BEST MANAGEMENT PRACTICES (BMPS) TO PROTECT HONEY BEES AND OTHER POLLINATORS IN SOYBEAN FIELDS

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INTRODUCTION

Soybeans are the world's top-produced oilseed crop, grown on about 84 million acres across the eastern two thirds of the USA in 2015 and 2016 (ref. 51-52). With such a large quantity of farmed land, soybean farmers have great potential to impact pollinating insects. Although insect pollinators like honey bees and wild bees are not necessary for soybean pollination, these insects commonly visit soybeans for nectar and pollen (ref. 1-5), and there is evidence that bees contribute to as much as 18 percent increased soybean yields when present (ref. 6-9).

At the same time, there is continued concern over the health of honey bees and other pollinators in agricultural environments. Arthropod pests/parasites, diseases, poor nutrition, and pesticides all may negatively affect bee health. Additionally, honey bees are managed in a variety of agricultural settings, ranging from orchards to fields, where they provide pollination services (e.g., for almonds and myriad blooming specialty crops) to areas where honey bees may be surrounded by commodity crops (e.g., soybean) that do not require pollination but are still attractive to pollinators. This allows for a broad window of possible pesticide exposure for honey bees, depending on the local climate, cropping system, season-long pest management strategy, chemicals used, application methods, and time of year. Therefore, each crop presents different challenges in terms of preventing undue stress on pollinators.

Soybean production is no exception, and different farming operations have different potentials for impacting pollinators. Herbicides, fungicides, nematicides, and insecticides are used on soybeans to protect against a wide variety of pests including weeds, diseases, nematodes, and insects in order to deliver a marketable and profitable crop. Direct sprays to soybeans and off-target drift of certain pesticides, including contaminated seed lubricants like talc or graphite, can be detrimental to honey bees and other pollinators (ref. 10). Because soybean flowers can attract bee pollinators, and soybeans make up a substantial amount of the agricultural landscape of the United States, it is vital to develop a set of best management practices (BMPs) that help conserve pollinator health while complying with profitable soybean production. In addition, to reach a balance between sustainable soybean production and pollinator health, education and cooperation among farmers, beekeepers, pesticide applicators, and crop consultants is needed to mitigate potential harm to pollinators in the production of soybeans in the United States. Currently, the most powerful practices to achieve protection of pollinators are 1) strong two-way communication between beekeepers and farmers, 2) increased grower awareness of production impacts on pollinators, and 3) adherence to pesticide label instructions.

This document presents BMPs for conserving and promoting the health of pollinators, particularly managed honey bees, in conjunction with soybean production. The recommendations attempt to identify potentially negative impacts of soybean agricultural practices on bees at each stage of soybean production and suggest steps to mitigate these impacts. These practices should be treated as recommendations that complement pesticide label instructions. The label is the law, and it is a violation to apply pesticides contrary to label instructions and warnings. However, voluntary adoption of BMPs may mitigate harmful effects to managed honey bees. Not all recommendations may be possible in all farming operations, but their adoption could be viewed as a roadmap for those interested in voluntarily improving pollinator health. Many of these recommendations involve strategies that have other benefits (e.g., reduced tillage, and conservation of natural enemies), so the potential improvements for pollinators may 'tip the scale' for some producers in deciding to implement these practices.

Document goals

The authors intend to:

- Demonstrate the importance of honey bees and explain both their biology and how they interact with soybean agriculture;
- Encourage soybean farmers to consider the impacts of farming practices on bees;
- Illustrate BMPs for soybean production that can be used by producers, crop advisors/consultants, and pesticide applicators to mitigate potential risk from agricultural practices;
- Inform outreach and education efforts to promote the adoption and implementation of BMPs;
- Improve communication, cooperation, and understanding between beekeepers and soybean producers.

HONEY BEES AND OTHER IMPORTANT POLLINATORS

The importance and decline of pollinators

Pollinators impact about one third of the human diet by volume (ref. 53), and bees contribute $18 billion in food and crop production in the United States each year; other pollinators' estimated contribution is around $3.5 billion (ref. 11). However, in the last decade, honey bee health has substantially declined. Agricultural use of pesticides is implicated as one of four principal factors leading to this decline, along with poor bee nutrition, high levels of parasites, and increased exposure to diseases (ref. 12, 13). These factors can be interactive and cumulative; for example, poor nutrition can make bees more susceptible to the effects of pesticides (ref. 14).

Increased overwinter losses for managed honey bee hives demonstrate the substantial declines in honey bee health. From 2007 to 2016, winter losses have ranged from approximately 23 to 36 percent (ref. 15). Prior to 2006, historical overwintering colony loss rates averaged 15 percent (ref.16). With this decrease in survival, and greater inputs necessary for successful beekeeping, the costs associated with pollination services also have increased (ref. 17, 18). There is no single cause for these losses – instead, losses appear to be driven by multiple interacting stressors: pests, pesticides, and lack of proper nutritional resources (ref. 19).

