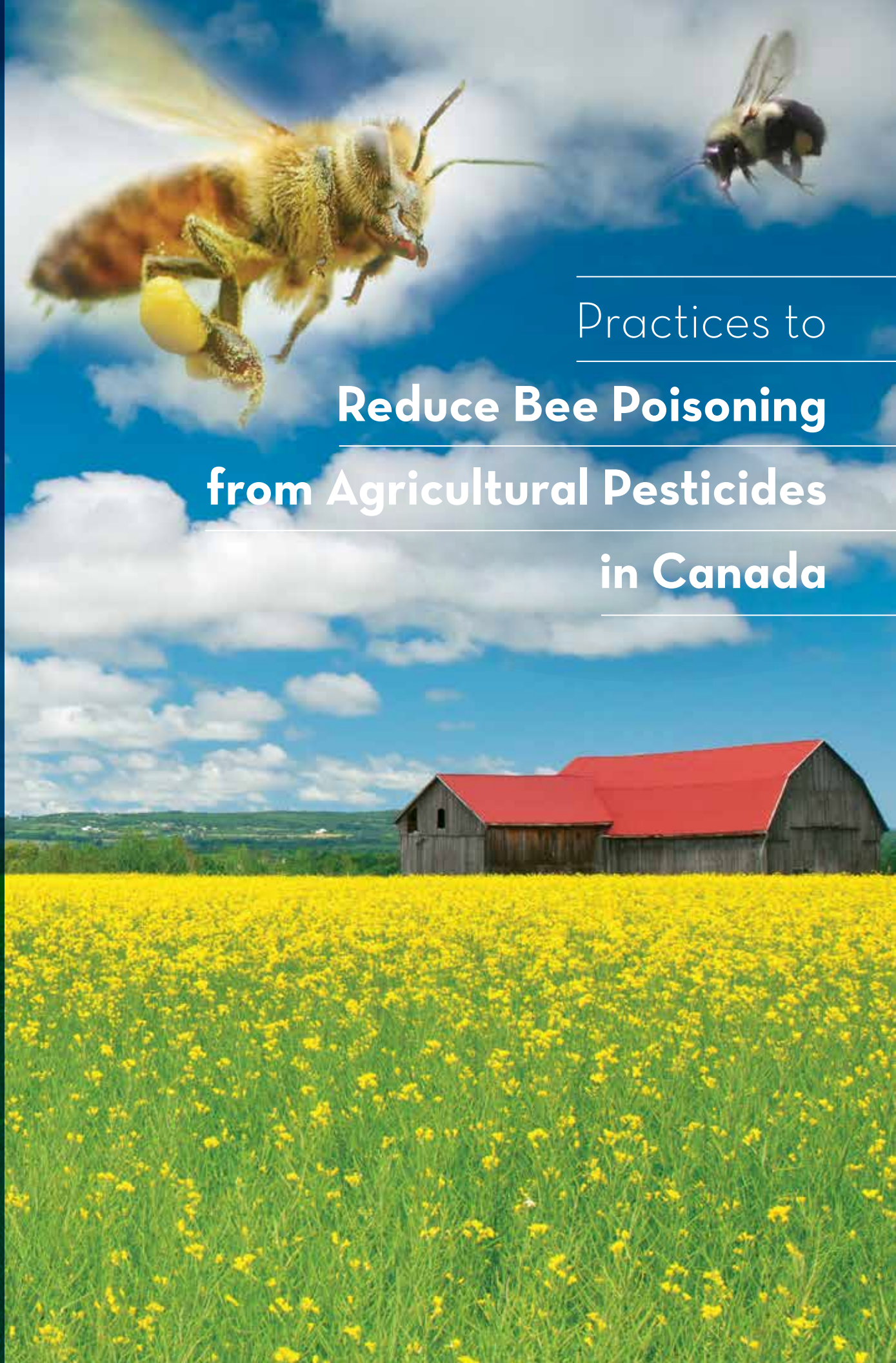
Consolidated Reference



Practices to

Reduce Bee Poisoning from Agricultural Pesticides in Canada

This guide entitled *Practices to Reduce Bee Poisoning From Agricultural Pesticides in Canada,* and produced by **Pollinator Partnership Canada**, was commissioned for discussion purposes by Agriculture and Agri-Food Canada (AAFC) on behalf of the Bee Health Roundtable, an industry-government forum.

The content of this guide does not necessarily reflect the opinions or interests of the entire Bee Health Roundtable membership or AAFC, nor does it necessarily reflect the opinions or interests of all parties interviewed during the researching of this guide.

POLLINATOR PARTNERSHIP CANADA

Oregon State University Extension Service

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Pollinators are Essential

A variety of crops in Canada including vegetables, berries, fruits, cucurbits, clover, and crops grown for seed, depend on pollinators. Pollinators provide many of the nutrient rich and high-antioxidant foods in our diet, and native pollinators are keystone organisms in ecosystems. Canada is the number one producer of canola and second highest producer of blueberries in the world. Honey bees alone account for $2 billion of Canada's economic output. The 700,000 honey bee colonies in Canada produce 41 million kg of honey annually, 44 percent of which is exported.

While honey bees are our most economically important pollinators, other managed bees are important as well. For example, alfalfa leafcutter bees are managed for production of alfalfa seed in Canada, and managed bumble bees are important for greenhouse tomato production and some field crops. Native, wild bees, including numerous species of bumble bees, mining bees, mason bees, sweat bees, leafcutter bees, and carpenter bees are all effective and important crop pollinators. There are more than 800 species of native bees in Canada. The full value of their pollination services to increased crop production is substantial, even in the presence of honey bees.

Both managed bees and wild bees potentially can be harmed by pesticides used on crops. For many beekeepers in Canada and globally, it has become increasingly challenging to keep honey bee colonies healthy, likely due to a number of factors including pests and diseases, lack of forage, and exposure to pesticides. Similarly, some native bee populations are declining, possibly due to various factors such as habitat loss, climate change, disease transfer from managed bees, and pesticide exposure.

Pesticides are an integral part of modern agriculture and widely used, particularly for large-scale farming. By using pesticides in a thoughtful manner, following label instructions, and considering managed and wild bees in crop protection plans, we can help reduce one source of harm to bees. Working together we ensure that we have healthy populations of managed and wild bees to pollinate agricultural crops and wild plants for future generations. This guide provides information for farmers, beekeepers, and pesticide applicators on how to reduce bee poisonings from agricultural pesticides.

Cooperation between beekeepers and growers is the most effective way to reduce bee poisoning. The underlying cause of most bee poisoning incidents is a lack of information or awareness. Both beekeepers and growers benefit from developing working relationships and familiarizing themselves with each other's management practices.

Rules to Protect Bees

PMRA Toxicity Testing Requirements for Bees

Health Canada's Pest Management Regulatory Agency (PMRA) is the branch of the Canadian federal government responsible for regulating pesticides under the authority of the Pest Control Products Act. PMRA's primary mandate is to prevent unacceptable risks to Canadians and the environment from the use of these products. PMRA applies modern, evidence-based scientific approaches to assess whether the health and environmental risks of pesticides are acceptable. When there is potential exposure of bees to a crop protection product, the PMRA requires information to assess the risk to bees. The pollinator risk assessment framework relies on a tiered approach which begins with conservative exposure assumptions and laboratory toxicity data conducted with individual bees. The initial laboratory toxicity data requirements include acute oral and contact honey bee adult toxicity, and additionally, larval toxicity and adult honey bee chronic oral toxicity information. If the Tier 1 risk assessment based on laboratory studies indicates the potential for harm to bees, then higher tier data may be required such as more realistic exposure measurements in nectar and pollen, as well as colony level bee studies conducted in the field. This information on acute and chronic toxicity, together with exposure information and colony-level studies, are incorporated into the risk assessment and risk mitigation, including label precautions (**Table 1**). Pesticides registered for use in Canada do not pose an unacceptable risk to bees and other pollinators when used according to the label. **It is critical that users read and understand the product label prior to use to minimize exposure and risk to pollinators.**

Photo: Diane Wilson

Follow Label Directions

The Environmental Precautions/Hazards section of the pesticide label contains specific precautionary statements designed to protect bees from exposure to pesticides that are toxic due to either acute, chronic, adult larval or colony exposure (**Table 1**).

- Review the entire label for precautionary and advisory statements. Look for "toxic" to bees.
- Crop-specific precautions may also be listed on the label. Although the 'bee' precautions are based on toxicity to honey bees, they are also relevant to other species of bees, with some exceptions noted in **Table 4**.
- Residual toxicity to bees varies greatly between pesticides, and can range from hours to a week or more (**Table 4**). When using insecticides with extended residual toxicity (residues expected to cause at least 25% mortality 8 or more hours after application), it is imperative that applicators and growers carefully consider potential exposures to both wild and managed bees, and avoid applying pesticides to blooming plants (crops or weeds).
- Growers are required to follow label restrictions. More information can be found at: www.canada.ca/pollinators

Properly reading pesticide labels is important from an economic point of view for the grower, as well as an ecological point of view for bees and other beneficial insects. Applying too much of one pesticide because of inattention to label details could cost the grower more money, and could increase the toxicity of the product to visiting bees. Even when using a product you are familiar with, always double check the label to ensure that the regulated amount is being used, as it is illegal to not comply with label directions and precautions. For the most current information on label restrictions, use the **PMRA online label search** or download the **PMRA pesticide label app** at: https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/registrants-applicants/tools/pesticide-label-search.html

Table 1.

table 1

Pollinator precaution levels, risk characterization considerations, and examples of pollinator protection requirements based on PMRA overall pollinator risk characterization for a pesticide. This risk characterization may include consideration of laboratory toxicity such as adult acute contact and oral toxicity, chronic adult oral toxicity, larval toxicity, and residual contact toxicity times. For all products and precaution levels, higher tier studies (e.g., tunnel studies, colony feeding studies, open field studies, and pollen and nectar residue information) may be available, considered in the risk characterization, and used to inform restrictions. Additionally, the attractiveness of crops to pollinators, and other agronomic considerations (such as whether the crop is harvested before bloom) are considered in the overall pollinator risk characterization. Three Pollinator Precaution levels are described here and correspond to the categories in **Table 4** of this document. Always refer to label directions when applying pesticides as restrictions are specific to products and crops, and are essential for minimizing harm to bees.

