How to Reduce Bee Poisoning from pesticides

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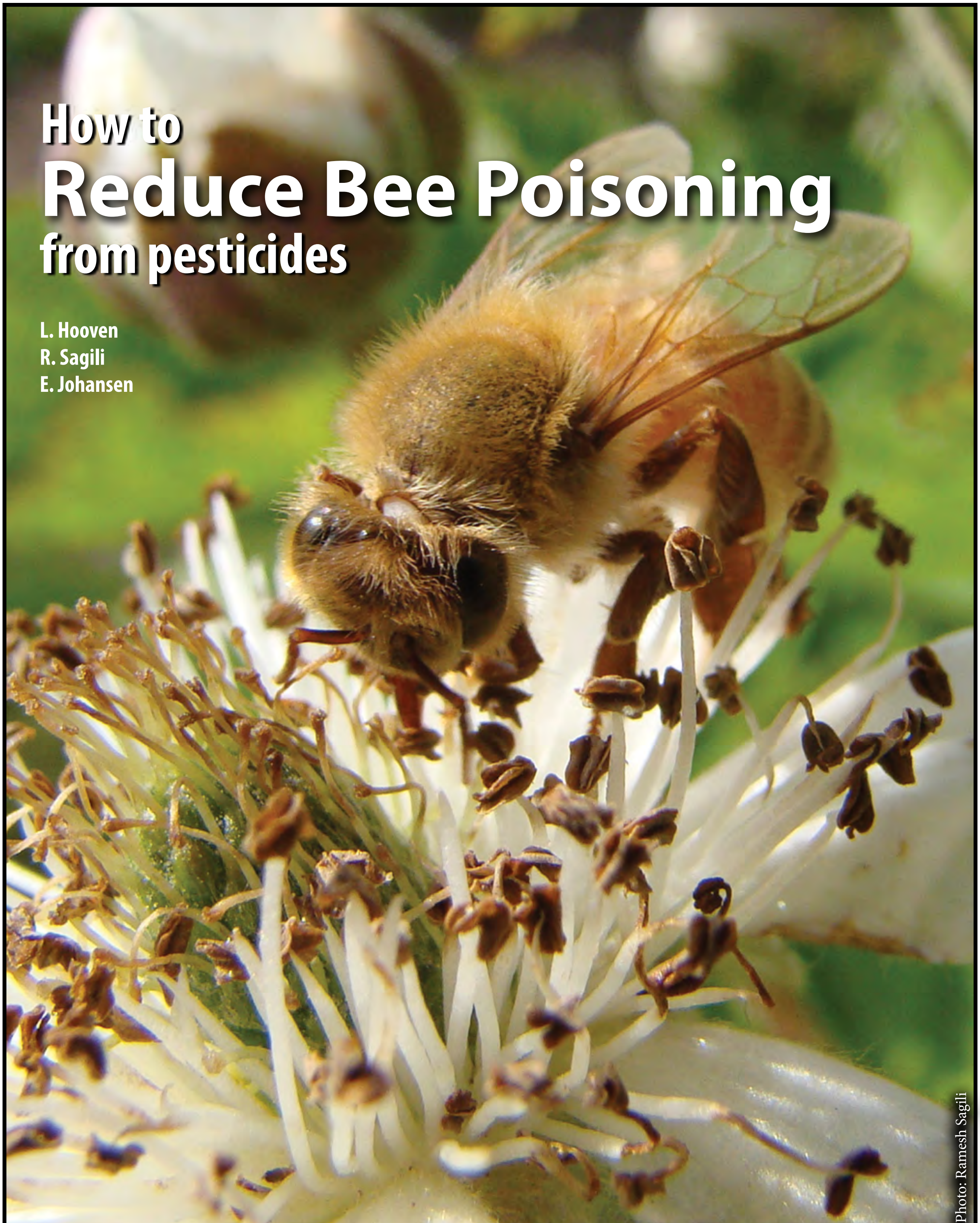

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Contents

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Honey bees pollinating cherries.

How to Reduce Bee Poisoning from Pesticides

Pollinators are essential to Pacific Northwest and California agriculture

Commercially managed honey bees pollinate a variety of crops in the West Coast region of the United States, including almonds, tree fruits, berries, kiwis, cotton, cucurbits, and crops grown for seed. This activity is economically significant. Beekeepers from California and the Pacific Northwest together perform nearly half of the nation's commercial pollination, valued at approximately $18 billion (Calderone 2012).

While honey bees are the most economically important pollinators, other managed bees are important as well. For example, alfalfa seed production in the western United States is dependent on alfalfa leafcutting bees and alkali bees for pollination, and managed bumble bees are important for greenhouse tomato production and some covered row crops. Native wild (pollen) bees, including numerous species of bumble bees, mining bees, mason bees, sweat bees, leafcutting bees, and carpenter bees, are all prolific pollinators. The estimated annual value of crops pollinated by wild, native bees in the U.S. is $3 billion or more (Losey and Vaughan, 2006, Chaplin-Kramer et al 2011). More than 1,600 species of bees are native to California, Idaho, Oregon, and Washington (Tepedino and Griswold 1995; U.S. Pollinating Insects Database 2013).

The full value of their pollination services to increased crop production is substantial, even in the presence of honey bees (Garibaldi et al. 2013), but their sensitivity to pesticides has not been studied extensively.

Rules to protect bees

Follow label directions

Specific precautionary statements designed to protect bees are usually found in the Environmental Hazards section of the pesticide label (Table 1). Review the entire label for precautionary and advisory

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statements. Key words to look for include "highly toxic to bees," "toxic to bees," and "residues." Crop-specific precautions may also be listed on the label. Although these precautions are based on toxicity to honey bees, they are also relevant to other species of bees, with some exceptions as 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 percent mortality 8 or more hours after application, Tables 2 and 4), 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).

The U. S. Environmental Protection Agency is currently revising the risk assessment data requirements and process for pollinators, and it is expected that the precautionary statements on the labels of newly registered pesticides will be based on the results of these risk assessments. Consult the EPA Label Review Manual, Chapter 8, for information regarding precautionary statements used on existing pesticide labels: (www.epa.gov/oppfead1/labeling/lrm/chap-08.pdf).

State rules to protect pollinators

The state agriculture departments in Oregon, Washington, and Idaho, and the California Department of Pesticide Regulation (CDPR), are the most reliable sources of current rules intended to reduce the hazard of insecticide applications to bees. See the links below for rules in your state, including specific pesticide application times. For more information, call the number listed under "Investigating a suspected bee poisoning."

Oregon

The Pollinator Incident web page at www.oregon.gov/ODA/PEST/Pages/Pollinator.aspx lists current use limitations. Apiary registration: www.oregon.gov/ODA/cid/Pages/bees.aspx.

Washington

The specific section of the General Pesticide Rules that deal with pollinator protection are WAC 16-228-1220(1) and WAC 16-228-1262, 1264, and 1266, and can be found at www.agr.wa.gov/PestFert/Pesticides/LawsRules.aspx. Hive registration information is available on the Washington State Department of Agriculture website: www.agr.wa.gov/PlantsInsects/Apiary/.

Table 1. Honey bee acute toxicity groups and precautionary statements (from EPA)

Toxicity Group	Precautionary Statement if Extended Residual Toxicity is Displayed	Precautionary Statement if Extended Residual Toxicity is not Displayed
I Product contains any active ingredient with an acute LD50 of 2 micrograms/bee or less	This product is highly toxic to bees exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product or allow it to drift to blooming crops or weeds if bees are visiting the treatment area.	Product is highly toxic to bees exposed to direct treatment on blooming crops or weeds. Do not apply this product or allow it to drift to blooming crops or weeds while bees are actively visiting treatment area.
II Product contains any active ingredient(s) with acute LD50 of greater than 2 micrograms/bee but less than 11 micrograms/bee.	This product is toxic to bees exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product if bees are visiting the treatment area.	This product is toxic to bees exposed to direct treatment. Do not apply this product while bees are actively visiting the treatment area.
III All others.	No bee caution required.	No bee caution required.