Bee pollinators: Who they are, where they live, and what they do

There are two main categories of bees that are likely present in soybean fields: the European honey bee (Apis mellifera), presumably managed by a nearby beekeeper, and a wide variety of wild bee species living in fields, field edges, or nearby natural areas, such as bumble bees, pumpkin bees, sweat bees, etc. All bees feed almost exclusively on flowers, collecting nectar as a sugar source and pollen as a source of protein and other nutrients (ref. 20), and there is substantial variation in the attractiveness and nutrition provided by different flowers. Flies, butterflies, and other insects also pollinate many plants. While their descriptions are beyond the scope of this document, many of the details and recommendations that could improve honey bee health would also apply to these other insect pollinators. Furthermore, there is evidence that pollinating insects are responsible for improved soybean yields, at least in some growing conditions (ref. 6-9).

Honey bees: European honey bees were introduced to the United States by European settlers for production of honey and wax, and later for crop pollination. Honey bee colonies are large, containing tens of thousands of individual workers, all produced by a single queen. These colonies can persist indefinitely with management by the beekeeper in the form of artificial feedings, replacing queens, and treating for Varroa mites (Varroa destructor), other arthropod pests (such as wax moths, hive beetles, etc.), and diseases (ref. 21). Because of their social nature, honey bees are extremely effective at finding and quickly collecting food from patches of flowers. Living in large colonies also provides honey bees some buffer against stress (e.g., fluctuations in weather, disease, and pesticides).

Nutrition is a hive chore in which many bees share the work of foraging and thus, reduce the stress of providing for the younger generations of bees. Foraging worker bees leave the colony to collect pollen, nectar, water or plant resins (propolis) from the surrounding environment.

These honey bees regularly fly one to two miles from the colony, and have been found to forage as far as five to10 miles in some circumstances. A foraging radius of just a single mile encompasses over 2,000 acres, meaning honey bee foragers have the potential to experience pesticide exposure over a large area (ref. 20, 21). Honey bees collect huge quantities of nectar, which is then processed and stored as honey. This honey is the fuel that keeps the brood area at a consistent 92°F in both summer and fall.

The majority of honey bees in the United States come from managed colonies owned and operated by hobby, sideline, or commercial beekeepers. Hobby beekeepers are the most numerous and they keep a comparatively a small number of hives, often from just two to a few dozen. Their goal is mostly hobby, with profit less critical. Still, they have made a sizeable time and financial investment in their bees and losses they incur are considerable to them. Sideline beekeepers generally have another job but make some significant income from their bees, usually through honey sales. They often have dozens to hundreds of hives. Commercial beekeepers own the bulk of hives nationwide, but make up only a very small proportion of the overall beekeeper population. Beekeeping is usually their sole occupation and they manage thousands of hives, sometimes with many employees. These beekeepers provide pollination services for crops like almonds, apples, cherries, and pumpkins; however, some manage their colonies to produce honey as well. Modern commercial beekeeping is a complicated agricultural operation that can involve moving thousands of hives across many states to service a variety of crops on tight timelines.

In general, honey bee hives are at their smallest and lightest in the spring; existing hives have just come through the winter, decreasing their population, and new hives are usually started. Bees collect pollen and nectar from spring blooming plants to grow their populations; a bigger population can make a larger honey crop in the summer, so beekeepers often manage hives to help them grow quickly. By the end of the spring, some beekeepers, especially those moving hives for pollination services, will set up their hives in a final location. During the summer, when the bulk of flowers are blooming, called a "nectar or honey flow," the bees will collect large quantities of nectar to process into honey. This honey is needed for the hives to survive the winter, and any excess can be removed as a marketable honey crop. Once hives are in place for the summer, bees can gain weight very quickly when flowers are in bloom; by midsummer, a strong colony can weigh several hundred pounds across five to eight hive bodies (the wooden boxes that make up the hive). Therefore, at the time of soybean bloom, moving hives will often be difficult or impossible, especially on short notice, and beekeepers may not have an alternate safe location available to relocate their colonies.

Depending on location, once the main nectar flow is over and the hives are at their heaviest (usually at the end of the summer), beekeepers will harvest excess honey. This is a busy time for beekeepers with many hives, as it entails removing what may amount to hundreds of pounds of honey from each colony and ensuring it is stored properly before processing and sale.

Once the honey harvest is over, beekeepers usually perform pest control and other management activities to improve hive health going into winter. Honey bees do not hibernate per se; they stay in the hive but remain active all winter, feeding on the honey they have stored to generate heat to maintain the colony at a specific temperature (95oF once young are produced). At this time, many large-scale beekeepers move hives to warmer climates or closer to areas using contract pollination services in the early spring. Winter is usually considered the most stressful time for bees, where stresses from earlier in the season can catch up to them and cause hive losses. At the end of the winter, surviving colonies that have overwintered successfully then begin the cycle again (ref. 21).

Wild bees: Throughout the United States, there are numerous and diverse wild bee species living in natural and agricultural areas. Almost all wild bees live for only one year, and many are only active for short times during the growing seasons. Surveys of soybean fields in the Midwest have shown an abundance and diversity of wild bees in fields, particularly during flowering, and have shown that at least some wild bees forage for soybean nectar and pollen. These include many solitary bees, like mason bees and sweat bees, as well as bees living in small colonies, like bumble bees (ref. 1-5).

