Real and Potential Impact of the European Pepper Moth on Ornamental Plant Production and Agriculture

James A. Bethke[1], Lance S. Osborne[2], Stephanie D. Stocks[2], Bryan Vander Mey[1], Amanda C. Hodges[2], Diane L. Schuble[3] and Lin Schmale[4]

[1] University of California Cooperative Extension (UCCE)
[2] University of Florida
[3] Coordinator for Official Control, USDA APHIS PPQ. Emergency and domestic Programs
[4] Senior Director Government Relations, Society of American Florists

The EPM, *Duponchelia fovealis* Zeller, was detected and considered established in the U.S. in the summer of 2010. The original distribution of EPM was the Mediterranean region and the Canary Islands, but it is now established in many countries in Europe, the Middle East and Africa. This insect expanded its native host range to include greenhouse vegetable and ornamental plant production, and it has been an economic pest in Europe for more than ten years. The cryptic and obscure nature of this pest makes it even more of a challenge to understand and control.

In recent years it has been established in Canada and now in the U.S. it has been detected in 15 states (Figure 1), including Alabama, Arizona, California, Colorado, Florida, Hawaii, Minnesota, Mississippi, New York, North Carolina, Oklahoma, Oregon, South Carolina, Texas, and Washington.

One of the major problems with this insect is that it is very difficult to detect until the numbers build to high levels and begin to cause significant damage. In addition, this insect will be easily moved when shipping stock plants since they are so cryptic and stealthy. This poses a great challenge for regulators that would not like to see this pest spread by the ornamental trade. Below, we describe the efforts put forth to limit the potential threat this insect poses to U.S. agriculture and provide as much information as possible to prepare the ornamental plant industry in controlling this pest.

Formation of EPM Task Force

Since the pest was considered a significant threat to U.S. agriculture, USDA APHIS had to make a determination on how to handle the infestation. However, since the infestation was so widespread, it was going to be difficult if not impossible to eradicate, and the endeavor would be very costly in a time when budgets are dwindling. Therefore, they decided not to regulate this pest, but decided instead to create a European Pepper Moth Task Force (McCarthy 2011), a method that has been successful in dealing with other invasions of this sort. The task force embodies three main groups, including: Industry Leadership (IL), Technical Working Group (TWG), and Interagency Working Group (IAWG). IL consists of representatives from potentially impacted industries, including fruit and vegetables, and floriculture and nursery and is responsible for providing the overall coordination and communication of the best management practices (BMP) developed by the TWG. The TWG consists of subject matter experts and specialists from universities, extension service, private industry, Federal, and State agencies, and is responsible for providing the technical support for the development of best management practices. The IAWG includes federal and state regulatory officials from potentially impacted states to provide operational and logistical support to the task force.

The authors listed above are some of the members of the TWG and have compiled the information below. For a full list of TWG members and our goals, see: http://mrec.ifas.ufl.edu/lso/dupon/dupon.html

Our first charge was to gather as much information from the scientific literature as possible in the hopes of providing short term solutions if necessary and develop a list of research priorities that will add to the body of knowledge. We (TWG) have conferenced on June 5 and Sept 1. On Oct 26, 2011 the Interagency Working Group conferenced. This conference included members of a wide variety of agencies to get input on their concerns and needs and it includes the co-chairs of the TWG, Jim Bethke and Dr. Lance Osborne. The IAWG included the following:

Carl Schulze (SPRO-NJ) Director Division of Plant Industry, FL
Tom Denholm (APHIS-PPQ) Pest Survey Specialist, NJ-DE
Catherine Marzolf (APHIS-PPQ) State Operations Support Officer, FL
Tyson Emery (FDACS DPI) Bureau Chief Plant & Apiary Inspection, FL
Courtney Albrecht (CDFA) Supervisor Pest Exclusion Branch, CA
Norm Mullaly (APHIS-PPQ) State Operations Support Officer, CA
Lance Osborne (Co-Chair, TWG) University of Florida
Jim Bethke (Co-Chair, TWG) UC Cooperative Extension, CA
Lin Schmale, (Chair, ILG) Society of American Florists, Sr Dir Gov't Relations
Diane Schuble (APHIS-PPQ, EPM Task Force Coordinator)

Information Gathering

The following is a list of goals we discussed in our first two meetings. We have made progress in all areas of our concern.

