IR-4 Ornamental Horticulture Pollinator Workshop

Summary

Organizers: Cristi L Palmer, Jerry Baron, Krista Coleman
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http://ir4.rutgers.edu/ornamentals.html

Executive Summary

Protecting pollinators is a unique challenge for the green industry. While the green industry is poised to provide plants to aid in habitat restoration, production systems must incorporate practices to manage pests without harming pollinators. What this means and its implementation are open questions. Scientific information is often overshadowed by other types of decision making information including emotional and economic drivers. The debate about using insecticides to protect crops and how to mitigate risk to pollinators is being held not only in scientific circles but in political and consumer circles and is being fueled by seemingly conflicting scientific data, misinformation readily discovered on the internet, and a passion to protect pollinators.

To refine the scientific questions and outline the needed research, IR-4 hosted a special workshop in December 2014 with scientists from land grant institutions who work with ornamental horticulture pests and pollinator biology, experts on risk assessment and product submission to EPA, those with expertise on chemical residue analysis and agricultural economics, and representatives of the ornamental horticulture industry. Presentations and discussions ranged from grower perspectives to risk assessments to bee biology and behavior to designing studies which address data gaps for assessing risk to pollinators in production of ornamental horticulture crops.

This workshop clarified necessary research activities to address risk assessment data gaps. Standard pollen and residue decline analysis protocols will need to be developed for common production practices using single foliar or drench application. Subsequently, these protocols for field residue studies should be implemented to address Tier 2 risk assessments. To determine the percentage of crops that are both bee-attractive and typically require systemic pest management intervention, a survey should be conducted to collect anonymously from growers the top 10 to 15 crop species grown along with their observations of relative attractiveness. An online database should be created to catalog pollinator attractiveness levels for ornamental horticulture crops and the likelihood of pest and/or pathogen mitigation actions. Determining consumer buying preferences related to bee-friendly practices and outreach impacts from point of purchase materials are important factors in educating consumers about green industry production practices and guidance on providing suitable backyard pollinator habitats. Outreach materials should be developed from research results being cognizant of different learning strategies and scientific literacy among the different potential audiences.

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Welcome, Introductions and Workshop Objectives (30 min) Cristi Palmer

This workshop began with a showing of a video created by the NJ Beekeepers association (https://www.youtube.com/watch?feature=player_embedded&v=WBVQGupoxEA). The video highlighted certain issues related to decline of pollinators including suitable habitat, encroachment of development. It also encouraged consumers to devote smaller areas of suburban landscapes to planting of native and non-native plants which provide nectar and pollen (floral resources). Native plants include New England aster, mountain mint, bee balm (*Monarda sp.*), Cardinal flower (*Lobelia sp*), and milk weeds (*Asclepia sp.*). Non-native plants include yarrow, black-eyed susan (*Rudbeckia hirti*), lavender (*Lavandula sp.*), and various aromatic herbs such as thyme and oregano. Another key factor in planting floral resources is ensuring that there are suitable blooming plants from mid-summer through fall as bees are building stores/supplies for overwintering in northern climates. Overall, the video effectively educates a relatively scientifically naïve audience. However, there were a few concerns raised including 1) the negative auditory tone associated with pesticides although the visuals were balanced and 2) “mountain mint” was not a plant known by any in the room.

To address the question of whether pre-importation neonicotinoid treatments could result in detectable residues once the cuttings have grown to salable plants, Flowers Canada has an observational study underway examining what pesticides are found on imported poinsettia cuttings upon arrival and then 8 and 16 weeks into production. While the results are preliminary, 34 different pesticides (fungicides, insecticides and plant growth regulators) were found on cuttings. By 8 weeks, most residues dropped to very low levels and at 16 weeks no pesticides were detected at analytical detectable limits. Neonicotinoids had dropped to non-detectable levels by 8 weeks.

The objectives of this workshop were 1) educate ourselves on regulatory processes, 2) hear about grower concerns and needs, 3) listen to updates on research activities, and 4) develop a general roadmap for future research.

Role of Systemic Insecticides in Ornamental Horticulture (45 min) Dan Gilrein

Gilrein will present how neonicotinoid insecticides fit within the spectrum of pest management tools, their use within Integrated Pest Management programs, and potential alternative products.

Several systemic insecticides from different chemical classes are available for use on ornamental plants. Systemic insecticides can be applied as foliar sprays, soil applications, trunk injections and trunk sprays. Each systemic insecticide has different characteristics and safety profiles. Some are labeled broadly for many use sites while others have more specific crop or site (e.g. indoor or outdoor) applications.

Neonicotinoid insecticides are a commonly used class of systemics with broad crop and site uses, application methods, (foliar sprays, soil drenches/injections/sprenches/premixes, basal bark sprays, trunk injections, granular broadcasts, tablets for soil use and added to irrigation water) and labeled target pests (Table 1 shows a list of target species included on neonicotinoid insecticide labels). Most are stand-alone materials, but there are also a number of pre-mixed combination products with pyrethroids and fungicides. Active ingredients used on ornamentals include imidacloprid, thiamethoxam, dinotefuran, clothianidin, and acetamiprid. Imidacloprid is the most widely used, with currently over 80 imidacloprid products labeled for use on ornamental plants in NY. The range of products is partly related to the wide use of imidacloprid (and neonicotinoids in general) to manage various insect species on diverse crops and plants in turf (landscape and sod production), for landscape trees, shrubs, flowers, and groundcovers, and in greenhouse and nursery production (previously mentioned plants plus vegetable transplants).

Table 1. Neonicotinoid Labeled Plant Pests

Full Management	Management of Some Members	Suppression of Populations
Aphids	Scales (some, esp. soft)	Plum curculio
Adelgids	Leafminers (some?)	Stink bugs
Whiteflies	Borers (some, e.g. flatheaded)	Thrips
Leafhoppers		Certain diseases
Mealybugs		Cutworms
Phylloxera		
Lace bugs		
Pine tip moths		
Psyllids		
Apple maggot		
Leaf beetles/veg (flea, CPB, cuke, Japanese)		
Leaf beetles/orn (Japanese, elm, viburnum)		
Fungus gnat larvae		
Black vine/strawberry weevils		
Sawflies		
Swede midge		
White grubs (turf, ornamentals, Christmas trees, strawberry)		
Crane fly larvae		
Annual bluegrass weevil		
Black turfgrass ataenius		
Billbugs		

The US patent for imidacloprid was filed in January 1986, then granted in May 1988. The first US EPA registration in March 1994 was soon followed by state registrations. In January 2005, commercial imidacloprid products became restricted use in NY with consumer products and soil injection prohibited for use on Long Island. The following January, the US patent expired. After a misapplication in OR of dinotefuran to linden trees in bloom, labels of imidacloprid dinotefuran neonicotinoids were revised to exclude use on linden. Starting in 2014, EPA now requires labels of certain nitroguanidine neonicotinoid insecticide (imidacloprid, dinotefuran, thiamethoxam, clothianidin) labels to include additional pollinator protection language. EPA is currently reviewing neonicotinoids in the re-registration cycle; the registration eligibility document for imidacloprid is due in 2017. Part of this process is reviewing the benefits along with the risks. In some cases neonicotinoid chemistries are alternatives to older insecticides with a less favorable safety profile to human beings, mammals and the environment. Systemic neonicotinoid applications can have long residual activity which may reduce the overall number of insecticide applications needed and worker exposure. Neonicotinoids have been used as key partners in IPM programs and have been instrumental in managing resistance to insecticides, when used as rotational partners with products having other mode of actions and other strategies. In certain situations, systemic uses of some neonicotinoids appear to be compatible with predators and parasitoids used in greenhouses. In addition, they have been key tools in the management of invasive species including *Bemisia tabaci* Q biotype, emerald ash borer and Asian Longhorned beetle. Some hard-to-control pests, such as boxwood leafminer, have been controlled well with neonicotinoids.

Some neonicotinoids are acutely toxic to honeybees and other pollinators from exposure through direct contact or ingestion. Labels warn against application when bees and other pollinators are present. Unfortunately, numerous bee kills were associated with neonicotinoid application to linden trees (*T. cordata*), with some estimating approximately 59,000 bumble bees killed in two incidents in 2013 (Figure 1). In one case, a foliar (or on some trees a drench) application was made during bloom but when bees were not present. This incident made national news and initiated appeals at local, state, and federal levels to ban all neonicotinoid uses. Subsequently, some regional and national retailers selling garden plants began to request their vendors (producers) provide plants free of neonicotinoids or be labeled as treated.

Figure 1. Bumblebees around the base of Linden trees after off-label application of dinotefuran.
Photo by R. Kachadoorian, Oregon Department of Agriculture

While used in some IPM programs, some beneficial organisms are sensitive to neonicotinoids, though some products or uses can be compatible (http://www.koppert.com/, http://www.biobestgroup.com). Adding to the picture, imidacloprid has been detected in groundwater on Long Island although at low levels. There are alternative controls and newer products for many of the key pests such as whiteflies, aphids, fungus gnats, and hemlock woolly adelgid, though some uses remain important (boxwood leafminer, hanging baskets in greenhouse production, emerald ash borer). In sites where foliar sprays are not possible or effective, neonicotinoid soil drenches and trunk applications can be reasonable alternatives.

Bell Nursery's Experiences in Managing Arthropod Pests without Neonicotinoids (45 min) Gary Mangum

In this presentation, Mangum will cover the pressures growers are facing to eliminate insecticides with the potential for negative impact on pollinators, and he will speak about their 2014 experiences growing quality plants without neonicotinoids.

In 2014, Bell Nursery undertook an experiment to grow without neonicotinoids. For poinsettias, they were able to produce them without this chemical class in both fall 2013 and 2014. Mangum is a heavy proponent of following the science, but protecting pollinators is currently more about politics and perceptions than scientific knowledge. A regional chain started implementing a ban on their growers from using neonicotinoids and the national retail chains began examining their options at the same time as activists began visible demonstrations.

It is very important to explain to the general public the difference in various bees. Native pollinators are different from the European honey bee in substantial ways. Honey bees develop very large colonies of thousands of individuals whereas native pollinators may be solitary or have much smaller colonies. The lifecycle of most native pollinators is annual with the colony being completely started/renewed each year, but the honey bee overwinters as a full colony with some winter loss annually depending upon the stored resources and weather. Some honeybee colonies have naturalized, but about 90% live in managed hives in America.

Current knowledge indicates that there are many causes of bee decline with the varroa mite being the primary agent, evidenced by an Australia report (AVPMA 2014) that documents honeybees in this country are healthy and thriving with the use of neonicotinoids in agriculture. Australia has very stringent regulations for exotic species and beekeepers have eradicated any varroa mite incursion to date.

Mangum advocates the use of integrated pest management (IPM) strategies. His definition of IPM is to use as few chemical tools as possible. Neonicotinoids are among the safest chemical class for people and mammals, and their introduction has reduce pesticide poundage by 70%. Because they are systemic and relatively long-lasting, fewer applications are needed leading to less worker exposure. Neonicotinoids have been well-used as resistance management tools for other products.

In the experiment Bell Nursery conducted, they asked the question what would happen if you removed neonicotinoids from the tool box. The alternatives are not as safe for people or the environment, and they discovered that they applied insecticides more frequently with an overall higher cost when factoring in additional supplies and applicator time.

Mangum is concerned that if neonicotinoids are banned either through regulatory or public perception pathways that the fall back tools with less safe profiles will be targeted next.

SAF and AmericanHort are supporting research to encourage retailers to wait to make critical business and marketplace changing decisions.

One of the initiatives from Home Depot is to label all neonicotinoid treated plants. Mangum, SAF and AmericanHort have worked with Home Depot representatives to modify the new label so that it includes the reason for treatment (aphids, thrips, whiteflies) without having a bee icon. One drawback to this is the potential for every class of chemistry being applied to need a similar tag, if the product applied has an unfavorable toxicity profile for bees. Another is that is brings attention to the neonicotinoids during a time when studies are just underway to better understand the potential impact neonicotinoids have on pollinators and the decline in systemic residues in pollen and nectar.

Neonicotinoid Registration Review and Pollinator Risk Assessment (45 min) Richard Allen

Allen will outline the current reregistration review process and pollinator risk assessment from a regulatory perspective. EPA required studies will be described.

EPA is required to review each registered pesticide every 15 years to ensure it meets the current FIFRA standard for registration with regard to human health and the environment. The scope and depth of review is customized for each pesticide based on its characteristics. The imidacloprid review starting in FY2008, and review timelines for other neonicotinoids were accelerated to begin in FY2012. For neonicotinoids, the review includes in depth study of the impacts on pollinators.

There are three steps to assessing ecological risk: problem formulation, risk hypothesis and conceptual model. To formulate the problem, it is critical to define the protection goals. Without clearly articulated goals, it is impossible to decide what should be done and how to evaluate impact. For neonicotinoids, the risk assessment problem is understanding honey bee populations and individual end points which impact colony strength needed for pollination services.

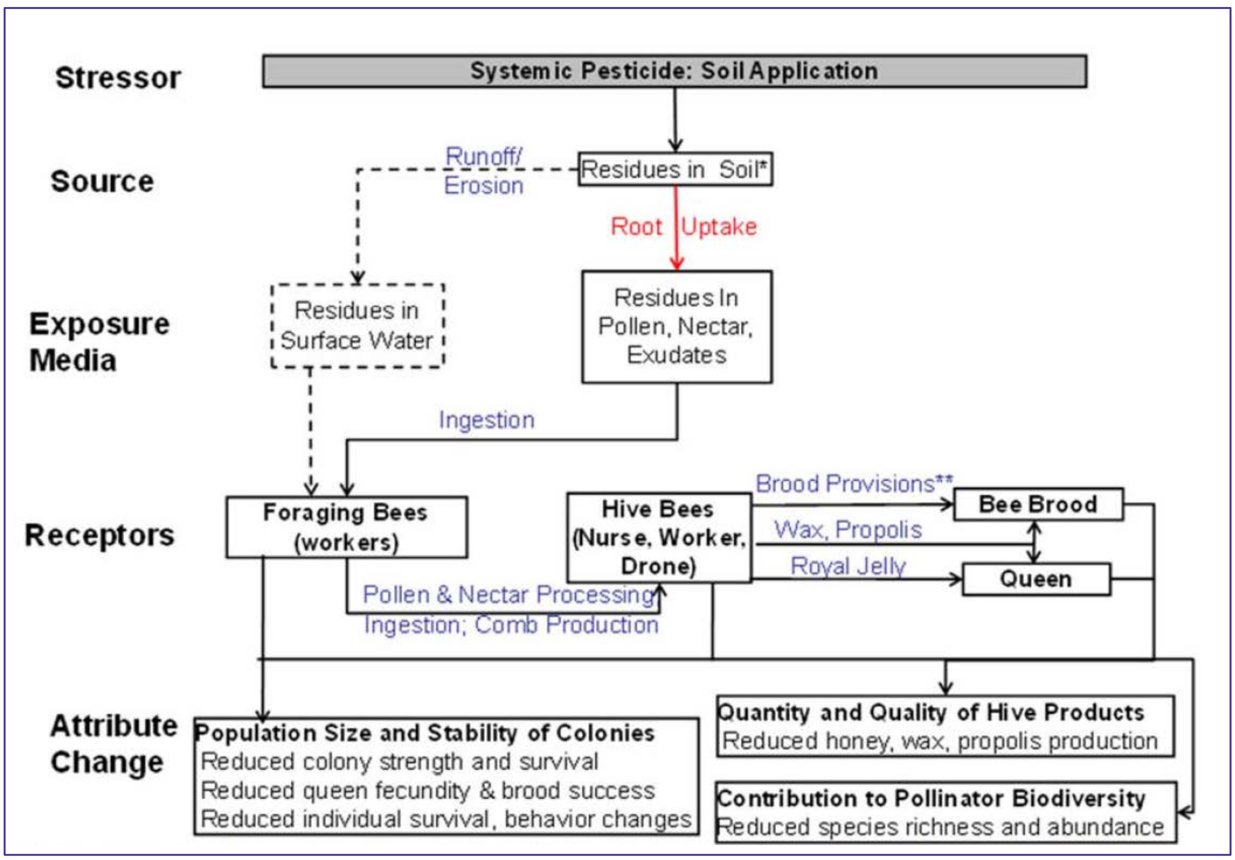
> The ***formulation*** of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skills.
> -- Albert Einstein

Risk hypotheses can be organized around three types: stressors, effects, values. The first two are specific and can be measured. For example, a stressor initiated risk hypothesis is that the physic-chemical properties of neonicotinoid insecticides enable them to be translocated from soil to pollen and nectar which results in adverse impact on honeybee colonies. The amount of insecticide can be measured in pollen and nectar and compared to the levels causing an observable impact. An example of an effect-initiated risk hypothesis is that honeybee colonies are adversely impacted when foraging adults are exposed to dust during mechanized planting of neonicotinoid-treated seed. Honeybee colony size and individual honeybee behavior can be measured and observed, respectively, over time. Alternatively, a value-initiated risk hypothesis is vague and not easily measured. An example of this is colony health declines are related to widespread use of neonicotinoid insecticides. This statement is very general and does not have a way to be evaluated.