A major difference between wild bees and honey bees is nesting habitat. Honey bees naturally live in large colonies in hollow trees (feral honey bee colonies), or when kept by beekeepers, in hive boxes. Most wild bees, including many solitary and bumble bees, live in nests they dig in the soil. Some live in holes in dead or fallen trees or various plant stems. For ground nesting bees, this introduces a new interface with agricultural practices, as tillage can destroy their nests.

Many of the same considerations taken to improve honey bee health will likely improve wild bee health. However, there are hundreds of different species of wild bees across the different habitats supporting soybean agriculture, each with its own lifecycle, nesting biology, and forage preferences. Partially because of this large diversity, less is known about wild bees compared to honey bees, so evaluations of any impact of agricultural practices on them are less available.

How do you know if bees are present in fields?

Honey bees can be observed in and around soybean fields for a variety of reasons: foraging on soybean flowers, primarily for nectar; foraging on nearby non-crop flowering plants (weeds); or flying through on their way to other areas. Some pesticide labels warn about applications if bees are visiting flowering crops or near flowering weeds onto which the pesticide could drift. However, it can be challenging to evaluate whether bees are present in fields. Bees are primarily attracted to fields if flowers are present – whether soybean flowers or flowers of other plant species (e.g., clover or weeds) in field edges. Conservatively, bees are likely present in or near fields during flowering if the weather is good (i.e., when it is over 55°F and not raining). Observation of flowers, particularly during mid-morning, can indicate the presence and type of pollinators. Honey bees in soybean fields are likely linked to nearby beekeepers (located within one or two miles). Farmers should communicate with these beekeepers directly, if possible.

Wild bees can be challenging to find during scouting, as their presence is dependent on weather, temperature, and the floral resources surrounding the fields. If attractive flowers are present and temperatures are above 55°F, wild bees are likely present.

Opportunities for enhancing bee forage

Access to nutritious food sources is another important aspect of bee health. Commodity crops that provide either little or short-term seasonal food resources (e.g., corn and soybeans) offer bees poor nutritional resources throughout the growing season (ref. 19). For honey bees, this can mean a lack of quantity, quality, or diversity of forage (ref. 37).

Without enough access to nectar and pollen, honey bee colonies will not grow properly and will not produce enough honey to survive a winter (let alone produce a surplus honey crop for a beekeeper to sell) (ref. 18). While honey bees can survive on a small number of plant species, they are generalists that thrive and resist stress better when they have access to a diverse diet (ref. 38, 39). Wild bees can be generalists or can have specific plant forage needs. They also usually have much shorter annual life cycles and smaller foraging ranges (reg. 40). Therefore, wild bees can be even more susceptible to nutritional stress.

Producers or landowners can improve bee forage and nutrition by including pollinator-supportive plantings adjacent to crop production (ref. 41). Deliberate pollinator plantings by roadways and along railways and waterways, as well as managing the timing of flowering weeds, can promote pollinator health. The Conservation Reserve Program (CRP) of the U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) encourages, and has programs financially supporting, the establishment and maintenance of 'Pollinator Habitat' to enhance pollinator habitat and bee forage (ref. 42).

It is important to remember, however, that these pollinator forage enhancements need to be protected from pesticide introduction when planning potential plantings, including drift. Bee-attractive plants that are downwind or adjacent to crop fields could be exposed to drift of pesticide-containing dust from chemically-treated seeds at planting (ref. 43). Proper planning in determining where to provide pollinator plantings is advised to avoid unintentional risk to the bees, and unintended obstacles for the farmer in managing the crop.

Depending on region, some cover crops may have the potential to act as an important bee food source. Cover crops like crimson clover, hairy vetch, and others that flower before removal are particularly good for bees. USDA-NRCS and other organizations have recommendations and guidelines for different cover crop mixtures and their value to pollinators. If desired, farmers should work with advisors or extension agents to find the best cover crop approach for their farm and account for pollinators when possible. Most importantly, farmers, crop advisors, and pesticide applicators should note that while cover crops can help bees, if they are sprayed with insecticides during bloom that exposure may harm bees (ref. 43).

How bees interact with soybean fields

If a farmer, crop advisor, or pesticide applicator is planning to adopt practices to improve pollinator health, no matter what the time of year, it is important to consider how pollinators interface with agricultural fields and how bees could be exposed to chemicals that are dangerous to them. Using what is known about bee biology and behavior, management practices can be modified to reduce exposure to pesticides while maintaining profitable soybean production. It is also important to consider how bees are affected by other agricultural production practices, like availability of wildflowers or other bee-attractive crops.

When foraging honey bees leave the hive, they are looking for resources – usually flowers from which to collect nectar and pollen. Once a bee finds a good source, it returns to the hive and recruits large numbers of other bees to return to forage on the resource (ref. 20, 21). In this way, bees can be exposed to pesticides while foraging in treated fields, by direct spray while seeking food sources, from drift onto hives, or by drift onto flowering non-crop plants. Exposed bees that are not immediately killed may bring contaminants back to the hive and potentially pose risks to the whole colony (ref. 10). Honey and wild bees are most likely to be in soybean fields during bloom, but they can also be present at other times (ref. 2).

