By increasing the number of sterile moths in the environment, one can increase the chances that they will get to the wild moths first. Over flooding ratios for fruit flies are typically up to 100 sterile to 1 wild flies. For moth programs the over flooding ratios are much lower in the range of 5-15:1 sterile: to wild moths.

SIT uses fully sterile moths. The moths are sterilized by exposing them either as pupae or adults to high energy waves (radiation) which disrupts activity dividing cells in the male and female reproductive system. The sterile moths are not radioactive, they do not glow in the dark and they are not able to reproduce.

SIT has not been used against LBAM. SIT and inherited sterility (see below) are the only LBAM specific tools potentially available for use in the eradication program. SIT was evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

M. Inherited (F-1) Sterility

Inherited (F-1) sterility also uses the releases of mass reared moths. In this tool, the male moths are only partially sterile. When they mate with wild females, the resulting eggs hatch and the caterpillars develop normally. However these offspring (F-1 generation) are completely sterile and when they mate with wild moths the resulting eggs are sterile (International Atomic Energy Agency 1991, Nguyen and Nguyen 2001, Bloem et al. 2005).

Inherited sterility offers several advantages over SIT. Fewer mass reared moths need to be released because each sterile-wild mating gives rise to multiple sterile F-1 offspring. Thus you amplify you initial release number. It is assumed that using a lower dose of energy to sterilize the moths will increase their competitive ability compared to fully sterile moths.

The major disadvantage is that the desired result occurs in the second generation after release. Thus the environment must endure a full generation of caterpillars eating their host plants before the population is decreased. This makes inherited sterility unacceptable to growers who need to stop the damage being caused by the caterpillars now not a full generation later.

Inherited sterility may be useful in eradication programs like this one because it requires fewer sterile moths and because it can be used in low density pest populations where there are not yet sufficient caterpillars to cause clearly visible damage.

Inherited sterility was evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

N. Mass Trapping- Male Moths

The LBAM pheromone is highly attractive to the male moths. This allows the program to use the pheromone in traps designed to find LBAM populations and determine their physical size and density.

In theory, one could deploy large numbers of traps and catch sufficient numbers of male LBAM to reduce mating to a level that would lower or eliminate the localized population. Unlike pheromone mating disruption, mass trapping directly eliminates the trapped males from the population. Dilworth (2007) has proposed that mass trapping be used to eradicate LBAM from California.

There are no data concerning the efficacy of mass trapping against LBAM. There are operational concerns about placing and retrieving large numbers of traps in urban and natural areas. The direct elimination of male LBAM from a population is attractive. Several species of moth closely related to LBAM are regularly captured in LBAM pheromone baited traps (Dowell 2007). Any mass trapping program will negatively impact these native moths.

Mass trapping of male LBAM was evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

O. Mass Trapping- female moths

Female LBAM can be caught in traps baited with dilute port wine (Bioresources 2009). There are no data on the efficacy of this trap and it is unknown if the lure is specific to LBAM. The direct removal of some female LBAM from a population is an attractive option in an eradication program. However, there are obvious limitations to the use of large numbers of port wine baited traps in urban settings.

The pheromone baited traps for the males is a better mass trapping alternative given the high level of attraction of the pheromone, the unknown level of attraction of the port wine for the females and the operational limitations to the use of port wine as a lure.

Female moth mass trapping was not evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

P. Male Moth Attractant Treatments

Male moth attractant treatments (MMAT) involve the mixing of the LBAM pheromone with a fast acting contact insecticide. This mixture is applied as discrete spots in the environment. The male LBAM are attracted to the spot looking for a female. As they contact the spot, they acquire a lethal dose of the insecticide and die. This tool, also known as an attracticide or an attract-and-kill system, has been shown to be effective against LBAM in field tests in New Zealand (Suckling and Brockerhoff 1999).

MMAT can be applied by workers on foot or by workers in slow moving vehicles. The elimination of male LBAM from a population is attractive to the operation of the eradication program. MMAT uses the LBAM pheromone and thus is not specific to LBAM. The tool will attract and kill males of several closely related moths that are attracted to the components of the LBAM pheromone (Dowell 2007).

MMAT was evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

Q. Quarantines

Quarantines are designed to restrict or eliminate the artificial movement of LBAM within and out of the infested area. Quarantines are necessary to a successful eradication program but they are independent of it. Quarantines against LBAM were instituted before the eradication program and they will remain in place should the eradication program be discontinued. Quarantines are not eradicative.

Quarantines were not evaluated further in the process to determine which tools would be used in the LBAM Eradication Program as they are not directly part of the eradication program.