Photo: Ramesh Sagili

Photo: Louisa Hooven

A bumble bee forages on a blueberry flower (left). Beekeepers inspect their colonies during almond pollination (right).

Idaho

Idaho Administrative Code: Pesticide and Chemigation Use and Application Rules. Apiary registration and bee inspection program: www.agri.idaho.gov/Categories/PlantsInsects/Bees/indexapiary.php

California

The pesticide regulation department (cdpr.ca.gov/), and the California Department of Food and Agriculture (cdfa.ca.gov/) are involved with pesticide use enforcement. The regulations concerning protection of bees from pesticides are found in the California Agricultural Code: Division 13, Chapter 1, Article 7, Sections 29100-29103 at www.cdfa.ca.gov/Regulations.html. Hive registration and other bee-related information: www.cdfa.ca.gov/plant/PE/interiorexclusion/bees.html

Investigating and documenting a suspected bee poisoning

If you have a question or concern regarding a suspected bee poisoning incident, contact your state agriculture department or, in California, your county agricultural commissioner. Provide photos or video of the incident, together with notes describing the previous health of the colony, prevailing wind, EPA registration number (from the pesticide label) name of the suspected pesticide, how you believe the bees may have been exposed, pesticide treatments you have applied to the hives, and other pertinent details. Preserving at least 2 ounces of adult bees, brood, pollen, honey, nectar, or wax by immediately freezing in clearly labeled, clean containers may be helpful if the incident is later determined to warrant laboratory analysis.

In the event of enforcement action, some states will need to collect their own samples. Do not disturb the hives or site until the representative from your state lead office listed below has finished collecting information.

Oregon Department of Agriculture

Pesticide Division
503-986-4635
pestx@oda.state.or.us

California Department of Food and Agriculture

County agricultural commissioners
916-654-0466
cdfa.ca.gov/plant/PE/interiorexclusion/bees.html

California Department of Pesticide Regulation

Pesticide Enforcement Branch
916-324-4100
cdpr.ca.gov/docs/dept/quicklinks/report.htm

Washington State Department of Agriculture

Pesticide Management Division
877-301-4555 (toll free)
compliance@agr.wa.gov

Idaho Department of Agriculture

Division of Agricultural Resources
208-332-8610
bspencer@idahoag.us

Report the incident to the EPA

The EPA requires multiple reports from beekeepers to detect any potential patterns related to specific pesticides. You can also notify the pesticide company, which is required by law to report adverse effects to the EPA. Report a bee incident to the EPA: www.epa.gov/opp00001/ecosystem/pollinator/index.html

Causes of bee poisoning in the Pacific Northwest and California

Highly toxic insecticides with residual toxicity longer than 8 hours are responsible for most of the bee poisoning incidents reported on the West Coast, primarily those in the following chemical families:

- Organophosphates (such as acephate, azinphos-methyl, chlorpyrifos, diazinon, dimethoate, malathion, and methamidophos)
- N-methyl carbamates (such as carbaryl)
- Neonicotinoids (such as clothianidin, imidacloprid, and thiamethoxam)
- Pyrethroids (such as deltamethrin, cyfluthrin and lambda-cyhalothrin).

Most bee poisoning incidents occur when:

- Insecticides are applied when bees are 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 the target crop
- Bees collect insecticide-contaminated pollen (such as corn), nectar (such as cotton or mint), or other materials from treated crops that do not require bee pollination
- Bees collect insecticide-contaminated nectar from plants treated with systemic pesticides
- Bees collect insecticide-contaminated nesting materials, such as leaf pieces collected by alfalfa leafcutting bees
- Bees collect insecticide-contaminated water (from drip tape or chemigation, for example)
- Beekeepers and growers do not adequately communicate

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 California Buckeye (*Aesculus californica*), death camas (*Toxicoscordion venenosum*), 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 if pesticides were responsible for an incident. State agriculture departments in Oregon, Washington, and Idaho, and the pesticide regulation department in California, investigate suspected bee poisoning incidents (see page 5 for contact information).

Photo: Ramesh Sagili

A bee on a caneberry blossom.

Signs and symptoms of bee poisoning

Honey bees

- Excessive numbers of dead and dying honey bees in front of the hives
- Increased defensiveness (most insecticides)
- Lack of foraging bees on a normally attractive blooming crop (most insecticides)
- Stupefaction, paralysis, and abnormally jerky, wobbly, or rapid movements; spinning on the back (organophosphates, organochlorines, and neonicotinoids)

- Forager disorientation and reduced foraging efficiency (neonicotinoids)
- Immobile, lethargic bees unable to leave flowers (many insecticides)
- Regurgitation of honey stomach contents and tongue extension (organophosphates and pyrethroids)
- Performance of abnormal communication dances, fighting, or confusion at the hive entrance (organophosphates)
- The appearance of "crawlers" (bees unable to fly). Bees move slowly as though they have been chilled (carbaryl).
- Dead brood; dead, newly emerged workers; or abnormal queen behavior, such as egg laying in a poor pattern (carbaryl)
- Queenless hives (acephate, carbaryl, malathion, methamidophos)
- Poor queen development in colonies used to produce queens, with adult worker bees unaffected (coumaphos)

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 available. If sufficient forage is unavailable, feed them with sugar syrup and pollen substitute, and provide clean water to aid their recovery. Protect them from extreme heat and cold, and, if needed, combine weak colonies.

If the pesticide has accumulated within pollen or nectar stores, brood and workers may continue to die until the colony is lost. Many pesticides readily transfer into beeswax, and you may consider replacing the comb with new foundation, drawn 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 3 to 5 years) may prevent accumulation of pesticides to deleterious levels in brood comb wax.

Managed solitary bees

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

Pesticide poisonings are more difficult to detect in alkali bees, but watch for a lack of activity at the nesting beds or more dead males than expected. The males tend to spend most of their time at the nesting sites, so that may be your first clear sign of mortality. Females are more likely to die in the field. Female alkali bees forage up to a mile or more away from the alkali bee bed, so they can be killed by insecticides that male bees do not contact. An alkali bee bed without females often will have male bees flying in circles above the surface for several days after the poisoning incident.

Bumble bees and nonmanaged native bees

Without a marked hive or nesting site, pesticide poisonings in wild bees can easily go unobserved. Bumble bees and other wild bees experience many of

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.

Tank mixing, surfactants, and adjuvants

Some active ingredients may become more toxic to bees when mixed together. For example, the fungicide propiconazole may increase the toxicity of lambda cyhalothrin to bees. 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.

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. RT of products with the same active ingredient, but different formulation, may also differ.

Photo: Melissa Scherr

Photo: Melissa Scherr

the same symptoms of pesticide exposures as managed bees. Bumble bee colonies are composed of fewer individuals than honey bees and can be more sensitive to pesticides (Table 4). Additional research is needed to fully understand the impact of pesticides on native bee populations, some of which are showing large population declines and even going extinct (Thorp 2005, Cameron et al. 2011, Burkle et al. 2012, Bartomeus et al. 2013). For information on bumble bee declines, see www.xerces.org/bumblebees.

Ways to reduce bee poisoning

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. 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, effective colonies for crop pollination
- Details of the grower's responsibility to safeguard bees from poisoning
- Agreement on 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 beehives 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. Registering colonies with your state agriculture department or pesticide regulation department can provide the location of apiaries to pesticide applicators.