Application of pesticides on windy days, without proper drift control, or placement of hives too close to the field edge can result in direct movement of pesticides into hives located in close proximity to the treated field. With acutely bee-toxic insecticides, this could cause rapid and substantial deaths in the affected colonies. Exposures to chemicals not acutely toxic may result in sub-lethal effects on the colony, such as immune suppression, reduced nutritional stores, or poor brood production (ref. 22-26). Wild, mostly solitary bees, can have similar routes of exposure, as they also are feeding on the same plants and flying through the same fields. Their nests often are in the ground, and therefore are more susceptible to mechanical disruption (e.g., from tillage) (ref. 27), and exposure to insecticides that could be sprayed on their nests in the soil.

While insecticidal chemicals are believed to pose the greatest risk to bees relative to other classes of pesticides, there has been increasing concern amongst beekeepers about the effects of other agrichemicals on bee health. Some recent research has shown sub-lethal effects of fungicides on bees, though much of this work has been done in laboratories or other cropping systems (ref. 24, 28-34). Therefore, it is not clear if the products and application approaches used in soybean production would have the same effect. Recent research also has shown that laboratory exposure to commonly used organosilicone adjuvants, mixed with pesticides to ensure their effectiveness, may adversely impact bee immune health (ref. 35, 36). While these studies are not directly linked to soybean production, it is important to be aware of these concerns; future research may continue to develop and inform BMPs.

Tank mixing of insecticides during fungicide or herbicide application also has caused concern among beekeepers. For this document, tank mixing is defined as the mixture of two or more, independently labelled, active ingredients in the same application (e.g., mixing an insecticide into a fungicide application). This is distinctly different from the use of a pre-mix (i.e., formulation), which is a singly-labelled mixture of multiple active ingredients (e.g., a formulation containing multiple herbicides). Farmers or applicators usually use tank mixing to save money on fuel and labor, as it reduces the number of passes through a field by applying treatments all at once. However, mixing active ingredients can change their toxicity and could potentially make them more toxic to bees than they would be alone (ref. 31). Farmers or applicators may also tank mix insecticides into other applications when pest pressure would not warrant an independent application; therefore, it is recommended not to add insecticide to other treatments if insect pest thresholds have not been reached. Also, farmers and applicators should check label information regarding the synergy between active ingredients and avoid mixing pesticides that will result in increased bee toxicity. Labels will sometimes, but not always explain what can be mixed during application.

In all of these cases, understanding of the complicated interplay of these chemicals is continually evolving. It is not clear how much effect these chemicals and their combinations in real-world soybean production can have on bees. These potential effects do, however, underline the importance of continued research on different chemicals, formulations, and mixtures. Farmers and applicators should stay up to date through contact with advisors and extension agents and remain vigilant about developing changes in BMPs.

THE SOYBEAN GROWING SEASON

Soybean production is a year-long process and each stage presents different risks to pollinators. The likelihood of pollinator presence also varies based on the stage of production. Here, we describe common crop production practices, their potential negative impacts on bees, and how to reduce those potential negative impacts.

Year-round

No matter what time of the season, one of the best ways for farmers to understand and mitigate potential exposure of honey bees to pesticides is to have clear lines of communication with nearby beekeepers. Many states have implemented Managed Pollinator Protection Plans (MP3) or similar programs to facilitate this communication. Other resources include state-based registries for apiary location which show pesticide applicators where honey bees are located. Depending on the state, applicators may be required to adjust the timing of an insecticide application when hives are within a mile of a registered hive. Many beekeepers are reluctant to publicly provide their apiary locations as these are proprietary and are vital to their continued success. Due to the proprietary nature of this information, some states only provide this information directly to applicators. In states where this is not the case, it is important for beekeepers that do not participate in registration systems to alert nearby farmers or landowners to the presence of their hives. Farmers and applicators do not want to harm hives, but cannot easily know their location without this communication. Farmers and applicators can contact the state or local department of agriculture, state apiarist, or similar organization to find out the best methods for contacting nearby beekeepers, but beekeepers also should take measures to make sure nearby farmers are aware of their operations.

When communicating with beekeepers, farmers should try to be receptive to their concerns, but also understand that some beekeepers may not be familiar with soybeans or other common crop production practices. They may not be knowledgeable about what pests are present or the timing of applications. Beekeepers will be best served by trying to learn about these issues, as it will give them a better understanding of the likelihood of when, where, and what could be applied, and can help them in choosing an apiary location. Both beekeepers and farmers should try to put themselves in the other's shoes in thinking about their interactions.

Beekeepers should try to communicate with farmers before the growing season begins, when both are more likely to have the time to communicate easily. Discuss hive location, what is applied nearby, and try to evaluate the likelihood of negative effects on bees. Before any problems arise, talk about what both parties want to do if there is a bee kill incident. It is likely in the best interest of beekeepers and farmers to have built the framework to amicably settle any issues personally.