R. Cultural Control-removal of over-wintering sites

The elimination of over-wintering sites is an integral part of the pink bollworm and boll weevil eradication programs. In these programs, there is a specified date by which the old crop must be destroyed and the fields plowed. This eliminates the over-wintering sites for the pests and thus greatly reduces their numbers in the following year (Grefenstette et al. 2007). The removal of old fruit or nuts (mummys) from fruit and nut trees achieves the same population reduction for moth pests whose larvae or pupae over-winter in these sites. Mummy removal is recommended for naval orange worm in almonds in California (University of California Pest Management Guidelines Almond 2005 Naval Orange Worm. UC IPM Online).

The removal of over-wintering sites is most effective against pests that do not breed continuously and that over-winter in a limited variety of sites within the field. LBAM breeds continuously in California (CDFA web site). The larvae and pupae are found on a variety of plants throughout the winter making the identification of specific over-wintering sites impossible. As with host removal, the highly polyphageous nature of LBAM makes the destruction of over-wintering sites impossible. Cultural control-removal of over-wintering sites was not evaluated further in the process to determine which tools would be used in the LBAM Eradication Program.

Table 1: Summary of Characteristics of Tools Considered for Use in the Light Brown Apple Moth Eradication Program

Candidate Tool	Known to be Effective at Lowering LBAM Numbers	Known to be Effective at Controlling Other Moth Pests	Used in Eradication Programs Aimed at Other Pests	Candidate Tool Considered Further
Integrated Pest Management (IPM)	Yes-IPM is an approach to dealing with pests and not a single tool. IPM as an approach is effective at lowering LBAM numbers	Yes IPM is an approach to dealing with pests and not a single tool. IPM as an approach is effective at lowering numbers of other moth pests	No	No
Host Removal- in field	Yes- Williams 2008, Cooperative Research Centre for Viticulture 2006, Mo 2006, Rapley and Sowditch 2006, Loch 2007	Unknown	No	No
Host Removal- large scale	No	No	Yes	No
Trap Plants	No	No		No
Repellents- Feeding	No		No	Yes
Repellents- egg laying	No	No	No	No
Insecticides	Yes- Rural Industries Research and Development Corporation 2000, Natural Resources and Environment Victoria 2003, Sutton et al. 2003, Baker 2005, Cooperative Research Centre for Viticulture 2006, Mo 2006, Loch 2007	Yes	Yes	Yes
Pheromone Mating Disruption	Yes- Code of Environmental Best Practice for Viticulture-Sunraysia Region, Suckling et al. 1994, Rural Industries Research and Development Corporation 2000, Mo 2006, Loch 2007	Yes-Bloem et al. 2005, Femenia-Ferrer et al. 2006, Marti et al. 2006, Stelinski et al. 2006, Welter and Cave 2006	Yes	Yes
Classical Biological Control	Yes- Williams 2008, Baker 2005, Mo 2006, Rapley and Sowditch 2006, Loch 2007	Yes	No	Yes-only if eradication is not possible

Table 1: Summary of Characteristics of Tools Considered for Use in the Light Brown Apple Moth Eradication Program

Candidate Tool	Known to be Effective at Lowering LBAM Numbers	Known to be Effective at Controlling Other Moth Pests	Used in Eradication Programs Aimed at Other Pests	Candidate Tool Considered Further
Inundative Releases of Parasites	Yes- Code of Environmental Best Practice for Viticulture-Sunraysia Region, Bugs for Bugs a,b accessed on-line November 5, 2008, Rural Industries Research and Development Corporation 2000, Williams 2008, Oag 2001, Baker 2005, Cooperative Research Centre for Viticulture 2006, Mo 2006, Rapley and Sowditch 2006, Loch 2007, Wine Grapes Marketing Board 2007, Domeney 2008, Williams 2008	Yes	No	Yes
Inundative Releases of Predators	No	No	No	No
Sterile Moth Releases	No	Yes- International Atomic Energy Agency 1991, Nguyen and Nguyen 2001, Bloem et al. 2005	Yes	Yes
Inherited (F-1) Sterility	No	No	No	Yes
Mass Trapping- Male Moths	No	No		Yes
Mass Trapping- Female Moths	No	No	No	No
Male Moth Attractant Treatments	Yes- Brockerhoff and Suckling 1999	Yes- Ioriatti and Angeli 2002	No	Yes
Quarantines	No	No	Yes	No
Cultural Control-removal of over-wintering sites	No	Yes	Yes	No

II. Final Tool Selection Process

Those potential tools that were moved forward from the initial screen (Table 1) were subjected to a further analysis.

A. Repellents- Feeding

How applied: Apply as full coverage foliar sprays from the ground. Full coverage requirement eliminates aerial application of this tool. Material is typically mixed with water. Frequent re-applications may be needed to cover new foliage and as the material degrades in the environment.