- Determine the most likely hosts in the U.S.
- Gather the scientific literature about the insect, and determine its life history
- Prioritize research needs
- Determine effective control measures
- Develop an effective management strategy (BMP)
- Break into subgroups that will address selected issues and report back to the TWG.

The TWG subgroups are the following:

- Diagnostics, detection & survey
- Management
- Communication
- Practical biology and ecology.

Dissemination of Information

The success of the Q biotype Technical Advisory Committee serves as a model for successful management of this new pest. Therefore, we used the Q biotype model and Dr. Osborne developed a web site with all the information about the EPM, one that can be revisited often as we gain more research knowledge about the bug.
http://mrec.ifas.ufl.edu/lso/dupon/dupon.html

On this site you will find many photos of all stages and all types of damage. In addition, as with the Q biotype web site, you will find notes on our meetings and our progress. So far, the site contains the following:

- Current publications, pest notes, and alerts that can be downloaded
- A long list of web links to informational pages
- A list of scientific references
- A list of the TWG members

We learned that there is a lot of research that still needs to be conducted in order to develop good strategies and practices. However, we already have a good working draft of a BMP against this pest. The following is a summary of what we know to date.

Host Range

Another important piece of information we needed to gather was a list of crops that were damaged in other countries and how extensive that host list might be, so that we could prepare the potentially affected industries.

EPM is a known pest of a wide variety of plants ranging from aquatic plants, agricultural crops, and plants grown in the nursery and floriculture trade (for a full list, see Stocks and Hodges 2010). For instance, Jaroslav and Bartova (1998) noted damage to greenhouse grown aquadic plants in the Czech Republic. The most serious damage was recorded on *Rotala macranda, R. wallichii, Bacopa lanigera, Nesaea pedicellata, Hygrophila rubela, Alternantea splendida and A. rosaefolia*. Aquadic plants hold the dubious distinction as the first host shipped with EPM from its native range in the Canary Islands to Northern Europe (Pijnakker 2001). Scientists in the Netherlands consider this pest to be a widespread problem in Dutch greenhouse ornamentals such as begonia, cyclamen, and kalanchoe (Messelink and Van Wensveen 2003). The host range appears to be quite significant, but further investigation revealed that the insect also feeds on detritus, decaying plant matter, and it has been noted that a favorite food is detached rose leaves lying on the surface of the soil. We have observed EPM caterpillars feeding on any leaves that touch the surface of the soil, and that we can rear a single caterpillar to an adult on a single cowpea leaf in a petri dish. This means that the insect has the potential to proliferate even in the absence of a host plant.

Basic Biology

There is little scientific literature written about this pest, and much of what is known are anecdotal observations from lepidopterists and official records from invaded countries in Europe. There is enough information though to provide a basic biology.

At 20°C (68°F), the developmental time from egg to adult is 47 days. The adult longevity is 7-14 days (Jackel et al. 1996, Pijnakker 2001) depending on temperature. The number of generations per year is variable and in coastal and Southern California, they may reproduce year round with a concomitant reduction in development time during the cooler winter months.

One female EPM (Figure 1) can lay up to 200 eggs (Jackel et al. 1996) as individual eggs or in small batches. The eggs are white when first laid but eventually darken to red or redish orange when mature. The egg stage lasts 4 to 9 days (Pijnakker 2001). Preliminary studies in our laboratory indicate that the eggs hatch in approximately

8 days at 25°C. As has been noted in the literature (Jackel et al. 1996), we have observed eggs laid on plants and on any other surface in the cloth rearing cages or plastic vials.