What pesticide applicators can do to protect honey bees

- Identify and confirm hive locations, and maintain appropriate buffers between treated areas and pollinator habitat. Check with your state agriculture departments in Oregon, Washington, and Idaho or the pesticide regulation department in California for hives that might be located in your area.
- Select insecticides that have the lowest toxicity rating to bees whenever possible. The relative hazard of insecticides, miticides, fungicides, and blossom-thinning agents to honey bees is presented in Table 4.
- Do not apply insecticides with long residual toxicity to bees to blooming plants, including weeds.
- Do not apply insecticides when unusually low temperatures or dew are forecast following

Table 2. Residual toxicity and possible application time

Residual Toxicity (RT)	Application time
Greater than 8 hours – extended residual toxicity (ERT)	Do not apply when hives are in area Ask beekeeper to relocate bees (may not be always feasible) Allow sufficient time between application and arrival of bees
4 to 8 hours residual toxicity	Late evening or night (after bees cease foraging) until midnight
Less than 4 hours residual toxicity	Late evening or night (after bees cease foraging) to first light
No residual toxicity	Late evening or night (after bees cease foraging) to early morning (before bees begin foraging) Depends on weather Depends on daily bee foraging pattern for each crop

treatment. Residues typically remain toxic to bees at least twice as long under these conditions.

- Apply pesticides with residual toxicity when bees are not present or inactive (Table 2). Bees generally forage during daylight hours and may visit some crops at specific times of day. Application times may be specified by pesticide rules of individual states (see "State rules and pesticide application times"). When abnormally high temperatures encourage bees to begin foraging earlier or continue later than usual, adjust application times accordingly.
- If possible, avoid tank mixing of insecticides and fungicides, as specific mixtures may cause synergistic toxic effects on bees, and most combinations have not been researched.
- It is generally impractical for beekeepers to cover hives during treatment.
- Choosing a product with short residual toxicity is more feasible than asking the beekeeper to move hives.
- Inform beekeepers where, when, and what you are applying. Some states may have rules for notifying beekeepers about pesticide applications in a timely manner.
- Minimize spray drift. Verify that wind will

Table 3. Pesticide formulations

Pesticide formulation	Bee exposure	Special precautions
Microencapsulated, dust, wettable powder, flowable	Particles similar in size to pollen, stick to bee hairs, and can be taken to hive and fed to brood	Avoid weather conditions that increase drift of dust.
Emulsifiable concentrate	Direct spray and residues	Ultralow volume (ULV) formulations may be more hazardous than other liquid formulations.
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 coatings	Applied directly to seed. Ideally, bee exposure not expected	Can transfer to talc 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 the alkali bee.
Systemic (soil, injection, or foliar applications absorbed by plant)	Some systemic insecticides may translocate to nectar, pollen, and guttation droplets, and can be ingested by bees.	Whether field concentrations are high enough to adversely affect bee colonies is a subject of research.

Photo: Ramesh Sagili

Control blooming weeds before spraying to avoid unintentional bee exposures.

not carry product in the direction of beehives, flowering weeds, adjacent habitat, or nontarget 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 it 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).

What growers can do to protect honey bees

- 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 of the bees and what pesticides, if any, will be applied while bees are present.
- Control blooming weeds, such as dandelion, 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 dandelion or mustard.
- 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.
- Scout for pest insects and use economic thresholds for routine insect pests. 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. In this equation, weigh the value of pollination to your crop and the value of hives to beekeepers.
- Avoid prophylactic application of pesticides, including fungicides, while bees are present.
- Consider alternatives to pesticides. Well-planned, integrated pest-management programs often are less dangerous to pollinators and other beneficial insects than last-minute efforts to suppress pest outbreaks. Details of pest-management practices can be found in the Pacific Northwest pest management handbooks at www.ipmnet.org/, Washington State University IPM website, www.ipm.wsu.edu/,

Photo: Louisa Hooven

Beekeepers feeding sugar syrup to honey bee colonies.

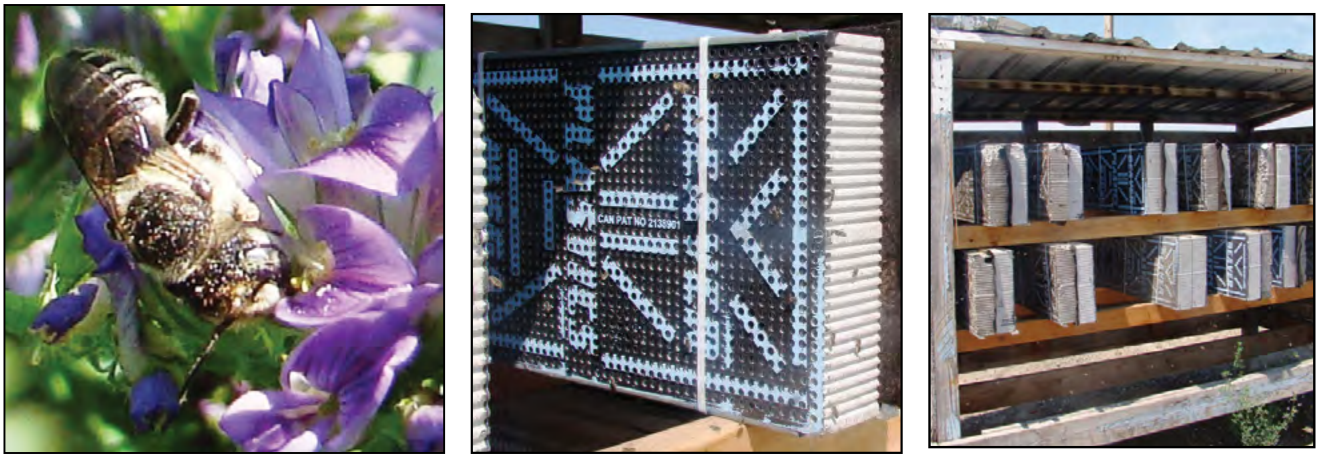
University of Idaho IPM Center, www.extension.uidaho.edu/ipm/, and the University of California Statewide IPM Program at www.ipm.ucdavis.edu/.

What beekeepers can do to protect honey bees

- Do not leave unmarked colonies of bees near orchards or fields. Post the beekeeper's name, address, and phone number on apiaries in lettering large enough to be read at a distance.
- Register your colonies with your state agriculture department so pesticide applicators can learn the location of your apiaries. Nonagricultural applicators (e.g. mosquito abatement programs) may also need to know the location of your apiaries.
- Communicate clearly to the grower or applicator or both 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 provides precautionary statements for bees.
- Do not return hives to fields treated with insecticides that are highly toxic to bees until at least 48 to 72 hours after application. Fifty to 90 percent of bee deaths occur during the first 24 hours following application. Some insecticides such as chlorpyrifos and thiamethoxam have longer residual hazards (Table 4).
- 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 apiaries on ridge tops rather than in canyon bottoms. Insecticides drift down into the canyons and flow with morning wind currents. Inversion conditions are particularly hazardous.
- Learn about pest-control problems and programs to develop mutually beneficial agreements with growers concerning pollination services and prudent use of insecticides.
- Miticides, such as those used for varroa control, are pesticides, too. Use care in controlling pests in and around beehives, apiaries, and beekeeping storage facilities. Use insecticides labeled for the intended use and follow all label directions carefully.
- 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 from initial hazards.
- Verify that a clean water source is available for bees.
- Feed bees during nectar dearths to prevent long-distance foraging to treated crops.
- In pesticide risk-prone areas, inspect behavior of bees often to recognize problems early.

