PROJECT DESCRIPTION

A. Problem Background and Justification

In a fall 2000 survey of beekeepers in the MAAREC (Mid-Atlantic Apiculture Research and Extension Consortium) region, which consists of Delaware, Maryland, New Jersey, Pennsylvania and West Virginia, Integrated Pest Management (IPM)and non-chemical control of varroa were listed as the most pressing research concerns, 79% and 84% respectively. Three Mid-Atlantic States, Delaware, Maryland and Pennsylvania, will be testing the IPM tactics to develop non-chemical control tactics for varroa. These tactics will be applicable to all regions of the country because beekeeping practices and varroa characteristics are similar throughout the country. The proposed approach will help to improve the current management of varroa by providing a non-pesticidal alternative for varroa control. By reducing pesticide use in colonies, residues in honey and other hive products will diminish, thereby reducing pesticide exposure for children and others. In addition, reducing pesticide use will slow the development of mite resistance, already a widespread problem for fluvalinate and a growing problem for coumaphos, which has only been used in honey bee colonies since 1998. Further, the possibility of sublethal and lethal effects on honey bees from the two approved miticides will be reduced. Beekeepers, regardless of the size of their operation, will obtain a cost-effective and labor efficient pest management alternative to organophosphate and pyrethroid insecticides.

This project addresses the management of an invertebrate pest on honey bees, an invertebrate that is essential to over 90 fruit and vegetable crops worldwide. Honey bees (*Apis mellifera*) are valued at $14.6 billion (Morse & Calderone 2000, Free 1993). Readily available, affordable and efficient pollinators of crops are essential for today's growers to produce not only the foods that consumers demand (whole, round and fully-formed), but also the seeds needed for future crops. However, colony populations are in jeopardy because of the 1988 introduction of *Varroa destructor* (=V. jacobsoni, Anderson & Trueman 2000). The accessibility of honey bee pollinators from beekeepers and the background pollination by feral colonies has declined over the past ten years due largely to varroa. In PA, for example, an average of 53% of managed honey bee colonies died between 1995 and 1996 (Finley et al. 1996). In many regions of the US, nearly all feral honey bee nests have died (Krause & Page 1995). The loss has been noticed by growers and others who have relied partially on feral bees for pollination, and has resulted in an increased demand for managed honey bee colonies. Increased losses have caused beekeepers to give up keeping bees, and this has increased the cost for leasing hives due to the shortage of colonies.

Current methods for varroa control are application of fluvalinate, a pyrethroid, and coumaphose, an organophosphate. Mite resistance to fluvalinate was reported in 1998 and is now widespread (Elzen et al. 1998, 1999). Resistance to coumaphos, used only since 1999, has been reported in Maine, New Jersey and Florida (Elzen and Westervelt 2002). Coumaphos and fluvalinate have been detected in hive products, e.g., honey (Lodesani et al. 1992, Garcia et al. 1996, Fernandez Muino et al. 1997, Wallner 1997, Bogdanov et al. 1998, Wallner 1999). Both these compounds are lipid soluble so concentrations in honey will be less than concentrations in wax. Fluvalinate in wax has been reported by Sokol (1996), Currie (1999), Rinderer et al. (1999), and Wescott & Winston 1999) to cause adverse effects on queens and drones exposed to fluvalinate. Coumaphos found in high concentrations in wax because of its very slow degradation rate (Wallner 1999), has been shown in queen rearing operations to increase

sublethal effects such as physical normalities and atypical behavior and to increase queen mortality rates (Haarmann et al. 2002). Similar studies investigating the effect of coumaphos on workers and drones have not been conducted.

Life History of Varroa

Varroa destructor, an external parasite similar to a tick, was originally confined to *Apis cerana*, the Asian honey bee. Varroa has spread to the European bee *A. mellifera*, via beekeeper movement, to all countries except Australia and the state of Hawaii. The spread of varroa is shown on an animated map at *http://www.csfnet/image/ animap2.gif*. In 1986, varroa was first reported in the U.S.; it is now the major killer of all bee colonies, wild or managed.

Adult female mites measure 1.1 mm long x 1.6 mm wide and are a reddish-brown color (Sammataro et al. 2000). The ovoid males are smaller, about 500 µm wide, and lighter in color. Adult bees serve as a short-term host and provide a site for female mite dispersal (phoresy). The mite pierces the soft tissues of the bee's abdomen, or behind the bee's head, and feeds on the hemolymph (blood).

Varroa populations are the highest during the summer months because honey bee reproduction is highest during these months and varroa requires bee brood for reproduction. Varroa prefer drone (male) larvae to worker (female) larvae; the mite is attracted to specific chemicals emitted by the immature drone (Donzé et al. 1998).

The female mite enters the open brood cells and remains hidden under the liquid brood food until the brood cell is capped. This behavior allows the mite to avoid discovery by the nurse bees. Once the bee pupa begins to form, the mite pierces the pupa and feeds on hemolymph. The first egg from a mite, a haploid male, is produced 60 hours after the cell is sealed. At 30-hour intervals, 2 to 6 female eggs are produced. The foundress mite keeps the feeding site on the pupa open to allow her offspring to eat (Donzé & Guerin 1994). Male mites mature in 5 to 6 days, then mate frequently with each emerging sister mite. The total life cycle of the male is completed in the brood cell. Female mites mature in 6 to 7 days (De Jong 1997) and emerge with the callow bee; female mites may be phoretic for 4 to 5 days on other adult bees before invading new brood. If mites invade drone cells, 2.6 female offspring are produced; in worker cells, the mean is 1.3 (Schulz 1984).