The larval stage lasts 21 to 30 days (Pijnakker 2001). Their color can vary from light brown to dark brown depending on the food source, and they always have a dark brown head capsule (Figure 3). When feeding on healthy green plant matter we have observed the lighter forms, but when they are feeding on decaying matter, the larva can be very dark, which makes them cryptic on potting media. The larvae prefer dark spaces (Marek and Bartova 1998) and can be found between the potted plant and the media, near the main stem, and even under the pots between the pot and the nursery floor. When in pots, they can even take advantage of spaces between the media and the main stem or the media and the pot surfaces, and they can feed on the stem and roots below the soil surface. Another interesting feature of this caterpillar is that they are silk producers and like to move through webbed tunnels along the soil surface and in the crown of the plant. They can move forward and backward through the tunnels with ease. In densely planted crops, larvae also occur higher up in the canopy where they feed on leaves and stems (Jackel et al. 1996, Messelink and Van Wensveen 2003). Lavae can also be found in the fruit (Pijnakker 2001).

Mature larvae create a cocoon composed of webbing and soil particles, and they pupate inside. The cocoon is usually attached to the undersides of leaves, the edge of a potted plant, or even the undersides of the pots. They take about 1-2 weeks to emerge as an adult (Pijnakker 2001).

The number of generations per year is variable in Europe, but it is certain to be multiple generations in warmer areas of the U.S. such as California and Florida, and we are likely to have multiple year-round generations in greenhouse production.

Damage

The EPM larvae can damage roots, leaves, flowers, buds and fruit (Ahern 2010, Bethke and Vander Mey 2010, Bonsignore and Vacante 2010, Murphy 2005, Messelink and Van Wensveen 2003, Pijnakker 2001). It has also been noted that when feeding on the aquatic hosts, they do not seem to mind the leaves being submerged in water (Billen 1994). In some crops such as roses, it will feed primarily on crop debris such as fallen leaves (Murphy 2005, Pijnakker 2001). In Canada it has been intercepted on many occasions on plant material entering most often on greenhouse peppers, resulting in the rejection or destruction of the shipment (Murphy 2010).

In southern CA we have observed damage to gerbera, echinacea, kalanchoe, begonia, and poinsettia. Some significant losses were observed. We observed damage on poinsettia during the 2010 cropping cycle and populations of the moth were generally being ignored as just another moth making its way through the greenhouse. Unfortunately, the infestations of the caterpillar and the damage they were causing were unnoticeable until the plants (Figure 4) were taken from the production area and prepared for shipping. Many of the poinsettia plants were girdled by the caterpillars and collapsed when moved. Growers in Southern California are now on the lookout for the pest and those that were impacted last year are on a preventative spray schedule.

Monitoring

It will be important to monitor for this pest especially if there is a susceptible host plant being produced. In many cases in ornamental plant production, the mere presence of the pest will require preventative treatment applications to prevent damage and to prevent movement of the pest. Detection can also be used to coordinate biological and chemical control measures.

Water traps seem to be the most effective means of capturing the adults, followed by delta traps, and funnel traps (DeVenter 2009). These methods require the use of a pheromone, which is now readily available from sources in Canada, the Netherlands and in the U.S.

Control

The scientific literature (Messelink and Van Wensveen 2003, Pijnakker 2001) and consultations with colleagues in France and Denmark have confirmed that products that contain *Bacillus thuringiensis* (or Bt) are effective when applied preventatively against early instars. Indeed, we were encouraged to note that growers that that recorded losses in California during 2010 and used a preventative program of Bt recommended by our European colleagues in 2011 averted significant losses.

Our studies in California have shown that other products (acephate) are effective against late stage larvae (Bethke and Vander Mey 2010), and we are in the process of identifying alternative control measures such as the biologicals for control of early stage larvae as well. This data will be available soon. For instance, some recent data from leaf dip assays suggests that ultra fine petroleum oil, an alternative to harsh synthetic pesticides, has a significant impact on hatchlings (JAB unpublished data).

Unfortunately, there is little scientific work completed on the effect of natural enemies on the EPM. Some studies suggest that available generalist predators like predatory mites (Jackel et al. 1996, Messelink and Van Wensveen 2003) and rove beetles *Atheta coriaria* (Messelink and Van Wensveen 2003) can be effective. In our laboratory studies in California, we have confirmed that in a no-choice test *Atheta* eat the first instars with alacrity. Another study demonstrated that combined releases of several species of Trichogramma, which are egg parasitoids, were effective in reducing EPM populations in crop production facilities in Germany (Jackel 1996). Much needs to be done in this area of research.

