Development of the Mason Bee, *Osmia cornifrons*, as an Alternative Pollinator to Honey Bees and as a Targeted Delivery System for Biocontrol Agents in the Management of Fire Blight

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Introduction

Pollination is a pivotal, keystone process in almost all terrestrial ecosystem food webs: it supports global and sustainable productivity in agriculture and forestry, and maintains the biodiversity of plant and animal life. Bees are the most important pollinators, but bee declines in abundance and species richness have been documented on 4 continents. This decline in pollinator abundance is accompanied by our lack of knowledge regarding the current contributions of native bees to crop pollination. This lack of understanding of the role of native bees in agriculture makes it difficult to make a case for native pollinator conservation to funding agencies looking for an economic benefit other than biodiversity conservation. Almost 100 crop species in the US rely to some extent on honey bee pollination and the value of honey bees to U.S. agriculture is estimated to be $15 billion annually ($1.4 billion for apple). Collectively these 100 crops make up about 1/3 of the US diet and consist mainly of high-value specialty crops (i.e. fruit, vegetable and nut crops) that provide the bulk of vitamins and other nutrients that contribute to healthy diets.

Honey bees are currently the most valuable pollinators in agriculture, because they are well understood, relatively easy to maintain, movable, and able to communicate rapidly the locations of new food sources. Honey bee populations, however, have declined for the past several years to the point that total reliance on them is increasingly risky. From 2006-09, N. American beekeepers lost approximately 1/3 of the honey bee colonies mostly due to Colony Collapse Disorder (CCD) and losses at this level or higher will probably continue in the near future. These losses were in addition to declines caused by: 1) the introduction of two parasitic mite species; 2) viral, fungal, and bacterial diseases; 3) insecticide poisoning; 4) hybridization with the African subspecies of honey bee; 5) economic threats from loss of honey bee price supports and global honey competition; and 6) agricultural intensification of monocultures to maximize yields which have removed much of the adjacent flowering and nesting resources. Despite increased need for pollination services for crops such as the $2 billion almond industry, honey bee colonies had already declined by over 40% in the US since 1947, even before CCD. Importation of bees from outside the U.S. to meet the demand for pollination began in 2005, but is a very risky solution because it greatly increases the chances of introducing new pests and pathogens to <u>all</u> of our bee species.

The economic impacts of pollinator shortages on US specialty crops such as fruit, vegetables and nuts could be considerable. Inadequate pollination can reduce crop quality as well as yield in these crops. In apple or pear, pollination efficiency affects seed set which in turn affects size and quality and hence the profitability to growers. The most conspicuous consequence of honey bee declines since CCD, has been a dramatic increase in the costs of producing bees which translates into rising costs for bee rentals for specialty crop growers – from $35/hive for Pennsylvania apple growers in 2006 to $75/hive in 2009. Feral honey bees, which many fruit farms relied on to some extent for pollination, have been almost completely eliminated in the last 5-10 years. Rising costs combined with declining yields would lead to higher prices of US nuts, fruits and vegetables which would reduce exports of major commodities during a record US trade deficit and lead to increased imports of cheaper commodities from foreign markets where CCD is not as much a problem.

There are, however, another 3,500 bee species other than the honey bee which are also important pollinators of most specialty crops in the U.S. These include the many species of bumble bees and what are often referred to as solitary bees. We will refer to both groups henceforth as “pollen bees” because their main value, in relation to people, is not the production of honey, but the collection and transfer of pollen for the fertilization of plants. It is obvious that pollen bees are critical components of food webs associated with wildlife habitats of all types in North America, because almost all of them were here long before honey bees were introduced by Europeans. The value of pollen bees as pollinators in agriculture is conservatively estimated at $3 billion annually in US agriculture. Because of the popular focus on honey bees, the services of pollen bees most often go unrecognized and their value for agriculture and especially for unmanaged ecosystems is probably much higher. For most bee species, the paucity of long-term population data and our incomplete knowledge of even basic taxonomy, life history and ecology make assessing their value and possible declines in some regions very difficult. It is well-known that honey bees are not the best pollinators for all crops. They are generalist foragers easily distracted from target crops like cucurbits, pears, and apples by other species such as dandelions and other better nectar sources. Wild and managed species of pollen bees can and unknowingly have supplemented honey bees for pollination in specialty crops. Under very specific situations, which we are still researching, pollen bees could possibly replace them.