Once a risk hypothesis has been formulated, a conceptual model can be built to encompass all the different factors involved for exposure and measurement of impact (Figure 2). In the stressor-initiated example above (neonicotinoid soil application), the source of the potential stressor is soil residues which can be absorbed and translocated by roots or which can move from the target application area as runoff or erosion. Residues in surface water and in pollen, nectar, and other plant exudate are considered exposure media. Foraging honey bees, the receptors, ingest residues in water, pollen and nectar passing them to hive bees, which process these into brood provisions, wax, propolis, and royal jelly. At the bottom of Figure 2 are the measurable attribute changes: colony population size and stability, quantity and quality of hive products, and contribution to pollinator biodiversity.

Risk quotients are calculations of the point estimates of exposure divided point estimates of effect. These ratios represent a way to assess risk and compare exposure to a level of concern. The level of concern (LOC) is based on an acceptable level of impact. For acute pollinator risk, the LOC is 0.4, which is based on historic dose response relationships for bees at a 10% mortality. For chronic pollinator risk, the LOC is 1.0.

Figure 2. Conceptual model of the risk to honeybees from a soil application of a systemic neonicotinoid insecticide



EPA pollinator risk assessments are conducted using a tiered approach to determine both exposure concentration and the effect of that potential exposure (Figure 3). The first tier uses Tier 1 acute and chronic laboratory studies to determine conservative estimates of risk using models. These models incorporate information about acute contact and oral exposure for adults and larvae, the level of toxicity of residues, and the routes of exposure (applications to foliage, soil, tree trunk, etc). The Tier 1 exposure risk assessments for both foliar and soil applications are based upon empirical measurements. With foliar assessments, the contact exposure, the ug per bee, is calculated by multiplying the application rate in lb ai per acre by 2.7 (Koch & Weisser, 1997). For oral exposure, the ug per bee is the application rate in lb ai per acre multiplied by the residues found in tall grass (Hoerger & Kenaga, 1972) and the daily consumption of nectar by foraging honeybees (EPA, 2012). With soil assessments, the equations for oral exposure become much more complex to incorporate plant uptake, soil characteristics, and chemical binding to soil organic matter (Figure 4). In examining the effects on adults and larvae, acute contact and acute oral exposure studies are undertaken to determine the lethal dose where 50% mortality occurs (LD_{50}) along with determining the length of time residues are toxic for 25% of the population (RT_{25}) and determining the no observable adverse effect concentration (NOAEC) in chronic feeding studies for adults and larvae. Risk quotients are calculated by dividing the exposure by the effect. If the risk quotient is higher than the level of concern, the active ingredient passes Tier 1, but some label mitigation may be required to ensure unintentional exposure does not occur for acutely toxic compound. If an active ingredient does not pass Tier 1, Tier 2 studies will be required.

Figure 3. Tiered risk assessment schema for pollinator impact

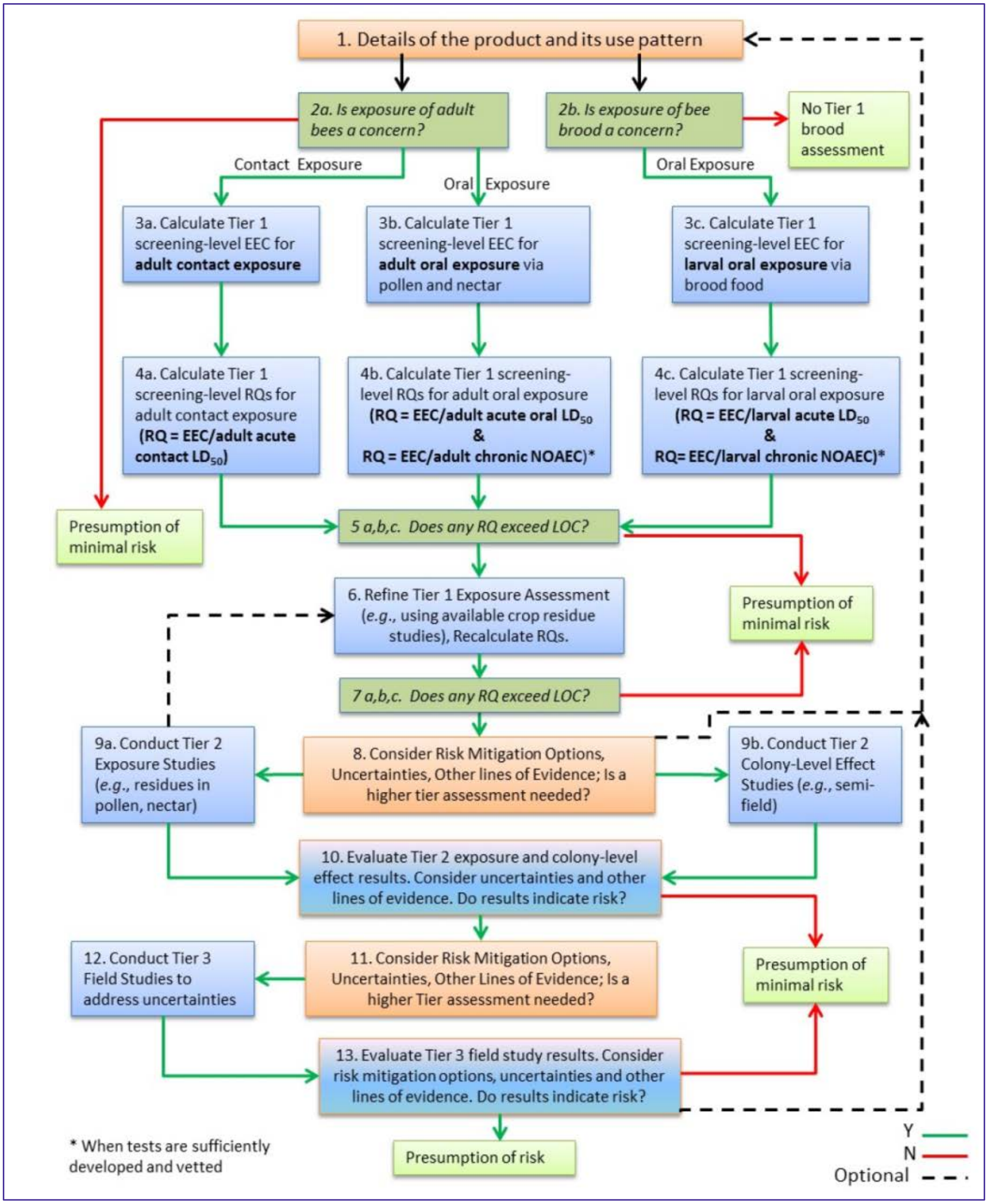
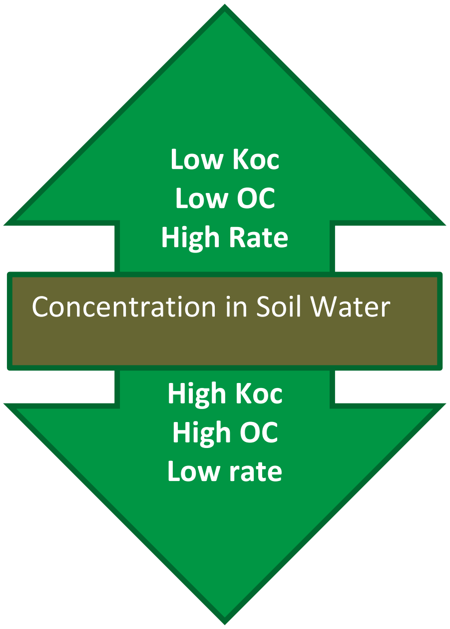


Figure 4. Uptake of active ingredients after soil application based on lipophilicity.



The second tier assessment characterizes the level of residues in pollen and nectar in Tier 2 semi-field scale studies under actual use conditions. Key variables include soil type, climate and weather, irrigation practices, application type, and timing between application and bloom. These studies factor in environmental variability for active ingredient uptake and degradation along with potential impacts of different application methodologies. In tunnel tests (Figure 5), surrogate crops provide large amounts of bee forage to assess acute hazard of a single active ingredient. If the target crop is attractive to bees, it can be planted in the tunnels. Limited extrapolation is possible from these studies because the bees are confined to a single crop in a defined area. Tier 2 colony feeding studies assess exposure via a sucrose solution placed inside the hive with the honeybees allowed to forage freely for other food sources. This methodology does not stress the bees by constraining them to a small forage area. Exposure is typically for 42 days to observe changes in colonies over time. Chronic NOAEC is calculated and can be compared to those from different test scenarios.

Figure 5. A study within a tunnel to restrict bee foraging to the treated crop.

The third and final tier consists of Tier 3 large scale field studies. These studies are designed to resolve very specific risk questions associated with certain use patterns. They are very resource intensive because these are conducted over large geographical areas to minimize the impact of other variables. Monitoring studies may be a viable alternative for certain questions.

There are challenges to applying current risk assessment models to ornamental horticulture production. Environmental risk assessment becomes more complex with increasing heterogeneity of the landscape. The current assessment tools, and supporting data, and processes were developed to assess risk of plant protection products in agriculture, largely a homogenous landscape. The diversity of use areas, application techniques, and behavior of receptors in use areas add to complexity.

Systemic Insecticides: Assessing Risk to Pollinators in Ornamental Horticulture (45 min) Rich Cowles
This presentation will identify the elements involved in risk assessment to bees for use of systemic insecticides to ornamental plants, including application method, insecticide inherent toxicity, mobility in plants, and application rates. The discussion will cover these topics and how they interact with plant attractiveness to bees, foraging behavior and landscape heterogeneity, and bee biology to appreciate the complexity of estimating risk to bees.

Assessing risk to pollinators for ornamental horticulture is a complex proposition. There are a number of characteristics for insecticides, plants, and pollinators that modify potential toxicity. For insecticides, the application method, rate, movement within plant tissues or soil, degradation or metabolism over time, and the potential reservoir in soil or plant tissues all contribute to varying concentration or exposure over time. Plants also contribute to the variability depending on plant species (herbaceous versus woody, monocot versus dicot), the time from application to bloom, plant uptake and metabolism, concentration in nectar and pollen, length of bloom, plant attractiveness to pollinators. The pollinators also factor into the equation in that there are differential intrinsic toxicity among species, number of visits to the same flower, quantity of nectar and pollen collected, and competition/dilution with other sources. Toxicity varies on the concentration of active ingredient, the volume consumed, the length of time, and pollinator sensitivity. Relative toxicity to honey bees varies more than 1,000 fold among the neonicotinoids (Table 2). It is important to shape policy on science and good risk analysis. The potential substitute products may have greater risk to bees.

Table 2. Oral neonicotinoid honeybee toxicity

Chemical Class (IRAC Code)	Active Ingredient	Method of Exposure	Oral LD_{50} (ng/bee)
Neonicotinoid (4a)	Acetamiprid	Oral	15,100.0
	Clothianidin	Oral	3.5
	Dinotefuran	Oral	7.6
	Imidacloprid	Oral	3.7
Sulfoxaflor (4c)	Sulfoxaflor	Oral	50.0
Diamides (28)	Cyantraniliprole	Oral	93.0
	Chlorantraniliprole	Oral	> 119,000.0
Pyrethroid (3a)	Bifenthrin	Contact	15.0

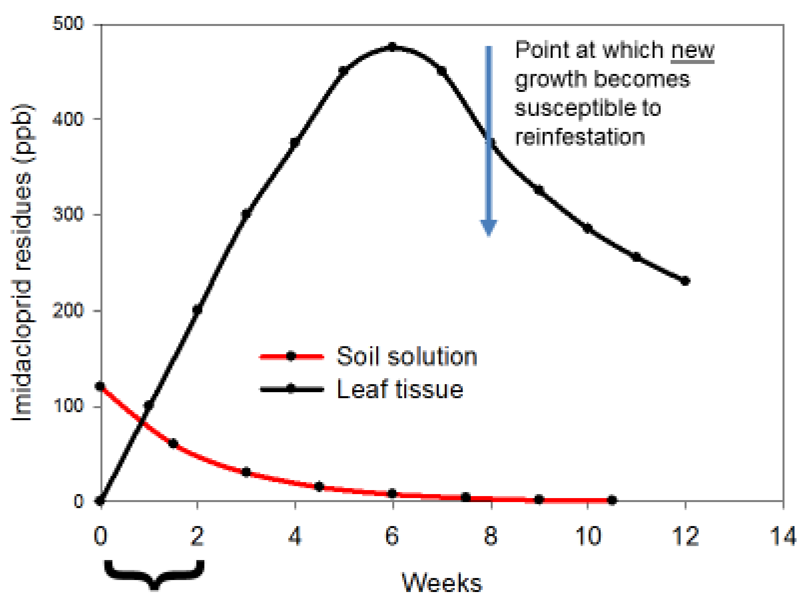
It is important to understand the characteristics of systemic molecules. Most systemic active ingredients only move upward, like the neonicotinoids. Foliar applications will lead to different residue profiles than soil drenches. Active ingredients differ in their mobility within plants. And plant species differ in vascular tissue structures, contributing to uptake and movement variability from species to species.