Advantages: Compatible with pheromone based tools, use of sterile moths and *Trichogramma* wasp releases

May have insecticidal activity

Disadvantages: Limited to treated plants
Full coverage required
Non-specific in action
May not directly kill the larvae
May not be acceptable in large scale use in urban or natural areas
No data on their effectiveness against LBAM
May require frequent re-applications

Alternate Effective tools: insecticides like *Bacillus thuringiensis* are more limited in their action and directly kill the exposed larvae.

Discussion: The biggest drawback to this tool is that it may not directly kill the LBAM larvae. The larvae can leave the treated surface and survive if they find untreated portions of the plant. This requires very complete coverage of the treated plants at frequent intervals. The very non-specific nature of the tool is a concern in urban and especially natural areas. Faster acting, more selective insecticides are available.

Decision: Do not include as a tool in the LBAM eradication Program

B. Insecticides (see Dowell 2009)

There are several uses of insecticides against LBAM. Each will be discussed individually.

How applied: For LBAM larvae, apply as full coverage foliar sprays from the ground. Full coverage requirement eliminates aerial application of this tool. Material is typically mixed with water. Frequent re-applications may be needed to cover new foliage and as the material degrades in the environment.

Advantages: Compatible with pheromone based tools, use of sterile moths and *Trichogramma* wasp releases

Quickly kills LBAM larvae
May be more specific in action than feeding repellents
Known to be effective against LBAM larvae
Application technology used by CDFA in other pest eradication programs

Disadvantages: Limited to treated plants
Full coverage required
May be non-specific in action
May not be acceptable in large scale use in urban or natural areas
May require frequent re-applications

Alternate Effective tools: no other effective tool is available for use against LBAM larvae

Discussion: Insecticides are the most effective, fastest acting tool to kill LBAM larvae. The full coverage of host plants means that they will be most effective in ground based application methods. Insecticides will be used only to treat high density populations of LBAM larvae. The insecticides will be applied to host plants on the infested residential property and perhaps adjacent residential properties if larvae are found there. In areas without residential properties, an area approximately equal to that treated in residential areas will be treated. All insecticide treatments will follow label instructions. Owners of the treated properties will be notified of the treatments in writing before they are applied. The notification will include the insecticide to be used, the date of the application, phone numbers where the land owners can get further information about the application and health information about the insecticide.

The process to select the insecticides to be used to treat large populations of LBAM larvae is discussed elsewhere in this document (Dowell 2009).

Decision: Include as a tool in the LBAM Eradication Program

How applied: For LBAM adults (Male Moth Attractant Treatments), apply as a mixture in a carrier with LBAM pheromone from the ground. Re-applications are applied at 45 to 90 day intervals. Although this tool can be applied by air, the program has elected to restrict its use to ground application methods. The mixture will be applied to street trees and utility poles from slow-moving vehicles

Advantages: Compatible with insecticides for LBAM larvae and *Trichogramma* wasp releases
Quickly kills LBAM adults
Activity limited to LBAM and several closely related moths
Known to be effective against LBAM adults
Application technology used by CDFA in other pest eradication programs
Can treat large areas quickly

With no drift of the material and limited non-target activity, this tool can be used in environmentally sensitive areas

Disadvantages: Limited to areas accessible by vehicle or foot

Alternate Effective Tools: more effective than mass trapping as a tool is to kill male LBAM

Discussion: The use of insecticides mixed with LBAM pheromone (see Male Moth Attractant Treatments below) is an effective method to quickly kill LBAM males over large areas. The tool is not eradicative alone as it will be used in this program. To be eradicative alone, the tool would need to be applied to front and backyard foliage and other sites by staff walking through an area. The program has elected not to do this but rather to apply the tool from slow-moving vehicles. This allows large areas to be treated quickly and limits non-target exposure to the material. All insecticide treatments will follow label instructions. The owners of properties in the treatment area will be notified of the treatments in writing before they are applied. The notification will include the insecticide to be used, the date of the application, phone numbers where the land owners can get further information about the application and health information about the insecticide.

The process to select the insecticide to be used to treat LBAM adults is discussed elsewhere in this document (Dowell 2009).

Decision: Include as a tool in the LBAM Eradication Program

C. Pheromone Mating Disruption

There are several methods available to dispense the LBAM pheromone. Each will be discussed individually.

How applied: Twist ties. The LBAM pheromone is contained in plastic covering a thin piece of metal. The twist tie is attached to a plastic unit that is used to hold the twist tie to the branch of plant. The pheromone slowly evaporates from the plastic and saturates the surrounding area and prevents male LBAM from finding the females. The twist ties are placed at a rate of about 250 per acre; the exact rate is dependent on the amount of foliage in the area. The twist ties are retrieved after use.