Pre-planting field preparation

SOIL TILLAGE

- **Agronomic background:** Tillage can help remove weeds and break up surface compaction if done at the proper soil conditions. No-till is very common in soybean production and can improve soil structure over time. However, no-tillage requires herbicides to remove weeds. Certain regions and soil types are better suited to no-till than others.
- **Negative bee impact:** Mechanical soil tillage has high potential to damage ground nesting bee habitat.
- **Steps to reduce impact on bees:** If tillage is performed, but the goal is also to conserve wild, ground-nesting bees, the presence of untilled areas nearby containing vegetation (e.g., riparian strip or terrace) could act as a habitat for bees. Note that in some areas, winter annual weeds that would be sprayed in a no-tillage system would be at flowering. Certain cover crops could be flowering at the time of herbicide application. So, no-tillage is better for ground-nesting bees, but no-tillage requires removing flowering winter annuals.

FERTILIZATION

- There is no evidence that fertilization practices used for soybean production significantly affect bees.

PRE-PLANTING HERBICIDE APPLICATION

- **Agronomic background:** Weeds are extremely harmful to soybean productivity. They compete for water, sunlight, and nutrients. Removing weeds prior to planting helps improve soybean yields. A pre-plant treatment is usually necessary in no-tillage conditions to remove winter annual weeds and some early-emerging summer annual weeds.
- **Negative bee impact:** Herbicide application and/or drift can kill plants important to the bee food supply.
- **Steps to reduce impact on bees:** Management of non-invasive flowering weeds along roadways, ditches, and/or edges of fields may be delayed to provide floral resources for bees. Preventing drift of herbicides can be particularly helpful in maintaining beneficial forage in field edges or adjacent uncultivated land. See label instructions for proper application procedures.

Planting

SEED TREATMENT USE

- **Agronomic background:** Seed treatments offer protection to germinating soybeans from certain early-season insects and diseases. Examples of those early season insect pests of soybeans include seed corn maggot, wireworm, overwintering bean leaf beetle, grubs, early aphid infestations, and thrips. Early season soybean diseases can include *Phytophthora, Pythium, Rhizoctonia,* and *Fusarium* spp.
- **Negative bee impact:** When planting seed with pesticide-treated coatings, vacuum planters and high-speed fans used to move the seed through the planter may create abrasions that remove a fraction of the seed treatment from the seed, mixing the treatment with lubricant dust (e.g., talc) and disturbed soil that can then drift to blooming plants nearby, drift onto cover crops that are attractive to bees, stick to bees flying in fields, or drift directly onto nearby hives (ref. 10). There also has been some concern that seed treatments could dissolve in water runoff and be taken up by nearby non-crop plants where bees can then collect nectar and pollen from these plants and be exposed to insecticide residues (ref. 44, 45). While there is some evidence this is a possibility, it is not clear that this route poses a risk of concern (ref. 46), especially compared to more acute contact through planter dust.
- **Steps to reduce impact on bees:** Farmers should discuss the need for, and benefits of, seed treatment versus the potential costs with their seed provider, extension agents, and crop consultants. As with other pesticide uses, if it is not needed, do not use it. To minimize these risks, treated seed should only be used when warranted by local conditions. If treated seed is used, there are steps that can be taken to steward these pesticides. Refer to *The Guide to Seed Treatment Stewardship* for detailed information.

  The Guide recommends:

  - Ensure seed was thoroughly cleaned before treatment and that proper coatings were used to improve adherence of the chemical; these approaches will reduce pesticides coming off the seed into planter dust. These concerns can be discussed with seed dealers or retailers.
  - Choose alternatives to the seeding equipment "lubricants" (fluency agents) talc and graphite, and follow seed tag and planter manufacturer recommendations during preparation for the planting season.
  - Be aware of improving technology produced by planter manufacturers.
  - To further minimize dust, reduce shaking of seed bags, use lubricants properly, clean up any spills, and be aware of weather conditions, like wind, that could increase drift of abraded seed coat dust outside fields.

Overall, the goal should be to minimize the dust drift onto hives and non-crop plants, especially those in bloom. Notably, there is active research and discussion regarding the benefits and risks of neonicotinoid treated seed in soybean production. Preliminary pollinator risk assessments have been completed for several neonicotinoid pesticides by the U.S. Environmental Protection Agency (EPA) (ref. 49) and additional evaluations are underway. Questions have also been raised about the overall benefits of treated seed (ref. 50) and pesticide resistance when neonicotinoid seed treatments are used prophylactically. This underscores the need to remain engaged and aware of developing science in this area.

Emergence to flowering (VE-R1)

PRE- AND POST-EMERGENCE HERBICIDE APPLICATION

- **Agronomic background:** Weeds that emerge with the soybean crop can be extremely competitive and reduce soybean yields. Removal of these weeds is necessary for profitable yields and excellent seed quality.
- **Negative bee impact:** Before and after plant emergence, herbicide application is common. Herbicide application and/or drift can kill plants important to the bee food supply.
- **Steps to reduce impact on bees:** Same as pre-planting herbicide application.