Contact exposure for pollinators is primarily through foliar applications while oral exposure is from systemic activity via foraging on nectar and pollen. Foliar applications can lead to systemic exposure, following absorption of the active ingredient into the plant. With a relatively quick half-life, there is a short period of high risk with foliar applications of imidacloprid, hence the prohibition of applications during bloom. The longer-term potential exposure for pollinators is oral via root uptake as a result of soil application.

Variation in the mobility of systemic molecules is demonstrated with efficacy data for hemlock woolly adelgid after soil applications. The time required for populations to decline varied from 2 weeks to 1 year when comparing dinotefuran, clothianidin, and imidacloprid. Variability also occurs in location within plant tissues. For example, imidacloprid is not detected in red maple nectar, but there is 10,000, 200, and 5 ppb, in leaves; flowers and pollen respectively. This can be explained in that leaves are a sink due to evapotranspiration and flowers and fruit are not photosynthetic. Another example is that soil application of imidacloprid to target spotted winged drosophila in blueberries led to high residues in leaves, but there were no detectable quantities in fruit, which probably reflects a barrier to insecticide movement across an abscission layer.

Based on general theory, for systemic soil drenches of systemic insecticides, the residues in the soil solution decline over time, mostly due to increasingly tight binding of insecticides to organic components in potting media (Figure 6). After an initial soil application, the concentration will continue to accumulate in leaf tissue, until the concentration in the soil solution declines, at which point any new growth may be unprotected with respect to target insect pests. The concentration of insecticide likely to be found in nectar or pollen will be dependent on the concentration of the systemic insecticide moving in the plant's xylem sap at the time these tissues are formed.

Figure 6. Imidacloprid residues over time in soil solution and leaf tissue.



Krishik has demonstrated that labeled nursery dosages of imidacloprid can lead to extreme nectar or pollen concentration in plants such as *Agastache* spp., *Asclepias* spp., and *Esperanza* spp. The advisability of using systemic insecticides on plants grown for their value to insects (such as *Asclepius* spp.) needs to be questioned. Labels may need to be adjusted to utilize the lowest effective dose for targeting pests that are especially sensitive to neonicotinoids; by using very low dosages, considerable pest management benefits are possible with the fewest potential negative interactions. As an example, the labeled imidacloprid dose is 0.75 to 1.5 g per foot of shrub height. Approximately 1 – 5 % of this amount may be effective for aphids and lace bugs.

How we assess risk is a critical question. Some plants are just not visited by pollinators, so the risk for exposure to neonicotinoids or other systemic molecules is zero. Other plants, such as lindens, are highly attractive to bees, and the risk is very high for mortality if applications are applied while the trees are in bloom. Poinsettias in most parts of the country will never be visited by bees because the flowers occur during winter cold periods. However, there are southern parts of the country where poinsettias may available to pollinators from November through February.

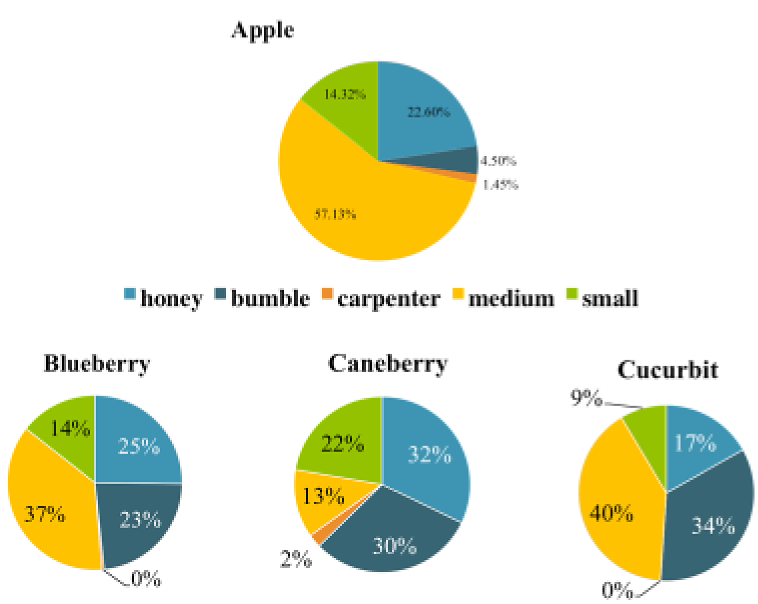
Interactions with pollinators may not be completely obvious. For example, ash trees are wind pollinated but bees may visit to collect pollen, and bees can collect pollen deposited on other surfaces.

Honey Bees, Bumble Bees, and Other Bees, Both Managed and Wild: Differences in Conservation Status, Feeding and Nesting Behavior among these Groups (30 min) Kim Stoner

Stoner will highlight foraging and nesting characteristics for key groups of pollinating bees. This presentation will also begin the discussion on which pollinators are the most appropriate representatives for ornamental horticulture studies.

Honey bees are the primary commercialized bees in the US. The colonies are large 10,000 to 40,000 individuals, and queens can survive up to three years, although many beekeepers replace queens more often. Garibali et al, 2013, demonstrated that wild insects pollinated 40 crops more effectively. As rates of visitation increase, yields increased more than twice as much with wild bees as with honey bees. It appeared that wild insects and commercial honey bees increase yield independently, so that honey bees supplemented wild insect pollination rather than replaced it. Supporting this, is research conducted by Adamson (PhD Thesis 2011 Virginia Tech) examining different species of bees pollinating several crops (Figure 7). Each crop had a different complement of bees providing pollinator services.

Figure 7. Diversity of bees pollinating four crops.



From Nancy Adamson, Ph.D. Thesis, 2011, Virginia Tech

Some bees are very specific. For example, the squash bee is a specialist and feeds only on cucurbit pollen. Others like honey bees are generalists. Bumble bees are generalists, but they have distinct differences that set them apart. Bumble bees utilize 'buzz pollination' to vibrate flowers to release pollen that would otherwise not be accessible. The maximum size of a bumble bee colony is generally around 250 bees. The bumble bee queen survives for only one year, and the bumble bee colony is active for only a single growing season. In the spring, mated queens emerge and look for suitable nesting sites. In the early stages of building the colony, the queen takes care of all foraging and nest duties. As the colony grows, workers take over all foraging and further develop the nest in the summer. Towards the end of the summer, the colony cycle ends with the die-off of workers and production of males and new queens. The males and new queens mate, then males die-off, and the newly mated queens hibernate for the winter to re-emerge in spring.

Forty-six species of bumble bees are native in North America. Of these, 15 species are in serious decline in range and abundance. In contrast, *Bombus impatiens*, the common eastern bumble bee, is used as a commercial pollinator and is increasing in abundance, and some other bumble bee species are also increasing in abundance.

Solitary bee species typically have a shorter period of activity than honey bees, bumble bees, or other social bees – six to eight weeks. Overwintered males typically emerge first, followed by females. Both sexes forage and mate. Each mated female makes her own nest, which depending on the species could be in the ground, hollow stems or tunnels in wood. In the nest, there is typically a cell for each offspring, provisioned with a ball of pollen mixed with nectar. An egg is laid on the pollen ball. The eggs hatch, larvae feed on the food source, and develop to the overwintering stage (typically a pre-pupa). At the appropriate time the following year, development is completed, and adults emerge to feed, mate, and start the next generation.

Several examples of solitary bees include carpenter bees, cellophane bees, and mason bees. While there are some commonalities among these bees each has a different preferred nesting area. Carpenter bees burrow into wood, often becoming a structural pest problem. Cellophane bees aggregate their solitary ground nests and are commonly visible in early spring. Mason bees utilize already present tunnels or hollow stems and wall off their cells with mud; mason bees are used commercially for orchard pollination, and the bees are provided with hollow tubes or straws in “mason bee houses” as nesting sites. Leaf-cutter bees are similar but cut leaf disks to seal cells. In addition to these, there are several other common genera of important crop pollinators with unique characteristics: *Andrena*, *Agapostemon*, *Augochlorella*, *Lasioglossum*, and *Halictus*.

Characteristics of honey bees, bumble bees and solitary bees are shown in Table 3.

Compiling the Data for Pollinator and Pests of Ornamental Horticulture Plants (15 min) Kim Stoner & Cristi Palmer

This presentation will cover the first forays into developing and intersecting two lists: pollinator attractiveness index and plant pests. Observations will be provided on what is currently known through public resources and what is missing.

There are many lists and databases of plants attractive to bees (Appendix 1: Lists of Plants Attractive to Pollinators). These resources have useful information. Some contain native plants that are favorable for native pollinators. Others are plant lists compiled to aid beekeepers with providing floral resources for honeybee hives. One of the challenges is that some lists are copies of previous lists and not necessarily an independent assessment. Some lists are national while others are local or regional. There is a distinct need to have a common method of assessment for pollinator attractiveness.

IR-4 has the ability to develop and maintain a database devoted to pollinator attractiveness and has the capability to link with other IR-4 databases such as efficacy research and biopesticide labels.

Table 3. Characteristics of different bees

Characteristic	Honey bee	Bumble Bee	Native Solitary Bees
Colony size	Ten of thousands Colonies reproduce by division or swarming	Up to 250 New colony started each spring	Single
Seasonal activity	Active throughout the winter, emerge for early spring pollination	Winter hibernation, mated queens emerge in spring Colony active until fall	Winter hibernation Active for a short season of 6-8 weeks (time of year depends on species)
Queen longevity	Up to 3 years, although queens may be replaced more often	Single season	Single season
Egg laying	Starting very early in spring, continuing into early fall	Begins after nest establishment in spring. Continues to early fall	After female emergence, mating, and a preliminary period of foraging. Continues until end of female activity
Communication	Scouts relay good sources of nectar and pollen through waggle dance to recruit foragers	Individual foragers learn best sources, do not recruit others	Females do not recruit others
Water	Honey bees must drink water and return to water source		
Foraging habit	Can forage up to several miles to an attractive resource if local resources are limited. Prefer simple flower structure, relatively shallow flowers	Radius depends on BB species and density of resources. Some species can travel up to 1.5 km to a highly attractive source if local sources are lacking. Learn to feed on complicated flowers; buzz pollinators, some species have long tongues and can exploit deep flowers	Highly dependent on species. Some species are specialists on one or two plant genera. Others are generalists or may specialize by flower structure. Foraging radius closely related to size of bee.
Worker role	Adult workers change roles over time, different potential exposures Drones do not forage, they are fed by colony	All bees forage for nectar. Workers (female) forage for both nectar and pollen	All bees forage for nectar. All females forage for pollen

Developing the Database: Pollinator Attractiveness and Management of Pests Resource (30 min) Kim Stoner & Lance Osborne

This session will build upon the previous two presentations to brainstorm and discuss pollinator, plant and pest characteristics needed to develop consistent and comparable data for a pollinator attractiveness index.

Plant attractiveness lists have some discrepancies based on how the ratings were made. In general, assessments were the number of bees at a certain time. This could shift depending upon the time of day when ratings were made because floral relative attractiveness changes throughout the day. While field assessments are realistic, controlled settings are needed to determine relative attractiveness. One goal would be to help growers by developing a method to assess plant attractiveness for their nurseries. However, to benefit the whole industry, there would need to a mechanism to compile grower input into a single resource.

For risk assessments, it will be important to examine method of application and season of application because uptake and degradation varies seasonally based on plant growth, water availability and other factors. This will lead to better understanding of percentage of diet that may contain neonicotinoids.

Pollinator communities are asymmetrical. There are keystone species that are specialists, feeding on one or a small number of plant species. There are also generalists. Bumble bees are close to monarch butterfly status for level of concern with habitat loss.

In a landscape setting, homeowner applications and risk will be different from commercial applicators for nursery or greenhouse settings.

We need to develop national grower survey to determine relative amount of plant materials that are applied with neonicotinoids and are also attractive to bees. This could be conducted by extension researchers with the key large growers in their state. This would be an iterative process where first the volume for the top 10 to 20 crops grown (plant species, cultivar lists as a sub-feature) will be assessed, then the level of pollinator attractiveness to those crops will be determined, and finally the percentage of those that may need pest management with neonicotinoids will be calculated.

One method to determine relative attractiveness is to examine bee visitations on 10 different plants including known unattractive and highly attractive plants as standards. The methodology would include sequentially removing the most attractive and re-evaluating. This could be repeated with blocks of 10 different species keeping the same standards. Then it would be possible to rank the list of plants for relative attractiveness.

At the moment, there is no alternative for imidacloprid to manage rhododendron leaf miner. Other classes have been examined, but nothing has been effective to date.

Neonicotinoid Residues in Pollen and Nectar from Food Crops (45 min) Dave Fischer

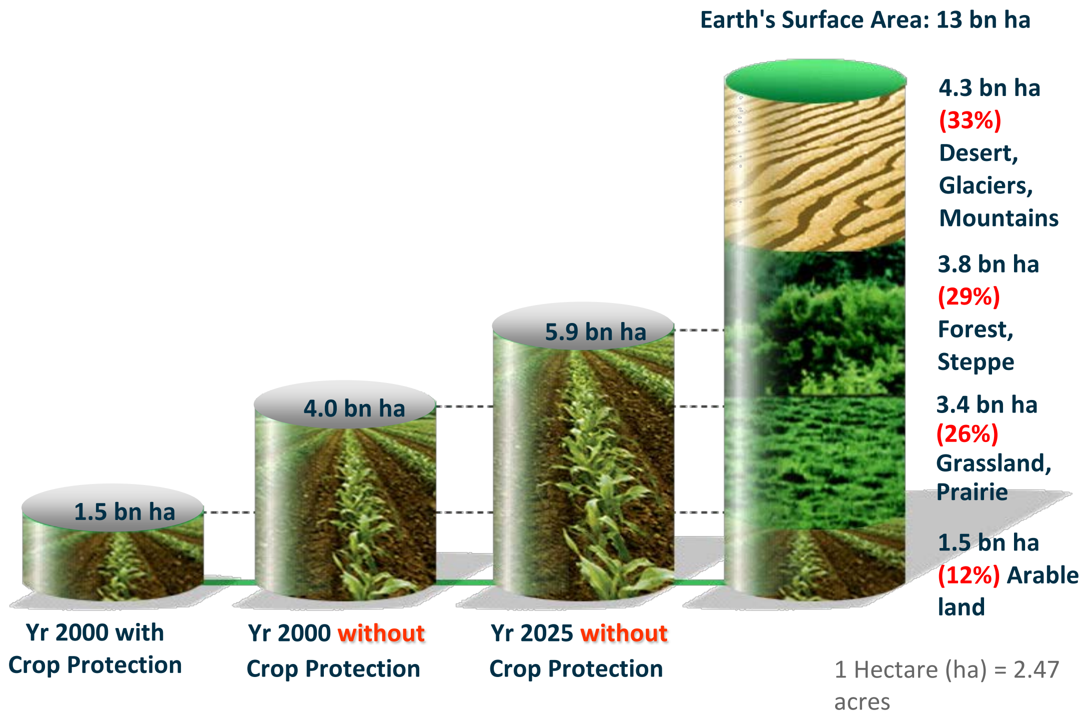
This presentation will highlight the data collected from food crops and discuss learnings that will be applicable for developing residue data for ornamental horticulture.