Advantages:
Compatible with insecticides for LBAM larvae and *Trichogramma* wasp releases
Activity limited to LBAM and several closely related moths
Have been used to eradicate several small, isolated LBAM populations
Retreat at 90-150 day intervals
Twist ties can be retrieved after application

Disadvantages:
Does not kill LBAM adults
Labor intensive to apply
Supplies insufficient to treat large areas
Must be applied to entire population to be effective

Alternate Effective Tools: other methods to disperse the pheromone (discussed below) and more frequent the release of sterile LBAM adults may achieve the same result in the same timeframe

Discussion: Twist ties have proven to be effective if the entire LBAM population can be treated. Availability of the twist ties and amount of labor needed to apply and then retrieve them limits their use to small, isolated outlier LBAM populations. The twist ties can be retrieved after application meaning that post-treatment monitoring can begin as soon as the twist ties are gone. All applications will follow label instructions. The owners of properties in the treatment area will be notified of the treatments in writing before they are applied. The notification will include the tool to be used, the date of the application, phone numbers where the land owners can get further information about the application and health information about the tool.

Decision: Include as a tool in the LBAM Eradication Program

How applied: Wax-based carrier. The LBAM pheromone is contained in a wax-based carrier that can be sprayed onto plants and other surfaces using ground based application equipment. The pheromone slowly evaporates from the carrier and saturates the surrounding area and prevents male LBAM from finding the females. The carrier is applied as discrete spots at a rate of 15 grams of pheromone per acre. The treatment is repeated at 45 to 60 day intervals.

Advantages: Compatible with insecticides for LBAM larvae and *Trichogramma* wasp releases
Activity limited to LBAM and several closely related moths
Have been used to eradicate several small, isolated LBAM populations
Retreat at 45-60 day intervals
Less labor intensive to apply than twist ties

Disadvantages: Does not kill LBAM adults
Must be applied to entire population to be effective
Material cannot be retrieved after application

Alternate Effective Tools: for small areas, only the use of wax-based or flake-based carriers from the ground or the more frequent the release of sterile LBAM adults may achieve the same result in the same timeframe

Discussion: The use of a wax-based carrier will allow larger areas to be treated by fewer staff than twist ties. The material cannot be recovered after application meaning that it must be allowed to degrade and loose all its pheromone before post-treatment monitoring can begin. All applications will follow label instructions. The owners of properties in the treatment area will be notified of the treatments in writing before they are applied. The notification will include the tool to be used, the date of the application, phone numbers where the land owners can get further information about the application and health information about the tool.

Decision: Include as a tool in the LBAM Eradication Program

How applied: Wax-based or flake-based carrier—ground based application. The LBAM pheromone is contained in a wax-based or a flake-based carrier that can be applied onto plants and other surfaces using ground based application equipment. The pheromone slowly evaporates from the carrier and saturates the surrounding area and prevents male LBAM from finding the females. The carrier is applied as discrete spots or flakes at a rate of 15 grams of pheromone per acre. The treatment is repeated at 45 to 60 day intervals.

Advantages: Compatible with insecticides for LBAM larvae and *Trichogramma* wasp releases
Activity limited to LBAM and several closely related moths
Have been used to eradicate several small, isolated LBAM populations
Retreat at 45-60 day intervals
Less labor intensive to apply than twist ties

Disadvantages: Does not kill LBAM adults
Must be applied to entire population to be effective
Material cannot be retrieved after application

Alternate Effective Tools: for small areas, only twist ties and frequent release of sterile LBAM adults may achieve the same result in the same timeframe

Discussion: The use of wax-based or flake-based carriers applied from the ground will allow larger areas to be treated by fewer staff than twist ties. The material cannot be recovered after application meaning that it must be allowed to degrade and loose all its pheromone before post-treatment monitoring can begin. All applications will follow label instructions. The owners of properties in the treatment area will be notified of the treatments in writing before they are applied. The notification will include the tool to be used, the date of the application, phone numbers where the land owners can get further information about the application and health information about the tool.

Decision: Include as a tool in the LBAM Eradication Program

How applied: Wax-based or flake-based carrier—air based application. The LBAM pheromone is contained in a wax-based or a flake-based carrier that can be applied onto plants and other surfaces using air based application equipment. The pheromone slowly evaporates from the carrier and saturates the surrounding area and prevents male LBAM from finding the females. The carrier is applied as discrete spots or flakes at a rate of 15 grams of pheromone per acre. The treatment is repeated at 45 to 60 day intervals.