What pesticide applicators, growers, and managers of alfalfa leafcutting, alkali, and orchard mason bees can do

- It is generally not feasible to move non-*Apis* bees from the field. Plan pest-control strategies early to avoid applying bee-toxic chemicals during the



Photos: Ramesh Sagili

Alfalfa leafcutting bees (left) are kept in nests (middle), and maintained in shelters (right) during alfalfa pollination.

crop-pollination period, and apply only those with low toxicity and short residual hazard to bees after bees cease foraging at night.

- Actively foraging mason bees may be removed from the field at night and stored at 45°F for up to 4 days. Even when nests are returned to the exact field location, movement during handling is likely to jostle eggs loose from pollen provisions and cause large-scale dispersal by females, resulting in high mortality.
- Alfalfa leafcutting 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 are protected.
- Do not place alfalfa leafcutting bee nest shelters into fields until at least 1 week after treatment with chlorpyrifos (Lorsban), dimethoate (Cygon), malathion ULV, or methidathion (Supracide).
- Alkali bees cannot be removed from the field, so pesticide applications should be made at least 1 week prior to expected bee emergence and the initiation of alfalfa bloom. Do not allow pesticides to drift onto the alkali bee beds. If pesticide applications must be made after bee emergence, use those with short residual toxicity (e.g., pyrethroids or pirimicarb), and apply only after dark.
- Special notes are in Table 4 if it is currently known that greater precautions are needed for managed solitary bees than for honey bees.

What growers and pesticide applicators can do to protect nonmanaged native bees, including bumble bees

- Provide nesting sites. Approximately 70 percent of native bees are ground nesters, burrowing into areas of well-drained, bare, or partially vegetated soil (O’Toole and Raw, 1999; Michener, 2000). Most other species nest in abandoned beetle galleries in snags or in soft-centered, hollow twigs and plant stems. Bumble bees nest in insulated cavities in the ground, such as old mouse burrows, or under grass tussocks.
- Provide pollen and nectar sources away from treated crops. Blooms of any type, including weedy species that are not classified as noxious by the state agriculture department, may provide pollen and nectar.
- Do not apply insecticides or allow 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 crop bees for ground nests of solitary bees (e.g., squash bees, long-horned bees, sweat bees, and mining bees) and bumble bees. Protect such nests from insecticide spray.
- Special notes may be found in Table 4 if it is currently known that greater precautions are needed for bumble bees than for honey bees.

Sources of uncertainty in toxicity of pesticides to bees

Pesticide toxicity to honey bees, as listed in Table 4, is generally determined by the effects of sprays and residues directly applied to adult honey bees. However, the social nature of honey bees, their long-range foraging habits, and intimate relationship with agriculture may lead to other types of exposures.

- Systemic pesticides translocate through plants and may be found in pollen, nectar, and guttation droplets, and can be consumed by pollinators. Particularly in the case of neonicotinoids, there is evidence that residues can reach high enough concentrations to be hazardous to bees. The length of time that systemic products remain toxic to bees may vary and has not been studied. Additional research and risk assessment approaches for systemic pesticides are needed.
- Products intended for homeowner use on ornamental plants, including systemic pesticides, may not include precautionary statements for bee protection.
- Pesticide-inert ingredients, adjuvants, additives, and spreader stickers are not expected to be toxic to bees, but little scientific information is available.
- Once brought into the hive with pollen or nectar, it is generally unknown how long pesticides persist in hive materials. Many pesticides accumulate in beeswax, and some studies indicate behavior, development, and longevity are affected by such contamination.
- Colonies may be exposed to one pesticide, moved to a new cropping system, then get exposed to a second pesticide. Research is needed to understand potential additive, synergistic, chronic, or delayed effects from multiple sources and types of exposures.
- Although fungicides are not thought to affect adult bees, certain fungicides, such as captan, iprodione, and chlorothalonil, affect brood development, or affect the micro-organisms that ferment bee bread in laboratory studies. Research is ongoing to determine the relevance of these results in the field.
- The mode of action of herbicides affects plants, not insects, and herbicides are unlikely to cause bee poisoning incidents under field conditions (Paraquat is a possible exception).
- Insect growth regulators such as diflubenzuron and novaluron are believed to be harmless to adult bees, but emerging research is taking a second look at possible effects on egg viability and brood development.
- Bt crops (crops genetically modified to make an insecticidal protein) have generally been found to have few if any adverse effects on bees, as they are designed to affect lepidopteran (moths and butterflies) and coleopteran (beetle) pests.
- When tank-mixed, some pesticides have been shown to be more toxic to bees together than alone, but little research is available on this topic.

Protecting wild native bees from pesticide poisoning

Where sufficient habitat is available, wild native bee species often provide all of the pollination services needed for high crop yields and fruit quality.

Depending on the species, native bees may nest in underground tunnels, hollow plant stems, and tunnels in wood. Bumble bee colonies favor small cavities under lodged grass, in abandoned rodent burrows, in trees, or old bird nests. 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, construct their nests in the midst of annual and perennial crop fields.

To protect these bees, ensure that drifting pesticides never contact 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. Visit the Xerces Society webpage to learn more about conserving a variety of insect pollinators: www.xerces.org/.

Special precautions

- Some pesticides hazardous to bees have been cancelled or certain uses discontinued, but may be used according to the label until stocks are exhausted. These include microencapsulated methyl parathion (Penncap-M), tetrachlorvinphos (Rabon, Gardona), and methamidophos (Monitor).
- Some granular formations can be a fumigation hazard when applied near apiaries. Do not use disulfoton G (Di-Syston) or phorate G (Thimet) near alfalfa leafcutting bee shelters, alkali bee nest sites, or honey bee apiaries because of possible fumigation hazards, especially during warm weather.
- Bees are temporarily inactivated by direct contact with oil sprays, even when no toxic materials are used. Some deaths may occur.
- Because alfalfa leafcutting bees that have been actively nesting in the field for 3 or more weeks have been shown to have increased sensitivity to insecticides, late-season applications should be timed to occur after the peak nesting and pollination period (i.e., 6 to 7 weeks after the start of field activity.
- Tank mixing may cause synergistic effects, resulting in increased hazards for bees.
- Insecticidal seed coatings may be abraded and drift with talc and graphite dust during planting, particularly with corn. This dust may be hazardous for bees if it drifts onto colonies or areas where bees are foraging.
- Do not apply insecticides during warm evenings when honey bees are clustered on the outside of the hives.
- Bees may collect pollen or nectar from treated crops that don't require pollination, such as corn, soybeans, or extrafloral nectaries in cotton. Emerging data from Iowa suggests that wild native bees primarily visit soybeans.
- Be aware that soil fumigants will kill ground-nesting bees, even when they are dormant.

Using the tables

In Table 4, pesticide active ingredients are listed alphabetically. Each active ingredient is marked as highly toxic, toxic, or no bee precautionary statement (PS), as currently found on pesticide labels, unless otherwise noted. A question mark (X?) indicates that although there is no precautionary statement on the label, additional research is available, pending, or needed.

Generally, products with single active ingredients are listed. Many pre-mixed products have entered the market containing multiple active ingredients. Refer to the pesticide label for bee precautions, or use Table 4 to look up each active ingredient separately.

If residual toxicity (RT) is indicated on the label or known from field research of representative products, it is noted below the toxicity rating. 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 some cases, "yes" indicates that the label lists residues as a potential hazard for bees but does not discuss how long precautions should be taken.

In addition to formulation and application rate, the actual hazard to bees may be affected by many other factors, as discussed in the text. Special precautions for non-*Apis* species and pertinent research are included in the column titled "Notes and Special Precautions." Although some laboratory research is cited in this column, it often suggests a need for field research, rather than providing definitive information about an active ingredient.