Approximately 50% of harvested crops would be lost without crop protection tools. Ten percent harvested would be lost through post-harvest issues, 13% through disease, 14% through weeds, and 15% through arthropod pests. Use of intervention tools enables the current level of food production and quality that would not be achieved otherwise. It has been estimated that 1 out of every 3 bites of food is the result of insect pollination. Of the top 100 crops, 70% are insect pollinated, while 90% of all flowering plants rely on insects for pollination. Without insect pollination, there is the potential for 10% yield reduction. (Oerke et al, 1995; Yudelman et al, 1998).

To fully feed the projected population growth over the next 50 to 100 years requires increased food production (Figure 8). Either we must grow more on existing land, or we must increase amount of farmland. To have a better sense of what this means, with the use of crop protection, we have been able to maintain the amount of land farmed even as the population has increased dramatically, because yields per hectare have improved by managing pests, diseases, and weeds. If crop protection interventions are removed, with today's current population almost three times the amount of farm land would be needed for the same quantity. As a society, we would have to decide where that land comes from – grassland, prairie, forest? What part of the environment is less valuable?

Given the population of 8 billion expected by 2025, without crop protection nearly half of the earth's surface would be farmed. This is not feasible. As we make improvements in our ability to grow crops in stressed conditions, we will still not meet the food, feed and fiber demands.

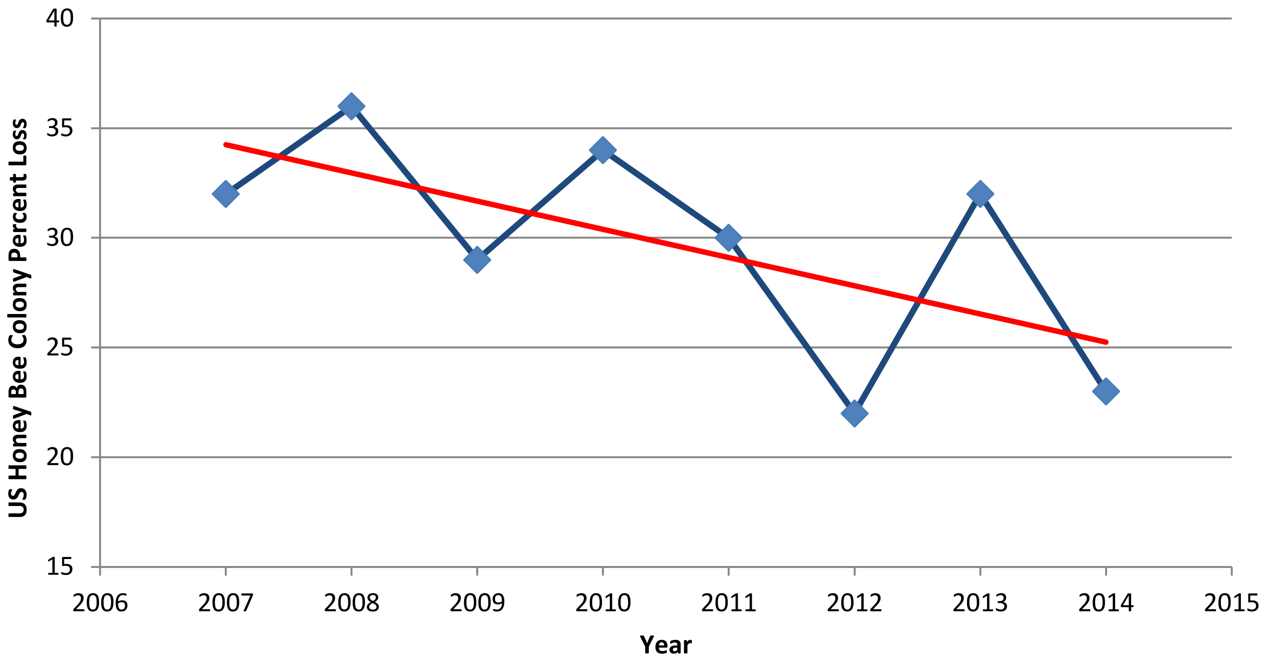
Figure 8. Current and projected arable land needed for agricultural production.



The average American farm feeds twenty times the people it did a hundred years ago. World population reached 3 billion in 1960, 6 billion in 1999, and is currently 7.2 billion. It is expected to reach 9 billion by 2045 and level off at 10 billion in 2060. To keep pace, the amount of food we'll need to produce in the next 20 years is twice the amount of the food we've produced in the past 10,000 years. The only way to meet the challenge of feeding the world is to continually increase crop yields.

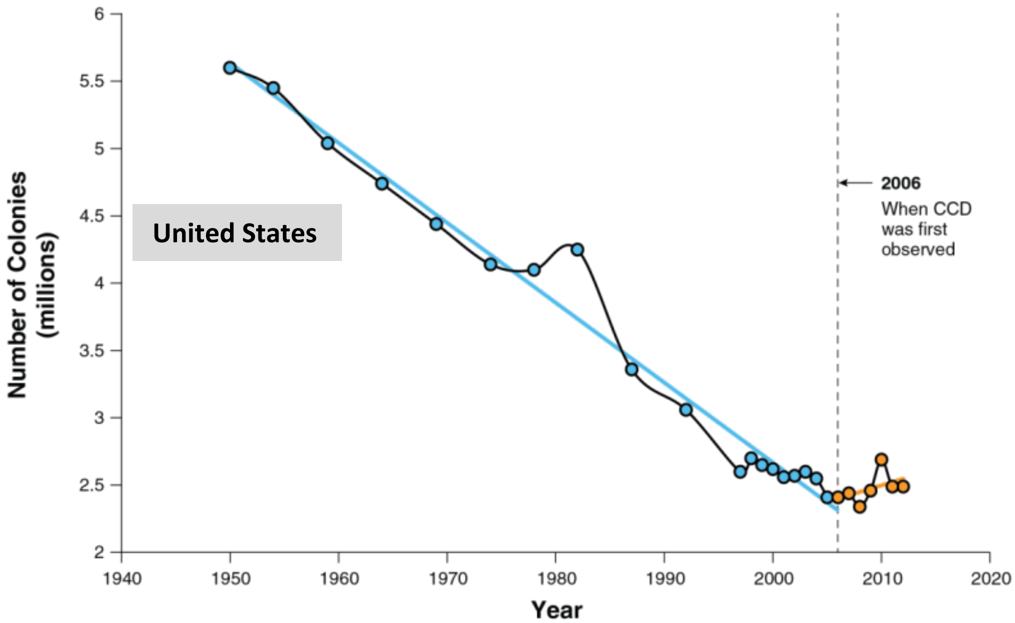
In the face of the challenge to feeding the world, it is also important to ensure that pollinators are maintained at sufficient levels and in good health. Some of the current claims for declining bee health include that neonicotinoids are the primary cause of this decline. However, overwintering losses of honey bee colonies have declined steadily since 2007 (Figure 9). While the total number of managed honey bee colonies have declined since the 1940's in the US, the number of colonies has increased since colony collapse disorder (CCD) was first observed in 2006 (Figure 10). For Canada, the number of colonies has increased since the 1940's with a small decline similar to previous years after 2006 with a sharp increase through 2013. These data are indicative that neonicotinoids are not a primary factor for CCD. Generally, poor honey bee health correlates well with *Varroa* mite and bee diseases, but not with neonicotinoid use. Colony health is less of an issue in Australia where *Varroa* mite is absent and neonicotinoids are used. Neonicotinoids are among the least frequently detected pesticides in US bee hives. Well-managed honey bee colonies pollinating crops treated with neonicotinoids have shown low, annual colony losses, consistent with typical winter losses where hives recover population levels in the spring. No improvement in bee health has occurred in the European Union despite bans. More than 100 bee studies have been conducted studying neonicotinoid impacts. Large-scale field studies confirm safety margins. No studies have shown colony collapse at field rates (Smith et al 2014). Primary negative effects are seen using artificial exposures at high doses in the laboratory. Bee mortality is negatively impacted as the percentage land use in agriculture increases, but this is not associated with any identifiable trend in pesticide use (USDA Managed Pollinator CAP Project 2011). The decline in bees predates by some decades the introduction of neonicotinoid insecticides (Godfray et al 2014).

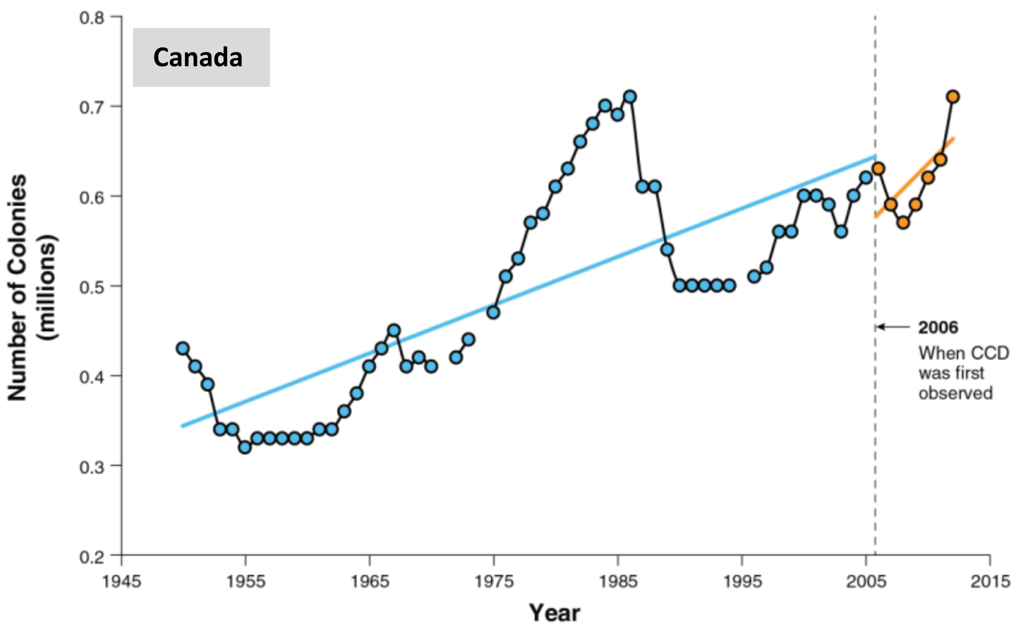
Figure 9. Beekeeper Self-Reported Overwintering Loss (%) of US Honey Bee Colonies



Source: Apiary Inspectors of America & Bee Informed Partnership

Figure 10. Historical Number of Honey Bee Colonies in North America





Designing residue studies in nectar and pollen is important because for systemic products that are not applied as foliar sprays, the main route of bee exposure is via diet. Dietary exposure could also be a route of exposure for foliar applications. The Tier 1 approaches for estimating residue levels in pollen and nectar are designed to overestimate real-world exposure, a conservative approach.

In designing studies, one must begin with the end in mind. What are we going to do with the data? There are two directions one can take: derive a point estimate of exposure to replace the Tier 1 estimate or develop a probability distribution. Timing and method of application and location can impact results dramatically. One hypothesis is that applying drenches when plants are not in bloom could result in less exposure to bees, particularly if application timings are shifted greatly. However, for imidacloprid, this may not be the case. In a study on citrus in California conducted by Byrne et al (2013), imidacloprid was drenched 6 – 7 months or 1 – 2 months prior to bloom. Higher amounts were found in pollen and nectar at the Bakersfield site (Figure 11). There appeared to be no significant difference in pollen and nectar concentration with the different pre-bloom application timings. In additional research, Byrne et al (2013) discovered that confinement of honey bees to treated crops increased exposure by analyzing the concentration of nectar regurgitated from foragers and in hive-deposited nectar (Figure 13). In other words, how the studies are conducted and samples collected will impact the analytical results.

Given high variability inherent in field production systems, residue studies should be designed to determine the probability distribution of potential exposure levels. Pollen and nectar residue levels vary by application method. All other things being equal, seed treatments have less residues than soil drenches than do foliar applications. Systemic uptake and translocation of neonicotinoids varies with plant species, soil type and weather (year to year differences). Measurements of samples collected by hand from flowers may or may not be representative of measurements from bees or from hive comb.

Figure 11. Concentration of imidacloprid and its primary metabolites in citrus pollen and nectar after application 1 – 2 months prior to bloom (Byrne et al 2013)

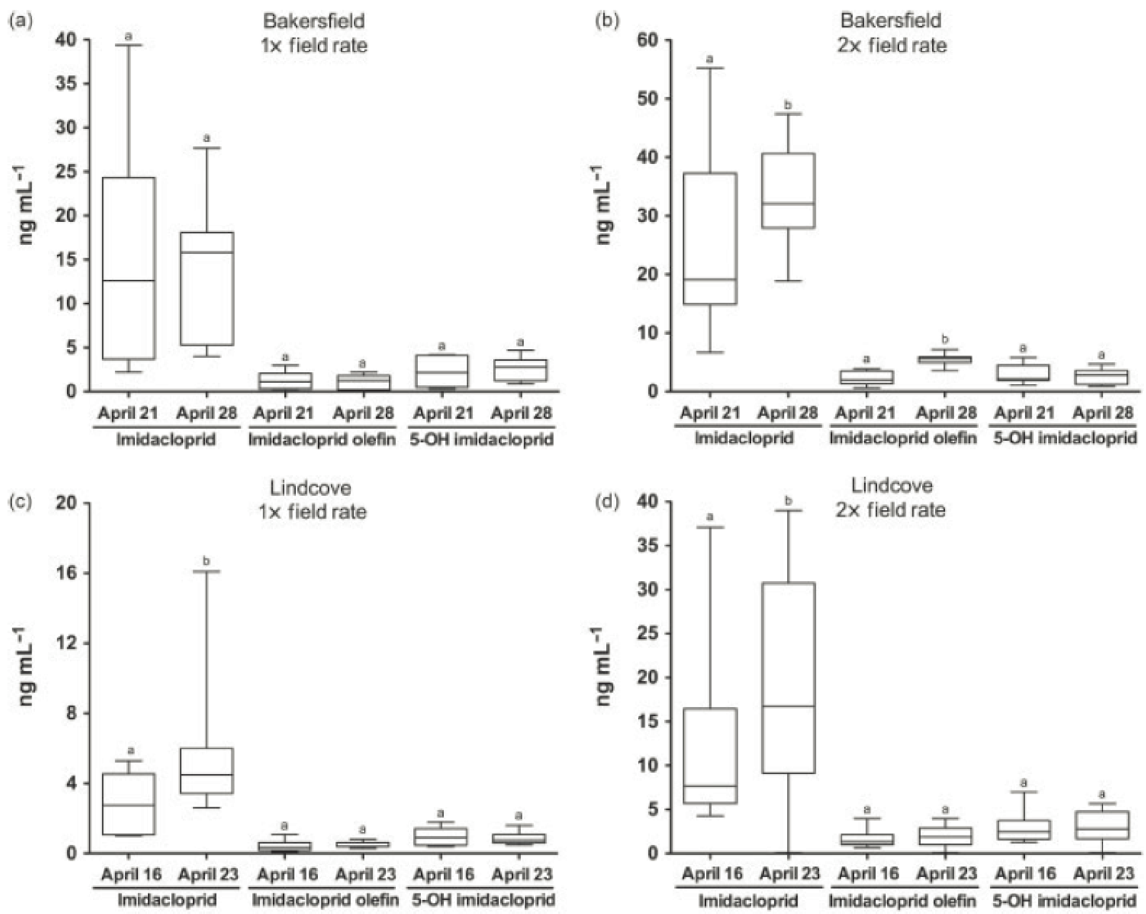


Figure 12. Concentration of imidacloprid and its primary metabolites in citrus pollen and nectar after application 6 – 7 months prior to bloom (Byrne et al 2013)