Advantages: Compatible with insecticides for LBAM larvae and *Trichogramma* wasp releases
Activity limited to LBAM and several closely related moths
Retreat at 45-60 day intervals
Less labor intensive to apply than twist ties or ground based application technologies

Disadvantages: Does not kill LBAM adults
Must be applied to entire population to be effective
Material cannot be retrieved after application

Alternate Effective Tools: for large areas, only the frequent the release of sterile LBAM adults may achieve the same result in the same timeframe

Discussion: The use of wax-based or flake-based carriers applied from the air will allow larger areas to be treated more quickly and with fewer staff than twist ties or ground based application technologies. The material cannot be recovered after application meaning that it must be allowed to degrade and loose all its pheromone before post-treatment monitoring can begin. All applications will follow label instructions. The owners of properties in the treatment area will be notified of the treatments in writing before they are applied. The notification will include the tool to be used, the date of the application, phone numbers where the land owners can get further information about the application and health information about the tool.

The program has elected not to continue the large scale use of pheromone disruption from the air over urban or residential areas, selecting the use of sterile moths instead. The aerial application of LBAM pheromone for mating disruption will be limited to agricultural settings or essentially uninhabited areas that cannot be treated from the ground. Should the release of sterile moths not prove effective in eradicating LBAM, this decision may be revisited.

Decision: Include as a tool in the LBAM Eradication Program

How applied: Mobile Mating Disruption. The LBAM pheromone is applied to a different insect species and large numbers of this other insect are released into the environment. The pheromone slowly evaporates from the insect carrier and saturates the surrounding area and prevents male LBAM from finding the females. The insect carrier is released at 7 to 14 day intervals.

Advantages: Compatible with insecticides for LBAM larvae and *Trichogramma* wasp releases
Activity limited to LBAM and several closely related moths
May be able to use Medflies or another fruit fly and have the carrier insect also prevent introductions of wild members of its species from establishing infestations in California

Disadvantages: Does not kill LBAM adults
Must be applied to entire population to be effective
Material cannot be retrieved after application
Requires a mass reared insect carrier
Unproven technology

Alternate Effective Tools: for large areas, only the more frequent the release of sterile LBAM adults may achieve the same result in the same timeframe

Discussion: This is an unproven technology that is not yet ready to be evaluated further for use as a tool in the LBAM Eradication Program Should it prove effective, the owners of properties in the treatment area will be notified of the treatments in writing before they are applied. The notification will include the tool to be used, the date of the application, phone numbers where the land owners can get further information about the application and health information about the tool.

Decision: Delay further review until the tool has been demonstrated as effective in the field.

D. Inundative Releases of Parasites

How applied: Cards containing moth eggs with the wasp pupae inside are placed on trees and shrubs in the treated area at a rate of about 1 million parasites per square mile**.** The treatment is repeated at 7 to 10 day intervals to be continuously effective. The wasps to be used are small (1/25th of an inch) and stingless. They are commercially available and require no permits to be used.

Advantages: Compatible with insecticides for LBAM larvae and pheromone-based tools

Activity limited to LBAM eggs
Does kill LBAM eggs
Known to be effective against LBAM
Commercially available
Can be used as a quick spot treatment

Disadvantages: Non-specific in action
Labor intensive to apply
Supplies are limited
Not acceptable in natural areas or near threatened or endangered insects when their eggs are present
Must be frequently reapplied to be continuously effective

Alternate Effective Tools: no other tool kills LBAM eggs. Insecticides aimed at LBAM larvae may be as effective in lowering LBAM populations.

Discussion: The wasps can be used to achieve a quick reduction in subsequent LBAM numbers. To be effective over long periods of time they must be continuously released every 7 to 10 days The wasps are non-specific and will attack any insect eggs of the proper size especially butterfly and moth eggs. The owners of properties in the treatment area will be notified of the treatments in writing before they are applied. The notification will include the tool to be used, the date of the application, phone numbers where the land owners can get further information about the application and health information about the tool.

Decision: Include as a tool in the LBAM Eradication Program

E. Sterile Moth Releases

How applied: Mass reared LBAM adults will be released from either slowly moving vehicles or by air

Advantages:
- Compatible with insecticides for LBAM larvae and Trichogramma wasp releases
- Activity limited to LBAM
- Acceptable in natural areas or near threatened or endangered plants and animals
- Can be used in all situations where LBAM is found
- Technology to rear and release similar moths is used by CDFA

Disadvantages:
- Supplies are limited
- Must be frequently reapplied to be continuously effective
- Details of use must still be worked out for California

Alternate Effective Tools: the only LBAM specific tool available. Large scale use of pheromone mating disruption may achieve the same result in about the same timeframe.

Discussion: The use of sterile LBAM adults has been selected by the program as the primary tool to be used in the eradication program. The owners of properties in the treatment area will be notified of the treatments in writing before they are applied. The notification will include the tool to be used, the date of the application, phone numbers where the land owners can get further information about the application and health information about the tool.