Potential Impacts on Agriculture

California has four main bell pepper (*Capsicum annuum* L.) production areas: the southern desert valleys (Imperial and Riverside Counties), Ventura County on the southern coast, the central coast (San Luis Obispo, Monterey, San Benito, and Santa Clara Counties), and the Central Valley (Kern, Fresno, and San Joaquin Counties) with a gross value of over $10,000 and acre (Hartz et al. 2008). As in northern Europe where outdoor production areas do not have a problem with the pest, Kern, Fresno, and San Joaquin Counties will most likely not experience problems with EPM. On the other hand, all other production areas are in good climates for continuous generations of the pest. As with other insects, there will be a slowing of the generation times in the winter months, and the populations should do well during the warmer times of the year.

It has also become a pest of strawberries grown commercially in Italy (Bonsignore and Vacante 2010, Guda et al. 1988). Strawberries should be a good host for

EPM because it grows low to the ground, has a dense crown, and many decaying leaves toughing the solid surface. The value of the California strawberry crop is approximately $1.8 billion (California Strawberry Commission 2007), and is the seventh most valuable fruit crop produced in California. California's rich sandy soil and temperate climate provides a 12-month growing season with production starting in the south because it's warmer earlier in the year and works its way north. The southern region includes San Diego, Orange, Los Angeles and Ventura counties and production is from January to August. The Northern region includes Santa Cruz and Monterey Counties and some acreage in Santa Clara and San Benito counties. The production times are from April to November.

California's ornamental production, which includes potted plants, bedding plants, cut flower production, and propagative material leads the nation with a value of $999 million in sales, comprising 25.1 percent of the U.S. total wholesale value (NASS 2011). As noted in the northern climates of Europe, this insect does not survive well outdoors but has become a pest of greenhouse production. We can assume that EPM will be a significant pest in greenhouse ornamental and greenhouse production in many parts of the state CA. Indeed, Pijnakker (2001) stated that the pest was one of the most dreaded to producers of potted plants. Due to the milder climates found in coastal and Southern California, however, and the susceptible agriculture grown in these areas that we will have field populations that will cause damage there as well. There are reports of field damage in Italy.

During the 2010 cropping cycle, we also found infestations causing economic losses to poinsettia, a popular annual Christmas crop that most floriculture and nursery producers use to fill in orders during the slower time of the year. We were also able to detect infestations of this pest in field nurseries, residing on the undersides of potted plants in both California and Florida (Figure 5), thereby posing the threat of moving the pest with the potted plant to other areas of the country.

Conclusion

What we have learned from this pest so far is that it can cause significant economic losses to producers of several ornamental plant species, and that the restriction to movement of infested plants can also have economic consequences. The trace back from Canada led to a grower that had a significant infestation. The majority of the plants he produced were on hold indefinitely, until the grower could eradicate the pest from his production. Unfortunately, a large annual shipment that helped him stay afloat in this tough economic time was destroyed to prevent the proliferation of the insect and the potential shipment from reaching another state. The loss was in the nature of a quarter of a million dollars. Not many growers of minor crops can afford that kind of loss. In addition to the loss of the shipment, the grower needed to double bag an additional 20,000 smaller potted plants that were mature and ready for sale. With great effort and again at great cost, the grower was able to use pesticides to eventually clean the rest of his crop and avert further losses.

One ornamental grower was noticing plant damage due to EPM in greenhouse ornamentals in Encinitas, CA, a city on the coast in San Diego County and decided to try the pheromone above a water trap outside his greenhouses to see what the surrounding population may look like. They found counts in traps in as high as 160 individuals per trap week. Observing a population of this size outdoors means that the impact on coastal agriculture and ornamental plant production in coastal and Southern CA could be significant, and that growers will have to be diligent in the next few years in detecting the presence and the damage caused by EPM. They will most likely have to take preventative measures in some of their crops to avoid significant losses.

Acknowledgements
The authors would like to thank IR4 and FNRI for partial funding of the research targeted at this pest.