Mites are spread when bees from an uninfested colony rob an infested one. If unchecked, mite parasitism will kill a colony. The cause of death of mite-infested colonies is still not clearly understood, but elevated incidences of viruses and other diseases may be involved (Shimanuki et al. 1994). Virus and bacteria are commonly found in colonies; death rates from these endemic diseases appear to increase when mites are present (Ball 1988). Recently mites have been shown to act as a disease vector (Shen et al. 2002). Varroa has also been recently shown to adversely impact bees by reducing their ability to fight infections (Yang 2000). This could exacerbate subclinical infections of nosema, foulbrood, chalkbrood, or viral diseases.

Queen Replacement

Varroa reproduction requires bee brood for reproduction. If honey bee reproduction is temporarily interrupted, varroa reproduction will also be interrupted. Caging existing queens, replacing existing queens but leaving the queen caged for an extended period and queen removal to trigger the making of new queen would all interrupt bee and mite production. Preliminary data from 2002 in colonies located on the eastern shore of Maryland indicate that queens can be confined in the colony for up to 15 days without ill effects to the queen or the colony. Mite

numbers were insufficient during 2002 to provide preliminary data on the efficacy of queen confinement on mite level reduction.

Changing the timing of queen replacement would not increase or only minimally increase the work required for colony management because beekeepers replace queens on an annual or bi-annual basis (Caron 1999, Sammatarro & Avitabile 1998). Spring queen replacement, the traditional time for changing queens, occurs when mite reproduction rates are slow while mid-summer replacement would interrupt mite reproduction when it is the highest. Some data indicated that fall replacement improves the rate of spring build-up in colonies (Sammatarro & Avitabile 1998) but mite reproduction rates are declining at this time of year. Summer replacement has the potential to interrupt mite reproduction at its peak, provides the colony with a younger queen for entering winter and allows for the use of local breed queens in cooler regions of the country. Currently most queens are purchased from areas where queen rearing can begin early in the year because of warmer winters. Queens bred in warm regions may not overwinter as well in cold regions.

Screen Inserts

Screen inserts are also being studied as a component of a successful mite control program. Khanbash & Ahmed (1999) Nasr & Kevan (1999) Pettis & Shimanuki (1999), and Sammataro et al. (in preparation) indicate that screens provide a barrier between bees and live mites that have fallen off of bees. Unpublished data from our lab indicate that in addition to providing a physical barrier, screens may also reduce the ability of mites to survive due to increased water loss. When these screened colonies in our protected and unprotected apiaries are compared, the mite levels are lowest in the unprotected apiary. The unprotected apiary was subject to constant air movement. Yoder et al. (1999) report that mites have difficulty retaining water and suggest that increasing the air flow inside a colony may be used as a control measure. Air flow may be increased by locating colonies in a windy area.

Controlling Varroa

Since 1988, the pyrethroid fluvalinate has been available to control varroa. In the last few years, reports of mites resistant to this pesticide have become common (Elzen et al. 1998, 1999). To control resistant mites, the organophosphate coumaphos was given a Section 18 registration each year starting in 1999. This is only a short-term solution to the mite problem. Coumaphos, as with other organophosphate pesticides, increases the risk of environmental and human adverse outcomes due to the toxicity of these compounds (Extoxnet 1996). Lodesani et al. (1992), Wallner (1997, 1999) Garcia et al. (1996), Fernandez Muino et al. (1997), and Bogdanov et al. (1998) report the detection of coumaphos and fluvalinate in hive products, such as honey, wax, and propolis. Honey is consumed in many forms by children and adults and is used in many home remedies for colds, sore throats, and other minor illnesses.

Exclusive chemical control programs are inherently limited because of resistance development. An IPM system is a tiered structure based upon knowledge of the biology of the pest and host. Combining the basic biology of bee/mite relationship and the four IPM strategies (biological, culture, physical and chemical controls) we propose to test strategies for varroa control using queen manipulation to interrupt brood production with screen bottom boards and to transfer the study results to the beekeeper community.

The importance of this project is due to large bee losses from varroa, development of pesticide resistance by varroa, and the substitution of a moderately toxic organophosphate pesticide for a

pyrethroid pesticide with low toxicity. Without reliable alternative tactics, beekeepers may resort to untested, and possibly dangerous, methods that could increase the risk of hive products and environmental contamination. Control of varroa is essential as further losses of managed bee colonies would cause even greater difficulties for growers of fruit and vegetable crops who rely on bees for pollination. Other IPM projects are being conducted in the Southeast and elsewhere and the tactics to be tested in this project will complement the work being done by others. A project being conducted by Calderone, Sheppard and Pettis (IFAFS 2001) is selecting queen strains that are more resistant to varroa. This project will contribute to the objectives proposed in this project as it will provide beekeepers with queens who are able to contribute to the suppression of mite population growth. Huang (PMAP 2002) is testing a devise that kills varroa by heating the comb with electricity. This devise will provide beekeepers with a method that may also contribute to the suppression of mite population growth. Skinner (SE IPM 2001) is testing two 'softer' chemicals controls for varroa; if tactics such as requeening fail in any particular year, formic acid or a thymol based miticide would be useful alternatives. Delplane, Skinner, and Hood are field testing the ability of SMR (suppression of mite reproduction) queens and screen inserts to prevent mite populations from exceeding their threshold. Harbo and Rindereer (USDA Bee Lab, Baton Rouge, LA) and Spivak and Reuter (University of Minnesota) continue to develop and test strains for bees for their ability to resist or tolerate mites or suppress their population growth rate. Noel, Amrine and Kovacs (2002) have report testing various IPM tactics for varroa control; their liquid formic fumigator provided the most efficacious results.