Prime flowering to beginning pod formation (R1-R3)

INSECTICIDE SPRAYING

- **Agronomic background:** Many insect pests have established thresholds for applications of insecticides in most states. Proper use of insecticides is part of an Integrated Pest Management (IPM) program. Examples of insects that infest soybean fields at this time are stink bugs, bean leaf beetles, soybean aphids, and loopers.
- **Negative bee impact:** Insecticides are necessary for a variety of soybean pests but also may be toxic to bees and other beneficial insects. Bees may be present in soybean fields throughout the growing season, as bees fly through these areas looking for flowering plants (ref. 2). However, soybeans themselves are only attractive to bees when blooming; research has shown numerous bee species are present and foraging on soybeans during this time period (ref. 2-4). Therefore, direct bee exposure to pesticide spraying is most likely to occur during soybean bloom.
- **Steps to reduce impact on bees:**
    - The first approach is to evaluate whether insecticide application is necessary. IPM, including use of insect-resistant soybean lines and identification of established treatment thresholds, can reduce insecticide use and may lead to more efficient, cost-effective pest management. If you do not need to spray, do not.
    - Read and follow pesticide label directions. Have a discussion with your insecticide provider/applicator to understand product choices and label directions.
    - When possible, avoid insecticide application during R1 and R2, when soybeans are most attractive to bees, or delay spray to avoid the peak of the day when foraging bees are most active. In other cropping systems, it is often recommended to spray at dusk with chemicals that have short (less than 12-hour) residual times. In these cases, insecticides are applied when few bees are present and lose most of their residual activity by the next day when bees

are again foraging. In soybean production, most effective insecticides have residual times over a week long, so this approach is unlikely to have as much impact.

  - If application during soybean flowering must occur, and the site cannot be treated outside of peak hours, communicate with nearby beekeepers prior to application. By identifying where hives are located, applicators can target the farthest-away fields first, spraying those closest to the hives near the end of the day. Communication can also give beekeepers the opportunity to take measures to limit exposure to their hives in application areas, though moving hives during this time is usually not an option.
  - As with other times of year, avoiding drift of pesticides onto hives or nearby flowering plants is an important way to decrease exposure. See pesticide labels for guidance regarding wind speed, nozzle size, and other information for controlling drift.
  - If products are available and effective with low toxicity to bees, choose these.

FUNGICIDE SPRAYING

- **Agronomic background:** There are established thresholds for applications of fungicides to control diseases in most states. Proper use of fungicides is part of an IPM program. Examples of diseases that can infest soybean fields at this time include frogeye leaf spot, brown spot, and Cercospora leaf blight.
- **Negative bee impact:** While fungicides are generally considered relatively safe for bees, they frequently show up in honey bee hives where pesticide testing has been performed (ref. 47). Research indicates that some fungicides (mostly those used in non-soybean crops) could make bees more susceptible to diseases (ref. 24, 30), and when mixed with certain insecticides, can result in increased toxicity or sub-lethal effects on bees (ref. 29, 31).
- **Steps to reduce impact on bees:** Remember that fungicide application during this phase will likely expose the largest number of pollinators to these chemicals. Overall, research is needed to understand how fungicides affect bees and to develop guidelines for reducing potential risks to bees, particularly in soybean production. If possible, similar approaches can be used as with insecticides to minimize exposure. As with other pesticides, if fungicides are used, drift onto nearby hives or weeds that attract bees must be minimized. Use pesticides of all types only when a need has been noted through biological and/or weather monitoring (scouting), and when the timing of application is appropriate. Be wary of the addition of other products, like insecticides, into fungicide applications. If you do not have a need for a product in the tank, do not mix/apply it. Follow all guidelines and label restrictions regarding pesticide application and take measures to restrict offsite movement. Have a discussion with your pesticide provider/applicator to understand product choices and label directions.

Pod filling to harvest (R4-R8)

INSECTICIDE AND FUNGICIDE SPRAY APPLICATION

- **Agronomic background:** Thresholds for both insects and diseases could be reached during these stages. Sometimes they occur together and warrant the application of both an insecticide and a fungicide (as separately-labeled active ingredients) in the sprayer. Applying both products together is more economical than applying separately.
- **Negative bee impact:** With the end of flowering comes a decrease in the attractiveness of plants to foraging pollinators. While pollinators may fly through fields to and from other resources, without flowers on which to forage, bees will spend less time in soybean fields. Therefore, drift from insecticide and fungicide applications onto flowering weeds or wild bee habitat adjacent to fields is the most likely concern during this phase.
- **Steps to reduce impact on bees:** As before, care can be taken to prevent chemicals from drifting directly into nearby apiaries or to attractive blooming plants adjacent to the crop. Follow recommendations to reduce drift. Again, consider the potential effects that mixing active ingredients can have, as some mixtures could have increased toxicity to bees. As with other pesticide applications, it is important to contact nearby beekeepers to inform them of application timing.
- **Read and follow pesticide label directions.** Have a discussion with your pesticide provider/applicator to understand product choices and label directions.

DESICCANT APPLICATION

- Desiccants are sometimes used in this stage but there is no documented evidence of risk to bees from these chemicals.