Pollinator Precaution Levels	Pollinator Risk Characterization: Considerations	Pollinator Precautions: Application Restriction Examples
Most Restrictive	**Acute adult contact/oral toxicity:** typically highly toxic with an acute toxicity LD50 of < 2µg/bee Note that some pesticides may be highly toxic but have moderately restrictive labels due to short RT times **Residual Toxicity:** typically > than 8 hours **Larval Toxicity:** possible **Chronic Toxicity:** possible **Higher Tier Studies:** as available **Crop Pollinator Attractiveness** **Specific Agronomic Considerations**	Typically requires the most restrictive precautions for application to bee-attractive crops **Examples:** May not allow application during bloom May restrict pre-bloom application May be specific timing restrictions for certain crops, or other specific restrictions (e.g., Restrictions when managed pollinators could be placed in crops relative to application timing) May be required to remove flowering weeds or groundcover prior to application (for example in orchards) Minimize spray drift
Moderately Restrictive	**Acute adult contact/oral toxicity:** typically moderately toxic with an acute toxicity LD50 of > 2µg/bee to < 10.9 µg/bee Note that some pesticides may be highly toxic but have moderately restrictive labels due to short RT times **Residual Toxicity:** typically 2 to 8 hours **Larval Toxicity:** possible **Chronic Toxicity:** possible **Higher Tier Studies:** as available **Crop Pollinator Attractiveness** **Specific Agronomic Considerations**	Typically requires some restrictions on application to bee-attractive crops **Examples**: May allow during bloom application in evening only Minimize spray drift
Least Restrictive	**Acute adult contact/oral toxicity:** practically non-toxic with an acute toxicity LD50 of ≥ 11µg/bee **Residual Toxicity:** typically < 2 hours or no residual toxicity **Larval Toxicity:** typically none **Chronic Toxicity:** typically none **Higher Tier Studies:** as available **Crop Pollinator Attractiveness** **Specific Agronomic Considerations**	Typically requires minimal or no restrictions

Provincial Rules and Resources to Protect Pollinators

The federal government is responsible for the registration of pest control products, and all three levels of government (Federal, Provincial/Territorial, and Municipal) play a role in regulating their sale and use. Ministries of certain provinces provide rules intended to reduce the hazard of insecticide applications to bees, as well as guidance on bee management. See the links below for the most current rules and resources in your province (**Table 2**). For more information, call the number listed under "Investigating a suspected bee poisoning".

Photo: Anthony Colangelo

Table 2.

table 2

Provincial rules and resources to protect pollinators. Rules and practices not specific to provinces can be found throughout this document.

Province	Rules for Protection of Bees and Pollinators	Links to Provincial Resources
Alberta	No pollinator protection rules specific to Alberta	**Alberta Agriculture and Forestry, How to Reduce Bee Poisonings from Pesticides** https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex704 **Crop Pests** https://www.agric.gov.ab.ca/app21/infopage?cat1=Diseases%2FInsects%2F%20Pests&cat2=Crop%20Insects
British Columbia	The Ministry of Agriculture introduced a new bee regulation in 2015 as part of the Animal Health Act B.C.'s Integrated Pest Management Act can restrict the use of specific pesticides by requiring a permit	**A summary of the Animal Health Act regulation** http://www2.gov.bc.ca/gov/DownloadAsset?assetId=967AEEE3507946A2A6CDFCB5ADE57AEE&filename=bee_regulation_summary.pdf **More information at:** https://news.gov.bc.ca/factsheets/bees-and-bee-health-in-british-columbia **Crop Pests** https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/plant-health/insects-and-plant-diseases
Manitoba	No pollinator protection rules specific to Manitoba	**Protecting and Supporting Pollinators** http://www.gov.mb.ca/agriculture/crops/insects/pollinators.html **Bees on Canola - What are the Benefits?** http://www.gov.mb.ca/agriculture/crops/insects/pubs/beesoncanolafactsheet.pdf
New Brunswick	The department registers every New Brunswick beekeeper on an annual basis as part of a legal requirement as stated in the Apiary Inspection Act for New Brunswick	**More information at:** http://www2.gnb.ca/content/gnb/en/departments/10/agriculture/content/bees.html
Newfoundland and Labrador	Varroa mites have not been a problem in Newfoundland and Labrador and agricultural pesticide use is low	**Canadian Best Management Practices for Honey Bee Health** http://www.honeycouncil.ca/images2/pdfs/BMP_manual_-_Les_Eccles_Pub_22920_-_FINAL_-_low-res_web_-_English.pdf
Nova Scotia	No pollinator protection rules specific to Nova Scotia	**Blueberry Insecticide Chart** http://www.perennia.ca/wp-content/uploads/2015/08/Wild-Blueberry-Insecticide-Chart-2016.pdf **Crop Pests:** https://novascotia.ca/nse/pests/
Ontario	Ontario Pollinator Health Action Plan – Neonicotinoid regulations for growers Honey bees and apiaries are required to be registered under the Ontario Bees Act	**Pollinator Health Action Plan:** http://www.omafra.gov.on.ca/english/pollinator/action_plan.htm **Honey bee Registration Form** (http://www.omafra.gov.on.ca/english/food/inspection/bees/info_registration.htm) **Crop Pests:** http://www.omafra.gov.on.ca/english/crops/field/news/news_croppest.html **Ontario Bees Act:** (https://www.ontario.ca/laws/statute/90b06). **Information on Pesticides** http://www.omafra.gov.on.ca/english/crops/pub360/pub360ch11.pdf
Prince Edward Island	Animal Health And Protection Act Chapter A-11.1 – Bee Health Regulations	**Animal Health And Protection Act Chapter A-11.1 Bee Health Regulations:** https://www.princeedwardisland.ca/sites/default/files/legislation/A%2611-1-2-Animal%20Health%20and%20Protection%20Act%20Bee%20Health%20Regulations.pdf. Also, see Nova Scotia. **Crop Pests** https://www.princeedwardisland.ca/en/topic/field-crops
Quebec	In Quebec a new regulation was adopted and the use and purchase of neonicotinoids for 2019, and seeds coated with neonicotinoids are no longer permitted without a justification and prescription delivered by an agrologist as of 2018 Planting cash crop coated seeds (with neonicotinoids) requires certification. The same certification required to spray other herbicides/ insecticides, etc.	**Québec Ministry of Environment legislation for pesticide control** http://www.mddelcc.gouv.qc.ca/pesticides/permis/code-gestion/ **Crop Pests** https://phytopath.ca/wp-content/uploads/2015/03/Diseases-and-Pests-of-Vegetable-Crops-in-Canada.pdf
Saskatchewan	In Saskatchewan, commercial beekeepers and producers with sensitive crop areas are encouraged to register locations on Driftwatch	**Pesticide Drift** https://sk.driftwatch.org/map. This tool is intended to aid identifying areas especially sensitive to pesticide drift for reference by commercial pesticide applicators. www.fieldwatch.com; www.driftwatch.org. **Crop Pests** https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/programs-and-services/information-services-for-agribusiness-farmers-and-ranchers/crop-production-news/cpn-archives/crop-production-news---2016-issues/crop-production-news-2016-issue-8/2016-insect-summary

Investigating and Documenting a Suspected Bee Poisoning

If you have a question or concern regarding a suspected bee poisoning incident, contact the appropriate federal or provincial authority. Provide photos or videos of the incident, notes describing the previous health of the colony, prevailing winds, registrant name on the product label, product name, or active ingredients (from the pesticide label or search in app at https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/registrants-applicants/tools/pesticide-label-search.html), how you suspect the bees may have been exposed, pesticide treatments you have applied to the hives, and any other pertinent details. Preserve at least 56 grams (1/4 cup) of adult bees, brood, pollen, honey/nectar, or wax by immediately freezing in clearly labelled, clean containers, and ensure the samples stay dry and protected from light which can lead to the degradation of pesticides. This may be helpful if the incident is later determined to warrant laboratory analysis. It is also a good idea to have a sample of the affected bees as well as a sample from an unaffected apiary. In the event of enforcement action, some provinces will need to collect their own samples. Do not disturb the hives or site until the representative from your provinces lead office (listed below) has finished collecting information

- **Alberta (Ministry of Agriculture and Rural Development): 780-415-2314**
  https://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/prm13239/$FILE/2014-recommendations.pdf
- **British Columbia (Ministry of Agriculture): 604-556-3129**
  https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/animal-production/bees/beekeeping-bulletins
- **Manitoba (Ministry of Agriculture,): 204-945-4825/204-945-3861**
  http://web2.gov.mb.ca/laws/statutes/ccsm/b015e.php
- **New Brunswick (Department of Agriculture, Aquaculture and Fisheries): 506-453-2108**
  http://www.nbba.ca/page/3/
- **Newfoundland and Labrador (Department of Natural Resources): 709-637-2662**
  http://www.nlbeekeeping.ca/beekeepers-corner/research/
- **Nova Scotia (Department of Agriculture): 902-679-8998**
  https://nslegislature.ca/legc/bills/59th_1st/3rd_read/b173.htm
- **Ontario (Ontario Ministry of Food and Rural Affairs): 1-877-424-1300**
  http://www.omafra.gov.on.ca/english/food/inspection/bees/apicultu.html
- **Prince Edward Island (Department of Agriculture and Forestry): 902-314-0816**
  https://www.princeedwardisland.ca/sites/default/files/legislation/A%2611-1-2-Animal%20Health%20and%20Protection%20Act%20Bee%20Health%20Regulations.pdf
- **Québec (Ministère de l'Agriculture, des Pêcheries et de l'Alimentation): 1-844-ANIMAUX (1-844-264-6289)**
  http://legisquebec.gouv.qc.ca/en/ShowDoc/cs/A-1
- **Saskatchewan (Ministry of Agriculture): 306-953-2304**
  http://www.agriculture.gov.sk.ca/

Report a Bee Incident to Health Canada

Bee incidents can be reported by contacting Health Canada's Pest Management Regulatory Agency at 1-800-267-6315.If you know which product may have caused the bee poisoning, you can also notify the pesticide company, which is required by law to report adverse effects to Health Canada. See the "For More Information" section at the end of this document for a link to report a bee incident to Health Canada.

Causes of Bee Poisoning in Canada

Inattentive use of insecticides can result in bee poisoning at an individual level, as well as at a colony level, either by greater mortality or sublethal effects (e.g., foraging impairment). This is especially the case for insecticides that have residual toxicity longer than 8 hours. Herbicides generally are of lower toxicity to bees than insecticides; however, responsible use is encouraged as herbicides can decrease flower abundance, reducing bee forage adjacent to fields (see section on "Herbicides" page 20).

Some of the active ingredients in the following chemical families have residual toxicity longer than 8 hours:

- Organophosphates such as acephate, chlorpyrifos, diazinon, dimethoate, and malathion.
- N-methyl carbamates such as carbaryl.
- Neonicotinoids such as imidacloprid, thiamethoxam, and clothianidin.
- Pyrethroids such as deltamethrin, cyfluthrin, and lambda-cyhalothrin. Esfenvalerate and permethrin have been found to be repellent to bees when used under arid conditions reducing the potential for bee poisoning normally observed in more humid areas.

Bee poisoning incidents can occur when:

- Insecticides are applied when bees are actively foraging.
- Insecticides are applied to bee-pollinated crops during bloom.
- Insecticides are applied to blooming weeds in orchards or field margins.
- Insecticides drift onto blooming plants adjacent to target crops.
- Bees collect insecticide-contaminated nesting materials, such as leaf pieces collected by alfalfa leafcutter bees.
- Bees collect insecticide-contaminated water (from drip tape or chemigation, or standing water near sprayed fields).
- Foraging bees flying through aerial dust from insecticide treated seed or foliar application.
- Beekeepers and growers do not adequately communicate (See Case Study on page 27).