B. Objectives

Objective 1: *Test the efficacy of delaying queen release or of queen caging as an IPM tactic to reduce varroa levels in honey bee colonies.*

IPM tactics need to be integrated into beekeeper management practices. Any IPM tactic that increases the already significant amount of time needed for normal colony management will not be adopted by beekeepers. An IPM tactic that replaces queens may require some additional time by beekeepers but the increase is likely to be small to non-existent because queens are replaced an annual or biannual basis in most operations.

We will evaluate several methods of queen confinement/replacement, each requiring a different amount of work by the beekeeper and each having the potential to reduce colony mite levels. The confinement/replacement of the queen has the potential to reduce mite numbers as mites require bee brood for reproduction. A foundress mite enters and hides in a brood cell before the nurse bee caps the cell, then the mite waits for the pupa to develop. Once the pupa begins to develop the mite feeds on the bee hemolymph and begins to lay eggs. Interrupting the reproduction of the honey bee would interrupt the reproduction of the mite. Timing of this interruption is important because it has been observed that mite reproduction is lowest in the spring and early summer and begins to grow exponentially by mid to late summer. If exponential growth can be avoided, then mite levels can be suppressed. European and American researchers (Schultz 1984, Eischen & Wilson 1998) have explored this tactic and found that it has potential.

Two control treatments will be used in the experiment. Some colonies will not be manipulated, leaving the original queen in the colony while other colonies will have queens

replaced in the traditional manner. Because neither of these treatments will interrupt honey bee reproduction, we anticipated that mite reproduction will not be interrupted. The remaining four treatments will interrupt honey bee reproduction and, we believe, mite reproduction. Colonies when queenless will rear a new queen. We will remove the existing queen from each of two groups colonies and randomly place caged queens into half of these colonies. The other colonies will remain queenless. The queenless colony will produce queen cells and will eventually rear a new queen. While queenless, the bee reproduction will be interrupted and mite reproduction will also be halted. Queens will emerge no sooner than 16 days after the removal of the old queen. Approximately six days after emerging, the queen leaves the hive on a mating flight; three days later she is ready to lay eggs (Sammataro & Avitabile 1998). No egg laying is expected in these colonies for at least 25 days. The colonies with the caged queen, because a queen is present, will not make queen replacement cells but the queen will be unable to lay any eggs. These queens will be released from the cages after 10 days and will be able to begin laying eggs at that time. The remaining two groups of bees will have their queen's caged for 15 and 21 days, thus interrupting bee and mite reproduction for different lengths of time.

We expect to demonstrate, by temporarily restricting bee reproduction, mite reproduction will be reduced and that this tactic can be used to keep mite levels below the damage threshold.

Objective 2: *Test the efficacy of the delaying queen release or of queen caging tactic chosen from Objective 1 with screen bottom boards to reduce varroa levels in honey bee colonies.*

Screen inserts have been shown to significantly reduce mite levels (Pettis & Shiminuki 1999, Szabo & Szabo 2000, Sammataro et al. in preparation) but this tactic is insufficient to keep mite levels below the economic injury level. When screens are used in conjunction with other tactics, the results are promising (Ellis et al. 2001, Imdorf et al. 1995). IPM projects conducted thus far at Penn State, the University of Delaware and the University Maryland have supported the above studies indicating that a single IPM tactic is insufficient to keep mite levels below the damage threshold.

We will combine the most efficacious of the queen manipulation tactics with screen bottom boards to determine if these two tactics will keep mite levels below threshold. Screen bottom boards have been chosen as a second IPM tactic because they are not a labor intensive tactic, once the hives have been assembled, there are indications that the increased ventilation provided by the screens may decrease mite survivorship (Yoder et al. 1999) and ventilation provided by screens may increase colony size (personal observation). Forty percent of mites that are found on bottom boards are alive, waiting to re-attach on an adult bee (Pettis &Shimanuki 1999). If those mites on the bottom board are unable to re-attach, mite survivorship will decrease because mites are very leaky and will die without a source of moisture (Yoder et al. 1999). Increased colony size can result from increased bee reproduction rates, increased survivorship of eggs, larvae or pupae, or decreased adult bee death rates. If the increase in colony size is due to increased survivorship of pupae or decrease adult bee death rates, then the number of mites per bee decreases and overall colony health is improved.

We expect to demonstrate that a combination of IPM tactics – temporary restriction of bee reproduction and screen bottom boards – will reduce mite reproduction and that these combined tactic can be used to keep mite levels below the damage threshold.