References

Ahern R. 2010. Amended New Pest Advisory Group Report. *Duponchelia fovealis* Zeller: Lepidoptera/Pyralidae. UF/IFAS Pest Alert. http://entomology.ifas.ufl.edu/pestalert/Duponchelia_fovealis_NPAG_ET_Report_20100917.pdf (Last viewed 10/8/2011)

Bethke J. A. and B. Vander Mey. 2011. *Duponchelia fovealis*: A new invasive moth for CA Agriculture. CAPCA Advisor. April 2011. 14(2): 28-32.

Billen W. 1994. On the harmfulness of *Duponchelia fovealis* (Zeller, 1847) in Germany (Lepidoptera, Pyralidae). Nota Lepidopterol 16(3/4): 212

Bonsignore, C. P. and V. Vacante. 2010. *Duponchelia fovealis* (Zeller). Une nuova emergenza per la fragola? Protezione delle colture, pp. 40-43.

Guda, C. D., A. Capizzi, and P. Trematerra. 1988. Damages on *Eustoma grandiflorum* (Raf.) Shinn. caused by *Duponchelia fovealis* (Zeller). Annali dell'Istituto Sperimentale per la Floricultura 19: 3-11.

Hartz, T. M. Cantwell, M. Lestrange, R. Smith, J. Aguiar, and O. Daugovish. 2008. Bell Pepper Production in California. Publication 7217. University of California Division of Agriculture and Natural Resources. 4pgs.

Jackel, B., B. Kummer and M. Kurhais. 1996. Biological control of *Duponchelia fovealis* Zeller (Lepidoptera, Pyralidae). Mitteilungen aus der Biologishen fur Land und Forstwirtschaft 321: 483.

Jaroslav, M. and E. Bartova. 1998. *Duponchelia fovealis* Zeller, 1847, a new pest of glasshouse plants in the Czech Republic. Plant Protection Science. 34(4): 151-152.

Marek, J. and E. Bártová. 1998. *Duponchelia fovealis* Zeller, 1847, a new pest of glasshouse plants in the Czech Republic. Plant Protection Science 34: 151-152.

McCarthy, R. 2011. Status of European pepper moth. NPDN News. August 2011. V6(8): 10pgs.

Messelink, G. and W. Van Wensveen. 2003. Biocontrol of *Duponchelia fovealis* (Lepidoptera: Pyralidae) with soil- dwelling predators in potted plants. Communications in Agricultural and Applied Biological Sciences 68(4):159- 165.

Pijnakker, J. 2001. *Duponchelia fovealis*, the dreaded lepidopteran of pot plants in the Netherlands. (*Duponchelia fovealis*, le lepidoptere redoute des plantes en pot aux Pays-Bas.) PHM Revue Horticole 429: 51-53.

Web Sites

California Strawberry Commision. 2007. http://www.calstrawberry.com/commission/. Last viewed Oct 24, 2011.

DeVenter P van. (2009). Water trap best for catching *Duponchelia*. In the Greenhouse. http://documents.plant.wur.nl/wurglas/C_bestwatertrap.pdf Last viewed on Oct 8, 2011.

Murphy, G. 2005. *Duponchelia fovealis* - pronouncing it is just the start of the battle. Ontario Ministry of Agriculture, Food and Rural Affairs. http://www.omafra.gov.on.ca/english/crops/hort/news/grower/2005/08gn05a1.htm Last viewed on 10/9/2011

NAPIS Pest Tracker: http://pest.ceris.purdue.edu/pest.php?code=ITBMGZA Last viewed on 10/7/2011.

NAPPO. 2010. Official Pest Reports: Thirteen new state detections of Duponchelia fovealis, United States. Phytosanitary Alert System. http://www.pestalert.org/oprDetail.cfm?oprID=466&keyword=Duponchelia%20fovealis Last viewed on 10/7/2011.

NASS. 2011. California Floriculture Report. United States Department of Agriculture National Agricultural Statistics Service. http://www.nass.usda.gov/Statistics_by_State/California/Publications/Field_Crops/201104florarv.pdf Last viewed on 10/8/2011

National Berry Report. 2010. California Strawberry Commission: http://public.calstrawberry.info/Reports/Public/BI%20Reports/NationalBerryReport.aspx Last viewed on 10/8/2011

Stocks, S. and A. Hodges. 2011. Featured Creatures: European pepper moth: http://entnemdept.ufl.edu/creatures/veg/leps/european_pepper_moth.htm Last viewed on 10/7/2011.