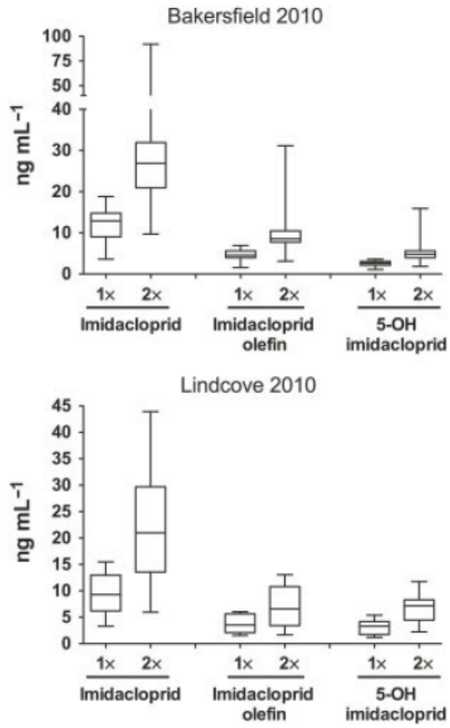
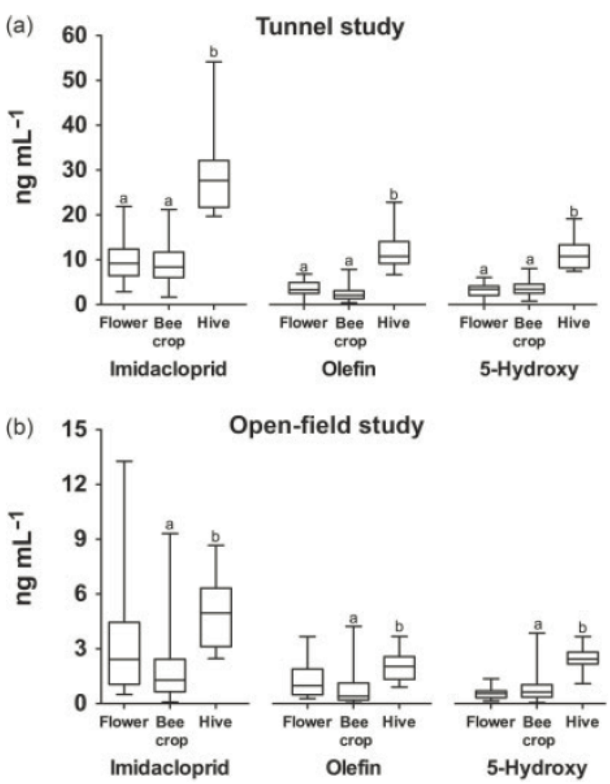


Figure 13. Concentration of imidacloprid and its primary metabolites in regurgitated nectar from honey bees confined in tunnel or free-foraging in open field (Byrne et al 2013)



Designing Pollen and Nectar Decline Studies (30 min) Jay Overmyer

Overmyer will lead the group in discussing elements of pollen and nectar decline studies including suitable representative plant materials, appropriate use patterns, frequency of sampling and longevity of studies, and methodologies for harvesting pollen and nectar.

The concentration of neonicotinoid residues varies depending on plant tissues. Concentrations typically are the highest in leaves, then flowers, pollen, and nectar. The latter two are the most relevant for dietary bee risk assessment. There are several factors that need to be considered in designing studies. Selected plants must be commercially available with flowers that produce both nectar and pollen at sufficient quantities that can be collected. Plants should be bee attractive and typically receive insecticide applications. Some examples include cotoneaster, crabapple and sweet autumn clematis. Whether plants bloom at a single period or have continuous flowers can be a factor along with the time of year for bloom.

There are two general methodologies for collecting pollen and nectar: 1) collect by hand or 2) allow the bees to harvest and collect from the bees. When collecting from bees, pollen can be removed through use of a pollen trap or by collecting bees at the hive entrance and manually removing; nectar can be harvested through forced regurgitation, dissection and removal of the honey stomach or extracting from cells inside the hive. When collecting pollen and nectar by hand, it is prudent to follow previously proven techniques rather than reinventing the wheel; however certain flowers could present unique challenges that might require new methods. Pollen can be extracted with a vibrating toothbrush or vacuum. Nectar can be extracted using a pipette or by collecting flowers and placing them into centrifuge tubes and lightly centrifuging. For outdoor plants, collection should occur in early morning prior to pollinator foraging and before nectar flow ends in the afternoon. For greenhouse plants, pollinator feeding is not typically an issue, but morning is best for nectar flow. Usually, nectar is collected first; then allow flowers to dry to collect pollen. Nectar sugar content is measured with a refractometer to ensure that nectar is being collected and not other plant fluids. To provide sufficient amounts for analysis, 100 ul of nectar is needed, 100 mg pollen, 100 g each for flowers and leaves.

Several factors affect residues in nectar and pollen including timing of applications, water or irrigation, soil type, and plant variety. These factors have differing levels of importance or potential effects on residue levels based on the type of application method. For foliar applications, timings closer to bloom tend to provide higher residues. Irrigation and rainfall can wash off some residues. However, soil type and plant variety do not appear to contribute to variability in residues. For soil applications, timings closer to bloom do not always result in increased residues because of uptake and decline variability. Irrigation and rainfall can influence plant uptake with some water needed for roots to absorb the active ingredient but too much water can move the active ingredient outside the root zone. Soil type does influence uptake with coarser soils having higher uptake but higher propensity for leaching; fine soils or those with high organic matter can retain active ingredients. Plant varieties can take up and metabolize active ingredients differently. The uptake and decline of neonicotinoids is not fully understood for ornamental horticulture plants. The timing of applications should result in peak concentrations at the time of pest pressure which could be prior to, during, or after bloom.

Key areas of research include 1) whether timing of applications can be adjusted to manage pests and minimize residues in pollen and nectar, 2) best management practices to minimize residues in nectar and pollen such as flushing potted plants with water, 3) length of time neonicotinoids remain in the root zone after planting into the landscape, and 4) potential for residues to be present in subsequent blooms (annually or during that season for continuously blooming or re-blooming plants).

Additional considerations for designing studies are collecting triplicate samples from three replicate plots or greenhouses, multiple locations with different soil types, timing of collections from plants with extended flowering times or multiple flower events, and having suitable controls to verify baseline active ingredient levels in various matricesand material for analytical method development.

When reporting data, the distribution of residue concentrations should be reported by using box and whiskers plots, centile values and/or medians rather than means. Values less than the limit of quantification (LOQ) should be included by using ½ the LOQ to appropriately represent values at the low end of the distribution. If possible, results should be discussed within the context of risk.

Research should focus on current pesticide use practices, and, if residues in nectar and pollen have the potential to pose risk to pollinators. Other lines of evidence need to be considered along with potential mitigation options.

Designing Studies to Examine Pesticide Impact on Pollinators (30 min) Dan Potter

Potter will facilitate group discussion studying pesticide impacts on pollinators. Topics may include level of exposure and subtle impacts, interacting factors that may influence impact, and how to identify and measure impacts.

> Future research should be with field-realistic concentrations, relevant exposure and evaluation durations.
>
> --Report on the National Stakeholders Conference on Honey Bee Health, USDA 2012,

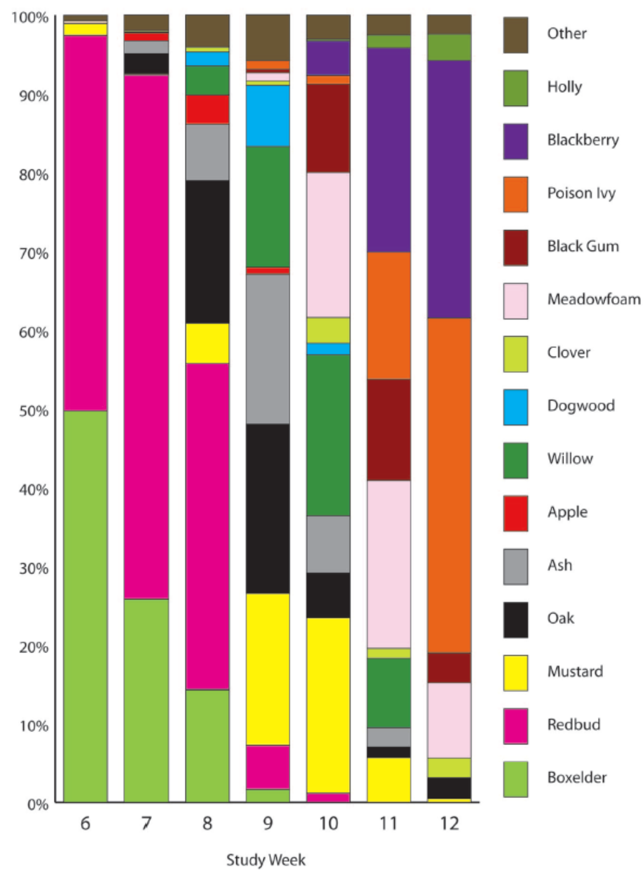
Food crop and turf studies can be applied to the greenhouse and nursery production of ornamental crops. However, very little is known about the extent of pollinator exposure to pesticides in urban landscapes. It is unknown whether bees go to treated plants and whether there are options for mitigation. For example, Deutzia attracts bees but very few pests. Key research questions are 1) which plant are most attractive? 2) do they have key pests where systemic insecticides are the best management tools? 3) if so, what percentage is treated and when? and 4) can hazard be mitigated by treatment timing, pruning or other practices?

Native bees may be the best model for urban landscapes to examine impacts on colony health. One, *Osmia lignaria*, is a solitary generalist bee feeding on many plant species throughout the season. In a study by Kraemer and Favi (Kramer and Favi 2005), *O. lignaria* fed on more than 14 different plant species from March through May in Virgina, primarily tree species (Figure 15). In another study by MacIvor et al (MacIvor et al 2014), *O. lignaria* display facultative specialist behavior by collecting pollen primarily from white clover, oaks, and birches, with 75% being from white clover. Native bees, in contrast to honey bees, have annual colony renewal where overwintering mated queens start colonies in the spring which develop over the summer. Mating occurs in autumn, and the colony cycle begins again. Bumble bees and mason bees have been commercialized to pollinate orchards, enabling the use of small colonies for replication.

Larson et al (2013, 2014) conducted tier 2-type studies examining impact of neonicotinoids on bumble bee populations foraging on white clover in turf. They tested direct versus systemic applications, spray versus granular, and measured foraging activity and bloom avoidance. Colonies were contained in open bottom cages over turf plots with flowering white clover for 6 days (Figure 14). Then the colonies were moved to areas without pesticide treatment. The weight of the colonies was measured weekly (Figure 16), and foraging behavior was observed. Bumble bees did not avoid treated blooms. The weekly mean weight of colonies foraging on imidacloprid treated weedy turf remained low and never recovered with neonicotinoid treatment, but colony weight of bees foraging on the anthranilic diamide treatment was not different from the non-treated controls. In addition, the colonies foraging on the neonicotinoid treated plots failed to produce new queens. Larson et al (2015) conducted supporting assays including analyzing residues in clover nectar and using *Orius insidiosus* as a bio-indicator for residue levels.

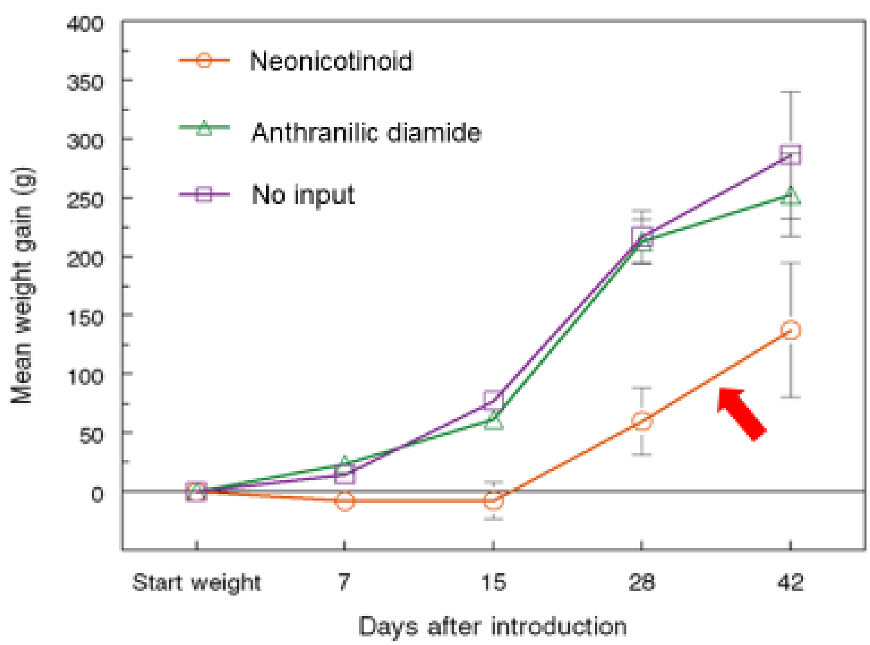
Figure 14. Site design for studying application of neonicotinoids on turf to bumble bees feeding on clover.

Figure 15. Weekly change in pollen species in the nest cell provisions of *O. lignaria* Say from averages from 28 March to 15 May 2003 and 2004.



(Kraamer and Favi 2005)

Figure 16. Weekly mean weight of bumble bee colonies after neonicotinoid application to weedy turf.



(Larson et al 2014)

During summer 2014, Smitley initiated studies into the acute effects of bumble bee exposure to sprayed flowers and systemically-treated flowering crops (Figure 17, Figure 18).

Potter and his lab members Bernadette Mach, Abiya Saeed, and Carl Redmond began sampling 40 woody landscape plants in 2014 for bee visitation. This will continue through 2016 to identify the pollinator assemblages that visit woody ornamentals in the Ohio Valley region. This will be critical in developing BMPs for systemic materials. Fifty bee samples will be taken from 5 distinct sites per plant species and 20 one-minute counts will be made. This includes previously known attractive and non-attractive plant species.

In addition, Potter initiated residue studies on three plant species with two neonicotinoids applied at three timings (November, April, July).