C. Approach and Procedures

Objective 1: *Test the efficacy of delaying queen release or of queen caging as an IPM tactic to reduce varroa levels in honey bee colonies.*

In the first year during May, forty-two nucleus colonies will be installed into single deep Langstorth hive bodies and allow to establish themselves in apiaries located in central Pennsylvania, Delaware and eastern shore Maryland. Colonies will be supered as necessary. Prior to the queen manipulation in July, colonies in each apiary will be equalized to ensure similar colony size and similar mite levels. One week after adjustment of colony size, natural varroa drops will be assessed in all colonies to determine if mite levels are equal in the colonies and to provide a pretreatment assessment of mite levels. Following the assessment of mite levels at the three apiaries, each colony will be randomly assigned to a treatment group (Table I) and queen manipulations will be performed. Within each apiary, the queen manipulations will be completed on the same day. The colonies will be manipulated as follows: 1) no queens replaced or confined, 2) old queens removed, caged queen inserted and queen released 24 hours later, 3) old queen removed, caged queen inserted, queen released 10 days later, 4) queen removed, natural supercedure allowed to occur, 5) old queen confined for 15 days and 6) old queen confined for 21 day. On the first day of queen manipulation, natural varroa drop assessments will begin and continue until all queens have been released. Mite drop assessments will change to every 14 days and continue until the end of the season, approximately mid-October. A final varroa drop will be assessed using sticky boards following treatment by coumaphos.

TABLE I: Year 1 Treatment Groups

Apiary Location	**Controls**		**Queen Replacement**		**Queen confinement**		**Total**
	No queen replacement	Standard queen replacement	10 days	Natural Supercedure	15 days	21 days	
U Delaware	5	5	5	5	5	5	30
U Maryland	5	5	5	5	5	5	30
Penn State	5	5	5	5	5	5	30
	15	15	15	15	15	15	90

To monitor varroa populations, wax/cardboard printed sheets (sticky board) are smeared with petroleum jelly and placed beneath a screen insert. The screen insert, elevated above the sticky board, prevents the bees from removing debris, including mites, from the sticky board. The boards will remain in the colonies for 3 days to provide an average mite drop per day (total number of mites on the sticky board/3 days). Counting of the sticky boards will follow the procedure developed by Ostiguy & Sammataro (2000).

Immigration of varroa from other bee colonies near the study site can be a source of varroa when bees from a healthy colony rob honey from sick or dying colonies. Robbing behavior will be prevented by feeding colonies when nectar and pollen sources are scarce. Monitoring for robbing behavior will be continuous. To prevent robbing of weak colonies, entrance reducers

will be used to reduce the area guard bees need to defend. If a colony dies, the hive will be removed from the yard.

Acceptance of a queen is an important component colony management. We will assess acceptance by the colony of the queen confinement/replacement tactic by recording the frequency of aggressive behavior by workers toward the queen, including balling, the occurrence of new queen cells and the replacement of the queen by the colony. It is likely that the replacement method that allows natural supercedure by the colony will have the lowest frequency of queen rejection. Aggressive behavior will be recorded using a Likert scale. The number of new queen cells in each colony will be recorded. Replacement of queens will be recorded as a yes/no variable.

Colony health will be assessed using several measures. Number of frames of bees for all colonies will be measured using the technique described by Nasr et al. (1990) following each assessment of mite level. The degree of chalkbrood infection will be measured by counting the number of chalkbrood mummies found in cells on both sides of two frames of capped brood (Spivak & Reuter 1999). Only mummies in uncapped cells will be counted and scored. Colonies will also be scored 0 or 1 for American Foulbrood; a score of one is assigned if one infected pupa in an uncapped cell is observed. Both disease measurements will be taken in the spring and fall. A healthy colony produces more honey; honey production will be recorded. Shallow supers (marked as to colony origin) used for honey storage will be weighed. The tare weight of supers and frames will be determined by weighing extracted supers and frames. Additionally, overwintering success of each colony will be recorded

To evaluate the mite drop data a 2-factor analysis of variance (ANOVA), followed by a means separation test, will be used (Zar 1999). The independent factors in this analysis will be apiary (block) and treatment. Colony strength (number of frames of bees) will be used as a covariate to increase the precision in this experiment **(**Snedecor & Cochran 1980**).** The strength of the colony will influence the number of mites; a small colony, if all else is equal, will have fewer mites than a large colony. Queen acceptance will be evaluated using χ^2 tests for frequency of aggressive behavior and the replacement of queens by colonies. Possible differences in the number of new queens cells among treatments will be evaluated using an ANOVA, followed by a means separation test. If the frequency of queen cells is low, the data will be evaluated to determine if non-parametric tests are more appropriate. Independent variables include treatment group and apiary location (block). Differences in overwintering success or colony health (chalkbrood and American foulbrood prevelance) will be evaluated using a chi-square tests. Honey production, an indirect indicator of colony health, will be evaluated by using a 2-factor ANOVA with apiary (block), and treatment as factors and colony strength as a covariate.

The replacing or confining queens will be considered successful if colonies remain alive, healthy and producing honey and mite levels do not exceed 100 mites per day, natural drop.