In Table 5, product names are listed alphabetically with their active ingredients. This table lists some common trade names, but there are many more trade and product names than can be listed here. Even if a product is not found here, the active ingredients are listed on the pesticide label and may be found in Table 4. The National Pesticide Information Center is an excellent resource for additional pesticide information and can be reached at www.npic.orst.edu/ or 1-800-858-7378.

Photo: Ramesh Sagili

A paint-marked experimental bee on a carrot umbel.

Key to abbreviations in the tables

RT — Residual Toxicity. 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 percent mortality for longer than 8 hours after application.

PS — Precautionary Statement. Language found on the pesticide label describing whether the pesticide or its residues are toxic or highly toxic to bees.

\> Greater than

≥ Greater than or equal to

< Less than

≤ Less than or equal to

Common formulation abbreviations

(Used in Table 4 and on product labels)

CS	Capsule Suspension
D	Dust
EC	Emulsifiable Concentrate
F	Flowable
G	Granular
SP	Soluble Powder
SC	Suspension Concentrate
ULV	Ultra-low Volume
WDG	Water Dispersible Granules
WP	Wettable Powder
XLR	Extra-long residual

Disclaimer

The Oregon State University Extension Service, University of Idaho Extension, and Washington State University Extension 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 state 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 state restrictions, before using it.

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The tables have been extensively revised from previous editions of this publication. C. A. Johansen and D. F. Mayer developed much of the information on the effects of insecticides on the alkali bee, *Nomia melanderi*, and the alfalfa leafcutting bee, *Megachile rotundata*, at Washington State University in the 1970s and 1980s.

Table 4. Active ingredients of commonly used pesticides and their effect on bees in California, Idaho, Oregon, and Washington

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
Abamectin (Avermectin) *Fermentation products derived from soil bacterium, affects nerve and muscle action of insects and mites*	**X** 0.025 lb ai/acre 1-3 days ERT , ≤ 0.025 lb ai/acre 8 hours RT [1] *Can vary with formulation and application rate*			Abacide, Abacus, Abba, Agmectin, Agri-Mek, Ardent, Avert, Avicta, Avid, Epi-Mek, Reaper, Solera, Solero, Temprano, Timectin, Zoro	ERT to bumble bees [2], short RT to alfalfa leafcutting bees and alkali bees at 0.025 lb ai/acre [1].
Acephate *Organophosphate insecticide*	**X** >3 days ERT [1] *Can vary with formulation and application rate*			Bracket, Orthene, Orthonex	Incompatible with bumble bees [2], ERT to alfalfa leafcutting bees and alkali bees [1].
Acequinocyl *Quinolone insecticide/miticide, metabolic poison*			**X**	Kanemite, Shuttle	
Acetamiprid *Neonicotinoid insecticide (cyano group)*		**X** Yes		Assail, Tristar, Transport	Length of residual toxicity to honey bees is unknown. ERT to alfalfa leafcutting bees and alkali bees [3]. 2 day ERT to bumble bees [2]. Cyano group neonicotinoids exhibit lower toxicity to bees than nitro group neonicotinoids [4].
Aldicarb *Systemic carbamate insecticide and nematicide*	**X**			Temik Only available as granular formulation [5]	Not hazardous to bees when applied at least 4 weeks prior to bloom [1]. May be a persistent contaminant of beeswax [6].
Alpha-cypermethrin *Pyrethroid insecticide*	**X** Yes			Fastac	Length of residual toxicity to bees unknown.
Aluminum tris O-ethyl phosphonate *Systemic organophosphate fungicide*			**X**	Aliette, Fosetyl-Al, Chipco, Flanker, Linebacker, Legion	
Azadirachtin *Insecticidal extract of neem oil Ecdysone antagonist*		**X** <2 hours RT [1] *Can vary with formulation and application rate*		Neemix, Amazin, Azera, Aza, Ecozin, Ornazin	Must be ingested to be toxic [7].
Azinphos-methyl *Organophosphate insecticide*	**X** 4 days ERT [1] 5 days ERT [8] *Can vary with formulation and application rate*			Guthion *is being phased out*	ERT to alfalfa leafcutting bees and alkali bees [1].
Azoxystrobin *ß-methoxyacrylate fungicide*			**X**	Abound, Dynasty, Heritage, Quadris	
Bacillus subtilis *Fungicide derived from naturally occurring soil bacterium*			**X**	Kodiak, Rhapsody, Serenade, Optiva, Companion, Cease	Laboratory tests suggest potential effects on bumble bees [9].

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
Bacillus thuringiensis *Bacterium that produces a number of chemicals toxic to butterfly and moth digestive systems*			**X**	BT, Agree, Jackpot, Thuricide, Condor, Vault	
Beauveria bassiana *Soil fungus that infects and kills insects*		**X**		Mycotrol, Botaniguard	Potentially pathogenic to honey bees (per Mycotrol label), and laboratory studies suggest effects on bumble bees [9].
Beta-cyfluthrin *Pyrethroid insecticide*	**X** >1 day ERT[10] *Can vary with formulation and application rate*			Baythroid, Leverage, Tempo	
Bifenazate *Carbazate acaracide, metabolic poison*		**X** Yes		Acramite, Floramite, Vigilant	Length of residual toxicity to bees unknown.
Bifenthrin *Pyrethroid insecticide*	**X** > 0.06 lb ai/acre > 1 day ERT, ≤ 0.04 lb ai/acre 4-6 hours RT [1] *Can vary with formulation and application rate*			Brigade, Capture, Discipline, Sniper, Talstar	> 0.032 lb ai/acre: > 1 day ERT for alfalfa leafcutting bees, ≤ 0.32 lb ai/acre: 4-6 hours RT toxicity for alfalfa leafcutting bees and alkali bees [1]. Incompatible with bumble bees [2].
Boscalid *Carboxamide fungicide*			**X**	Endura, Pristine	
Buprofezin *Insect growth regulator, chitin synthesis inhibitor*			**X**	Applaud, Centaur, Courier, Talus,	
Calcium Polysulfide *Inorganic fungicide*			**X**	Lime Sulfur, Sulforix	
Capsaicin *Insect and animal repellant derived from hot peppers*		**X** [7]		Hot pepper wax	
Captan *Dicarboximide fungicide*			**X?**	Captan, Merpan, Captec, Captevate	Up to 7 day ERT for mason bees [1]. Effects on honey bee brood in laboratory, but not in field tests [11-13].
Carbaryl *Carbamate insecticide*	**X** Carbaryl D (Sevin): 2-14 days ERT. Carbaryl 4F (Sevin) 2 lb ai/acre & Carbaryl WP (Sevin): 3-7 days ERT. Carbaryl XLR (Sevin) > 1.5 lb/acre: > 1 day ERT. Carbaryl 4F (Sevin) ≤1 lb ai/acre & Carbaryl XLR (Sevin) ≤ 1.5 ai/acre not > 1:19 dilution: 8 hours RT. [1] *Can vary with formulation and application rate*			Sevin Bees are unlikely to be exposed to granular and bait formulations	Hazardous if applied to blooming trees as a blossom-thinning agent [1]. Carbaryl has ERT to alfalfa leafcutting bees [1], alkali bees [1], and bumble bees [2].