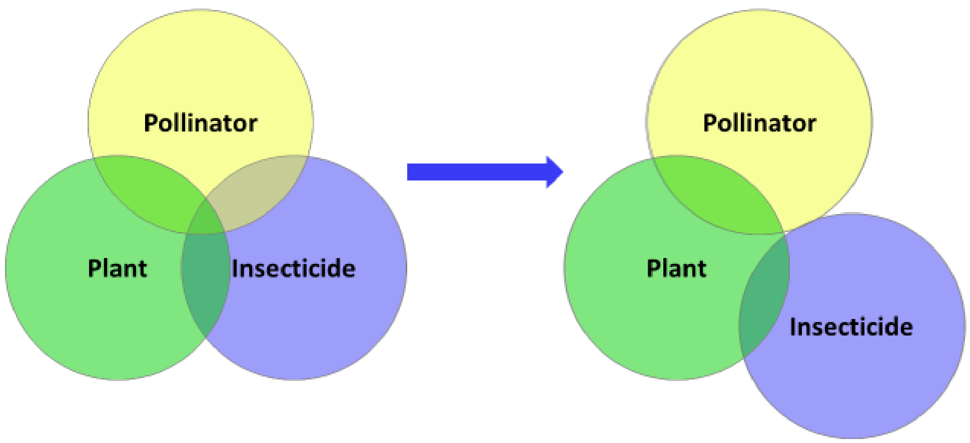
Figure 17. Flowering bedding plant study at MSU.
Photos by D. Smitley, Michigan State University

Figure 18. Counting bumble bees in the cold room.
Photos by C. Palmer, IR-4 Project

Discussion: **Additional Elements for Risk Assessment/Parking Lot** (30 min) Joe Chamberlin
This discussion session will be focused on other elements impacting pollinator risk assessment including density of insecticide treated plants within ornamental horticulture production and landscape, relative pollinator diet, and field realistic visitation rates.

Risk characterization for protecting pollinators involves three interacting primary factors: the insecticide, the plant and the pollinator. The best way to disentangle these factors is to mitigate the insecticide (Figure 19) by understanding the characteristics of each factor and how they interact with each other.

Figure 19. Pollinator risk characterization factors



Historically, acute toxicity of insecticide upon direct spray or ingestion was the measure of impact. Currently, research into behavioral changes after ingestion of non-toxic doses indicates that individual honeybees can be impacted. The different pollinator species have differential sensitivities to insecticides with smaller species affected more than larger species.

Insecticides are needed to manage pest species to produce high quality plants. It is important to better bracket appropriate rates for systemic applications; for some products, the level of systemically-applied active ingredient is much higher than the effective dose. Characteristics that impact the level of residues in nectar and pollen include the application rate, timing and method and the time between treatment and bloom. Uptake is affected by the insecticides' physiochemical properties, soil and plant characteristics, and the environmental conditions. Plant metabolism and vascular structure affects degradation prior to reaching flowers. Determining the concentration in nectar and pollen will rely on appropriate sampling and analytic method validation for different matrices.

The primary plant-pollinator interaction is whether plants are attractive to pollinators and whether blooms produce accessible food sources (nectar, pollen, extra-nectary liquids). While not an absolute, many double flowered blooms are not favorable for pollinators because they cannot reach the stamens. Other plants may not be attractive to certain pollinators because of flower color or shape or because breeding has made modern cultivars sterile.

Of course, all three factors are intertwined. It is not a simple process to disentangle one from the others. Determining pollinator exposure levels will depend on understanding tripartite factors for exposure: likelihood of pollinator attractive plants being treated for pests, timing and length of individual blooms after treatment, and whether treated plants are repeat or continuous bloomers. Questions directly related to exposure are listed in Table 4 along with potential measurements.

The final question discussed is what is a reasonable pollinator protection goal for an urban landscape? The definition of this will directly impact grower practices. Determining whether protecting individual workers or colonies is critical. In other words, is it acceptable for a few workers to be impacted but the larger colony has little impact? The other concepts that play into an overall risk scenario are the benefits of using systemic neonicotinoids for IPM and invasive species and the human and environmental risks associated with older chemical classes.

Table 4. Questions and measurements for pollinator exposure to systemic materials

Question	Measurement
How much residue is in the nectar/pollen?	Analysis of residues in nectar and pollen over time
How likely will pollinators be exposed?	
Plant attractiveness	Surveys of horticulturists, growers, and master gardeners Literature review Research into bee foraging patterns
Likelihood of treatment	Survey growers and entomologists for top produced plants and whether pest management is needed, along with what is used
Abundance of treated plants	Survey growers on quantity of plants produced and/or retailers for which sold plants
Abundance of non-treated bee attractive plants in the landscape	Surveys of landscape materials

Understanding Consumer Preferences and Demand for Ornamental Plants: The Role of Economic, Environmental, and Human Well-Being Benefits Information (45 min) Hayk Khachatryan

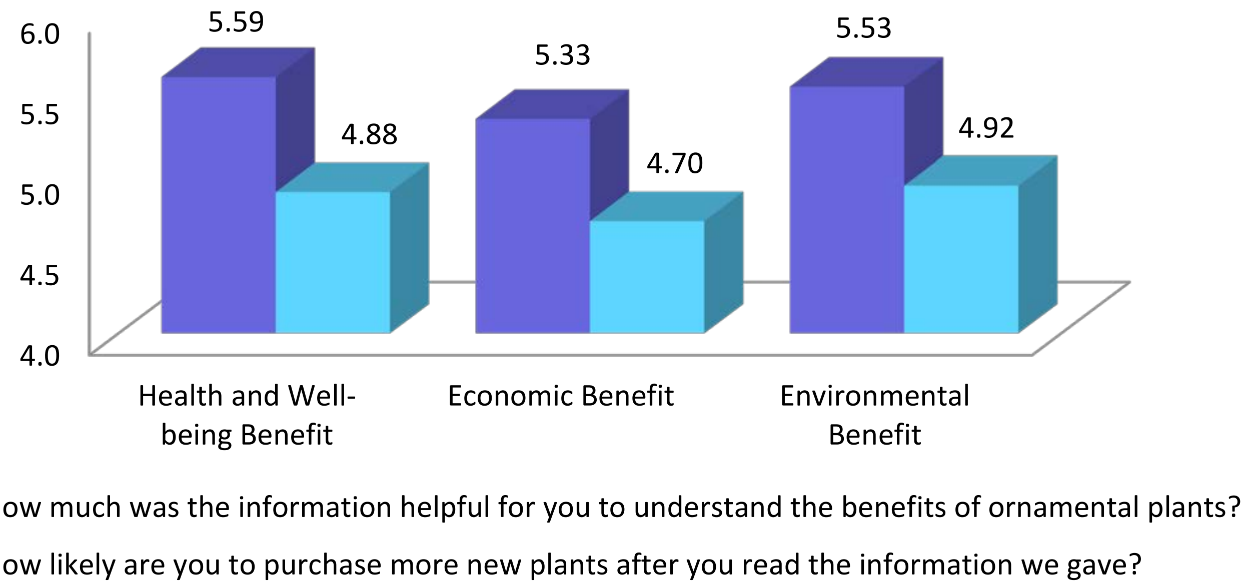
This presentation and discussion session will cover consumer preferences for ornamental horticulture plants and initiate the discussion on how to present benefits.

Major factors affecting the economics of the ornamental horticulture industry include production costs, market demand and competition. Production costs – such as cost of raw materials and labor, investing in technical innovation – drive the base pricing as does the economy of scale. Larger growers can produce higher quantities with a lower cost per unit. Market demand – consumer tastes and preferences, advertising and marketing, consumer income and responsiveness to price changes – influence demand and consequentially profit margins.

Khachatryan studied consumer preference for plant attributes and how they are modified by environmental concerns (EC). The objective was to calculate the premium as defined as willingness to pay (WTP) by egoistic altruistic, and biospheric orientations of the EC scale. Through an online survey, 2,500 people participated in the questionnaire. There were three attributes studied: production methods (conventional, sustainable, energy-saving, water-saving), container types (plastic, compostable, plantable, recyclable), and origin of production (domestic, local, imported); the first level listed within each attribute was considered the base level. Consumers were willing to pay for energy-saving production methods, any non-plastic container, and for locally produced plant materials over domestic. An intriguing result was that consumers were clearly ready to pay less for plants produced internationally.

The next part of this survey included two questions related to the information provided on the health and wellbeing, economic, and environmental benefits of plants. In general, the information provided helped consumers understand the benefits of ornamental horticulture plants and slightly increased the likelihood they would purchase more plants (Figure 20).

Figure 20. Average effects of information on purchase behavior
(1 = very useless/very unlikely; 7 = very useful/very likely)



The next study Khachatryan conducted was determining the influence of future and immediate consequences on consumer willingness to pay for plants. This was set up as a choice experiment for 160 consumers in Texas, Minnesota, and Ontario. Individuals tend to underestimate and/or give less importance to future consequences. For example, people tend to undervalue the positive consequences related to dieting, exercising, saving, and recycling – activities that may have little immediate benefit but have significant future benefits. The same attribute matrix was used as in the study described above. The results when aggregating immediate and future consequences was similar to the previous study with the exceptions that consumers were willing to pay for all production methods other than conventional and that consumers were not willing to pay more for recyclable pots. When the immediate and future consequences were analyzed separately, there were difference. For immediate consequences, consumers were only willing to pay more for water-saving production methods and for compostable pots. For future consequences, consumers were willing to pay more for sustainable and energy-saving production methods, but not water-saving ones; consumers were willing to pay more for compostable and plantable container types; consumers were willing to pay more for local production and wanted to pay less for imported production.

Khachatryan embarked on a study examining consumer perceptions of pollinator-friendly plants. To date, very few studies have been conducted for consumers while many have been for production. However, this research is important because urbanization decrease and fragments pollinator habitat. In, the US, 68 million acres are urban (Cox 2012), and 90 million households have the potential for developing pollinator habitats (Kiesling & Manning 2010). Pollinators live in urban gardens but have distinct plant preferences (Frankie et al 2005, McIntyre & Hostetler 2001). There is a great potential to influence consumer plant selection through in-store marketing to increase pollinator habitat.

The research goals for this study included 1) determine the impact of pollinator-friendly attribute on consumer purchasing decisions and visual attention, 2) identify what factors affect consumer perceptions toward pollinator health, and 3) assess current actions consumers use to improve pollinator health. There were two steps to this research. First, a conjoint analysis and eye tracking was conducted followed by a questionnaire about perceptions, attitudes, actions, and demographic information. In this study, there were five attributes assessed: plant type (petunia, pentas, hibiscus), price ($10.98, $12.98, $14.98), production method (conventional, organic production, certified organic), origin (imported, domestic, in-state *Fresh from Florida*), and pollinator (pollinator-friendly). The first level for each attribute was the base with the exception of pollinator-friendly which had no contrasting level.

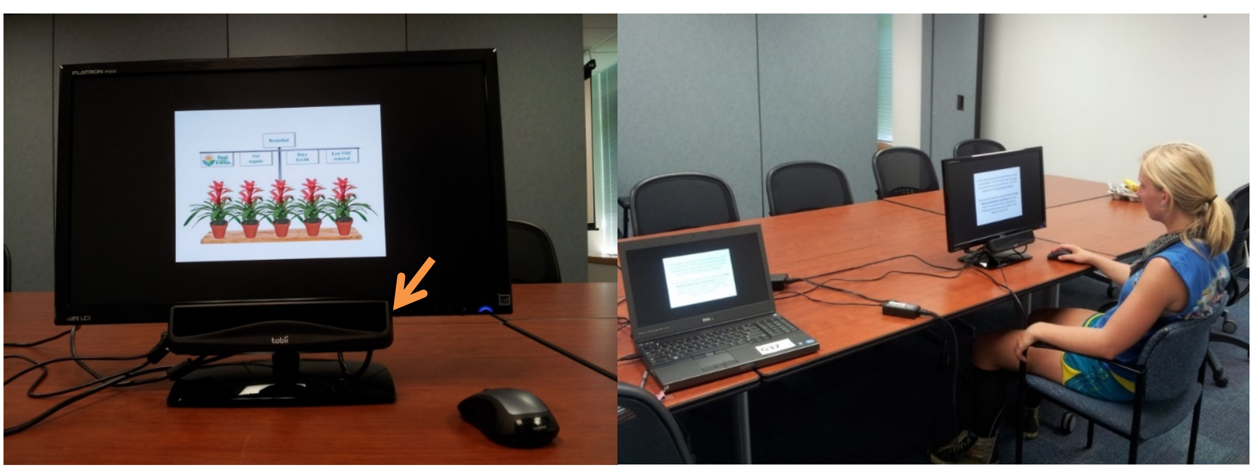
Of the 104 participants in this study, the average age was 53 years, 61% were female, the 2013 average income fell between $51,000 and $60,000, and most households had 1 to 2 people. The education level ranged from some high school through completing a post-graduate degree with 62% completing some college classes through obtaining a college diploma.

The conjoint analysis combined with eye tracking (Figure 21) enabled analysis of not only what choices people made but also how long people spent looking at portions of the screen (Figure 22) with the different attributes. The price and pollinator friendly attributes were looked at most frequently. Eye fixations were positively correlated with preference and purchase likelihood.

Consumers were willing to pay more for pollinator friendly plant, but certified organic, organic production, local and domestic production yield higher WTP value with the local Fresh from Florida yielding more than a $6 premium over international production. Consumer attitudes towards pollinator health were highly influenced by impact on food supply and insecticides, and colony collapse disorder, but less influenced by GMOs, allergies, and neonicotinoids. When assessed, likelihood of a pollinator friendly plant label would alter purchasing, 75% responded with very likely or likely. More than 70% of participants also indicated they used plant selection to improve pollinator habitat.

In general, pollinator-friendly is perceived positively among consumers and increases purchase likelihood with a purchase premium of $1.85. Greater visual attention to pollinator friendly is correlated with increased consumers' purchase likelihood. Consumers are already actively trying to aid pollinators through plant selection, addition of landscape features and low pesticide use. In-store promotions and point of purchase materials are needed to inform and educate consumers, differentiate pollinator friendly plants, and influence plant selection and purchasing decisions.