Objective 2: *Test the efficacy of the delaying queen release or of queen caging tactic chosen from Objective 1 with screen bottom boards to reduce varroa levels in honey bee colonies.*

Any colonies that fail to overwinter will be replaced with nucs to bring the total number of colonies in each apiary to 28 (Table II). Colonies will be supered as necessary. In mid-June prior to queen manipulation in July, colonies in each apiary will be equalized to ensure similar colony size and similar mite levels. Colonies will be randomly assigned to treatments. Screen

bottom boards and data loggers will be installed when colonies are equalized. Screen bottom boards will be used rather than screen inserts because screen bottom boards provide greater potential for air circulation within the colony and have lower risk for wax moth build up on the bottom board. Data loggers will provide information about temperature and humidity within the hive, thus providing information that may explain potential differences in mite levels due to the presence or absence of screens. One week after adjustment of colony size, natural varroa drops will be assessed in all colonies to determine if mite levels are equal in the colonies and to provide a pretreatment assessment of mite levels. Following the assessment of mite levels, queen manipulations will be done. Within each apiary, the queen manipulations will be completed on the same day. The queen manipulation will be chosen on the basis of the results of the Year 1 study. If more than one manipulation effectively reduces mite levels, the top 3 methods will be used, one in each apiary.

TABLE II: Year 2 Treatment Groups

Apiary Location	**Queen Manipulation**		**No Queen Manipulation**		**Total Colonies**
	Screens	**No screens**	**Screens**	**No Screens**	
Delaware	7	7	7	7	28
Maryland	7	7	7	7	28
Pennsylvania	7	7	7	7	28
	21	21	21	21	84

On the first day of queen manipulation, natural varroa drop assessments will begin and continue until all queens have been released. Mite drop assessments will change to every 14 days and continue until the end of the season, approximately mid-October. A final varroa drop will be assessed using sticky boards following treatment by coumaphos. Colony strength (frames of bees), health (frames of brood, chalkbrood and American foulbrood), honey production and overwintering will be assessed as described for year one.

A 3-factor ANOVA, followed by a means separation test, will be used to evaluate the data (Zar 1999). The independent factors in this analysis will be apiary (block), queen manipulation, and screen. Colony strength (number of frames of bees) will be used as a covariate in the analysis. Differences in overwintering success or colony health will be evaluated using a χ^2 tests. Honey production, an indirect indicator of colony health, will be evaluated by using a 3-factor ANOVA with apiary (block), queen manipulation, and screen as factors. Colony strength will be used as a covariate. Colony temperature and humidity will be evaluated using a 2-factor ANOVA with apiary (block) and screen as factors. It will also be possible to evaluate differences in the rate of colony buildup between treatments by using linear regression. A split plot design will be used for data analysis if more than one queen manipulation is tested.

The queen manipulation method and screen bottom board combination will be considered successful if colonies remain alive, healthy and producing honey and mite levels do not exceed 60 mites per day, natural drop.

Timetable

• Late spring 2003: establish colonies in Delaware, Maryland, and Pennsylvania, super colonies as necessary

• Mid-summer 2003: equalize colonies within each apiary, perform queen manipulations, measure initial mite levels and colony strength
• Mid to late summer – fall 2003: measure natural mite drop, colony strength and health, and queen acceptance until mid-October, prepare colonies for overwintering.
• Winter 2003-2004: analyze data from summer 2003, determine which of the queen manipulation methods is the most efficacious, write preliminary reports and articles
• Late spring 2004: analyze data on overwintering success, replace colonies that failed to overwinter, super colonies as necessary
• Mid-summer 2004: equalize colonies within each apiary, install screen bottom boards and data loggers, perform queen manipulations, measure initial mite levels and colony strength
• Mid to late summer – fall 2004: measure natural mite drop, colony strength and health, and queen acceptance until mid-October, prepare colonies for overwintering.
• Winter 2004-2005: analyze data from summer 2004, write reports and articles
• Spring 2005: analyze overwintering success, complete reports and articles

D. Cooperation and Institutional Units Involved

Lead State: The Pennsylvania State University – Pennsylvania
University of Maryland – Maryland
University of Delaware – Delaware

Penn State is the lead institution for this project. The University of Delaware and University of Maryland are also participating in this project. The three institutions have a history of research and extension cooperation through MAAREC (Mid-Atlantic Apiculture Research and Extension Consortium). All work will be performed in cooperation with MAAREC.

Penn State, University of Delaware and University of Maryland each will maintain colonies, collect data, and carry out both objectives. Penn State is responsible for coordinating data collection and data analysis. Penn State is also responsible for budget oversight. Decisions about queen manipulation methods to be used in the second year of the study will be made at a meeting during the winter of the first year. Authorship and primary writing responsibility on reports and papers will be circulated alphabetically among the cooperating individuals/institutions.

E. Implementation and Evaluation Plans

Background

At one time, nearly all of the states in the Mid-Atlantic Region had active honey bee research and extension programs. However, with shrinking budgets many states have chosen to discontinue these programs. The states that have abandoned or reduced their apiculture programs are Vermont, New Hampshire, Maine, Rhode Island, Connecticut, Massachusetts, New Jersey, and Maryland. Two states, Delaware and West Virginia have beekeeping specialists, each of whom have major responsibilities in several other program areas. Pennsylvania has maintained a strong commitment to bee research and extension, and has taken the lead to establish a regional

research and extension program to address the mite and disease management crisis facing the beekeeping industry. A Working Group established MAAREC (Mid-Atlantic Apiculture Research and Extension Consortium) with representation from the departments of agriculture, state beekeeping organizations, and land-grant universities from New Jersey, Maryland, Delaware, Pennsylvania and West Virginia. The working group also has representation from USDA/ARS (Beltsville Bee Lab, MD).