Many projects are dealing with the various threats to the honey bee industry in the U.S., but to truly address the threats to pollination there should be contingency plans that include the development of alternative pollinators and baseline data to measure future impacts on our native bees. The folly of relying on a single pesticide, tactic or cultivar has been seen repeatedly in the development of IPM programs for specialty crops. In the case of pollinators, a similar reliance on one pollinator such as the honey bee is no less a folly. Developing multiple tactics with multiple pollinator species represents the most robust management approach for a future of uncertain climate, environmental disruptions, and invasive species introductions. We do know, however, that: a) the supply of honey bees in the U.S. will not be able to meet the demand for pollination services in the near future; b) that production costs for apiculturists will go up; and c) that the cost to growers to rent honey bee hives will continue to increase.

The importance of native bees in the pollination of fruits and vegetable crops in the Mid-Atlantic region has probably been underestimated. Our unique landscape ecology of agricultural and non-agricultural lands and a mosaic of diversified fruit and vegetable farms in the Northeast and Mid-Atlantic likely impart unique advantages in pollinator conservation and utilization compared to the monocultures of the Midwest or dry areas of the West. A recent study by Winfree et al. (2007) demonstrated a guild of 46 species of native bees provided full pollination of watermelon on >90% of 23 farms in Pennsylvania and New Jersey. Some of the largest fruit growers in Pennsylvania have relied completely on feral honey bees and wild pollinators for their pollination needs for over 5 years now, with no noticeable loss in fruit quality or yields. These growers still have to pay to chemically or manually thin their crop every year, but with a recommended rate of 1-2 hives/acre for apples, are saving $75-$150/acre in rental fees. As production costs have gone up, it is much more common for fruit growers in the state to use only1 hive to every 5 acres or more.

<u>Research</u>

Over the last two seasons, a team of several entomologists from Penn State, Long Island University, and the Pennsylvania Dept. of Agriculture have been striving to address research priorities set forth by the SHAP Research Committee regarding the conservation and development of alternative fruit pollinators (i.e. solitary bees and bumble bees). We have been developing management protocols for *Osmia* Orchard Bees and, with a Penn State Plant Pathologist, we have been evaluating their ability to deliver biocontrol agents for fire blight protection in pome fruit bloom as alternative to the antibiotic Streptomycin.

Alternative Insect Pollination Surveys: The “forgotten” pollen bee species are contributing to pollination in PA fruit orchards. In cooperation with the Pennsylvania Department of Agriculture our surveys of fruit orchards have found over 150 species of bees present sometime during the season, with about half this number actively pollinating both stone and pome fruits during bloom. The other 75 or so species appear to be nesting and utilizing other flowering plants in the ground cover within and adjacent to orchards. This cooperative effort with PDA is the first survey of bees ever undertaken for Pennsylvania, and we have found many species which are state records and have found one or two new undescribed species. A core group of about 30 bee species appears to be present during bloom in fruit orchards each season, but some of the species vary greatly in abundance each season or at different orchards.