Figure 21. Conjoint analysis with eye tracking



Tobii 1x Light Eye Tracker

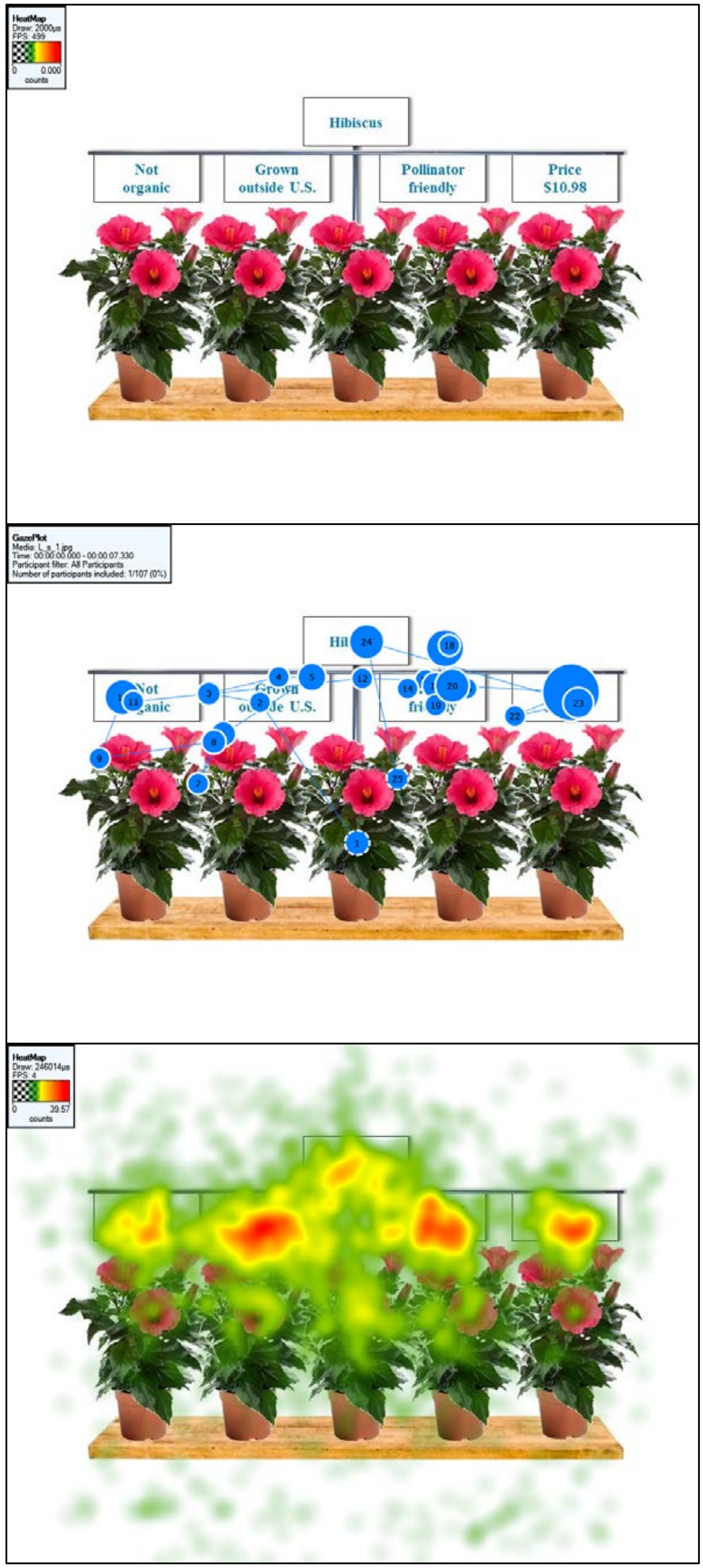
Recordings – Fixation counts (FC)

Figure 22. Images of conjoint analysis, glaze plot, and heat map

A) Original Image

B) Gaze plot of image (n=1)

C) Heat map of image (n=104)



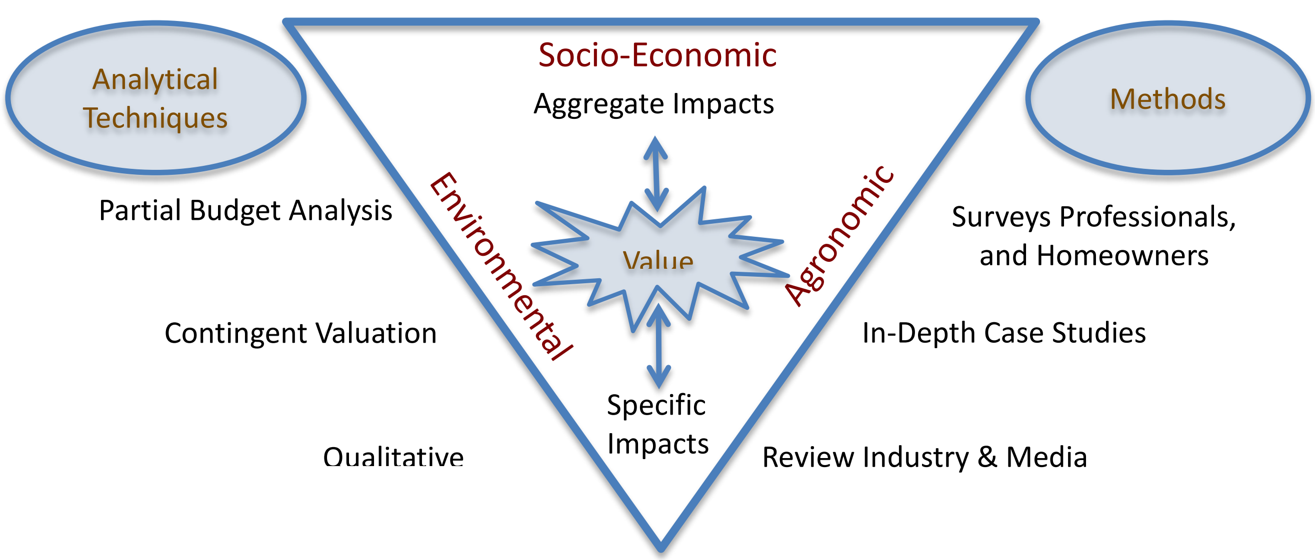
The Value of Neonicotinoids in Turf and Ornamentals (45 min) Pete Nowak

Nowak will present the findings from recent surveys of consumers and professionals within the green industry determining benefits of neonicotinoid applications for ornamental horticulture crops. The results from a national survey of homeowners (n=7,742) will be presented where economic valuation methods were used to assess the dollar value of different attributes of neonicotinoids. In addition, four professional associations (AmericanHort, PLANET, Society of American Florists and the Tree Care Industry Association) cooperated in implementing a web survey (n=750) on the value of neonicotinoids to their members. Finally, three case studies were conducted to gain insights to the use of neonicotinoids to manage pests. These cases examined the southern chinch bug in Florida in St. Augustine grass, a Midwestern city's response to the Emerald Ash Borer, and efforts to manage whitefly infestations in the ornamental industry. A summary of the highlights from these studies will be presented as a precursor to a discussion on the value of neonicotinoids in the turf and ornamental industry (i.e., the Green Industry).

Establishing the value of neonicotinoids will aid public policy. Future actions related to pollinator health and neonicotinoids should be guided by both costs and benefits. To date, media accounts have largely presented costs whether real or perceived, while scientific accounts have provided mixed messages regarding costs. Since the value of neonicotinoids has not been conducted in a robust, scientific manner, a rational discussion on how to optimize public good has been hindered. The best methodology for this type of assessment is a counterfactual analysis which asks about consequences if the item in question, in this case neonicotinoid insecticides, were absent and no longer available. A counterfactual analysis will assess what would happen: would there be lower yield, would prices increase, would the crop product no longer be available? Value is established by identifying, describing, and quantifying impacts, substitutions, and unanticipated consequences. Unintended consequence in this type of analysis can be unexpected. For example, during the corn study, an unintended consequence would be that as a result of lower yields farmers would start planting marginal lands that are currently in the Conservation Reserve Program (CRP), lands that USDA has targeted to increase and improve pollinator habitat. In other words, removal of neonicotinoids for seed-treatment from that marketplace could reduce pollinator populations. A comprehensive effort is required to perform the analyses to disclose value as part of a counterfactual analysis (Figure 23).

All of the completed studies, including "The Value of Neonicotinoids in Turf and Ornamentals", are posted at www.growingmatters.org.

Figure 23. Comprehensive effort to a counterfactual analysis



The turf and ornamental marketplace is diverse. Three surveys were conducted for homeowners, professional landscape applicators, and for production ornamentals.

For the homeowner survey, similar methodology was used as described by Khachatryan for conjoint analysis. The survey included questions to measure attribute preferences and willingness to pay for nine different insecticide attributes used to manage pests in the landscape. Price was included in the bundles of attributes. This allowed for ranking of the attributes. Consumers were surveyed for either 1) flowers & shrubs, 2) lawn, or 3) tree. The attributes included effectiveness of control (very high, high, medium), number of applications required (1 time, 2 to 3 times, 4 or more times), safety to humans, pests and wildlife (excellent, very good, good), safety to bees (high, medium, low), application timing (prevention, curative, both), sold in combination with fertilizer (yes, no), flexibility in application methods (soil, foliar spray, both), speed of control (fast/hours, medium/days, slow/weeks), cost per year. Safety to humans, pets, and wildlife ranked in the top three for each plant-type questionnaire (Table 5). Very high level of effectiveness and the ability to prevent & cure the pest problems ranked highly also. For trees, the second highest attribute was a single application require for efficacy, while, for flowers & shrubs, a medium safety to bees ranked third.

When compared to other insecticides on the marketplace, consumers were willing to pay $105 per year more on average for neonicotinoid insecticides than other insecticides for flowers or shrubs. Similar trends were observed for home lawns and trees with consumers being willing to pay $136 more annually except for chlorantraniliprole and $84 more except for emamectin, respectively. One can think of these as premiums the homeowner is willing to pay for an insecticide's effectiveness, safety to humans, pets and wildlife, and with curative and preventive properties.

Table 5. Top three consumer attributes and their value

Importance	Flowers & Shrubs	Lawn	Trees
First attribute	Prevents & cures insect pest problems DIY = $40 Both DIY and Pro = $69 Pro = $142	Very high level of effectiveness DIY = $54 Both DIY and Pro = $135 Pro = $266	Very high level of effectiveness DIY = $51 Both DIY and Pro = $119 Pro = $195
Second attribute	Very good safety to humans, pets & wildlife DIY = $35 Both DIY and Pro = $85 Pro = $81	Very good safety to humans, pets & wildlife DIY = $51 Both DIY and Pro = $118 Pro = $174	One application required DIY = $43 Both DIY and Pro = $53 Pro = $76
Third attribute	Medium safety to bees DIY = $27 Both DIY and Pro = $35 Pro = $64	Prevents & cures problems DIY = $49 Both DIY and Pro = $116 Pro = $160	Very good safety to humans, pets & wildlife DIY = $42 Both DIY and Pro = $83 Pro = $146
Number of completed surveys	2,698	2,268	2,506

DIY = Do it yourself
Pro = Hire a professional
Both = Survey participant does a little do it yourself and hires a professional

For the surveys of professionals, an online survey was designed to measure current insecticide use changes insecticide use without neonicotinoids, and probably impacts on their business without neonicotinoids. During the three-week period when the survey was available, 750 members of AmericanHort, PLANET, Society of American Florists, and the Tree Care Association completed the survey. Each selected a main area of business; among the surveys, the areas represented were trees (25%), greenhouse (24%), lawn (19%), nursery (15.5%), and landscape ornamentals (15.5%).

While it was thought that insecticide cost might be a major factor for professionals selecting insecticides, this was not as important as other factors. Protecting plant quality and consistent pest control were considered very important (Table 6). Also highly ranked were safety to applicators and customers with time and labor, pollinator safety, and convenience ranked lower.

Table 6. Importance of factors in insecticide selection for professionals

Factor	Not important	Somewhat Important	Important	Very Important	Total of Important + Very Important
Protecting quality of the plant	0.5%	1.6%	20.3%	77.7%	97.9%
Consistent pest control	0.7%	3.4%	22.0%	73.9%	95.9%
Safety to applicator	0.5%	4.3%	21.6%	73.9%	95.4%
Safety to customer	1.8%	4.1%	22.0%	72.8%	94.8%
Time and labor	2.1%	15.3%	50.2%	32.4%	82.6%
Pollinator safety	6.6%	18.1%	36.1%	39.2%	75.3%
Convenience	3.0%	25.5%	47.6%	23.9%	71.5%
Insecticide cost	6.4%	42.7%	37.7%	13.2%	50.9%

When queried on acceptable alternatives to neonicotinoids, 14% said there were no acceptable alternatives, 59% said there were not enough acceptable alternatives, and 27% said there were enough or more than enough acceptable alternatives. These percentages varied by industry with lawn care more likely to see no alternatives while greenhouse is more likely to see alternatives.

Across the board, all sectors indicated the loss of neonicotinoids would reduce income (about half of participants), with a large number of greenhouse and landscape professional indicating the loss would not impact income. Some of the operations, though, did indicate the loss of neonicotinoids would increase income possibly due to new market niches.

The anticipated business impacts if neonicotinoids were no longer available included 1) increased labor costs for training, applications, and record maintenance and 2) more frequent applications of alternatives (Table 7). Customer satisfaction would remain the same or decline because of the perception that alternatives are not as efficacious or have the same longevity of control. The ability to manage pest resistance would decrease with the loss of this class of chemistry, and the ability to practice IPM would diminish because many of the alternatives are more problematic for beneficial insects.

In addition to the above described surveys, three case studies were examined. The first case study presented examined the use of neonicotinoids to manage whiteflies in greenhouses. This chemical class is critical for managing the silverleaf whitefly (*Bemisia tabaci*) B and Q biotypes. With the potential for severe population pressure, it is imperative to have multiple tools to manage resistance development. Neonicotinoids are major tools to prevent the spread of invasive and quarantine pests. The systemic nature of neonicotinoids is very beneficial in that it reduces exterior residues on foliage and flowers enabling use of beneficial insects. Specific impacts for neonicotinoid loss in greenhouse and nursery production include loss of plant material; increased use of older insecticides and the accompanying concern about worker exposure; faster development of pest resistance; inability to control Q biotype whitefly leading to spread to other crops; disruption of plant trade with foreign markets rejecting US grown plants; and higher production costs.

Table 7. Anticipated business impacts for turf & ornamental professionals

Business Factor	Large Decrease	Decrease	Stay the Same	Increase	Large Increase	Don't Know
Labor (records, training, applications)	0.3%	0.5%	28.2%	41.4%	25.5%	4.1%
More frequent applications of alternatives	0.3%	1.9%	15.6%	39.1%	38.5%	4.6%
Customer satisfaction with product or services	9.9%	36.6%	31.7%	6.3%	3.6%	11.8%
Ability to manage pest resistance	9.5%	34.4%	29.3%	9.5%	4.5%	12.8%
Ability to practice IPM	5.8%	26.3%	39.5%	13.4%	7.9%	7.1%

The second case study examined was the use of neonicotinoids to manage emerald ash borer (EAB), an invasive beetle species decimating urban, suburban, and rural forests. While rural forests have few options at the moment, urban and suburban communities have three options: 1) remove live trees now, 2) remove dead trees, or 3) treat to control EAB. The community of Naperville, IL, a suburb of Chicago, faced these choices. Through community meetings where the choices were clearly presented and discussed openly, the residents chose to treat to control EAB knowing that the cost to remove trees was about $1,500 per tree and that replacing those trees would present additional monetary, aesthetic, and environmental costs. Without neonicotinoids, the removable option would have been followed in Naperville because the alternatives tended to be more expensive and might have require certified applicators. Involving citizen groups in learning about the options was critical to the final decisions by elected leaders. The citizens have maintained property values and the environmental amenities associated with an urban forest. See the video at this link (http://growingmatters.org/studies/eab/video-neonics-saving-ash-trees/) for residents' perspectives in their own words.

The final case study involved managing chinch bugs on turf. Chinch bugs destroy St. Augustinegrass in Florida and the southern US. Over time populations have developed resistance to other insecticides leaving neonicotinoids one of the only remaining options. Because FL lawn care companies guarantee customer lawns as part of the contractual agreements, many would not be able to absorb the cost of replacing dead turf with live sod. In addition, there are safety concerns for both customers and applicators with the probably return to previous chemical classes with less favorable human and mammal safety profiles.