Post-harvest practices

COVER CROPPING

- **Agronomic Background:** Cover crops are planted in the fall and removed in the spring and are not harvested for grain or hay. Cover crops can help reduce soil erosion, capture nutrients, build soil organic matter, and may help reduce pressure from certain weeds. However, cover crops could increase populations of certain insects that may feed on young soybeans.
- **Negative bee impact:** Cover crops can provide beneficial forage for bees. Therefore, extra care should be taken to protect flowering cover crops from contamination with insecticides.
- **Steps to reduce impact on bees:** When choosing cover crops, consider ones that flower and provide food resources for bees. Avoid spraying flowering cover crops with insecticides if possible. If insecticide treatment is needed, try to apply before or after bloom. If spraying in bloom occurs, take precautions, assuming bees will be present.

PRIMARY RECOMMENDATIONS, RESPONSIBILITIES AND OTHER CONSIDERATIONS

Soybean farmers and beekeepers are both agricultural producers trying to successfully run operations in the same landscapes. Cooperation is in the best interest of both parties to adopt practices that provide opportunities for profitable soybean production and beekeeping. These same practices will often benefit the wild bee communities that live throughout the United States. Both farmers and beekeepers can take responsibility for considerations to successfully and voluntarily reduce negative impacts on bees.

Farmers, their consultants and applicators

- ***Use IPM*** (e.g., monitoring, weather modeling, etc.) to inform product application and do not use unless indicated.
- ***Follow the label for application of all products***, including restrictions related to bees. The label is the law.
- ***Be knowledgeable regarding the differing risks*** associated with different formulations of the same pesticide.
- ***Use your state or local department of agriculture*** to identify hive locations. Many states have registration systems in place where beekeepers are able to register their hive locations and applicators can check before spraying. At the beginning of the growing season, map apiary locations with beekeeper contact information for easy access and communication to applicators. If your state does not have a hive registry system, be receptive to communication from nearby beekeepers.
- ***Communicate spraying to nearby beekeepers*** (those within about one mile of your target field) whenever using pesticides likely to harm bees.
- ***Open lines of communication*** earlier rather than later to make sure you have a clear contact stream for when application does occur. Some beekeepers move hive locations throughout the year, so early communication will help both parties.
- In the event of a bee kill incident, ***be receptive to the concerns of nearby beekeepers***. It is often in the interest of both parties to come to an agreement personally.
- ***Put yourself in the shoes of the beekeeper*** and try to understand their reasoning and approach to protecting their hives.
- ***Work with your product providers***, extension contacts and crop consultants to stay informed on emerging information regarding risks associated with pesticides and pesticide combinations.
- ***Reduce drift of all possible pesticides***; this keeps treatments on your crops, away from hives, and away from plants bees use for foods. Spray when wind is minimal (less than eight to10 mph) and use correct nozzle sizes to minimize drift. Be aware of wind direction and potential downwind targets. The pesticide label contains guidance for reducing drift.
- ***Prevent contamination of water sources that bees access***; clean up seed and pesticide spills near loading areas and water. Wash out areas with any puddled contaminated water; in hot weather, bees will collect water from these contaminated puddles.

Beekeepers

- ***Have a sign or label on your hives*** with your contact information in lettering large enough to be read at a distance. A one mile radius encompasses 2000 acres and could involve production by several farmers. With multiple apiaries, the number of applicators in range of your hives increases.
- ***Register your hives*** with your state or county department of agriculture or use another accessible registry. Hive registration with state agencies gives applicators and producers the ability to identify your hives and take appropriate measures when applying pesticides. Many pesticide labels have requirements if bees are present nearby, but if applicators are not aware of your hives, these may not be implemented. If hive registration is not possible or desired, it is even more important to make personal connections with nearby farmers to ensure they know about your operation.
- ***Learn about the land use around your hives***, what crops are being grown, and what pesticide application occurs. You can view agricultural land use around your apiary though the USDA National Agricultural Statistics Service (NASS) CropScape website: *https://nassgeodata.gmu.edu/CropScape/*
- ***Be an active participant in communication*** and try to find out when and what pesticides will be applied. If you know the schedule, it may be possible to manage the colonies to minimize their exposure.
- ***Put yourself in the shoes of a farmer*** and try to understand the reasoning and approach they are using to protect their crop.
- When communicating with farmers or pesticide applicators, ***have a plan for what you will do*** in the case of a nearby pesticide application.
- ***Contact farmers before the growing season begins***. Like beekeepers, farmers are very busy during certain times of year and will be harder to communicate with if they are extremely busy. Therefore, start communication as early in the year as possible, before planting begins. Even with farmers you have had previous communication with, touch base at the beginning of each year.
- ***Establish apiaries further from the edge of crops likely to be sprayed with insecticides***. Increasing the distance from spraying can reduce the risk of direct contact with pesticides from drift. Natural barriers such as tree or heavy brush lines may reduce pesticide drift onto hives.
- In some situations, especially for small scale operations, it may be possible to ***help bees recover if an exposure event weakens them***. Be vigilant in monitoring hives for indications of poor bee health and/or incidence of mortality. If it is suspected that collected pollen/nectar with a toxic contaminant is building up inside the hive and adversely affecting the bees, remove pollen frames and feed clean pollen or pollen supplement. Feed syrup and make clean water accessible if appropriate.
- If acute pesticide exposure is suspected, there are several possible routes to take. In many cases, ***directly contacting the farmer or applicator first may provide positive results***. Farmers and applicators do not want to harm beekeeping operations, and often are happy to come to an agreement privately if hives have been affected by pesticides.