We have monitored with colored water pan traps and net collections the bee diversity in the 12 apple orchards from the USDA-RAMP program run by Penn State that developed reduced risk IPM programs from 2002-9. We found that diversity does not vary as much with the pesticide programs (reduced risk vs. grower conventional programs), but more on a site to site basis that appears to be linked with orchard size and surrounding habitat. In many orchards, a definite “edge effect” can be seen, with the greatest bee diversity within 200 yards of wooded areas or fence rows. A recent study in Michigan blueberries, found pesticide use patterns as having a strong effect on bee diversity, but most of the important bee species were ground nesting types that may have been nesting within the blueberry plantations. Our bee surveys over the last 3 seasons, indicate that some of most important and abundant pollinators of apple are “cavity nesters” which utilize holes in dead trees or bore nests into old bramble canes and are thus probably not nesting within the orchards currently. These include all of our *Osmia* species, the Carpenter Bee, *Xyocopa virginica*, and two small carpenter bees, *Ceratina calcarata* and *C. dupla*. The *Ceratina* species can be especially abundant along the edges on the orchard and nest in old bramble canes, bushes with pithy stems such as elderberry, or artificial nesting bundles of mullein plant seed stalks. Unlike many of the other apple pollinators we have found, *Ceratina* have multiple generations throughout the season and are commonly found on blackberry and goldenrod blossoms later in the season. The large Carpenter bee (often mistaken for a bumble bees) can also be very common pollinating apple, but can be a pest boring into people's decks and barns. They have hairless black abdomens and the males with a yellow patch on their head often aggressively hover in front of people in territorial displays. In addition, we found an invasive species, *Osmia taurus*, which was somehow introduced from Japan, in several counties in Pennsylvania for the first time. They are very similar in appearance to our Japanese Orchard Bee (JOB), *Osmia cornifrons*, and may have been introduced inadvertently with that species during the original ARS introductions into Pennsylvania orchards, or may have been brought in by mistake through the sale for *O. cornifrons* from commercial sources.

As a whole, bee species that nest in the ground make up about 80% of the bee species in the world. From our surveys in about 10 stone fruit orchards, the majority of the pollinating bee species are ground nesting, and mostly of the genus *Andrena*. Softer insecticide programs (i.e. reduced pyrethroids and OP sprays) might allow some of these bees to nest within orchards. Establishing unsprayed pollinator strips in fruit orchards would allow bees with shorter foraging ranges both habitat and additional pollen resources so that they would not have to fly long distances from natural habitat or fence rows. Most growers incorrectly think that stone fruits do not require bees for pollination, which is probably a reflection of the unrecognized "free" pollination by a number of native bee species and the fact that only a small proportion of stone fruit blossoms need to be set in order to have a good crop. Ground nesting bees are proportionally less abundant in pome fruits, but include at least 4 species of Bumble Bees. *Bombus impatiens, B. perplexus, B. vagans*, and *B. bimaculata* are the most abundant species respectively, and nest in cavities in the ground such as old rodent burrows. Bumble bee colonies in Pennsylvania die in the fall with cold weather, with only the queens overwintering. Only the large queens are present at the early season apple bloom and it is only later in the season that colonies increase enough to be effective pollinators. Commercially available bumble bees are also *Bombus impatiens*. Other important apple pollinators species that are ground nesting in habit are a dozen species of *Andrena* of which *A. carlini, A. crategi*, and *A. rugosa* are most abundant. The metallic green sweat bee *Augochlora pura* is often relatively common on apple bloom.

Managed Osmia Pollinators - Mason bees of the genus *Osmia* are particularly good pollinators of early spring orchard crops because they rarely sting unless handled and concentrate on gathering pollen rather than nectar. The Blue Orchard Bee (BOB), *Osmia lignaria*, is native to North America, but wild populations seem to be somewhat sporadic in PA orchards. The BOB is popularly used by small organic growers, but are not thought to aggregate in adequate numbers for pollination of eastern orchards. This may change as protocols for managing BOB are being developed for the California almond industry and we develop specific strains of BOB. We have found the blueberry pollinator *O. atriventris* in small numbers in our surveys, but not *O. ribifloris*, a more widely managed pollinator of blueberries in the eastern US. We have, however, found surprisingly high numbers of *O. pumila* in apple orchards during our surveys, but they emerge too late for stone fruit pollination and peak only at the end of apple bloom. *O. pumila* looks like a much smaller version of BOB, and appears to be a good pollinator of blackberries and raspberries later in the season. The large *O. bucephala* looks similar to a small bumble bee can also be found pollinating apple, but also peaks later during bramble bloom. The European mason bee, *O. cornuta,* is used extensively to pollinate pears in Europe because honey bees are not attracted to the low sugar nectar of their flowers. *O. cornuta* is also used for the pollination of fruit crops in urban areas where keeping of honey bees is not allowed for safety reasons. We are working to develop management protocols not only to increase wild populations of our various *Osmia* species by providing additional nesting sites and floral resources, but also to develop management protocols for growers wishing to keep populations on their own.