Since its establishment in late 1997, MAAREC has had several significant achievements including the funding of a FRA (Fund for Rural America) proposal and a PMAP (Pest Management Alternatives Program), the completion of several research projects funded by industry sponsors, the development of a regional newsletter, and other extension materials including two slide shows, a varroa mite video, and a pest/disease guide. MAAREC extension personnel have developed a very active web site and presented a poster on this regional effort at the national farm bureau meeting in 1999.

A fall 2000 survey of more than 700 beekeepers in the Mid-Atlantic region showed strong support for research leading to IPM and/or non-chemical approaches to honey bee mite and disease control. While chemical treatments are seen as a necessary short-term control tactic, beekeepers are becoming increasingly concerned about the rapid development of resistance to these materials, chemical contamination of honey, bees, and wax, and health risks associated with using these materials.

Future

After the introduction of varroa into the United States in 1988 efforts were focused on eradiation. First fluvalinate, a pyrethroid, was used to kill mites in colonies and when resistance developed coumaphos, an organophosphate was introduced. Resistance to coumphos is now being reported (Elzen and Westervelt 2002). The search for a chemical magic bullet continues but several years ago researchers and extension agents began to suggest to beekeepers that eradiation would not be possible and is unnecessary. Researchers have begun to determine mite threshold levels and to search for tactics to reduce mite population growth. Anecdotal evidence from beekeepers about honey bee colonies tolerating low mite levels is beginning to grow. As these innovator beekeepers talk about their experience, more beekeepers are open to the idea that every mite in a colony does not have to be killed. This development was necessary to provide an environment where IPM could be introduced.

This project will provide a non-chemical method for control of varroa. The single tactic of requeening of colonies mid-summer may be insufficient to prevent exponential growth of mite populations during all years but the combination of requeening and screen bottom boards has an excellent chance of suppressing mite populations in years when a single tactic would be inadequate. Once mid-summer requeening is developed, we will test the combination of requeening and screen bottoms and then incorporated both tactics into the existing extension and education efforts of MAAREC.

Once the results from both years of the study are tabulated, we will update the University of Delaware, Penn State and MAAREC sponsored honey bee extension publications and other tools to include IPM techniques generated by this and other relevant studies. Current extension materials that would be updated with the appropriate information include: *The Fundamentals of Beekeeping* (publication); *Honey Bee Parasite, Pest, Predators and Diseases* (field guide); *Honey Bee Diseases* (slide show); *Honey Bee Parasites, Pests and Predators* (slide show); thirty new MAAREC extension brochures; the *Bee Aware* regional newsletter; the newly developed decision support tool – *BeeAware 2000*, an interactive CD-ROM for the care and management of

honey bees; and the MAAREC web site. Northeast regional beekeepers and MAAREC representatives have suggested that we develop a new video emphasizing an IPM approach to the management of varroa mites. We have begun to investigate sources of funding to produce this video.

All materials generated by the proposed project supporting an IPM approach to honey bee parasite and disease management will be made available free of charge to state beekeeping associations in the Northeast region. County cooperative extension offices and apiary inspection services will also be given the information. Updating apiary inspectors and county extension agents in the Mid-Atlantic region is also an important part of dissemination of information we plan to do.

In the MAAREC region, we have organized two 2-day workshops on IPM and bee health – in 1999 at PSU (85 attended) and 2001 in New Windsor, MD (102 attended); a comprehensive resource manual was prepared for the latter (Caron, 2001). Current plans include conducting an IPM workshop in 2003 in south-central Pennsylvania, using the comprehensive resource manual. In alternate years we assist the Eastern Apicultural Society (EAS) with their annual beekeeping short course that proceeds their August conference; one of us (Caron) organized the 2000 EAS in Massachusetts and will do so again for the 2004 EAS conference in Pennsylvania. The results from this study will be used as a focal point for future courses and workshops.

During the project, articles and news releases will be written describing interim and final results. The professional journals we will submit articles to include: *Apidologie*, *Experimental and Applied Acarology, Journal of Apicultural Research, Bee World,* and, *Journal of Economic Entomology*. In beekeeping, the trade journals are an important means of communication to the industry. We will submit articles to *Bee Biz, American Bee Journal, Bee Culture* and *Speedy Bee* to inform beekeepers about effective non-pesticidal varroa control. Presentations at professional and trade meetings will be made. The presentations at trade meetings will emphasize the benefits of implementation of an IPM program

REFERENCES

Anderson DL, Trueman JWH. 2000. *Varroa jacobsoni* (Acari: Varroidae) is more than one species. *Experimental & Applied Acarology*. 24: 3, 165-189.

Ball B. 1988. The impact of secondary infections in honey-bee colonies infested with the parasitic mite *Varroa jacobsoni*. In *Africanized honey bees and bee mites*, ed. Needham G.R., R.E. Page Jr., M. Delfinado-Baker & C.E. Bowman. Chichester, UK: Ellis Horwood, pp. 457-461.

Bogdanov S, Kilchenmann V, Imdorf A. 1998. Residues in wax and honey after Apilife Var treatment. *Apidologie*. 29:513-524.

Caron DM. 1999. *Honey Bee Biology and Beekeeping*. Wicwas Press, Cheshire, CT.