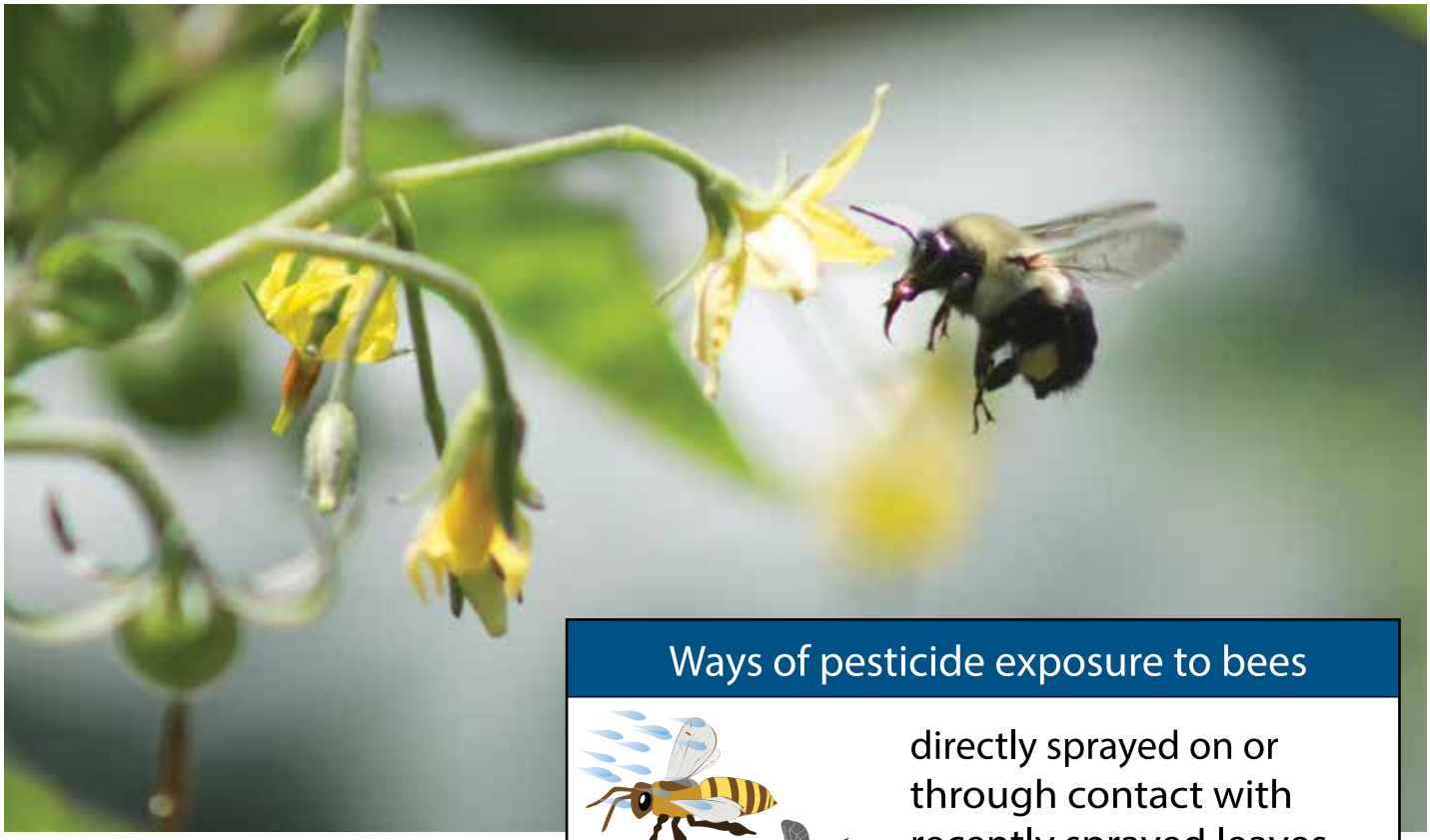
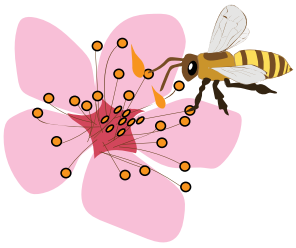


Figure 1
Ways bees can be exposed to pesticide contaminants.

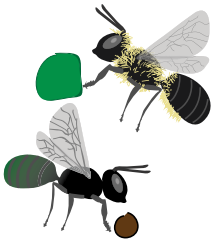
Courtesy Iris Kormann, Oregon State University

Ways of pesticide exposure to bees

directly sprayed on or through contact with recently sprayed leaves and flowers



consumption of contaminated pollen and nectar



contact with contaminated nesting material

effects on larvae through contaminated nectar, pollen and cell material

Signs and Symptoms of Bee Poisoning

A list of signs and symptoms of bee poisoning is given below. These signs and symptoms can be the result of inattentive use of pesticides, but some can also be a result of viruses or other diseases. Careful observation of individual bee and colony behaviour, as well as preserving samples for testing, can help determine the underlying causes. In some cases pesticide poisoning can be exacerbated when hive health is initially poor, emphasizing the importance of nutrition, water supply, and proper management practices by beekeepers to maintain the health of their colonies.

Signs and Symptoms that May Indicate Pesticide Poisoning in Honey Bees

- Excessive numbers of dead and dying honey bees in front of hives.
- Severe colony imbalance, large brood size with few bees.
- Lack of foraging bees on a normally attractive blooming crops.
- Stupefaction, paralysis, and abnormal jerky, wobbly, or rapid movements; spinning on the back.
- Forager disorientation and reduced foraging efficiency.
- Immobile, lethargic bees unable to leave flowers.
- Regurgitation of honey stomach contents and tongue extension.
- The appearance of "crawlers" (bees unable to fly). Bees move slowly as though they have been chilled.
- Dead brood, dead newly emerged workers, or abnormal queen behaviour, such as egg laying in a poor pattern.
- Queenless hives.
- Poor queen development in colonies used to produce queens, with adult worker bees unaffected.

Pesticide poisoning isn't always obvious and may be confused with other factors

- Delayed and chronic effects such as poor brood development are difficult to link to specific agrochemicals, but are possible when stored pollen, nectar, or wax comb become contaminated with pesticides. Severely weakened or queenless colonies may not survive the winter.
- Poisonous plants such as death camas (Zigadenus venenosus), cornlily (Veratrum viride), and spotted locoweed (Astragalus lentiginosus) can injure and occasionally kill bee colonies. Viral paralysis disease, starvation, winter kill, and chilled brood can cause symptoms that may be confused with bee poisoning. Beekeepers may request a laboratory analysis of dead bees to determine the cause of an incident. Provincial Departments of Agriculture or Health Canada investigate suspected bee poisoning incidents (see page 8 for contact information).

Honey bee recovery from pesticide poisoning

If a honey bee colony has lost many of its foragers, but has sufficient brood and adequate stores of uncontaminated pollen and honey, it may recover without any intervention. Move bees to a pesticide-free foraging area if possible. If sufficient forage is unavailable, feed them with sugar syrup and pollen substitute, and provide clean water to aid their recovery. Protect them from extremes of heat and cold, and if needed combine weak colonies.

If pollen or nectar stores are contaminated, brood and workers may continue to die until the colony is lost. Additionally, pesticides applied by beekeepers can accumulate in colonies. If there is a possibility that pesticides have transferred into the hive beeswax, consider replacing the comb with a new foundation, using comb from unaffected colonies, or shaking the bees into a new hive and destroying the old comb and woodenware. Replacing brood comb on a regular schedule (typically 2 to 5 years) may prevent accumulation of pesticides in brood comb wax, and is good practices for managing disease accumulation in comb.

Managed Bumble Bees and Solitary Bees

A distinctive sign of poisoning in alfalfa leafcutter bees is an unusually large number of dead males on the ground in front of a shelter, or a lack of nesting activity by the females. Female alfalfa leafcutter bees usually forage within a couple hundred meters of a field shelter, so the shelters closest to the source of the insecticide are more severely affected.

Managed bumble bees and managed solitary bees experience many of the same symptoms of pesticide exposures as honey bees. Bumble bee colonies are composed of fewer individuals than honey bees, and can be more sensitive to certain pesticides, as seen in **Table 4.**

Non-Managed Native Bees

Without a marked hive or nesting site, poisoning of wild bees can easily go unobserved. There is an increasing amount of research on risks of pesticides to native pollinators. Additional research is needed to fully understand the impact of factors such as habitat loss, diseases, climate change, and pesticides on native bee populations, some of which are showing large population declines, and are even going extinct.

Photo: Anthony Colangelo

Photo: Lisa Britz

Ways to Reduce Bee Poisoning

Many of the practices that reduce honey bee exposure to pesticides may also help to protect wild bees.

Beekeeper–Grower Cooperation

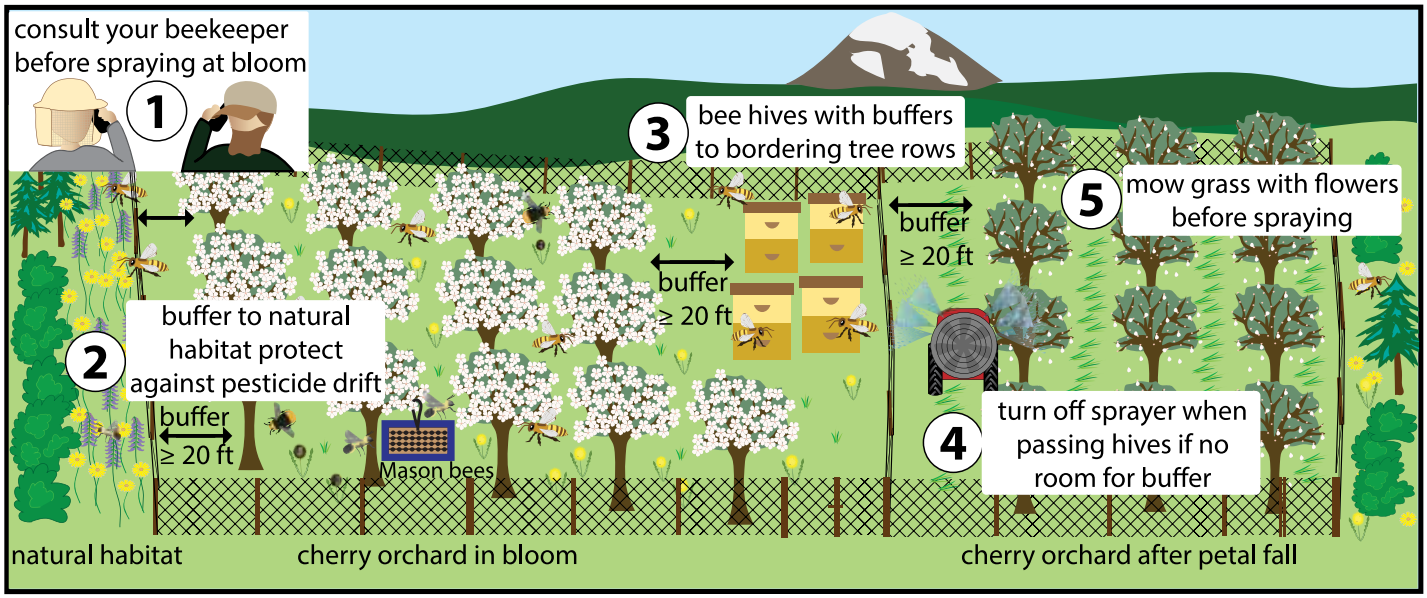
Beekeeper–grower cooperation is the most effective way to reduce bee poisoning; its importance cannot be overstated. The underlying cause of most bee poisoning incidents is a lack of information or awareness, rather than intent to do harm. Most pest control programs can be modified so that little or no bee poisoning occurs, without undue cost or inconvenience to the grower. Both beekeepers and growers benefit from developing working relationships and familiarizing themselves with each other's management practices.