Open personal communication has allowed many beekeepers and farmers to work side-by-side. Alternatively, or after a failed personal communication, beekeepers can contact the local or state apiarist or agriculture department. If this route is taken, provide a bulleted list that indicates acute exposure (e.g., excessive numbers of dead and dying honey bees in front of the hives, increased defensiveness, stupefaction, paralysis, and abnormal jerky, wobbly, or rapid movements) and, if possible, remove and properly store several frames for residue sampling. For investigation purposes, a state official will also probably need to take samples.

- It is key to ***use good beekeeping practices*** to keep other stressors in check, particularly infestation of Varroa mites and presence of disease symptoms. Bees that are healthier in other ways will be better able to tolerate or recover from pesticide exposure. Use appropriate screening and treatment methods to control for mites and pathogens. (See Honey Bee Health Coalition tools for Varroa management (ref. 48)).
- ***Beekeepers should maintain photographic evidence of their hives*** in all seasons to be able to prove an incident with irresponsible use of agricultural chemicals.

CONCLUSIONS

Soybean production covers nearly 84 million acres in the United States, and therefore has the potential to impact bees across a wide area of the nation where large populations of honey bees co-occur. Pesticide labeling and registration has increased focus on protecting pollinators from risk of pesticide exposure. Most producers are concerned with understanding how their actions contribute to potential harms to pollinators in and around their fields, and want to contribute to finding solutions. Overall, protecting pollinators can come down to a few main components:

1. ***Think before you spray.*** Use IPM approaches that reduce unneeded or poorly-timed pesticide applications. Be aware that pesticides, especially several commonly used insecticides, can kill bees and other pollinators.

2. ***When applying pesticides, always follow label instructions.*** Doing otherwise is a violation of the law.

3. ***Improve food and water resources for bees by providing habitat that includes flowering plants*** (e.g., in field margins, riparian buffers, terraces, etc.), avoiding pesticide exposure to non-target plants that bees use for food, and by cleaning up pesticide- spills.

4. ***Build and enhance communication and cooperation between farmers/applicators and beekeepers***. Open lines of communication can help both parties understand each other's concerns and help to ensure healthy pollinator populations remain viable.

5. ***Manage hives to reduce stress from other factors such as Varroa mites and diseases.*** Strong, healthy colonies are less susceptible to the sub-lethal effects of pesticide exposure.

6. ***Use extension agents, technology providers, and crop/beekeeping advisors*** to keep up to date on developing research and best management practices.

There are still many unknowns when it comes to understanding how pollinators are impacted by agriculture. Many recommendations are based on understanding of bee biology coupled with a mixture of laboratory and field testing. However, future research needs to be done to test different practices in a variety of real-world settings to understand their relative benefits to honey bees and wild bees.

RESOURCES

Forage enhancements and cover crops for pollinators

Conservation Reserve Program Benefits to Pollinators:
https://www.fsa.usda.gov/programs-and-services/economic-and-policy-analysis/natural-resources-analysis/pollinators/index

Cover Cropping for Pollinators and Beneficial Insects:
http://www.sare.org/Learning-Center/Bulletins/Cover-Cropping-for-Pollinators-and-Beneficial-Insects

BMPs for other cropping systems

Honey Bee Best Management Practices for California Almonds:
http://www.almonds.com/pollination

How to Reduce Bee Poisoning from Pesticides:
https://catalog.extension.oregonstate.edu/pnw591

Protecting and Enhancing Pollinators in Urban Landscapes:
http://msue.anr.msu.edu/resources/how_to_protect_and_increase_pollinators_in_your_landscape

Minimizing Pesticide Risk to Bees in Fruit Crops:
http://msue.anr.msu.edu/uploads/236/68700/E-3245.pdf

Protecting Honey Bees from Pesticides:
https://extension.entm.purdue.edu/publications/E-53.pdf

Beekeeping

University of Georgia beekeeping resources:
http://caes2.caes.uga.edu/bees/beekeeping.html

Bee Informed Partnership:
https://beeinformed.org/

Honey Bee Health Coalition Varroa Control Strategies:
http://honeybeehealthcoalition.org/varroa/

IPM in soybeans

Soybean Research & Information Initiative:
http://soybeanresearchinfo.com/pests/ipm.html

Integrated Soybean Pest Management for soybean insects:
https://www.cropscience.bayer.us/learning-center/articles/integrated-pest-management-for-soybean-insects

Soybean Pest Management Purdue University:
https://extension.entm.purdue.edu/fieldcropsipm/soybean.php

NC Soybeans Integrated Pest Management:
https://ipm.ces.ncsu.edu/ipm-soybeans/

Soybean Insect Pests University of Nebraska:
http://cropwatch.unl.edu/insect/soybeanpestmgt

Soybean IPM Iowa State University:
http://www.ipm.iastate.edu/

Seed Treatments

The Guide to Seed Treatment Stewardship:
http://seed-treatment-guide.com/

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