The Japanese orchard bee (JOB), *O. cornifrons,* is used for apple and pear pollination in most of Japan. It was introduced into the US in 1977 by the USDA-ARS lab in Beltsville, MD and most of the early releases and research were made in orchards in Adams County, PA by ARS scientist, Dr. Susan Batra and the local Johnny Miller. JOB is generally more amenable to higher densities for pollination of larger scale fruit orchards than the native BOB. It appears to be well adapted to the environmental conditions of the mid-Atlantic region, and gives effective pollination with only half the bees necessary with BOB. JOB is available commercially and has been used extensively for the pollination of cherries in Michigan and Utah because of it is ability to pollinate in temperatures 10^{o}F cooler than the honey bee and because it is not affected by cloudy weather or light rain. Cherry yields in these states have been shown to double using this bee over honey bees in some seasons.

Successful pollination with mason bees does not require a large population of bees. JOB and the European *O. cornuta* are **80 times more effective** in pollinating apple than the honey bee. Only 250-500 *O. cornifrons* are required per acre for pollination compared to 60,000 to 120,000 honey bees. **A single *Osmia* can visit 15 flowers/min, setting 2,450 apples/day compared to 50 flowers set by a honey bee** (Greer 1999). This high level of pollination efficiency occurs because mason bees land directly upon the reproductive structures of the fruit tree blossom. The abdomens of foraging female bees are loaded with pollen, and the repeated and direct contact with the anthers and stamens results in higher levels of pollen transfer. Female bees collect pollen while constructing nests to provide food for bee larvae. Therefore, the key to heavy pollination in the orchard is to promote maximum nesting activity in the orchard bee population. With each female will lay approximately 30 eggs if provided adequate pollen and nesting sites, populations can increase greatly in a single season to be used in additional sites. Promoting alternative pollinators may be seen as a threat to the honey bee industry, but lower numbers of mason bees can be used to supplement honey bee pollination under adverse weather conditions. A number of beekeepers in the western US now offer the services of both honey and orchard mason bees for almond and fruit pollination.

JOB is widely used in smaller-scale organic fruit production throughout the US and several fruit growers in Pennsylvania have experience with it from early research interactions with ARS and Johnny Miller, but have lost populations over time due to a lack of sanitation procedures to minimize impacts from predators and parasites. In 2007, the Penn State Fruit Research & Extension Lab at Biglerville started enough JOB colonies to pollinate 20-30 acres of fruit at the FREC and it has been used successfully for several years to pollinate small plantings of fruit trees at the PSU Rock Spring Research Station at State College. In 2009, we developed management and sanitation protocols for JOB, which we are formulating for publication with the Xerces Society and USDA-NRCS.

<u>Management Summary:</u>

From observations of JOB kept under natural conditions outdoors in an insectary at the station and from field observations of wild populations, we now know that the normal emergence time for JOB coincides with the very early season bloom of apricot, red bud, and red maple. This is normally from the middle to end of April. We have observed wild populations doing best in mixed orchards where they can move from cherry, peach and plum bloom to apple and pear bloom over time. JOB will also feed on a variety of willow bloom, some early blooming ornamental bushes such as *Pieris japonica* and *Lonicera fragrantissima* (Chinese Honeysuckle). Apparently some early blooming mustards, such as *Brassica napus* which is used to produce canola oil, are good sources of pollen, but we have not observed them foraging on the wild mustard we find commonly around orchards. We plan to pursue this further in the future because it would also benefit in nematode control as a cover crop. It is also known that when JOB emerge in the spring that they conduct orientation flights of their nest sites and surrounding habitat. If the nests are moved as much as 6 inches after JOB emergence, they will abandon the nests and move to new sites. Placing the nests on or next to large structures such as barns or posts painted a light color apparently improves this “mental picture” of what their home and fewer emerging bees will disperse to new sites. Once the adults are done provisioning the nests, however, nesting materials can easily be moved for summer and winter storage as long as they are place into the new site before adult emergence the following spring. In selecting nesting sites, the current best estimates are that JOB will forage 300-500 yards in radius which we hope to quantify in a future grant. All *Osmia* need water for a source of mud to make their nests and if not place near a pond, creating a mud puddle near the nests will increase numbers.