See the **BeeConnected app** available for beekeepers and growers which creates an open platform for discussion and planning for bee protection in farmlands http://www.beeconnected.ca/

Discussions and contracts between growers and beekeepers should include:

- Coordination of crop timing with dates of apiary arrival and departure.
- Details of the beekeeper's responsibility to provide strong and effective colonies for crop pollination.
- Details of the grower's responsibility to safeguard bees from poisoning.
- Who is responsible for providing supplemental water and feed.
- Pest management practices in the cropping system before colonies are delivered.
- Pesticides to be used on a crop while bee colonies are present.
- Buffers between treated areas and apiaries.
- Informing neighboring growers and applicators of apiary locations.
- Possible pesticide use in adjacent crops.
- Location of honey bee colonies.
- Some provinces provide regional information on crop pests and spraying schedule (see **Table 2**. Provincial rules and resources to protect pollinators).

Cooperation



Ways beekeepers and growers can reduce bee poisoning by creating buffers between sprayed fields, colonies, and bee forage areas.

Courtesy Iris Kormann, Oregon State University.

What Pesticide Applicators Can Do to Protect Honey Bees

Hive Location

- Identify and confirm hive locations, and maintain appropriate buffers between treated areas and pollinator habitat. Check with your Provincial Ministry/Department of Agriculture for hives that might be located in your area and use the **BeeConnected app** http://www.beeconnected.ca/
- Be aware that there likely are more honey bee colonies than those you are currently aware of in any area. Honey bees have a large foraging range and bees can be present in the crop even if hives are located a few km away.

Product Selection and Use

- Select insecticides that have the lowest pollinator precaution levels whenever possible. The pollinator precaution level is based on the pollinator risk characterization (**Table 1**); the precaution level of insecticides/miticides and fungicides to bees is presented in **Table 4**.
- Be aware of other blooming crops or flowering weeds in the immediate vicinity when applying insecticides to a crop.
- If possible, choose a product with a short residual toxicity.
- Do not apply insecticides with long residual toxicity to bees onto blooming plants.
- Do not apply insecticides when unusually low temperatures or dew are forecast following treatment, as these conditions can extend residual times.
- Apply pesticides with residual toxicity when bees are not present or inactive. Bees generally forage during daylight hours and when temperatures exceed 13 – 18 °C, and may visit some crops at specific times of day. Application times may be specified by pesticide rules of individual provinces (see "Provincial rules to protect pollinators"). When abnormally high temperatures result in foraging activity earlier or later in the day than normal, adjust application times accordingly to avoid bee exposure.
- Be aware that tank mixing of insecticides and fungicides may result in synergistic effects, and there is little research on the effects of pesticides on bees when applied together.

Product Selection and Use continued

- Minimize spray drift. Verify that wind will not carry product in the direction of beehives, flowering weeds, adjacent habitat, or non-target crops. Choose sprayer and nozzle technologies designed to reduce drift and minimize droplets less than 150 microns, which drift farther. Turn off sprayers near water sources (ponds, irrigation ditches, or leaking irrigation pipes), when making turns, and at the ends of fields.
- Less drift occurs during ground application than aerial application. During aerial application, do not turn the aircraft or transport materials back and forth across hives, blooming fields, or water sources.
- Err on the side of caution and avoid spraying any pesticide near bee colonies and on flowering plants, whether or not the pesticide has a bee caution on the label.
- Inspect chemigation systems to verify that bees cannot access chemigation water.
- Choose the least hazardous insecticide formulation whenever possible (**Table 3**).

Communication

- It is generally impractical for beekeepers to cover or move hives during treatment, therefore it is encouraged that beekeepers and growers communicate and work together on the timing of pesticide application (see Case Studies).
- Download the BeeConnected app http://www.beeconnected.ca/ for locating hives in your area and for discussion with beekeepers.

Table 3

table 3

Pesticide formulations

Pesticide Formulation	Bee exposure	Special precautions
Microencapsulated, Wettable powder, Flowable	Particles similar in size to pollen, stick to bee hairs, and can be taken to hive and fed to brood	Avoid vapour drift by spraying during cool temperatures. Flowable or micro-encapsulated are mixed with water before they are applied. If formulation is not mixed with water, avoid weather conditions that increase drift of dust.
Emulsifiable concentrate	Direct spray and residues	Avoid vapour drift by spraying during cool temperatures.
Solution, Soluble powder	Direct spray and residues	Ultralow volume (ULV) formulations may be more hazardous than other liquid formulations. Chemigation drips or puddles may attract bees.
Seed treatment	Applied directly to seed. Minimal bee exposure expected.	Lubricants may cause abrasion and remove the seed treatment coating from the seed during planting and drift onto blooming crops, weeds, or adjacent habitat.
Granular	Applied to soil, honey bees do not pick up	Avoid applying near known nesting beds of ground nesting bees, such as digger and long-horned bees.

Premixes

Pre-mixed pesticide products contain multiple active ingredients. Refer to the pesticide label for bee precautions, or use **Table 4** to look up each active ingredient separately. When looking up active ingredients individually, use the most restrictive pollinator precaution regulations.

Formulation and Residual Toxicity

Many of the Residual Toxicity (RT) and Extended Residual Toxicity (ERT) values describing the length of time pesticides remain toxic to bees are from products existing in the 1970s and 1980s. Current products and formulations may have significantly different RTs from those listed in **Table 4**, and RT of products with the same active ingredient, but different formulation, may also differ.

Tank Mixing, Fungicides, Surfactants, and Adjuvants

Be aware that some active ingredients may become more toxic to bees when mixed with other active ingredients. For example, fungicides have been considered to have low toxicity towards bees, but fungicides such as propiconazole may increase the toxicity of lambda-cyhalothrin to bees. Bees can come into contact with both fungicides and insecticides when foraging on sprayed fields, and research on synergistic effects of fungicides and insecticides is increasing. Most surfactants and adjuvants have not been tested for potential effects on bees, nor have combinations of products that may be tank mixed before application.

In Canada, adjuvants can only be added to a tank mix if specifically required by one of the tank mix partner labels. If the label does not state that an adjuvant is required, it cannot be added to the tank mix.

Users of commercial class pest control products used for crop production are permitted to apply unlabelled tank mixes of registered pest control products, subject to the following conditions:

- Each tank mix partner is registered for use in Canada on the crop of interest, including genetically modified crops.
- The application timings of all tank mix partners are compatible with regards to crop and pest staging.
- Each tank mix partner is applied in accordance with its registered product label. In cases where information on the tank mix partner labels differs between them, the most restrictive directions must be followed.

- The tank mix is not specifically excluded or contra-indicated on either tank mix partner label.
- The use of the tank mix provides additional value to the user (for example, increased scope of pests controlled, contributes to resistance management or integrated pest management, cost- or time-savings).

See the "For More Information" section at the end of this document for information on incident reporting, recalls and alerts, new cosmetic notifications, product safety education and consumer product requirements.

Herbicides

Herbicides target unwanted plants and generally are considered to have negligible direct effects on bees. However, more recent research, on glyphosate herbicides show mixed results; some studies show little or no effect on honey bees, while others indicate that they can reduce bees' ability to find nectar and pollen, or locate their hive. Wide use of broad-spectrum herbicides can remove weeds and flowers from landscapes; however, it can also reduce important nectar and pollen sources for bees.

Other Considerations

- Avoid selecting for resistance or cross-resistance by repeated application within the crop cycle, or year after year, of the same insecticide or related products with in same Mode of Action (MoA) class http://www.irac-online.org/modes-of-action/
- Bees are temporarily inactivated by direct contact with oil sprays, even when no toxic materials are used. Some deaths may occur.
- Do not apply insecticides during warm evenings when honey bees are clustered on the outside of the hives.
- Be aware that bee-toxic soil fumigants could harm ground nesting bees, even when they are dormant.

What Growers Can Do to Protect Honey Bees

Planning and Scheduling

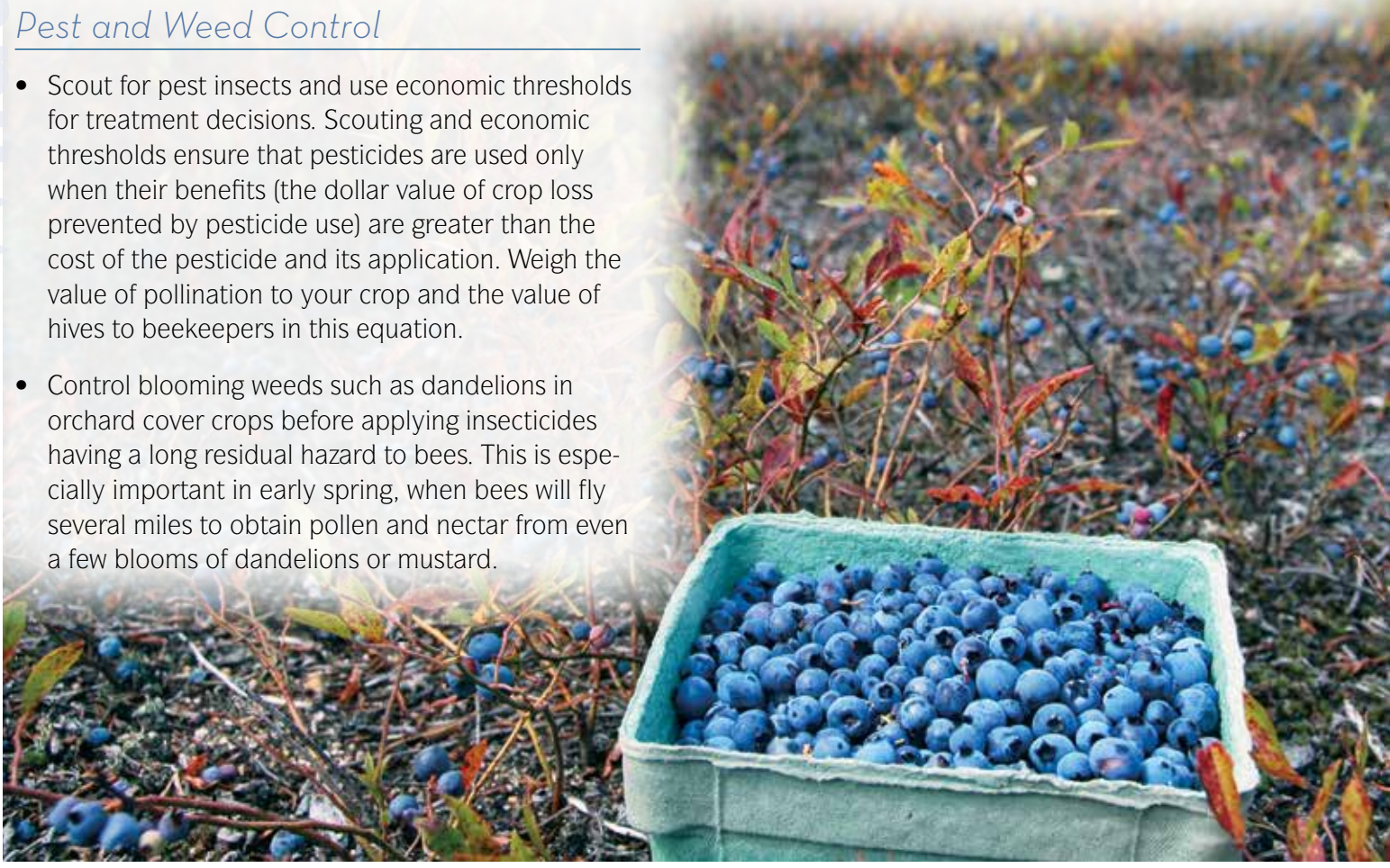
- Learn the pollination requirements of your crops, and if (and when) they are attractive to bees. Plan your pest control operations with bee hazards in mind.
- Consider your spray schedule and the establishment of no-spray buffers when coordinating apiary placement with beekeepers.
- Tell the beekeeper what was sprayed before the scheduled arrival, and what pesticides, if any, will be applied while bees are present.
- Avoid spraying crops when bees are foraging during daylight hours, or when crops are flowering.
- Keep track of weather patterns including wind, precipitation, humidity, and daily temperatures to avoid any unintentional pesticide drift to bee foraging areas nearby.