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
***Chenopodium ambrosioides* extract** *Antifeedant insecticide*			**X**	Requiem	
Chlorantraniliprole *Anthranilic diamide insecticide: Insect neurotoxin affecting muscle regulation, causing paralysis and death*			**X**	Altacor, Acelepryn, Coragen, Grubex	No impact on bumble bees [14].
Chlorfenapyr *Pyrrole insecticide/acaricide, metabolic poison*		**X** <4 hours RT [1] Foraging behavior may be affected > 2 days [10] *Can vary with formulation and application rate*		Phantom, Pylon	8 hour ERT for alfalfa leafcutting bees[1]. Incompatible with bumble bees [2].
Chlorothalonil *Chloronitrile fungicide*			**X?**	Bravo, Echo, Daconil, Equus, Legend	Tentatively associated with "entombed pollen" [15]. Common contaminant of beeswax [6].
Chlorpyrifos *Organophosphate insecticide*	**X** EC 4-6 days ERT, ULV 0.05 lb ai/acre or less <2 hours RT [1] *Can vary with formulation and application rate*			Dursban, Cobalt, Lorsban Bees unlikely to be exposed to granular formulations	Up to 7 day ERT for alfalfa leafcutting bees, 3-6 days ERT for alkali bees [1]. Common contaminant of beeswax [6]. Incompatible with bumble bees [2].
Chromobacterium subtsugae *Insecticide derived from bacteria, acts through complex mechanism of action*		**X** Yes		Grandevo	Length of residual toxicity to bees unknown.
Cinnamaldehyde *Cinnamon flavoring, insecticide, miticide, fungicide*			**X**	Cinnacure	
Clofentezine *Tetrazine ovicide/miticide, mite growth inhibitor*			**X**	Apollo	
Clothianidin *Systemic neonicotinoid insecticide (nitro group)*	**X**[5] >5 days ERT (per Clutch label) *Can vary with formulation and application rate*			Arena, Belay, Clutch, Poncho, Sepresto	Dust from planting seeds coated with neonicotinoids have been associated with colony losses [16]. Incompatible with bumble bees [2].
Copper Hydroxide *Inorganic fungicide/bactericide*		**X**[17]		Badge, Champ, Kocide, Nu-Cop	
Copper Sulfate + lime *Inorganic fungicide/bactericide*	**X**[17]			Bordeaux Mixture	Other sources indicate that this pesticide can be applied at any time with reasonable safety to bees [18].
Cryolite *(aka Sodium aluminofluoride) Inorganic insecticide*			**X**	Kryocide, Prokil	
***Cydia pomonella* granulosis virus** *Naturally occurring virus that infects codling moth*			**X**	Carpovirusine, Cyd-X	

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
Cyflufenamid *Phenylacetamide fungicide*			X	Miltrex, Torino	
Cyfluthrin *Pyrethroid insecticide*	X >1 day ERT [1] *Can vary with formulation and application rate*			Baythroid, Tombstone, Tempo	Incompatible with bumble bees [2].
Cymoxanil *Cyanoacetamide oxime fungicide*			X	Curzate, Tanos	
Cypermethrin *Pyrethroid insecticide*	X >0.025 lb ai/acre, >3 days ERT <0.025 lb ai/acre, <2 hours RT [1] *Can vary with formulation and application rate*			Up-Cyde, Tenkoz	Incompatible with bumble bees [2].
Cyprodinil *Anilino-pyrimidine fungicide*			X	Palladium, Switch, Vangard	No impact on bumble bees [14].
Cyromazine *Insect growth regulator, chitin synthesis inhibitor*		X <2 hours RT [1] *Can vary with formulation and application rate*		Trigard	> 1 day ERT for alfalfa leafcutting bees and alkali bees [1], short RT for bumble bees [2].
Deltamethrin *Pyrethroid insecticide*	X <4 hours RT [1] *Can vary with formulation and application rate*			Batallion, Grim Reaper	<8 hours RT for alfalfa leafcutting bees and alkali bees [1]. Formulated products may have a repellent effect lasting 2-3 hours [7]. 2 days ERT for bumble bees [2].
Diatomaceous earth *Naturally occurring silicon dioxide, abrasive, fossilized remains of diatoms, used as insecticide*		X [1] <2 hours RT [1] *Can vary with formulation and application rate*			Although no PS on label, some toxicity observed in field studies [1, 17]
Diazinon *Organophosphate insecticide*	X 2 days ERT [1] *Can vary with formulation and application rate*				Incompatible with bumble bees [2], ERT for alfalfa leafcutting bees and alkali bees [1].
Dichloran *Aromatic hydrocarbon fungicide*			X	Botran	
Dicofol *Organochlorine miticide*			X		Mixing with insecticides increases hazard to bees [1].
Difenoconazole *Triazole fungicide*			X?	Dividend, Inspire, Quadrus, Revus	Potential effects on learning in honey bees [19]
Diflubenzuron *Benzoylurea insect growth regulator, chitin synthesis inhibitor*			X?	Dimilin	Laboratory studies suggest effects on larval development [20], while field studies do not indicate any effects to honey bees [1, 21]. Toxic to bumble bee larvae [21] and alfalfa leafcutting bees [1].
Dimethoate *Organophosphate insecticide*	X Up to 3 days ERT [1] 1-3.5 days ERT [8] *Can vary with formulation and application rate*			Dimate	ERT to alfalfa leafcutting bees and alkali bees [1]. Do not place alfalfa leafcutting bee nest shelters into fields until at least 1 week after treatment. Incompatible with bumble bees [2].

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
Dinotefuran *Neonicotinoid insecticide (nitro group)*	**X** 39 hours ERT [5] *Can vary with formulation and application rate*			Venom, Safari, Scorpion	Reported residual toxicity to honey bees tentative [5]. Incompatible with bumble bees [2].
Disulfoton *Organophosphate insecticide*		**X** ≥ 1 lb ai/acre 7 hours RT, ≥0.5 lb ai/acre 2 hours RT [1]		Di-Syston *is being discontinued*	
Dodine *Guanidine fungicide*			**X**	Syllit	
Emamectin benzoate *Avermectic class insecticide, affects nerve and muscle action*	**X** >24 hours ERT [5] *Can vary with formulation and application rate*			Denim, Proclaim	1 day ERT for bumble bees [2].
Endosulfan *Organochlorine insecticide*		X > 0.5 lb ai/acre 8 hours RT, 0.5 lb ai/acre or less 2-3 hours RT [1] *Can vary with formulation and application rate*		Thionex Is being discontinued	1-3 days ERT for alfalfa leafcutting bees, 14 hours ERT for alkali bees [1].
Esfenvalerate *Pyrethroid insecticide*	**X** Up to 1 day ERT [1] *Can vary with formulation and application rate*			Asana	Incompatible with bumble bees [2].
Ethoprop *Organophosphate insecticide*		**X**		Mocap	
Etoxazole *Oxazoline insecticide/acaricide, growth regulator likely to affect chitin synthesis*			**X?**	Beethoven, Tetrasan, Zeal	3 days ERT for bumble bees [2].
Famoxadone *Oxazolidine dione fungicide*			**X**	Tanos	
Fenarimol *Pyrimidine fungicide*			**X**	Rubigan, Vintage	
Fenbuconazole *Triazole fungicide*			**X**	Enable, Indar	
Fenbutatin-oxide *Organotin acaracide*			**X**	Vendex	
Fenhexamid *Hydroxyanilidine fungicide*			**X**	Decree, Elevate, Judge	
Fenpropathrin *Pyrethroid insecticide/acaricide*	**X** 1 day ERT [1] *Can vary with formulation and application rate*			Danitol, Tame	>1 day ERT for alfalfa leafcutting bees and alkali bees [1]. Incompatible with bumble bees [2].
Fenpyroximate *Pyrazole acaracide, metabolic poison*			**X**	Fujimite, Akari	