In choice tests of cardboard tubes, bamboo, *Phragmites* reeds, and BinderBoards®, JOB generally prefers bamboo if emerging from adjacent cardboard tubes, followed by the reeds as a next choice (Fig. 1). In trying to trap nest wild populations of JOB and BOB in wooded areas adjacent to orchards, however, BinderBoards were preferred over bamboo. We identified two species of parasitic wasp of the genus *Monodontomerus* attacking JOB larvae in cardboard nesting straws and *Phragmites* reeds. One of the species is the native *M. obscurus* (metallic green and has a very long ovipositor) and the other is a newly identified invasive species, *M. osmia*e, from Japan. It was first found in the US in 2002 in Maryland, and we have now identified it for the first time from several locations in Pennsylvania. It a metallic blue color, smaller than the native species and has an ovipositor that is shorter than its abdomen. It has been recovered from JOB and the invasive *O. taurus* and may have been introduced with either species. Movement of JOB from the mid-Atlantic to other regions of the US should follow strict quarantine procedures or be restricted to delay the spread of *M. osmiae* as it is not known whether this parasitoid will attack other native *Osmia* species such as BOB. While using nesting materials impervious to attack from these wasps is preferred, those materials are often more expensive and harder to distribute than card board tubes and Phragmites reeds. If tubes and reeds are going to be used, withdrawing the tubes from the orchards at the beginning of petal fall and placing them into bags of fine mesh screen will prevent attack by *Mondodontomerus* species. Care must be taken if moving JOB nests from the orchards to not jostle or bump them violently as this can dislodge the JOB eggs or small larvae trying to feed on the pollen balls in the tubes and cause excessive mortality.

In maintaining JOB populations at PSU, we have found that the initial cardboard straws issued to many growers by ARS and since sold commercially for BOB, are very susceptible to attack by both of these species. The *Phragmites* reeds used for nesting are also thin walled and susceptible to attack, but are hard and may be somewhat resistant to the smaller *M. osmia* with its shorter ovipositor. The use of wooden blocks with bore holes or BinderBoard® nests, however, eliminate attack by either of the parasitoids. None of the nesting materials, prevent attack by the metallic green cuckoo wasp, *Chrysura kyrae*, which waits by JOB nests while the adult bees are collecting pollen and then lay eggs in their pollen provisions. The cuckoo wasp eggs hatch and kill the JOB egg or larvae and develop on the pollen store to emerge at the same time as the next generation of JOB adults the following season. This is a new host record for this parasitoid. *C. kryae* attacks the native BOB and several other *Osmia* species in the US, but this is the first record of it attacking JOB in the US. Fortunately, it appears to be relatively rare and kills only a small proportion of JOB in our experience. *Leucopsis affinis* is another rare native parasitoid we found attacking JOB. It usually attacks BOB and can bore through up to 1 inch of wood, but the BinderBoards® and thick walled wood blocks drilled with holes will protect them. This is a new host record for this parasite.

In addition, a very serious parasitic mite has been found attacking the larvae and pollen stores of JOB in nests utilizing old nesting tubes, reeds or wooden blocks for several years. We have tentatively identified it as *Chaetodactylus krombeinii*, but have sent specimens to USDA-APHIS for identification by a specialist, since there is also a similar species in Japan that may have been introduced with *O. taurus* or JOB. Cells infested with this mite can be identified by the fluffy tan colored remains of shed mite skins and pollen that fill the cells. We have identified over 1,500 mites clinging to a single freshly emerged adult JOB. This is their main means of dispersal and they will drop off as the bee visits new flowers, come into contact with other JOB during mating, or move to new nest sites. Left uncontrolled this pest can wipe out large managed populations of JOB and BOB after only a few seasons. Sanitation of nesting materials is the best way to control these mites. In the late fall, after pupae have eclosed to adults, cocoons should be separated by unraveling cardboard tubes, splitting reeds or bamboo, or by opening BinderBoards® to remove excess debris and pollen in the cells and discarding the contents of any cell showing evidence of the mites. The loose cocoons can then be stored overwinter and placed in contact with new nesting materials or cleaned BinderBoards® each season. Drilled wooden blocks are cheaper than BinderBoards, but should be replaced every couple of years as they are impossible to sanitize.