Currie R. 1999. Fluvalinate queen tabs for use against *Varroa jacobsoni* Oud. efficacy and impact on honey bee, *Apis mellifera* L., queen and colony performance. *Am. Bee J*. 139: 871-76.

De Jong D. 1997. Mites: varroa and other parasites of brood. In *Honey bee pests and predators*, ed. RM Morse, PK Flottum, 14: 281-327. Medina OH: A.I. Root. 3rd ed.

Donzé G, Guerin PM. 1994. Behavioral attributes and parental care of Varroa mites parasitizing honeybee brood. *Behav. Ecol. Sociobiol.* 34: 305-319.

Donzé G, Schnyder-Candrian S, Bogdanov S, Diehl P-A, Guerin P.M, Kilchenman V, Monachon F. 1998. Aliphatic alcohols and aldehydes of the honey bee cocoon induce arrestment behavior in *Varroa jacobsoni* (Acari: Mesostigmata), an ectoparasite of *Apis mellifera*. *Arch. Insect Biochem. Physiol*. 37: 129-145.

Eischen F.A. & W.T. Wilson. 1998. Natural products, smoke and varroa. *Am. Bee J.* 138: 293.

Ellis Jr. JD, Delaplane KS, Hood WM. 2001. Efficacy of bottom screen device, Apistant®, and Apilife Var ®, in controlling *Varroa destructor*. *Am. Bee J.* 141: 813-816.

Elzen PJ. Westervelt D. 2002. Detection of Coumaphos resistance in Varroa destructor in Florida. *Amer Bee J.* 142:291-292.

Elzen PJ, Eischen FA, Baxter J.R, Elzen GW, Wilson WT. 1999. Detection of resistance in U.S. *Varroa jacobsoni* Oud. (Mesostigmata: Varroidae) to the acaricide fluvalinate. *Apidologie* 30:13-18.

Elzen PJ, Eischen FA, Baxter JR, Pettis J, Elzen GW, Wilson WT. 1998. Fluvalinate resistance in *Varroa jacobsoni* from several geographic locations. *Am. Bee J.* 138: 674-676.

Extoxnet,1996.http://ace.orst.edu/cgibin/mfs/01/pips/coumapho.htm?8#mfs.

Fernandez Muino MA, Sancho MT, Simal-Gandara J, Creus-Vidal JM, Huidobro JF, Simal-Lozano J. 1997. Acaricide residues in honeys from Galicia (N.W. Spain). *Journal of Food Protection* 60:78-80.

Finley J, Camazine S, Frazier M. 1996. The epidemic of honey bee colony losses during the 1995-1996 season. *Am. Bee J.* 136: 805-808.

Free JB. 1993. *Insect Pollination of Crops.* Academic & Harcourt Brace Jovanovich, NY.

Garcia MA, Fernandez MI, Herrero C, Melgar JJ. 1996. Acaricide residue in honey. *Bull. Environ. Contam. Toxicol.* 56:881-887.

Imdorf A, bogdanov S, Kilchenman V, Maquelin C. 1995. Apilife Var: A new varroacide with thymol as the main ingredient. *Bee World* 76: 77-83.

Haarman T, Spivak M, Weaver D, Weaver B, Glenn T. 2002. Effects of Fluvalinate and Coumaphos on Queen Honey Bees (Hymenoptera: Apidae) in Two Commercial Queen Rearing Operations. *J. Econ. Entomol.* 95:28-35.

Khanbash MS, Ahmed AM. 1999. The influence of wire net bottom on the control of *Varroa jacobsoni* and honeybee colonies. *University of Aden Journal of Natural & Applied Sciences.* 3: 2, 13-21.

Krause B, Page RE Jr. 1995. Effect of *Varroa jacobsoni* (Mesostigmata: Varroidae) on feral *Apis mellifera* (Hymenoptera: Apidae) in California. *Environmental Entomology* 24:1473-1480.

Lodesani M, Pellacani A, Bergomi S, Carpana E, Rabitti T, Lasagni P. 1992. Residue determination for some products used against *Varroa jacobsoni* infestation in bees. *Apidologie* 23:257-272.

Morse RA, Calderone NW. 2000. The value of honey bees as pollinators of U.S. crops in 2000. *Bee Culture Ma*gazine insert, March. 16ppg.

Nasr ME, Kevan,PG. 1999. Diseases and parasites, eradication or management: what strategy for honey bee health. *Bee World*. 80: 53-54.

Nasr ME, Thorp RW, Tyler TL, Briggs DL. 1990. Estimating honey bee (Hymenoptera; Apidae) colony strength by a simple method: Measuring cluster size. *J. Econ. Entomol*. 83: 748-512.

Noel B, Amrine J, Kovacs A. 2002. Integrated Pest Management Combined with Mite Resistant Queens to Combat Acaricide-Resistant Varroa. *Am. Bee J.* 142: 672-673.

Ostiguy N, Sammataro. D 2000. A Simplified Technique for Counting Varroa Sticky Boards, *Apidologie* 31: 707-716.

Pettis JS, Shimanuki H. 1999. A hive modification to reduce varroa populations. *Am. Bee J.* 139 (6) 471-473.

Rinderer TE, de Guzman LI, Lancasater VA, Delatte GT, Stelzer JA. 1999. Varroa in the mating yard: I. The effects of *Varroa jacobsoni* and Apistan® on drone honey bees. *Am. Bee J.* 139: 134-139.