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
Fipronil *Phenylpyrazole insecticide*	**X** <8 hours ERT [1] to 7-28 days ERT [10] *Can vary with formulation and application rate*			Regent	>1 day ERT for alfalfa leafcutting bees [1]. Incompatible with bumble bees [2].
Flonicamid *Pyridinecarboxamide insecticide, antifeedant*			**X?**	Beleaf, Carbine	Possible effects on honey bees, further research needed [22]. Short RT for alfalfa leafcutting bees and alkali bees [3]. Short RT for bumble bees [2].
Flubendiamide *Diamide insecticide, affects nerve and muscle action*			**X?**	Belt, Synapse, Tourismo, Vetica	Possible effects on honey bee larval development, further research needed [23].
Fludioxonil *Phenylpyrrole fungicide*			**X**	Graduate, Maxim, Scholar, Switch	No impact on bumble bees [14].
Fluopicolide *Benzamide fungicide*			**X**	Adorn, Presidio	
Fluopyram *Pyridinyl-ethyl-benzamide fungicide*			**X**	Luna, Propulse	
Flutriafol *Triazole fungicide*			**X**	Topguard	
Fluvalinate *Pyrethroid insecticide*		**X** <2 hours RT [1] ½ day ERT [8] *Can vary with formulation and application rate*		Mavrik, Zoecon	Ubiqiutous contaminant of beeswax [6].
Formetanate *Formamidine insecticide/acaracide, affects nerve action*		**X** <8 hours RT [1] *Can vary with formulation and application rate*		Carzol	>14 hours ERT for alfalfa leafcutting and 9 hour ERT for alkali bees [1]. Incompatible with bumble bees [2].
Gamma-cyhalothrin *Pyrethroid insecticide*	**X** Yes			Bolton, Cobalt, Declare, Proaxis	Length of residual toxicity to honey bees unknown. >1 day ERT for alfalfa leafcutting bees [1].
Hexythiazox *Thiazolidine acaricide, growth regulator*			**X?**	Onager, Savey	>2 hours RT for alfalfa leafcutting and alkali bees [1].
Horticultural oil *Refined paraffinic oils used as insecticide*		**X** [1] <3 hours RT [1] *Can vary with formulation and application rate*		Superior, Supreme, Dormant, Summer	Although no PS on label, some toxicity observed in field studies.
Imidacloprid *Neonicotinoid insecticide (nitro group)*	**X** 0.25 lb ai/acre >1 day ERT, 0.1 lb ai/acre <8 hours RT [2] *Can vary with formulation and application rate*			Admire, Alias, Benefit, Brigadier, Couraze, Dominion, Gaucho, Macho, Merit, Nuprid, Pasada, Provado, Premise, Widow	Imidacloprid is often used as a systemic insecticide, and has been found in pollen and nectar of plants [4, 24]. Whether these concentrations represent a hazard to bees is under scrutiny [4]. Bumble bees may be more sensitive to imidacloprid than honey bees [25]. Incompatible with bumble bees [2].

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
Indoxacarb *Oxadiazine insecticide, affects nerve action*	**X** Yes			Avaunt, Steward	Short RT for honey bees [1], 3 days ERT for bumble bees [2].
Iprodione *Dicarboximide fungicide*			**X?**	Rovral, Dovetail, Nevado, Tazz	Laboratory studies suggest effects on honey bee larval development [12], field studies needed.
Kaolin clay *Naturally occurring clay*			**X**	Surround	
Kresoxim methyl *Oximino acetate fungicide*			**X**	Cygnus, Sovran	
Lambda-cyhalothrin *Pyrethroid insecticide*	**X** >1 day ERT [1], >7 days ERT [10] (encapsulated) *Can vary with formulation and application rate*			Warrior, Cyzmic, Demand, Voliam	May be more toxic to bees when mixed with propiconazole. >1 day ERT for alfalfa leafcutting bees [1]. Incompatible with bumble bees [2].
Lime Sulfur *Calcium polysulfides*			**X**[17]		
Malathion Organophosphate insecticide	**X** Malathion ULV, $\geq$8 fl oz ai/acre 5.5 days ERT, $\leq$3 fl oz ai/acre 3 hours RT, Malathion WP 2 days ERT, Malathion EC 2-6 hours RT [1] *Can vary with formulation and application rate*			Fyfanon	Up to 7 days ERT for alkali bees and alfalfa leafcutting bees [1]. Incompatible with bumble bees [2].
Mancozeb *Dithio-carbamate fungicide*			**X**	Dithane, Fore, Gavel, Manzate, Mankocide, Penncozeb, Ridomil	
Mandipropamid *Mandelic acid amide fungicide*			**X**	Micora	
Mefenoxam *Acylalanine fungicide*			**X**	Apron, Maxim, Ridomil, Ultra Flourish	
Metalaxyl *Acylalanine fungicide*			**X**	Acquire, Allegiance, Belmont, Metastar, Sebring, Vireo	
Metaldehyde bait *Molluscicide*			**X**	Deadline, Slug-fest, Snail & Slug Killer	
Metarhizium anisopliae *Soil fungus that parasitizes insects*			**X**	Met52	

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
Metconazole *Triazole fungicide*			X	Quash, Caramba	
Methidathion *Organophosphate insecticide*	X 1-3 days ERT [1] *Can vary with formulation and application rate*			Supracide	Do not place alfalfa leafcutting bee nest shelters into fields until at least 1 week after treatment [1]. Incompatible with bumble bees [2].
Methomyl *Carbamate insecticide*	X 2 hours RT[1] 1.5 days ERT [8] *Can vary with formulation and application rate*			Lannate, Nudrin	Up to 15 hours ERT for alfalfa leafcutting bees and 1 day ERT for alkali bees, depending on application rate. More hazardous to bees in a humid climate [1]. 3 days ERT for bumble bees [2].
Methoxyfenozide *Insect growth regulator, ecdysone receptor agonist*			X	Intrepid	
Metrafenone *Benzophenone fungicide*			X	Vivando	
Milbemectin *Milbemycin acaricide, affects nerve and muscle action*	X Yes			Ultiflora	Length of residual toxicity to honey bees unknown. 3 days ERT for bumble bees [2].
Myclobutanil *Triazole fungicide*			X	Laredo, Rally, Sonoma, Spera, Stride, Systhane	No impact on bumble bees [14].
Naled *Organophosphate insecticide*	X 1 lb ai/acre 12-20 hours ERT, 0.5 ai/acre 2 hours RT [1] 1-1.5 days ERT [8] *Can vary with formulation and application rate*			Dibrom, Trumpet	Up to 4.5 days ERT for alfalfa leafcutting bees and 2 days ERT for alkali bees [1].
Neem oil *Insecticide from seeds of neem tree*			X	Turbo, Trilogy	Must be ingested to be toxic [7].
Novaluron *Benzoylurea insect growth regulator, chitin synthesis inhibitor*		X Yes		Diamond, Mayhem, Pedestal, Rimon, Shackle	Length of residual toxicity to honey bees unknown. Effects on egg hatch and larval development in alfalfa leafcutting bees [26]. Effects on brood development and colony strength in honey bees [27]. 3 days ERT for bumble bees [2].
Oil: cottonseed, clove, garlic *Contact fungicide, miticide and insecticide*			X	Pest Out, GC-mite	
Oxamyl *Carbamate insecticide*	X $\geq$ 1 lb ai/acre 8 hours RT, $\leq$ 0.5 lb ai/acre 3 hours RT [1] 3-4 days ERT [8] *Can vary with formulation and application rate*			Vydate	>1 day ERT for alfalfa leafcutting bees and 2 days ERT for alkali bees [1]. Incompatible with bumble bees [2].