***Alternative Fire Blight Management Strategies* –** Fire blight, caused by the bacteria *Erwinia amylovora*, is one of the most serious diseases currently limiting apple production in the eastern US. It is such a severe problem on pear in this region that the production acreage is kept quite small. Fire blight is capable of infecting blossoms, fruits, vegetative shoots, woody tissues, and rootstock crowns. There are several distinct phases on the disease including blossom blight, shoot blight, and rootstock blight. Effective management of the disease requires integrated approaches that are aimed at: a) reducing the amount of inoculum available to initiate new infections; b) imposing barriers (antibiotics & biopesticides) to the successful establishment of fire blight on its host; and c) reducing host susceptibility to infection. Most fire blight management strategies up to this time have focused on the reduction of inoculum in the orchard (early season sprays of copper or with the pruning of cankers and infected tissues) and with the use of antibiotic treatments to prevent infection during the blossom blight phase. To date, biological control agents have not provided consistently high levels of control, possibly due to inability to target applications to the flowers with airblast sprayers. When broadcast at high rates over the entire tree with this type of application, costs are also expensive. A targeted delivery system with *Osmia* could greatly improve efficacy, while at the same time greatly reducing costs by reducing the amount of biopesticide applied. Preliminary studies of fire blight control on pear in Italy using *Osmia cornuta* support this hypothesis (Maccagnani et al. 2006) and our trials found that JOB carried 20X more *B. subtillus* to apple flowers than did honey bees in similar studies in blueberries.

Control of the blossom blight phase of the disease remains the critical component in fire blight management and approximately 10,000 lb ai of Streptomycin are applied prophylactically each year to apples and 7,000 lb ai are applied to pears in the US (EPA 2006). Properly timed applications of this antibiotic during bloom can provide over 90% control of sensitive strains of the pathogen, but resistant strains have developed in most areas of western North America and in Michigan that greatly reduce its effectiveness. If alternative the effectiveness of the bicontrol products can be improved, they would serve as a tool for resistance management in PA orchards. If growers fail to control blossom blight, no control strategies have been available to control shoot blight and rootstock blight during the summer months.

Evaluation of Alternatives to Synthetic Pesticides: Several biocontrol products based on antagonistic bacteria that competitively inhibit *E. amylovora* have been evaluated, registered, or are at an advanced stage of registration for management of the blossom blight phase of fire blight under commercial conditions. These include Serenade (*Bacillus subtilis*), BlightBan A506 (*Pseudomonas fluorescens*) both registered for use in many states, as well as several strains of *Pantoea agglomerans* which is in the registration stage. However, except in the Pacific States, the effectiveness of the biocontrol agents has met with mixed success elsewhere in the US. For example, whereas *B. subtilis* provides effective disease control in field trials in Michigan, *P. fluroscens* which is widely used in the Pacific Northwest is not effective (http://www.ipm.msu.edu/CAT05_frt/F04-26-05.htm). All of these products would be compatible with organic and reduced risk fruit production.