Sammataro D, Ostiguy N, Frazier M, Finley J, Degrandi-Hoffman G, Wardell G. A novel IPM approach to managing varroa mite (Acari: Varroidae) levels in honey bee (Hymenoptera: Apidae) colonies. *in preparation*

Sammataro D, Gerson U, Needham GR. 2000. Parasitic Mites of Honey Bees: Life History, Implications and Impact. *Ann. Rev. Entomol*. 45: 517-546.

Sammataro D & Avitabile A. 1998. *The Beekeeper's Handbook 3rd edition*. Cornell University Press, Ithca NY.

Schulz AE. 1984. Reproduction and population dynamics of the parasitic mite *Varroa jacobsoni* Oud. in correlation with the brood cycle of *Apis mellifera Apidologie* 5:401-419.

Shen M, Ostiguy N, Cui L, Cox-Foster D. 2002. How can viruses be transmitted among honey bees. Poster, Entomological Society Meeting, Fort Lauderdale, FL.

Shimanuki H, Calderone NW, Knox DA. 1994. Parasitic mite syndrome: the symptoms. *Am. Bee J.* 134: 827-828.

Snedecor GW, Cochran WG. 1980. *Statistical Methods,* 7th edition. The Iowa State University Press, Ames, IA.

Sokol R. 1996. The influence of a multimnth persistence of Fluworal in a hive of a honey bee colony. *Med. Weter.* 52:718-720.

Spivak M. & D.L. Downey. 1998. Field assays for hygienic behaviour in honey bees (Hymenoptera: Apidae). *J. Econ. Entomo*. 91: 1, 64-70.

Szabo TI. 1998. Progress report on selective breeding of honey bees for resistance to parasitic mites. *Am. Bee J*. 138: 6, 464-466.

Szabo TI. 1999. Selective breeding of honey bee colonies for resistance to *Varroa jacobsoni* and the effects of management techniques on Varroa infestation levels. *Am. Bee J.* 139: 537-40.

Szabo TI. & D.C. Szabo. 2000. Attempts to reduce the varroa jacobsoni populations in honey bee colonies: Research Report for 1999. *Am. Bee J.* 140: 654-58.

Wallner K. 1999. Varroacides and their residues in bee products. *Apidologie* 30: 235-248.

Wallner K. 1997. The actual beeswax quality in foundation on the market. *Apidologie* 30:235-248.

Westcott LC, Winston ML. 1999. Chemical acaracides in *Apis mellifera* (Hymenoptera: Apidae) colonies; do they cause nonlethal effects. *Canadian Entomologist*. 131: 3, 363-371.

Yang X, Camazine S, Cox-Foster D. 2002. Effects of Varroa Mites on the Immune System of Honey Bees. Poster, Entomological Society Meeting, Fort Lauderdale, FL.

Yoder J, Sammataro D, Peterson JA, Needham GR, Bruce WA. 1999. Water requirements of adult females of the honey bee parasitic mite, *Varroa jacobsoni* (Acari: Varroidae) and implications for control. *International J. Acarology* 25: 239-335.

Zar G. *Biostatistcal Analysis*. 4th Edition, Prentice Hall, Upper Saddle River, NJ.

KEY PERSONNEL

The following should be included, as applicable:

a) *The roles and responsibilities of each PD and/or collaborator should be clearly described; and A current 2 page CV (excluding publications from the past 4 years) of the PD and each co-PD, senior associate, and other professional personnel. The CV "should be limited to 2 pages in length, excluding publications listing. The CV should include a presentation of academic and research credentials, as applicable, e.g., earned degrees, teaching experience, employment history, professional activities, honors and awards, and grants received. A chronological list al all publications in refereed journals during the past 4 years, including those in press, must be provided for each project member for whom a curriculum vitae is provided. Also list only those non-refereed technical publications that have relevance to the proposed project. All authors should be listed in the same order as they appear on each paper cited, along with the title and complete reference as these usually appear in journals.*

Nancy Ostiguy, The Pennsylvania State University

Dr. Ostiguy is the Principle Investigator for this project. She is responsible for completing Objective 1 and 2 in Years 1 and 2, respectively, at the Penn State apiary. She is responsible for coordinating data collection among the three institutions, call and organizing meetings needed to conduct the project, and conducting the data analysis. She will also assist Dr. Caron with the extension efforts resulting from this project. Dr. Ostiguy is also responsible for budget oversight and insuring the completion of reports and papers resulting from this project.

Dewey Caron, University of Delaware

Dr. Caron is a Co-Principle Investigator for this project. He is responsible for completing Objective 1 and 2 in Years 1 and 2, respectively, at the University of Delaware apiary. Dr. Caron is responsible for providing the data needed for data analysis and completing reports applicable to the work done at the University of Delaware. He will also have responsibility for writing research papers as applicable. Dr. Caron will oversee the incorporation of all study results in the extension efforts of MAAREC and insure that beekeeping publications received information on the results of this project.

Mike Embrey, University of Maryland

Mr. Embrey is a Co-Principle Investigator for this project. He is responsible for completing Objective 1 and 2 in Years 1 and 2, respectively, at the University of Maryland, Eastern Shore. Mr. Embrey is responsible for providing the data need for data analysis and completing reports applicable to the work carried out at the University of Maryland. He will also assist Dr. Caron in the extension efforts resulting from this project.