Decision: Include as a tool in the LBAM Eradication Program

F. Inherited (F-1) Sterility

How applied: Mass reared partially sterile LBAM adults will be released from either slowly moving vehicles or by air

Advantages:
Compatible with insecticides for LBAM larvae and Trichogramma wasp releases
Activity limited to LBAM
Acceptable in natural areas or near threatened or endangered plants and animals
Can be used in all situations where LBAM is found
Technology to rear and release similar moths is used by CDFA
Needs fewer moths released than sterile moth technique

Disadvantages:
Supplies are limited
Must be frequently reapplied to be continuously effective
Details of use must still be worked out for California
Larval damage continues for one full generation after moth release
Delay in results for one generation
Never used in any pest eradication program

Alternate Effective Tools: the only LBAM specific tool available. Large scale use of pheromone mating disruption may achieve the same result in about the same timeframe.

Discussion: The delay in seeing a population reduction and the continued larval feeding for one generation after moth release are concerns. The program proposes to use this tool while mass-reared moths are available and the LBAM colony is being built-up to full strength. This will limit the tool to being used only on discrete, fairly small populations of the pest. The owners of properties in the treatment area will be notified of the treatments in writing before they are applied. The notification will include the tool to be used, the date of the application, phone numbers where the land owners can get further information about the application and health information about the tool.

Decision: Include as a tool in the LBAM Eradication Program

G. Mass Trapping- Male Moths

How applied: Large numbers of pheromone baited traps are dispersed throughout the treated area

Advantages: Compatible with insecticides for LBAM larvae and *Trichogramma* wasp releases
Activity limited to LBAM and several closely related moths
Retreat at 45-60 day intervals
Material can be retrieved after application
Does kill male adult LBAM

Disadvantages: Has been reviewed and found unacceptable by the LBAM Technical Working Group (Mastro 2008).

Alternate Effective Tools: pheromone mating disruption and the release of sterile moths

Discussion: The LBAM Technical Working Group (LBAM TWG) has reviewed a citizen generated proposal to use this tool and found it to be unacceptable. The LBAM TWG has recommended that mass trapping not be used in this program.

Decision: Do not include as a tool in the LBAM Eradication Program

H. Male Moth Attractant Treatments

See the discussion of this tool in the insecticide section above.

Table 2: Specificity of the Candidate Tools for Use in the LBAM Eradication Program

Candidate Tool	Specific to LBAM	Specific to Moths Closely Related to LBAM	Nonspecific in Action	Recommended by Technical Working Group
Repellents- Feeding				
Insecticides			●	●
Pheromone Mating Disruption		●		●
Inundative Releases of Parasites			●	●
Sterile Moth Releases	●			●
Inherited (F-1) Sterility	●			
Mass Trapping- Male Moths		●		
Male Moth Attractant Treatments		●		●

Table 3: Concurrent use compatibility of the selected tools for use in the LBAM Eradication Program

Candidate Tool	Insecticides for larvae	Pheromone Mating Disruption	Inundative Releases of Parasites	Sterile Moth Releases	Inherited (F-1) Sterility	Male Moth Attractant Treatments
Insecticides for larvae		●	●	●		●
Pheromone Mating Disruption	●		●			
Inundative Releases of Parasites	●	●		●	●	●
Sterile Moth Releases	●		●		●	
Inherited (F-1) Sterility	●		●	●		
Male Moth Attractant Treatments	●		●			

Table 4: Operational Characteristics of Candidate Tools

Tool	Action of tool	Duration of action	Immediate impact on trap catch of wild moths	Ultimate effect on trap catch of wild moths
Insecticides for larvae	Kills larvae	7 to 14 days per treatment	None	Reduces trap catch one generation later
Pheromone Mating Disruption	Stops mating	60-150 days depending on how it is applied	Stops trap catch	Reduces trap catch one generation later
Inundative Releases of Parasites	Kills eggs	7 to 10 days per release	none	Reduces trap catch one generation later
Sterile Moth Releases	Produces sterile eggs	Estimated as 7 to 10 days per release	None	Reduces trap catch one generation later
Inherited (F-1) Sterility	Produces sterile adults one generation later		None	Reduces trap catch two generations later
Male Moth Attractant Treatments	Kills male moths reducing mating	60 to 90 days per treatment	Stops or reduces trap catch	Reduces trap catch one generation later

Table 5: Summary of Decisions on Whether to Use Candidate Tools in the Light Brown Apple Moth Eradication Program

Candidate Tool	To be Used in the LBAM Eradication Program
Insecticides for larvae	Yes
Pheromone Mating Disruption	Yes
Inundative Releases of Parasites	Yes
Sterile Moth Releases	Yes
Inherited (F-1) Sterility	Yes
Male Moth Attractant Treatments	Yes
Mass Trapping-Male moths	No

References

Appropriate Technology Transfer for Rural Areas. Reduced-Risk Pest Control Factsheet. Insect IPM in Apples. Kaolin Clay. (accessed on-line November 5, 2008).