Pest and Weed Control

- Scout for pest insects and use economic thresholds for treatment decisions. Scouting and economic thresholds ensure that pesticides are used only when their benefits (the dollar value of crop loss prevented by pesticide use) are greater than the cost of the pesticide and its application. Weigh the value of pollination to your crop and the value of hives to beekeepers in this equation.
- Control blooming weeds such as dandelions in orchard cover crops before applying insecticides having a long residual hazard to bees. This is especially important in early spring, when bees will fly several miles to obtain pollen and nectar from even a few blooms of dandelions or mustard.

Considerations

- Consider non-chemical pest control, such as beneficial insects and other cultural practices (such as crop rotation and planting resistant varieties), for long-term control of insect pests. Details of Integrated Pest Management (IPM) practices can be found at https://ipmcouncilcanada.org/ and http://www.agr.gc.ca/eng/?id=1288805416537
- Use the BeeConnected App to locate hives near your fields www.beeconnected.ca
- Look into programs that support planting forage and habitat areas on your farm for honey bees, other pollinators, and other beneficial insects such as Operation Pollinator (https://www.syngenta.ca/commitments/operation-pollinator/), Bees Matter (http://www.beesmatter.ca/), or build your own bee habitat using Pollinator Partnership's Ecoregional Planting Guides or the Canadian Honey Bee Forage Guide (http://pollinator.org/canada#Resources).



What Beekeepers Can Do to Protect Honey Bees

Communication and Registration

- Do not leave unmarked colonies of bees near orchards or fields. Post the beekeeper's name, address, and phone number on apiaries, large enough to be read at a distance.
- Register your colonies with your Provincial Ministry/ Department of Agriculture. You can notify pesticide applicators of the location of your apiaries using the **BeeConnected app** http://www.beeconnected.ca/. Non-agricultural applicators may also need to know the location of your apiaries (e.g. mosquito abatement programs).
- Communicate clearly to the grower and/or applicator where your colonies are located, when they will arrive, and when you will remove them.
- Ask the grower what pesticides, if any, will be applied while bees are in the field, and whether the label includes precautionary statements for bees.

Pest Control

- Learn about pest control problems and programs to develop mutually beneficial agreements with growers concerning pollination services and prudent use of insecticides. Seek information on major crop pests and treatment options for your region (also see **Table 2** for provincial links).
- Miticides, such as those used for varroa control, are pesticides too. Use care when controlling pests in and around bee hives, apiaries, and beekeeping storage facilities. Use insecticides for their intended use and follow all label directions carefully. Regularly replacing brood comb to reduce exposure to residual miticides.

Protecting Honey bees from Contamination

- If it is not feasible to move your colonies prior to a pesticide application, protect honey bee colonies by covering them with wet burlap the night before a crop is treated with a hazardous insecticide. Keep these covers wet and in place as long as feasible (depending on residual toxicity of pesticide) to protect bees.
- Do not return colonies to fields treated with insecticides that are highly toxic to bees until at least 48 to 72 hours after application. Bee deaths are most likely to occur during the first 24 hours following application (**Table 4**).
- If practical, isolate apiaries from intensive insecticide applications and protect them from chemical drift. Establish holding yards for honey bee colonies at least 4 miles from crops being treated with insecticides that are highly toxic to bees.
- Place colonies on ridge tops rather than in depressions. Insecticides drift down into low-lying areas and flow with morning wind currents. Inversion conditions are particularly hazardous.
- Verify that a clean source of water is available for bees, and if there is not one available, provide one.
- Feed bees when nectar is scarce to prevent long-distance foraging to treated crops.
- In pesticide risk-prone areas inspect behaviour of bees often to recognize problems early.


Photo: Anthony Colangelo

What Pesticide Applicators, Growers, and Keepers of Managed Bumble Bees, Alfalfa Leafcutter, and Orchard Mason Bees Can Do

- It is generally not feasible to move non-Apis bees from a field. Plan pest control strategies early to avoid applying bee-toxic chemicals during crop pollination periods, and apply only those with low toxicity and short residual times, after bees cease foraging at night.
- Bumble bee, alfalfa leafcutter bee, and mason bee shelters can be constructed so that they can be covered or closed for night applications of pesticides. When bees are not active, the developing bees inside the tubes or hive are protected.
- Do not place alfalfa leafcutter bee nest shelters into fields until at least 1 week after treatment with chlorpyrifos (Lorsban), dimethoate (Cygon), and malathion.
- Notes may be found in **Table 4** if it is currently known that greater precautions are needed for managed solitary bees or managed bumble bees than for honey bees.

Photo: Anthony Colangelo

What Growers and Pesticide Applicators Can Do to Protect Non-Managed Native Bees, Including Bumble Bees

Native bee species are increasingly recognized as being important to the contribution of agricultural pollination. In addition, they are keystone species in natural ecosystems. Where sufficient habitat is available, relative to crop field size, wild native bees can provide all of the pollination services needed for some crops. These unmanaged pollinators are an on-site natural resource, and unlike honey bees, cannot be moved from the field when pesticides are used. In fact, many ground-nesting species, such as squash bees, long-horned bees, mining bees and sweat bees, sometimes construct their nests in crop fields. To protect these bees, ensure that drifting pesticides are minimized to reduce contact with adjacent habitat, even when crops or wildflowers are not in bloom. Scout crop fields and protect ground nests of solitary bees and bumble bees from insecticide spray. Providing habitat, areas with nesting opportunities and floral resources, is a great way to help native and managed pollinators. Visit the Pollinator Partnership webpage to learn more about conserving a variety of insect pollinators: www.pollinator.org.

To protect and help wild native bees:

- Provide nesting sites. Approximately 70 percent of native bees are ground nesters, burrowing into areas of well-drained, bare, or partially vegetated soil. Most other species nest in abandoned beetle galleries in snags or in soft-centered, hollow twigs and plant stems. Bumble bees nest in ground cavities such as old mouse burrows, at the ground surface under grass tussocks, or in elevated cavities such as hollows in trees.
- Provide habitat with pollen and nectar sources away from treated crops. Blooms of any type, including weedy species, may provide pollen and nectar. However, it is important not to plant, and to remove, weeds that are noxious. These habitat areas can benefit managed bees as well.
- Find programs that support habitat creation such as Operation Pollinator (https://www.syngenta.ca/commitments/operation-pollinator/), Bees Matter (http://www.beesmatter.ca/), or build your own bee friendly habitat using Pollinator Partnership's Ecoregional Planting Guides or the Canadian Honey Bee Forage Guide (http://pollinator.org/canada#Resources)
- Do not apply insecticides or minimize drift to adjacent wild land or fence rows, particularly around red clover, cranberry, or other berry crops. These areas provide nest sites for bumble bees, which are important pollinators for these crops.
- Scout for bees on crops, and for ground nests of solitary bees (e.g. squash bees, long-horned bees, sweat bees, and mining bees) and bumble bees. Protect nest areas from insecticide spray.
- Notes may be found in **Table 4** if it is currently known that greater precautions are needed for bumble bees or solitary bees than for honey bees.

case studies

CASE STUDY 1

Communication Protects Colonies

I have learned over the decades that prevention of bee poisoning is most effective through beekeeper – grower networking prior to colony placement. Incidences of bee poisoning most often occur when growers next to, or near apiaries are not aware of the colonies. To remedy a case of poisoning after the fact most often leads to failure. Even when the source of poisoning is known, the application may have been within approved label use. I recall cases of large-scale bee poisonings in southern Alberta in the early 1980s when alfalfa growers often needed to apply Furadan on short notice to control explosive aphid populations. Beekeepers often experienced significant losses through outright colony deaths and colonies weakened to the point that they were no longer viable production units. In response, beekeepers developed a phone number network (at the time, there were no such thing as cell phones!) with growers and pesticide applicators so that beekeepers could be alerted. Bee poisoning incidences stopped almost overnight! It proved that a beekeeper-initiated alert system does pay off. Beekeepers need to be proactive rather than reactive to poisoning issues. Prevention is the key and with today's convenience of cell phones, and new apps that allow beekeepers and growers to connect [See the **BeeConnected App** at http://www.beeconnected.ca/], most bee poisonings can be averted.

Paul van Westendorp, Provincial Apiculturist, British Columbia

CASE STUDY 2

Communication in Many Forms Benefits Bees

In addition to the BeeConnected App promotion campaign between the Manitoba Aerial Applicators Association (MAAA) and the Manitoba Beekeepers Association (MBA), some of the other activities done to improve communication between growers and beekeepers has been to publish articles and notices in growers newsletters such as those of commodity groups like Manitoba Corn Growers, Keystone Agricultural Producers and Canola Council of Canada, talking about the importance of pollinators and the beekeeping industry for agriculture. In the past, Manitoba Agriculture has set up demonstration hives at variety trial sites and spoken at their field days about protecting pollinators. Nationally, there is a Bee Health Roundtable (BHRT) that is made up of a larger diversity of stakeholders of which grower groups play a very active role. Initially the role of the BHRT was to identify strategies to avoid negative interactions between agricultural pest management and bee poisoning, but it also evolved into "how do we make the bees healthy again"? In most cases, developing and adopting Best Management Practices (BMPs) to minimize bee exposure to pesticides, promoting pollinator friendly plantings, and improving bee health in general has been the principal focus areas.