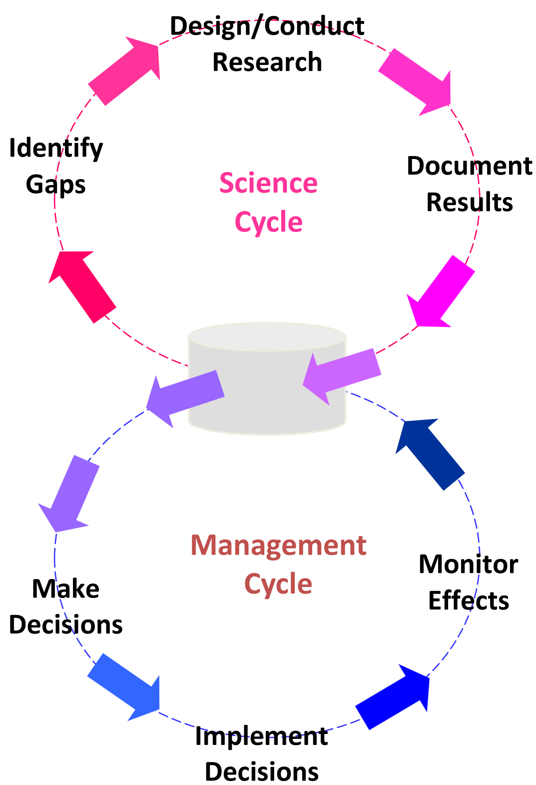
To summarize the findings of this series of studies, the green industry is an important part of our economy, and professionals, homeowners, and local citizens have clearly indicated the vital value of neonicotinoids to this industry. The green industry is a service industry and is dependent on customer satisfaction. Contributing to this relation is one of the highest values of neonicotinoids. Neonicotinoids have multi-dimensional value for ornamental horticulture plant production and maintenance.

AmericanHort/SAF Stewardship Initiative: Five Identified Research Areas (45 min) Joe Bischoff and Lin Schmale

Bischoff and Schmale will describe the five research areas identified by a grower empaneled stewardship taskforce. These areas include: 1) flower characteristics for forage production and access; 2) bee attractiveness; 3) pollinator exposure to pesticides from pollen and nectar; 4) alternative practices development; and 5) native pollinator health survey.

Science advises public policy, but it is not the only voice. The law, public need, and traditional or experiential knowledge also inform public policy. Sometimes those other voices are louder or more immediate. The ideal science and management cycles are shown in Figure 24. The science cycle starts with identifying gaps followed by conducting research and documenting and presenting results. The management cycle, theoretically, is to make decisions based on that new knowledge, implement those decisions, and monitor the effects. In reality, decision makers have many, many voices providing information for what are the "best" decisions, not just the scientific community.

Figure 24. Science and management cycles for developing knowledge and making decisions



There are many challenges to bee health above and beyond pesticides. Some include nutrition, genetic weakness, weather patterns, beekeeping practices, diseases and parasites. Many of these are more closely linked to bee health than the use of neonicotinoids in agriculture and the green industry. Neonicotinoids have value to the green industry in many ways. One of the most impactful is management of invasive species whether to prevent establishment or to prevent additional movement beyond a quarantine zone. For example the Japanese beetle harmonization plan contains the use of neonicotinoids prior to shipment to states outside the current established zone. State nursery licensing expectations include the treatment of plants found with injurious insects. Approximately 1.5 billion cuttings are shipped into the US each year from off shore production facilities in south and central America, Africa and the middle east. All shipments are inspected, and if any pest is found a mandatory destruction or fumigated is ordered.

A pollinator stewardship initiative task force was developed with nine breeder, grower and retail members, with two scientific advisors, a manager and participants from AmericanHort and SAF. The initial focus of this group was to develop a research agenda with five key areas. The first is studying flower morphology, pollen, and nectar production. The second is assessing bee attractiveness. The third is concentrations of neonicotinoids in pollen and nectar following application of field rates. The fourth area develops alternative practices where caution is warranted. The final area is native pollinator forensics as defined by studying the native pollinators in urban environments and their foraging habits.

The next area of focus for this task force is to develop a stewardship program. While not final, elements of this program will include developing expanded foraging sites for pollinators, integrated pest management strategies, and best management practices for pollinator attractive plants.

Discussion (75 min)

This final discussion session will cover topics raised throughout the meeting and placed into the parking lot or those topics which need more time. Additional topics can include:

- *Communicating science and the outcomes of residue data analysis to diverse audiences (growers, retailers, consumers, media, NGOs, scientists, etc.)*
- *Perceived versus actual risk*
- *Additional consumer or professional perception studies*
- *Developing consensus on grower recommendations*
- *Additional stewardship and mitigation initiatives (Best Management Practices)*
- *Funding avenues for proposed research activities*

Marketing opportunity for bee friendly program for production and landscape management.
The impact of international rules or regulations for neonicotinoids may very well determine decisions growers will make because of international markets. Local regulations for applications in public spaces such as parks and schools may also impact grower decisions.

A key question is residue levels in plants at the time of sale. The detectable level may or may not pose risk to pollinators depending upon results of other not-yet-conducted studies. If there are detectable amounts found, what would Home Depot or other retailers do right now?

State management plans for neonicotinoid use may be developed in lieu of federal label restrictions. State Departments of Agriculture, bee organizations, and grower organizations are communicating about this issue. In many states, there are rules for notifying hive managers prior to any sprays for food production scenarios. Currently, these have not been applied typically to ornamental horticulture growers because managed hives do not play a role in production.

It is important to study how previous crises were handled. For example, Alar applications for apple production and tainted apple sauce. Much misinformation was communicated to the general public about Alar. The resulting public pressure ended the use of this product. During the 1990's, Benlate had been contaminated with an herbicide during formulation of a limited number of batches, possibly just one. While a small amount had been contaminated, Dupont paid out millions in claims, some with very little connection to herbicide damage, and pulled the label from ornamental horticulture use sites.

Once residue analysis studies are complete, communication about these results and actual risks will need to be handled thoughtfully with consideration to the various audiences for this information including EPA, state regulatory bodies, the scientific community, the grower community, consumers and other interested parties. How these scientific results are communicated to regulatory officials is very different from how they would be presented to the general public. Smitley provided a short additional presentation on how he is currently presenting his early results to growers. His first study as mentioned previously during Dan Potter's presentation utilized bumble bees caged with surrogate plants species for hanging baskets. He also assessed floral dislodgable residues. In Dave's extension talks, he highlights this study and provides recommendations such as no foliar applications for 2 – 3 weeks prior to shipment and no drenches after 5 weeks before shipment. In addition to extension talks, Dave's group has created technical information sheets so that growers can show they are informed about this issue to buyers and retailers.

Risk assessments should be based on studies as close to realistic situations as possible. Spiked sugar experiments under laboratory conditions will not be fully predictive of what pollinators encounter for ornamental horticulture production or landscape maintenance. For ornamental horticulture production, while complicated given polycultural crop production, it is far less challenging than examining risk in landscapes where the forage area may have patches with non-treated plants or plants treated at different times for different pests, areas with excellent floral resources or food deserts. It is virtually impossible to fully map out treatments for private lands with multiple owners.

Crop labelling for neonicotinoid treatments. There may be added value in that the current direction does provide information about why the insecticides were used: protection against aphids, thrips, and whiteflies. However, there is a cost for labor and the label itself. Over time, this could either be a stigma or something people see and not pay much attention to like the little flags put into commercial landscapes after treatment.

Residue safety results needs to be made public.

Concerns were raised about funding for the needed research. Quite a bit of funding is needed to conduct nectar and pollen residue studies as well as the tier 3 field level studies. Public funding will lend the studies a different perspective of validity versus privately funded studies, even though the privately funded studies may be conducted under GLP. Under GLP, auditors can reconstruct the study based on the detailed records collected before, during and after the research was conducted.

There is a need to develop common protocols: caged honey bee studies, free range bee studies, impact of treatments during production when plants are placed with untreated plants?

Recommended Future Directions

Outcomes from this workshop include a clearer understanding of the risk assessment process and the types of studies needed to determine risk for honeybees, the primary commercial pollinator in the US. While the green industry does not use commercial pollinator services like fruit, nut and vegetable growers, the honeybee is the model pollinator for regulatory studies. Second, even though systemic insecticides represent a hazard when applied incorrectly, actual exposure levels after crops leave the greenhouse and nursery are largely unknown because pollinators are not attracted equally to the thousands of different crops the green industry produces. For example, some marigolds and salvias are very attractive to pollinators and provide a good source of pollen and/or nectar while double flowered roses are not typically visited because the petals prevent pollinators from accessing stamens and nectaries. The percentage of bee-attractive crops is needed to get a better idea of the actual exposure levels. Another learning of this workshop is that while making science-based decisions is important how the scientific results are communicated is even more important.

Future research activities include:

1) Develop common pollen and residue protocols (1 - common production practices with surveys for pollen and nectar over time; 2 - single foliar or drench application and follow residues over time);
2) Implement field residue studies to examine decline of residues in pollen and nectar;
3) Survey several key growers in each state for top 10 to 15 crop species grown (possibly down to cultivar) for sales volume (units not $) and for relative attractiveness for pollinators in their operations;
4) Develop database to catalog pollinator attractiveness levels which also includes likelihood of pest and pathogen mitigation actions;
5) Study consumer buying preferences related to bee-friendly practices and outreach impacts from point of purchase education materials;
6) Develop outreach materials based on study results being cognizant of different learning strategies and scientific literacy.

Workshop Sponsors *(in alphabetical order)*: BASF, Bayer, Syngenta, Valent

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Appendix 1: Lists of Plants Attractive to Pollinators

Compiled by Kimberly Stoner, December 15, 2014

Most of the resources below focus on native plants and native bees and are grouped roughly geographically. Attractiveness is generally not quantified being based on observations. However, these resources do provide guidance on pollinator attractiveness. This list is not exhaustive and other resources have been identified since the initial compiling. Exclusion of other resources is <u>not</u> a statement of their quality or value.

North East/ Eastern US

Tuell, J. K., Fiedler, A. K., Landis, D., & Isaacs, R. (2008). Visitation by wild and managed bees (Hymenoptera : Apoidea) to eastern US native plants for use in conservation programs. Environmental Entomology, 37(3), 707-718.

New England NRCS Pollinator Biology and Habitat Technical Note: ftp://ftp-fc.sc.egov.usda.gov/NH/WWW/Technical/New_England_NRCS_Pollinator_Tech_Note_FINAL.pdf

http://dda.delaware.gov/plantind/forms/publications/Delaware%20Native%20Plants%20for%20Native%20Bees.pdf (Ongoing research: Deborah Delaney and her students are comparing wild types and cultivars of Coreopsis, Phlox, and Monarda for bee attractiveness)Connecticut: Alternative floral resources on vegetable farms: Planting Flowers for Bees in CT: http://www.ct.gov/caes/lib/caes/documents/publications/fact_sheets/entomology/planting_flowers_for_bees_in_connecticut.pdf

University of Maine – Bee Friendly Landscapes: http://umaine.edu/gardening/master-gardeners/manual/ecology/how-to-create-a-bee-friendly-landscape/ Ongoing research: Alison Dibble, Lois Stack, and Frank Drummond – evaluating perennial plants for bees in 4 locations across Maine for 5 years. Nearing publication)

New Book: Garden Plants for Honey Bees by Peter Lindtner. 2014. Wicwas Press. Ratings as pollen source and nectar source for honey bees. Occasional notes about visitation by bumble bees. Observations from southeastern PA and Delaware.

Southern US

Herb Garden, NC: http://www.lincolnlandbeekeepers.com/uploads/1/0/6/4/10649295/herb_plants_for_bees1.05.pdf

Georgia: Beyond Butterflies: Gardening for Native Pollinators. http://extension.uga.edu/publications/detail.cfm?number=B1349

Kentucky (ESA Poster) http://organiccucurbit.plp.iastate.edu/docs/Assessing%20the%20attractiveness%20of%20the%20Entomological%20Society%20of%20America.pdf

Midwest

Midwest Native Plants Database: http://www.illinoiswildflowers.info/flower_insects. Based on Robertson's observations in Illinois for over 30 years (with some more recent Midwestern additions). Covers syrphid flies, butterflies, skippers, moths, beetles as well as bees. All plants and insects identified to species.

Book: Holm, Heather.2014. Pollinators of Native Plants. Pollination Press, Minnesota. Focus on native herbaceous plants of Upper Midwest. Covers a broad range of native pollinators. Tables in the back have about 60 plant species and 18 genera of native bees, 30 plant species and 15 species

of wasps. Pages on each plant include butterflies (including larval host plants), some moths, larger predatory wasps, syrphid flies, some beetles. Listed by plant habitat. Notes plants attractive to honey bees. Based on literature and database search, personal observations. Huge number of photographs of insects on flowers

Western

Frankie, G. W., Thorp, R. W., Schindler, M., Hernandez, J., Ertter, B., & Rizzardi, M. (2005). Ecological patterns of bees and their host ornamental flowers in two northern California cities. *Journal of the Kansas Entomological Society*, 227-246.

Cranshaw, Whitney. 2013. http://bspm.agsci.colostate.edu/files/2013/03/Ranking-of-Flowering-Plants-for-Use-by-Honey-Bees.pdf

Gardening for Native Bees in Utah and Beyond (information on attractiveness of many garden plants to bees) http://www.ars.usda.gov/SP2UserFiles/Place/20800500/Gardening.pdf

Best Bee Plants for California http://www.helpabee.org/best-bee-plants-for-california.html

New Book: Frankie, G., R. Thorp, R. Coville, B. Etter. 2014. California Bees & Blooms. Heyday Books

National/North American

Russo, L., DeBarros, N., Yang, S., Shea, K., & Mortensen, D. (2013). Supporting crop pollinators with floral resources: network-based phenological matching. *Ecology and evolution*, *3*(9), 3125-3140.

Database: Collection records: Discover Life. http://www.discoverlife.org/. Search on plant species name, scroll down and click on “Associates.” Bee records will be listed from recent databases. (From bee names, you can get plant listings from older references such as Mitchell 1962, Bees of the Eastern United States; Millrion 1971, A monograph of the Western Hemisphere bumble bees; etc.)

Database: Eco-Regional Planting Guides: http://www.pollinator.org/guides.htm. 32 Planting Lists of native plants for different Ecoregions across North America with native plants – Trees & shrubs, Perennials, Vines. Covers butterflies in some depth, other pollinators very general – bees, beetles, flies

Improving Forage for Native Bee Pollinators – AgroForestry Notes. Focuses on trees, shrubs http://plants.usda.gov/pollinators/Improving_Forage_for_Native_Bee_Crop_Pollinators.pdf

Book: Attracting Native Pollinators. Mader, E. et al. 2011. Storey Publishing. Lots of biological information about native pollinators. Plant list in the back, with native wildflowers, native trees and shrubs and garden flowers.

Old Book: Honey Plants of North America by John H. Lovell. 1926. Originally published by A.I. Root Company, reprinted by Wicwas Press. Most of the book is a listing by plant of the value of the plant for beekeepers (including quality of honey). Has chapters on flowers of little value to bees (but pollinated by flies, moths, birds, etc.).

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British Columbia: http://www.sfu.ca/biology/faculty/elle/Bee_info.html

International (Europe)

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