Baker, G. 2005. Light brown apple moth. Fact Sheet No. 07/04. Government of South Australia. Primary Industries and Resources.

Bioresources 2008. *Trichogramma carverae*. (accessed on-line April 6, 2009).

Bloem, K. A. and S. Bloem. 2000. SIT for codling moth eradication in British Columbia, Canada. Pgs 207-214. In: Area-Wide Control of Fruit Flies and Other insect Pests. K.H. Tan (ed.).

Bloem, K., S. Bloem and J. Carpenter. 2005. Impact of moth suppression/eradication programmes using the sterile insect technique or inherited sterility. Abstract. USDA ARS. (accessed on-line November 5, 2008).

Brockerhoff, E. G. and D. M. Suckling. 1999. Development of an attracticide against light brown apple moth (Lepidoptera: Tortricidae). J. Econ. Entomol. 92: 853-859.

Bugs for bugs. Trichogramma wasps for light brown apple moth. (Accessed on-line November 5, 2008).

Charleston, D. Science in Africa. Hope for the humble cabbage-biological pest management program. (Accessed on-line November 5, 2008)

Ciborowski, J. 2007. Definition of Integrated Pest Management. Minnesota Department of Agriculture.

Cloyd, R. A. 2003. Gypsy moth: mating disruption and trapping. Home, yard and garden pest Newsletter. University of Illinois Extension.

Code of Environment Best Practice for Viticulture-Sunraysia Region. (accessed on-line November 5, 2008).

Cooperative Research Centre for viticulture. 2006. Developing a cost-effective monitoring program for light brown apple moth.

Cremers, K. T. 2006. 2006 treatments for gypsy moth management using mating disruption. Slowing the spread of gypsy moth North Shore Minnesota July-August 2006. Minnesota Department of Agriculture.

Domeney, P. 2008. Beneficial Wasps:(Trichogramma carvarae). Department of Primary Industries and Water, Tasmania.

Dowell, R. V. 1988. Exclusion, detection and eradication of exotic fruit flies in California. Chapter 8 in Ecology and Management of Economically Important Fruit Flies. M. T. AliNiazee. Agric. Exp. Stn. Oreg. State Univ. Spec. Rpt. 830.

Dowell, R. V. 2007. Response to LBAM Task Force Issues and Concerns. CSDFA LBAM web site.

Dowell, R. V., I. A. Siddiqui, F. Meyer, and E. L. Spaugy. Early results suggest sterile flies may protect S. California from Medfly. Calif. Agric. 53: 28-32.

Dowell, R. V, Isi. A. Siddiqui,Fred. Meyer and E. Leon Spaugy. 2000. Mediterranean fruit fly preventative release programme in southern California. Pp 369-375. *In* K. H. Tan (ed.). Area-Wide Control of Fruit Flies and Other Pests. Penerbit Universiti Sains Malaysia, Penang

Dufour, R. 2001. Kaolin clay for management of glassy-winged sharpshooter in grapes. University of California. Division of Agriculture and Natural Resources.

Femenia-Ferreri, B., D. Bosch, P. Moya, J. Avilla and J. Primo. 2006. Field assays of a new biodegradable controlled-release pheromone dispensers for mating disruption of *Cydia pomonella* (L.). International Workshop on Arthropod Pest Problems in Pome Fruit Production. International Organization for Biological Control. Bulletin Vol. 30(4) 2007. J. Avilla, J. Cross and C. Loriatti (eds.).

Fouche, C., M. Gaskell, S. T. Koike, J. Mitchell and R. Smith. 2000. Insect Pest Management for Organic Crops. University of California, Division of Agriculture and Natiral Resources. Pub. 7251.

Grant, G. H., J. W. Snow and M. V. Teran. 2000. The New World Screw-worm as a pest in the Caribbean and plans for its eradication from Jamaica and other infested Caribbean Islands. 2000. pgs 87-94. In: Area-Wide Control of Fruit Flies and Other insect Pests. K.H. Tan (ed.).

Grefenstette, B., O. El-Lissy, and R.T. Staten. Pink bollworm eradication plan in the U.S. 2007. (accessed on-line November 5, 2008).

Harder, D. and J. Rosendale. 2008. Integrated pest management practices for the Light Brown Apple Moth in New Zealand: implications for California. Unpublished report. Accessed online October 10, 2008.

Hendricks, J. Use of the sterile insect technique against key insect pests. Sustainable Development International. (Accessed on-line November 5, 2008).

International Atomic Energy Agency. 1991. Radiation Induced F1 sterility in Lepidoptera for area-wide control. Proceedings of the Research Co-ordination meeting, Phoenix, Arizona.

Ioriatti, C. and G. Angeli. 2002. Control of codling moth by attract and kill. Pgs 1-9. In Use of pheromones and other semiochemicals in integrated production. International Organization of Biological Control Bull. 25.