Rheal Lafreniere, Provincial Apiarist, Manitoba

Sources of Uncertainty in Toxicity of Pesticides to Bees

Canada has a robust and comprehensive pesticide risk characterization protocol which informs pollinator precautions, and use restrictions. These risk characterizations and label restrictions help prevent harm to bees. However, it is important to note that there are some uncertainties in effects of pesticides on bees.

- Current risk assessment procedures do not consider all routes of pesticide exposure or differences in toxicity of pesticides to non-Apis bees. For example, leafcutter bees could have greater exposure to pesticides than honey bees through leaf cuttings, and ground nesting bees from pesticides in soils.
- Non-active ingredients are not considered in toxicity testing on bees. However, there is indication that some inert ingredients can negatively impact bee health.
- Once brought into the hive with pollen or nectar, or applied by beekeepers, it is generally unknown how long pesticides persist in hive materials. Pesticides can accumulate in beeswax, and some studies indicate behaviour, development, and longevity are affected by such contamination.
- Colonies may be exposed to one pesticide, moved to a new cropping system, and then exposed to a second pesticide. Therefore, research is needed to understand potential additive, synergistic, chronic or delayed effects from multiple sources and types of exposures.
- Fungicides have traditionally not been thought to affect bees. However, there is some research demonstrating that certain fungicides impact brood development and may increase toxicity of some insecticides when they are used in combination.
- When tank mixed, some pesticides have been shown to be more toxic to bees together than individually, while others have not been observed to have a negative synergistic effect. Research is being conducted on the use and safety of tank mixes.

Photo: Anthony Colangelo

Using Table 4

In **Table 4**, pesticide active ingredients are listed alphabetically, within pesticide categories of 1. insecticide/miticide and 2. fungicides. There is an 'others' section listed at the end of the table which includes all pesticides that do not fall into the aforementioned categories. Each active ingredient has been classified using PMRA Pollinator Precaution Levels (**Table 1**): 'Most restrictive pollinator precaution', 'Moderately restrictive pollinator precaution', and 'Least restrictive pollinator precaution'. A question mark (X?) indicates that although there is no pollinator precaution statement on the label, some research has identified potential for harm, and/or research is pending, or needed.

Many pre-mixed products have entered the market containing multiple active ingredients. Refer to the pesticide label for pollinator precautions, or use **Table 4** to look up each active ingredient separately.

If residual time to 25% mortality (RT_{25}) is known, from field research of representative products, it is noted in the RT_{25} column. RT information has been synthesized from a variety of sources including the Oregon State University extension document 'How to reduce bee poisoning from pesticides', the Canadian Western Committee on Crop Pests document: 'Hazards and safeguards in applying insecticides to crops in bloom', and from the US EPA RT_{25} data found here: https://www.epa.gov/pollinator-protection/residual-time-25-bee-mortality-rt25-data. RT data only represents acute contact, foliar tests for honey bees, and does not encompass the full range of risk characterization. RT can vary with formulation and application rate (usually crop specific), and typically has been calculated only for honey bees. In some cases studies have been conducted on other managed bees, including alfalfa leafcutting bees and bumble bees. ***In many cases, RT is based on products existing in the 1970s and 1980s. Current products and formulations may have significantly different RT from those listed.***

In addition to formulation and application rate, the actual hazard to bees may be affected by many other factors, as discussed in the text. Further information, including special precautions for non-Apis species, and pertinent research are included in the column titled "Additional Information [where available]". Also note that the pesticide mode of action (MoA) needs to be considered as part of an overall crop rotation plan in order to avoid products from becoming ineffective due to resistance. Information for MoA can be found here: http://www.irac-online.org/modes-of-action/

Pollinator Partnership Canada, Agriculture and Agri-Food Canada (AAFC) on behalf of the Bee Health Roundtable neither endorse these products nor intend to discriminate against products not mentioned. Some of the pesticides listed may not be registered for use in your province, or may not be registered for use on your crop. It is the user's responsibility to check the registration status of any material, and any provincial restrictions, before using it. In addition to using this table to look up pollinator precaution levels, the PMRA has a tool called the 'Pesticide Label Search' which allows the user to either download an app to access product labels from their mobile device, or to use the online label search tool https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/registrants-applicants/tools/pesticide-label-search.html

Table 4

Active ingredients of commonly used pesticides in Canada and the corresponding pollinator precaution levels based on PMRA risk characterization framework described in **Table 1**. Active ingredients frequently change and new information may change its precaution level, refer to PMRA for the most current information.

Key to abbreviations used in Table 4

RT **Residual Time**.
The length of time the residues of the product remain toxic to bees after application.

ERT **Extended Residual Toxicity**.
Residues are expected to cause at least 25% mortality for longer than 8 hours after application.

> **Greater than**

≥ **Greater than or equal to**

< **Less than**

≤ **Less than or equal to**

ACTIVE INGREDIENT	Most Restrictive Pollinator Precaution	Moderately Restrictive Pollinator Precaution	Least Restrictive Pollinator Precaution	RT_{25} (< 24 hours – hours; > 24 hours – days)	Additional Information (where available)
INSECTICIDES / MITICIDES					
Abamectin *Avermectin insecticide/miticide*	X			0.025 lb ai/acre (11.3 g ai/acre) 1–3 days; ≤ 0.025 lb ai/acre (11.3 g ai/acre) 8 hours [1] 0.1 lb ai/acre (45.4 g ai/acre) < 2 days; ≤ 0.003 lb ai/tree (1.36 g ai/acre) < 8 hours [2]	ERT to bumble bees [3], short RT to alfalfa leafcutting bees 0.025 lb ai/acre (11.3 g ai/acre) [1].
Acephate *Organophosphate insecticide*	X			> 3 days[1] 2.5–> 3 [28]	ERT to alfalfa leafcutting bees [1].
Acequinocyl *Acequinocyl insecticide/miticide*			X	None	
Acetamiprid *Neonicotinoid insecticide*		X		< 1 day [28]	Length of residual toxicity to honey bees is unknown. ERT to alfalfa leafcutting bees [4]. 2 day ERT to bumble bees [3]. Cyano group neonicotinoids exhibit lower toxicity to bees than nitro group neonicotinoids [5].
Azadirachtin *Systemic insecticide – extract of neem oil*	X			< 2 hours [1, 28]	Must be ingested to be toxic [6]. Toxic to bee brood [7].
Bacillus thuringiensis, var. kurstaki *Bt microbials, bio-insecticide*			X	None	

ACTIVE INGREDIENT	Most Restrictive Pollinator Precaution	Moderately Restrictive Pollinator Precaution	Least Restrictive Pollinator Precaution	RT_{25} (< 24 hours – hours; > 24 hours – days)	Additional Information (where available)
Bacillus thuringiensis, var. israelensis *Bt microbials, bio-insecticide*			X	None	
Bacillus thuringiensis, var. aizawai *Bt microbials, bio-insecticide*		X		–	
Beauveria bassiana *Bio-insecticide*		X		–	Potentially pathogenic to honey bees (per Balence label), and laboratory studies suggest effects on bumble bees [8].
Bifenazate *Bifenazate miticide/acaricide*		X		0.733 lb ai/acre (332 g ai/acre) < 3 hours [2, 28]	
Bifenthrin *Pyrethroid insecticide*	X			> 0.06 lb ai/acre (27.2 g ai/acre) > 1 day ≤ 0.04 lb ai/acre (18.1 g ai/acre) 4–6 hours [1]	≤ 0.032 lb ai/acre (14.5 g ai/acre): 4–6 hours RT toxicity for alfalfa leafcutting bees [1].
Buprofezin *Insect growth regulator*			X	–	
Carbaryl *Carbamate insecticide*	X			0.25 – 2 lb ai/acre (113 – 907 g ai/acre) > 1.5 days [2] > 1–7 days [28]	Hazardous if applied to blooming trees as a blossom-thinning agent [1]. Carbaryl has ERT to alfalfa leafcutting bees [1] and bumble bees [3].
Chlorantraniliprole *Diamide insecticide*		X		0.1 lb ai/acre (45 g ai/acre) < 3 hours [2]	No impact on bumble bees [9].
Chlorfenapyr *Pyrrole insecticide/miticide*	X			< 4 hours [1] 0.34 lb ai/acre (154 g ai/acre) < 3 hours [2] Foraging behaviour may be affected > 2 days [10]	8 hour ERT for alfalfa leafcutting bees [1]. Residues on plants or soil may harm bees and other beneficial insects used in greenhouse production [7].
Chlorpyrifos *Organophosphate insecticide*	X			2–6 days [28] 1 lb ai/acre (454 g ai/acre) > 1 day; 0.25 lb ai/acre (113 g ai/acre) 16 hours [2]	Up to 7 day ERT for alfalfa leafcutting bees [1]. Common contaminant of beeswax [11]. > 24 hours RT at 0.25 lb ai / acre (113 g ai/acre) for alfalfa leafcutting bees [2].
Cinnamon oil (*Cassia*) *Bio-mycoinsecticide*		X		–	
Clofentezine *Clofentezine miticde; Mite growth inhibitor*			X	–	

ACTIVE INGREDIENT	Most Restrictive Pollinator Precaution	Moderately Restrictive Pollinator Precaution	Least Restrictive Pollinator Precaution	RT_{25} (< 24 hours – hours; > 24 hours – days)	Additional Information (where available)
Clothianidin *Neonicotinoid insecticide*	X			0.198 lb ai/acre (90 g ai/acre) 21 days; 0.066 lb ai/acre (30 g ai/acre) 4.6 days [11] > 3 days [28]	Dust from planting seeds coated with neonicotinoids has been associated with colony losses [3].
Cyantraniliprole *Diamide insecticide*		X		–	
Cyclaniliprole *Diamide insecticide*	X				
Cydia pomonella granulovirus *Bio-insecticide*			X	None	
Cyflumetofen *Beta-ketonitrile derivative miticide*			X	–	
Cypermethrin *Pyrethroid insecticide*	X			> 0.025 lb ai/acre (11 g ai/acre) > 3 days; < 0.025 lb ai/acre (11 g ai/acre) < 2 hours [1] 0.06 – 0.14 lb ai/acre (27.2 – 63.5g ai/acre) > 4 days [2]	
Cyromazine *Cyromazine insecticide; insect growth regulator*		X		< 2 hours [1] < 1 day [28]	> 1 day ERT for alfalfa leafcutting bees [1], short RT for bumble bees [3].
Deltamethrin *Pyrethroid insecticide*		X		< 4 hours [1] 0.02 lb ai/acre (9 g ai/acre) 5.2 hours [2]	< 8 hours RT for alfalfa leafcutting bees [1]. Formulated products may have a repellent effect lasting 2–3 hours [6]. 2 days ERT for bumble bees [3].
Diazinon *Organophosphate insecticide*	X			2 days [1] 0.5 – 1 lb ai/acre (227 – 454 g ai/acre) > 1.5 days; 0.125–0.25 lb ai/acre (57 – 113 g ai/acre) < 1.5 days [2]	ERT for alfalfa leafcutting bees [1].
Dimethoate *Organophosphate insecticide*	X			Up to 3 days [1] 1–3.5 days [12] 0.5 lb ai/acre (227 g ai/acre) < 5 days [2] 3 – 7 days [28]	ERT to alfalfa leafcutting bees [1]. Do not place alfalfa leafcutting bee nest shelters into fields until at least 1 week after treatment [3].