As a rosaceous specialist pollinating tree fruit, and with a relatively limited foraging range, the Japanese Orchard Bee (JOB), *Osmia cornifrons*, is a good candidate to serve as a vector for delivering biological control agents to control fire blight, while limiting the spread of this disease from hosts outside the orchard and from spreading the disease between orchards. Biopesticide alternatives to Streptomycin for fire blight control have suffered from lack of efficacy most often associated with the inability to adequately deliver the biological agent directly to the flower stigma at a high enough dose with current sprayer technology. As a more efficient pollinator of apples and pears than the honey bee and being less affected by weather, *Osmia* may also be a more effective vector of these biological control agents than conventional sprayers. These biocontrol products are compatible with organic production and are considered of reduced risk to the environment by EPA. If their efficacy can be improved through targeted delivery to open flowers, they would form a key tool in strategies aimed at reducing the risk of resistance to streptomycin in Pennsylvania pome fruit orchards. Successful implementation would also help alleviate concerns over possible impacts of antibiotics on the environment and the possible development of cross-resistance in human pathogens.

Summary of JOB-Vectored Biorational Control Experiments for Fire Blight Control

We confirmed the 2008 vector trials with two additional replicated trials in 2009 that JOB can use the nest dispenser we developed to vector biological control agents such as Serenade and BlightBan A506 to crab apple blossom. The rates of transfer were measured to be 20 to 50 times higher than in comparable studies on blueberries with honey bees. We also determined through replicated trials that secondary transmission of Seranade was possible from flowers initially inoculated by JOB to new unexposed blossoms on new trees at distant locations with JOB that had never been exposed to the biocontrol agents. This was important because it meant that Serenade transmitted to the first king blooms could grow on those flowers and subsequent visits by other bees would transmit the *B. subtillus* to new flowers or trees. This perpetuation and magnification of the sources of biocontrol agent would be in addition to any additional agent being distributed from the nest dispenser with JOB at later dates.

Efficacy of the various biological control agents was very disappointing- giving only 1% control in replicated trials using potted crabapple trees that were inoculated at 25 to 50% bloom by JOB using Serenade dispensers for 24 hours. All unopened flowers were removed before these trees were isolated in a fire blight free greenhouse for 48 hours. This was in order to allow the *B. subtillus* colonies to grow before they were inoculated with a fire blight solution in another green house. Blossom infection of a control group of trees not previously exposed to JOB and Serenade was 100%. This trial was repeated twice over time on a total of 15 trees. We ran out of suitable potted trees and JOB colonies before we could complete the same trials with BlightBan. Ngugi (2009) in a recent meta-analysis of 47 published biocontrol trials from 1999 to 2007 for fire blight control demonstrated that Serenade is the most effective biocontrol agent for fire blight currently, but give no more than 34% efficacy compared to Streptomycin at 70%.

We have developed a working dispenser for fire blight biocontrol agents and have shown that the JOB can vector at least Serenade at much higher levels than the honey bee. Unfortunately, the biocontrol agents themselves appear to be the weak link in this concept, because they just lack enough efficacy for fire blight control in the eastern U.S. We have no plans to continue this work with bee vectored biocontrol agents until it is demonstrated that more effective biocontrol agents have been developed. Using JOB to vector Streptomycin is another possibility, but would eventually kill off the adults and any larvae by destroying gut bacteria needed for digestion.

Future work will concentrate on the conservation of our wild populations of pollen bees, and developing protocols to manage populations of JOB and BOB. While we are beginning to understand their biology better and the pests that can limit population buildup, many fundamental questions about our pollen bees need to be addressed in the future including: a) foraging distances, b) susceptibility to pesticides, c) how to build populations through alternative pollen and nesting resources (NRCS), and under which conditions and landscape variables can we rely on our wild populations. In 2010, we will have 20,000 JOB cocoons for use in NRCS pollinator strip research and for research at the PSU FREC lab in Biglerville and have submitted a large USDA-Specialty Crop Research Initiative Grant to examine these basic questions.

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Fig. 1 Japanese Orchard Bee Nesting Preference

M. Frazier – 2009 (49 empty holes or tubes/treatment)

Number or Holes or Tubes Filled

BAMBOO 15	*Phragmites* Reed 6	Empty Cardboard Tubes 0
BinderBoard 0	Cardboard Tubes w/ Bees Emerging n=164	BAMBOO 4
Empty Cardboard Tubes 0	BinderBoard 2	*Phragmites* Reed 1