Loch, A. 2007. Primefacts. Grapevine pests and their management.

Marti, S., A. Zaragoza and T. Larsen. 2006. Mating disruption of codling moth *Cydia pomonell*a (L.) using puffer CM, on apple orchards. International Workshop on Arthropod Pest Problems in Pome Fruit Production. International Organization for Biological Control. Bulletin Vol. 30(4) 2007. J. Avilla, J. Cross and C. Loriatti (eds.).

Master Garden Products. 2008. Benefic and value of insects.

Mastro, V. C. 2008. Letter to R. V. Dowell. TWG response to H.O.P.E.'s proposal to eliminate LBAM through trapping. Dated 2 May 2008.

Mo, J. 2006. Light brown apple moth in citrus. Primefact 216. New South Wales Department of Primary Industries.

Msangi, A. R., K. M. Saleh, N. Kiwia, I. I. Malele, W. A. Mussa, F. Mramba, K. G. Juma, V. A. Dyck, M. J. B. Vreysen, A. G. Parketr, U. Feldmann, Z-R. Zhu and H. Pan. 2000. Success in Zanzibar: Eradication of tsetse. Pgs. 57-66. In: Area-Wide Control of Fruit Flies and Other insect Pests. K.H. Tan (ed.).

Natural Resources and Environment Victoria. 2003. Common pests of summer fruit in Western Australia. Bulletin No. 4585. July 2003.

Nguyen, T.Q.H. and T. T. T. Nguyen. 2001. Radiation induced F1 sterility in *Plutella xylostella* (Lepidoptera: Plutellidae): potential for population suppression in the field. Fla. Ent. 84: 199.

Oag, D. 2001. 3. Grape Production in Australia. Grape Production in the Asia-Pacific Region. M.K.. Papademetriou and F.J. Dent (eds.). FAO Regional Office for Asia and the Pacific.

Pickett, H., J. C. Ball, K. C. Casanave, K. M. Klonsky, K. M. Jetter, L. G. Bezark and S. E. Schoenig. 1996. Establishment of the ash whitefly parasitoid *Encarsia inaron* (Walker) and its economic benefit to ornamental street trees in California. Biological Control 6: 260-272.

Pickett, C. H. and R. Wall. 2003. Biological control of ash whitefly *Siphoninus phillyreae* (Haliday) (Homopteras: Aleyrodidae) by *Encarsia inaron* (Walker) (Hymenoptera: Aphelinidae) in northern California: 1990-2000. Pan-Pacific Entomologist 79:156-158.

Rapley, P. and T. Sowditch. 2006. Integrated pest and disease management calendar for Tasmanian apples. Horticulture Branch, Department of Primary Industries and Water.

Roltsch, W. J. Pink hibiscus mealybug biological control in Imperial Valley, CA. (accessed on-line November 7, 2008).

Rural Industries Research and Development Corporation. 2000. Pests and Pest Management Impact of Climate Change.

Stelinski, L. L., L. J. Gut, P. McGhee and J. R. Miller. 2006. Towards high performance disruption of codling moth, *Cydia pomonella* (L.). International Workshop on Arthropod Pest Problems in Pome Fruit Production. -International Organization for Biological Control. Bulletin Vol. 30(4) 2007. J. Avilla, J. Cross and C. Loriatti (eds.).

Suckling, D. M., G. M. Burnip, J. R. Clearwater, P. W. Shaw, G. F. McLaren, D. Thompson and C. H. Wearing. 1994. Mating disruption for caterpillar control in organic pipfruit orchards in New Zealand. HortResearch New Zealand.

Sustainable Agriculture Research and Education. 2009. Manage insects on your farm: a guide to ecological strategies.

Sutton, J., S. Trainer and M. Sivyer. 2003. Pome and stone Fruit Orchard Spray Guide 2003/04. Bulletin 4596. Director General of the Department of Agriculture 2003. Australia.

University of California Statewide Integrated Pest Management Program. 2008. UC IPM Online. Accessed November 7, 2008

Weaver, L. The Caribbean fruit fly protocol. Florida Laws. (accessed on-line November 5, 2008).

Weems, H. V., J. B. Heppner, T. R. Fasulo and J. L. Nation. 2001. Featured Creatures. Caribbean fruit fly. (accessed on-line November 5, 2008).

Welter, S. and F. Cave. 2006. Evaluation of alternative pheromone dispensing technologies for codling moth. Walnut Research Reports. University of California Fruit and Nut Research and information Center.

Williams, D. Light brown apple moth in orchards. 2000. Information Notes. State of Victoria. Department of Primary Industries.

Williams, D. 2008. Light brown apple moth in orchards. Information Notes. State of Victoria, Department of Primary Industries.

Wine Grapes Marketing Board. 2007. Sep-Oct 2007.