ACTIVE INGREDIENT	Most Restrictive Pollinator Precaution	Moderately Restrictive Pollinator Precaution	Least Restrictive Pollinator Precaution	RT_{25} (< 24 hours – hours; > 24 hours – days)	Additional Information (where available)
Etoxazole *Oxazoline insecticide/acaricide,*		X		–	3 days ERT for bumble bees [3]. Greenhouse use only. Toxic to immature beneficial arthropods. Not acutely toxic to adult bees but may affect reproduction and development [7].
Fenbutatin-oxide *Organotin miticide*			X	0.4375 –1.75 lb ai/acre (198 – 794 g ai/acre) < 3 hours [2]	Greenhouse use only [7].
Fenpyroximate *METI acaricide/insecticide*			X	–	
Flonicamid *Flonicamid insecticide*			X?	< 1 day	Possible effects on honey bees, further research needed [13]. Short RT for alfalfa leafcutting bees [4]. Short RT for bumble bees [3].
Flupyradifurone *Butenolide insecticide*		X		–	Toxic to adult bees in laboratory studies via oral exposure, however, not toxic to bees through contact exposure, and field studies conducted with this product have shown no effects on honeybee colony development (Sivanto Prime Label) [7].
Fluvalinate *Pyrethroid miticide*		X		< 2 hours [1] ½ day [12]	Ubiquitous contaminant of beeswax [11]. Fluvalinate is used to manage varroa mites in honey bee colonies.
Horticultural/Mineral oil *Refined paraffinic oils used as insecticide*		X		< 3 hours [1] < 1 day [28]	Although no pollinator precaution on label, some toxicity observed in field studies [1].
Imidacloprid *Neonicotinoid insecticide*	X			0.25 lb ai/acre (113 g ai/acre) > 1 day; 0.1 lb ai/acre (45 g ai/acre) < 8 hours [1] 0.045 – 0.167 lb ai/acre (20 – 76 g ai/acre) < 2 hours [2] < 1 – > 1 day [28]	Bumble bees may be more sensitive to imidacloprid than honey bees [15].
***lambda*-Cyhalothrin** *Pyrethroid insecticide*		X		> 1 day [1, 28] > 7 days [10] (encapsulated) 0.031 lb ai/acre (14 g ai/acre) 2 days; 0.013 lb ai/acre (6 g ai/acre) 22 hours [2]	May be more toxic to bees when mixed with propiconazole. > 1 day ERT for alfalfa leafcutting bees [1].

ACTIVE INGREDIENT	Most Restrictive Pollinator Precaution	Moderately Restrictive Pollinator Precaution	Least Restrictive Pollinator Precaution	RT_{25} (< 24 hours – hours; > 24 hours – days)	Additional Information (where available)
Malathion *Organophosphate insecticide*	X			Malathion ULV, ≥8 fl oz ai/acre (227 ml ai/acre) 5.5 days, ≤3 fl oz ai/acre (85.2 ml ai/acre) 3 hours; Malathion WP 2 days; Malathion EC 2–6 hours [1] < 1 – 7 days [28] 1.6 lb ai/acre (726 g ai/acre) < 24 hours [2]	Up to 7 days ERT for alfalfa leafcutting bees [1].
Metarhizium anisopliae *Bio-insecticide*			X	–	
Methomyl *Carbamate insecticide*	X			2 hours [1] 1.5 days [12] < 1 –1.5 days [28]	Up to 15 hours ERT for alfalfa leafcutting bees, depending on application rate. More hazardous to bees in a humid climate [1]. 3 days ERT for bumble bees [3].
Methoxyfenozide *Diacylhydrazine insecticide*			X	< 1 day [1]	
Naled *Organophosphate insecticide*	X			1 lb ai/acre (454 g ai/acre) 12–20 hours; 0.5 ai/acre (227 g ai/acre) 2 hours [1] 1–1.5 days [12] < 1 – 4.5 days [28]	Up to 4.5 days ERT for alfalfa leafcutting bees [1].
Novaluron *Benzoylurea insecticide; insect growth regulator*		X		1 day [28]	Length of residual toxicity to honey bees unknown. Effects on egg hatch and larval development in alfalfa leafcutting bees [16]. Effects on brood development and colony strength in honey bees [17]. 3 days ERT for bumble bees [3].
Permethrin *Pyrethroid insecticide*	X			0.5 to 2 days [1] > 5 days [12] < 1 – 5 days [28]	Up to 3 days ERT for alfalfa leafcutting bees. May be repellent in arid conditions [1].
Petroleum/Paraffinic oil *Refined paraffinic oils used as insecticides*		X		< 3 hours [1]	
Phosmet *Organophosphate insecticide*	X			> 3 days [1] 1 – 5 days [28] 1 lb ai/acre (454 g ai/acre) > 1 day [2]	Up to 5 days ERT for alfalfa leafcutting bees [1]. 2–3 days ERT for bumble bees [3].

ACTIVE INGREDIENT	Most Restrictive Pollinator Precaution	Moderately Restrictive Pollinator Precaution	Least Restrictive Pollinator Precaution	RT_{25} (< 24 hours – hours; > 24 hours – days)	Additional Information (where available)
Piperonyl butoxide *Synergist for insecticides*			X	< 3 hours [2]	Low toxicity alone, increases the toxicity of insecticides by blocking cytochrome P450 activity.
Potassium salts of fatty acids *aka insecticidal soap*			X	–	
Pymetrozine *Pyridine azomethine derivative insecticide*		X		< 24 hours [28]	
Pyridaben *METI miticide/insecticide*	X			< 2 hours [1] < 24 hours [28] 0.5 lb ai/acre (227 g ai/acre) 20 hours [2]	> 8 hours ERT for alfalfa leafcutting bees [1]. 1 day ERT for bumble bees [3].
Pyriproxyfen *Pyriproxyfen insecticide; insect growth regulator*			X?	< 24 hours [28]	< 2 hours RT for alfalfa leafcutting bees [1]. May be toxic to bumble bee brood [18].
Spinetoram *Spinosyn insecticide, affects nerve action*	X			3 hours [1] 0.109 lb ai/acre (49 g ai/acre) < 3 hours [2]	
Spinosad *Spinosyn insecticide*	X			3 hours [1] to 1 day [10] < 24 hours – > 1 day [28] 0.16 lb ai/acre (73 g ai/acre) < 3 hours [2]	> 1 day ERT for alfalfa leafcutting bees [1].
Spirodiclofen *Tetronic and Tetramic acid derivative; insect growth regulator*	X			1 day [28]	Toxic to bee brood [7].
Spiromesifen *Tetronic and Tetramic acid derivative; insect growth regulator*		X		–	May be toxic to bee brood [7].
Spirotetramat *Tetronic and Tetramic acid derivative; insect growth regulator*	X			–	Length of residual toxicity to honey bees unknown. 1 day ERT for bumble bees [3]. Toxic to bee brood [7].
Sulfoxaflor *Sulfoximine insecticide*	X			3 hours [1]	
Sulphur *Naturally occurring element containing compounds of unknown or uncertain MoA*			X?	–	While most sources say sulphur poses little risk for bees, other sources suggest sulphur may cause toxicity for bees for up to a day and a half [20].
Tebufenozide *Diacylhydrazine insecticide; insect growth regulator*			X	< 24 hours [28]	

ACTIVE INGREDIENT	Most Restrictive Pollinator Precaution	Moderately Restrictive Pollinator Precaution	Least Restrictive Pollinator Precaution	RT_{25} (< 24 hours – hours; > 24 hours – days)	Additional Information (where available)
Thiacloprid *Neonicotinoid insecticide*		X		0.16 lb ai/acre (73 g ai/acre) < 2 hours [2]	Less toxic to bees than most other neonicotinoids [5]. 1–2 days ERT for bumble bees [3].
Thiamethoxam *Neonicotinoid insecticide (nitro group)*	X			7–14 days [1, 28] 0.088 lb ai/acre (40 g ai/acre) > 3 days; 0.004lb ai/acre (2 g ai/acre) < 24 hours [2]	Documented incidents have demonstrated some degree of hazard with these treatments [13, 14].
FUNGICIDES					
Ametoctradin *Triazolo-pyrimidylamine fungicide*			X		
Aureobasidium pullulans *Bio-fungicide*			X		
Bacillus amyloliquefaciens *Microbial disruptor bio-fungicide*			X		
Bacillus mycoides isolate J *Bacillus cereus bio-fungicide*		X			
Bacillus subtilis *Microbial disruptor bio-fungicide derived from naturally occurring soil bacterium*			X		Laboratory tests suggest potential effects on bumble bees [8].
Benzovindiflupyr *Pyrazole-4-carboxamide fungicide*			X		
Bicarbonate *Fungicide*			X		
BLAD polypeptide *Polypeptide (lectin) fungicide*			X		
Boscalid *Pyrazole-4-carboxamide fungicide*			X		Boscalid will also increase the toxicity of insecticide seed treatments to honey bees [19].
Calcium polysulphide *Inorganic fungicide*			X		
Captan *Phthalimide fungicide*			X		Up to 7 day ERT for mason bees [1]. Effects on honey bee brood in laboratory, but not in field tests [21 – 23].
Carbathiin *Carboxamide fungicide*			X		
Chlorothalonil *Chloronitrile fungicide*			X		Common contaminant of beeswax [11].
Citric acid *Lacto-fermented fungicide and bactericide*			X		
Coniothyrium minitans *Bio-fungicide*			X		
Copper hydroxide *Inorganic fungicide/bactericide*			X		

ACTIVE INGREDIENT	Most Restrictive Pollinator Precaution	Moderately Restrictive Pollinator Precaution	Least Restrictive Pollinator Precaution	RT_{25} (< 24 hours – hours; > 24 hours – days)	Additional Information (where available)
Copper octanoate *Inorganic fungicide/bactericide*			X		
Copper oxychloride *Inorganic fungicide/bactericide*			X		
Copper sulphate, tri-basic *Inorganic fungicide/bactericide*			X?		Other sources indicate that this pesticide can be applied at any time with reasonable safety to bees [24].
Cyazofamid *Cyano-imidazole fungicide*			X		
Cymoxanil *Cyanoacetamide oxime fungicide*			X		
Cyprodinil *Anilino-pyrimidine fungicide*			X		No impact on bumble bees [9].
Difenoconazole *Triazole fungicide*			X		Potential effects on learning in honey bees [25].
Dimethomorph *Cinnamic acid amide fungicide*			X		
Dodine *Guanidine fungicide*			X		
Ethaboxam *Thiiazole carboxamide fungicide*			X		
Famoxadone *Oxazolidine dione fungicide*			X		
Fenamidone *Imidazolinone fungicide*			X		
Fenbuconazole *Triazole fungicide*			X		
Fenhexamid *Hydroxyanilidine fungicide*			X		
Ferbam *Dithio-carbamate fungicide*			X		
Fluazinam *2,6-dinitro-aniline fungicide*			X		
Fludioxonil Phenylpyrrole fungicide			X		No impact on bumble bees [9].
Fluopicolide *Pyridinylmethyl-benzamides fungicide*			X		
Fluopyram *Pyridinyl-ethyl-benzamide fungicide*			X		
Fluoxastrobin *dihydro-dioxazine fungicide*			X?		
Flutriafol *Triazole fungicide*			X		
Fluxapyroxad *Pyrazole-4- carboxamide fungicide*			X		
Folpet *Phthalimide fungicide*			X		