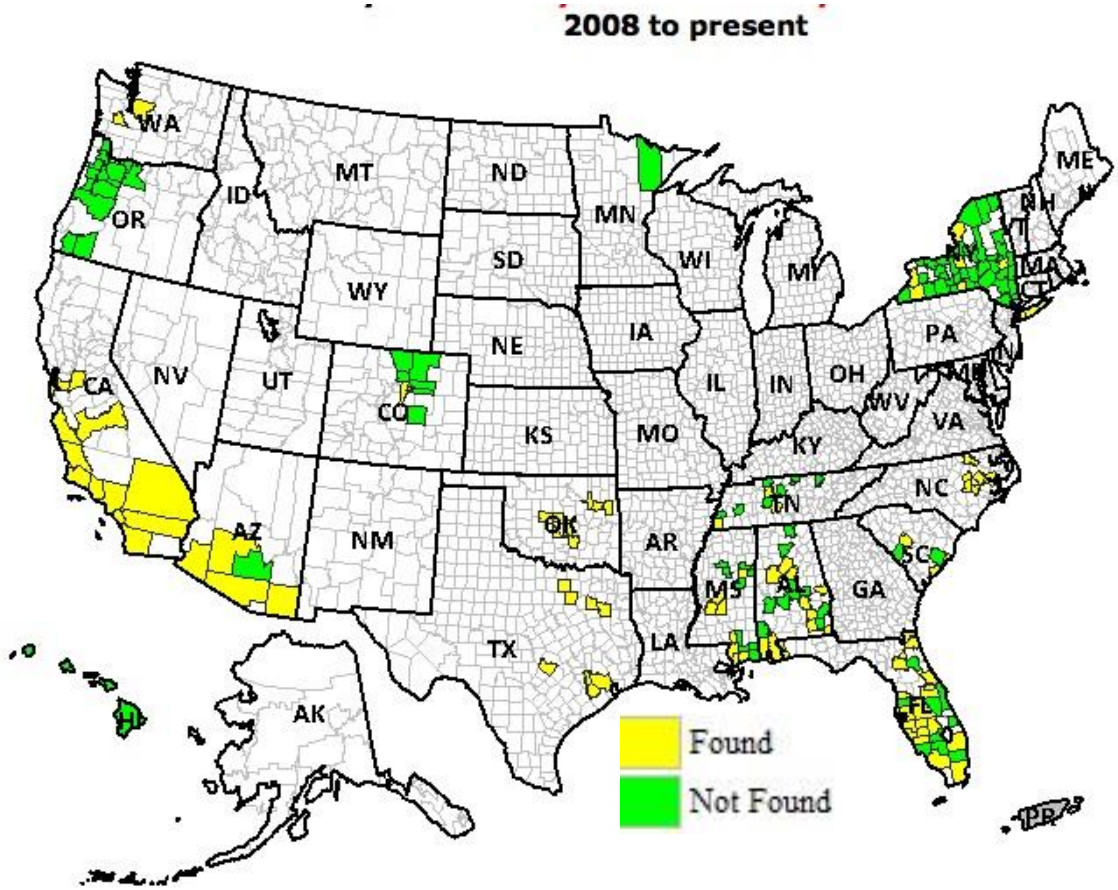

Figure 1. Present distribution of EPM in U.S.
http://pest.ceris.purdue.edu/map.php?code=ITBMGZA

Figure 2. Adult female European pepper moth, *Duponchelia fovealis* Zeller

Figure 3. Larval stage resting on potting media and surrounded by webbing that is typically found in potted plants.

Figure 4. Typical damage observed on poinsettia plants during the 2010 cropping cycle. Note the brown stem where EPM ate away the green stem tissue. Plants appeared fine in place, but when moved for shipping, they collapsed due to the stem damage.

Figure 5. An infestation of EPM, *Duponchelia fovealis* Zeller, on the undersides of potted plants in an outdoor nursery setting.