ACTIVE INGREDIENT	Most Restrictive Pollinator Precaution	Moderately Restrictive Pollinator Precaution	Least Restrictive Pollinator Precaution	RT_{25} (< 24 hours – hours; > 24 hours – days)	Additional Information (where available)
Fosetyl al *Ethyl phosphonate fungicide*			X		
Garlic powder *Bio-fungicide*			X		
Ipconazole *Triazoles fungicide – Seed treatment*			X		
Iprodione *Dicarboximide fungicide*		X			Laboratory studies suggest effects on honey bee larval development field studies needed [22].
Isofetamid *Phenyl-oxo-ethyl thiophene amide fungicide*			X		
Kresoxim-methyl *Oximino acetate fungicide*			X		
Lactic acid *Lacto-fermented liquid fungicide and bactericide*			X		
Mancozeb *Dithio-carbamate fungicide*			X		
Mandipropamid *Mandelic acid amide fungicide*			X		
Metalaxyl *Acylalanine fungicide*			X		
Metalaxyl-m and s-isomer *Acylalanine fungicide*			X		
Metconazole *Triazole fungicide*			X		
Metiram *Dithiocarbamates fungicide*			X		
Metrafenone *Benzophenone fungicide*			X		
Myclobutanil *Triazole fungicide*			X		No impact on bumble bees [9].
Oxathiapiprolin *Piperidinyl-thiazoleisoxazolines fungicide*			X		
Pantoea agglomerans *Bio-fungicide*			X		
Penflufen *Pyrazole-4- carboxamides fungicide*			X		
Penthiopyrad *Pyrazole-4-carboxamide fungicide*			X		
Phosphites; mono- and dibasic ammonium, sodium and potassium *Inorganic fungicide*			X		
Phosphorous acid, mono and di-potassium salts *Inorganic fungicide*			X		
Picoxystrobin *Methoxy-acrylates fungicide*			X		

ACTIVE INGREDIENT	Most Restrictive Pollinator Precaution	Moderately Restrictive Pollinator Precaution	Least Restrictive Pollinator Precaution	RT_{25} (< 24 hours – hours; > 24 hours – days)	Additional Information (where available)
Polyoxin D zinc salt *Peptidyl pyrimidine nucleoside broad spectrum fungicide*			X		
Potassium bicarbonate *Naturally occurring mineral salt used as a fungicide*			X		No impact on bumble bees [9].
Propamocarb *Carbamate fungicide*			X		
Propiconazole *Triazole fungicide*			X		Mason bees more sensitive than honey bees [26]. If mixed with lambda-cyhalothrin, may increase toxicity [29].
Prothioconazole *Triazolinthione fungicide*			X		
Pseudomonas syringae *Bio-fungicide*			X		
Pyraclostrobin *Methoxy-carbamate fungicide*			X		
Pyrimethanil *Anilino-pyrimidine fungicide*			X		
Quinoxyfen *Aryloxyquinoline fungicide*			X		
Sedaxane *Pyrazole-4- carboxamides fungicide*			X		
Streptomycin sulfate *Glucopyranosyl antibiotic fungicide*			X		
Sulphur *Naturally occurring element Inorganic fungicide*			X?		While most sources say sulphur poses little risk for bees, other sources suggest sulfur may cause toxicity for bees for up to a day and a half [20].
Tea tree oil (*Melaleuca alternifolia*) *Terpene hydrocarbon/terpene alcohol/terpene phenol bio-fungicide*			X		
Tebuconazole *Triazole fungicide*			X?		2 days ERT for bumble bees [3].
Tetraconazole *Triazole fungicide*			X?		1 day ERT for bumble bees [3].
Thiabendazole *Benzimidazole fungicide*			X		
Thiophanate-methyl *Thiophanate fungicide*			X		
Thiram *Dithio-carbamate fungicide*			X		
Trifloxystrobin *Oximino-acetates fungicide*			X		
Triforine *Piperazine fungicide*			X		
Triticonazole *Triazole fungicide*			X		

ACTIVE INGREDIENT	Most Restrictive Pollinator Precaution	Moderately Restrictive Pollinator Precaution	Least Restrictive Pollinator Precaution	RT_{25} (< 24 hours – hours; > 24 hours – days)	Additional Information (where available)
Ziram *Dithio-carbamate fungicide*			X?		Laboratory studies suggest effects on honey bee larval development, field studies needed [22].
Zoxamide *Toluamide fungicide*			X		
OTHERS					
1-naphthaleneacetic acid *Plant Growth Regulator*			X		
6-benzyladenine *Plant Growth Regulator*			X		
Aviglycine hydrochloride *Plant growth regulator*			X		
Diphacinone *Rodenticide*			X		
Ferric phosphate *Slug and Snail bait*			X		
Gibberellic acid *Plant Growth Regulator*			X		
Kaolin clay *Naturally occurring clay Crop Protectant*			X	–	
Kasugamycin *Bactericide*			X		
Oriental mustard seed meal (*Brassica juncea*) *Bio-fumigant*			X		The active ingredient in Mustgrow is considered highly toxic to bees although risk is low due to minimal exposure.
Paraquat *Quaternary ammonium herbicide*			X?		Although no pollinator precaution on label, laboratory studies suggest effects on honey bee larvae [27].
Prohexadione calcium *Plant growth regulator*			X		
Zinc phosphide *Mouse Bait*			X		

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http://www.beeconnected.ca/

Bee Health Roundtable
http://www.agr.gc.ca/eng/industry-markets-and-trade/value-chain-roundtables/bee-health/?id=1409832956249

Canadian Best Management Practices for Honey Bee Health
http://www.honeycouncil.ca/images2/pdfs/BMP_manual_-_Les_Eccles_Pub_22920_-_FINAL_-_low-res_web_-_English.pdf

Incident reporting, recalls and alerts, new cosmetic notifications, product safety education and consumer product requirements
https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/registrants-applicants/product-application/memo/frequently-asked-questions-use-unlabelled-tank-mixes-commercial-class-pest.html

Integrated Pest Management Practices (IPM)
https://ipmcouncilcanada.org/ and http://www.agr.gc.ca/eng/?id=1288805416537

Mode of Action
http://www.irac-online.org/modes-of-action/

Pollinator Partnership Protecting Pollinators Training Module
http://pollinator.org/pesticide-education

Project Apis m. Best Management Practices
http://projectapism.org

Pest Management Regulatory Agency (PMRA)
https://www.canada.ca/en/health-canada.html

Pesticide Environmental Stewardship
https://pesticidestewardship.org/

Pollinator Partnership Planting Guides
http://pollinator.org/guides

Report a Bee Incident
https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/public/protecting-your-health-environment/report-pesticide-incident.html

Photo: Steve Fletcher

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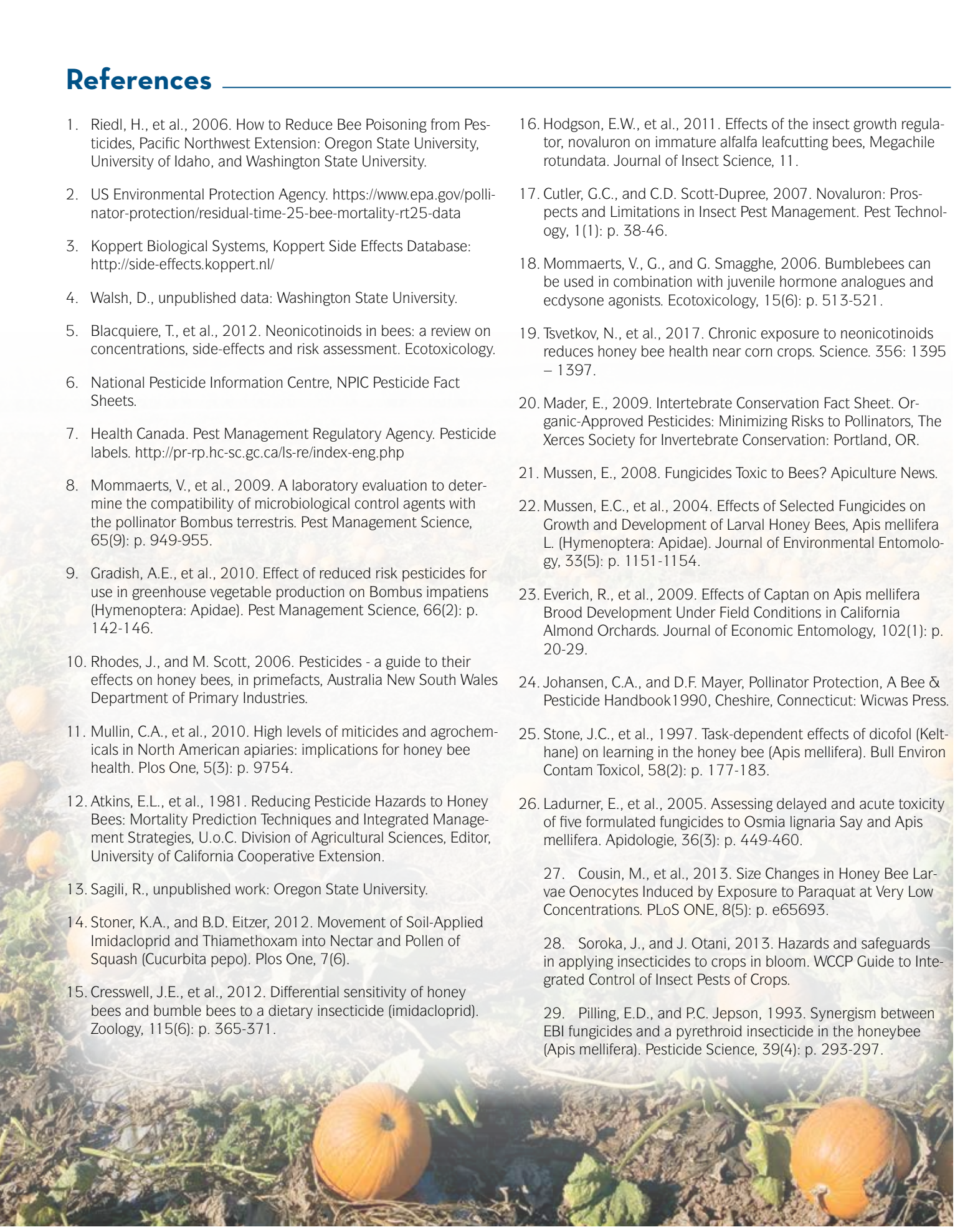

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Consolidated Reference of Practices to Reduce Bee Poisoning from Agricultural Pesticides in Canada