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
Oxydemeton-methyl *Organophosphate insecticide*		**X** <2 hours RT [1] *Can vary with formulation and application rate*		Metasystox-R, MSR	Up to 8 hours ERT for alfalfa leafcutting bees [1]. Incompatible with bumble bees [2].
Paraquat *Bipyridylium herbicide*			**X?**		Although no PS on label, laboratory studies suggest effects on honey bee larvae [28], and paraquat has been associated with colony losses [29].
Penthiopyrad *Pyrazole-4-carboxamide fungicide*			**X**	Fontelis, Velista	
Permethrin *Pyrethroid insecticide*	**X** 0.5 to 2 days ERT [1] >5 days ERT [8] *Can vary with formulation and application rate*			Ambush, Bee Gone, Pounce, Permastar	Up to 3 days ERT for alfalfa leafcutting bees. May be repellent in arid conditions [1]. Incompatible with bumble bees [2].
Petroleum/Paraffinic Oil *Refined paraffinic oils used as insecticides*		**X**[1] <3 hours RT [1] *Can vary with formulation and application rate*		Biocover, SunSpray, JMS	
Phorate *Organophosphate insecticide*	**X**			Thimet *(granular formulations may not result in honey bee exposures)*	<2 hours RT for alfalfa leafcutting bees and alkali bees. Possible fumigation hazard [1].
Phosmet *Organophosphate insecticide*	**X** >3 days ERT *Can vary with formulation and application rate*			Imidan	Up to 5 days ERT for alfalfa leafcutting bees and alkali bees [1]. 2-3 days ERT for bumble bees [2].
Phosphorous acid, mono and di-potassium salts *Inorganic fungicide*			**X**	Fosphite, Kphos, Organocide, Prophyt	
Piperonyl butoxide *Synergist for insecticides*			**X**	Exponent *May be tank mixed, or active ingredient included in insecticide formulations*	Low toxicity alone, increases the toxicity of insecticides by blocking cytochrome P450 activity.
Pirimicarb *Carbamate insecticide*		**X** [1] <2 hours RT [1] *Can vary with formulation and application rate*		Pirimor	Although no PS on label, some toxicity observed in field studies. 1 day ERT for bumble bees [2].
Polyoxin D zinc salt *Metabolite of Streptomyces bacteria, broad spectrum fungicide*			**X**	Endorse, Oso, Ph-D, Tavano, Veggieturbo	
Potassium bicarbonate *Naturally occurring mineral salt used as a fungicide*			**X**	Armicarb, Greencure, Kaligreen	No impact on bumble bees [14].
Potassium salts of fatty acids *aka insecticidal soap*			**X**	M-Pede, Safer's Soap	
Propargite *Miticide*			**X**	Omite, Comite	Mixing with insecticides increases hazard to bees [1].

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
Propiconazole *Triazole fungicide*			X	Banner Maxx, Bumper, Dorado, Kestrel, Propicure, Protocol, Quilt, Tilt	Mason bees more sensitive than honey bees [30]. If mixed with lambda-cyhalothrin, may increase toxicity.
Propylene glycol monolaurate *Miticide based on fatty acids*			X	Acaritouch	
Pymetrozine *Pyridine Azomethine insecticide, antifeedant*		X [1] <2 hours RT [1] *Can vary with formulation and application rate*		Endeavor, Fulfill	Although no PS on label, some toxicity observed in field studies [1].
Pyraclostrobin *Methoxy-carbamate fungicide*			X	Cabrio, Coronet, Headline, Insignia, Pristine, Stamina	
Pyrethrin *Insecticidal compounds occurring in specific chrysanthemums*	X <2 hours RT [1] *Can vary with formulation and application rate*			Azera, Natria, Pyganic, Pyrenone, Pyrocide	Commonly formulated with piperonyl butoxide (PBO), a synergist. 1.5 days ERT for bumble bees when formulated with PBO [2].
Pyridaben *Pyridazine miticide/insecticide, metabolic poison*	X <2 hours RT [1] *Can vary with formulation and application rate*			Nexter, Pyramite, Sanmite	>8 hours ERT for alfalfa leafcutting bees and alkali bees [1]. 1 day ERT for bumble bees [2].
Pyrimethanil *Anilino-pyrimidine fungicide*			X	Penbotec, Luna, Philabuster, Scala	
Pyriproxyfen *Insect growth regulator, juvenile hormone agonist*			X?	Esteem, Distance, Knack, Nyguard, Pitch, Seize, Terva,	<2 hours RT for alfalfa leafcutting and alkali bees [1]. May be toxic to bumble bee larvae [31]. Avoid direct application or spray drift to honey bee hives (per label).
Quinoxyfen *Aza-naphthalene fungicide*			X	Quintec	
Reynoutria sachaliensis *Biofungicide, plant extract*			X	Regalia	
Rotenone *Plant-derived insecticide and piscicide*		X[1] <2 hours RT [1] *Can vary with formulation and application rate*		Only piscicidal (fish-killing) uses registered	
Sabadilla *Plant derived insecticide, affects nerve and muscle action*	X[17] ≥ 1 day ERT [17] *Can vary with formulation and application rate*			Veratran-D	No PS on label, other sources suggest ERT to bees.

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
Sodium tetraborohydrate decahydrate *Borax®, used as insecticide and fungicide*			**X**	Borax, Prev-am	
Spinetoram *Spinosyn insecticide, affects nerve action*		**X** 3 hours RT [1] *Can vary with formulation and application rate*		Assurity, Delegate, Radiant	
Spinosad *Spinosyn insecticide, affects nerve action*		**X** 3 hours RT [1] to 1 day ERT [10] *Can vary with formulation and application rate*		Bull's Eye, Entrust, Natular, Protector Pro, Success	>1 day ERT for alfalfa leafcutting bees, short RT for alkali bees [1].
Spirodiclofen *Mite/insect growth regulator, lipid biosynthesis inhibitor*		**X**		Envidor	Toxic to honey bee larvae through direct contamination of pollen and nectar (per Envidor label). Incompatible with bumble bees [2].
Spiromesifen *Mite/insect growth regulator, lipid biosynthesis inhibitor*			**X?**	Forbid, Judo, Oberon	Structure and mechanism of action similar to spirodiclofen and spirotetramat, which are potentially toxic to honey bee larvae.
Spirotetramat *Mite/insect growth regulator, lipid biosynthesis inhibitor*		**X** Yes		Kontos, Movento	Practically nontoxic to adult bees, but residues in pollen and nectar potentially toxic to larvae (per Movento label). Length of residual toxicity to honey bees unknown. 1 day ERT for bumble bees [2].
Streptomyces lydicus *Biological fungicide*			**X**	Actino-Iron, Actinovate	
Sucrose octanoate esters *Sucrose fatty acid ester insecticide/miticide*			**X**	Sucrashield, Sucrocide	
Sulfoxaflor *Nicotinic acetylcholine receptor agonist, affects nerve action*	**X** 3 hrs RT *Can vary with formulation and application rate*			Closer, Transform	Label instructions include crop-specific restrictions and advisory statements to protect pollinators.
Sulfur *Naturally occurring element*			**X?**	Sulfur	See also lime sulfur. While most sources say sulfur poses little risk for bees, other sources suggest sulfur may cause toxicity for bees for up to a day and a half [17] .
Tebuconazole *Triazole fungicide*			**X?**	Adament, Amtide, Buzz Ultra, Luna, Monsoon, Orius, Unicorn	2 days ERT for bumble bees [2].
Tebufenozide *Insect growth regulator, ecdysone agonist*			**X**	Confirm, Mimic	
Tetraconazole *Triazole fungicide*			**X?**	Eminent, Mettle	1 day ERT for bumble bees [2].
Thiacloprid *Neonicotinoid insecticide (cyano group)*			**X?**	Calypso	Less toxic to bees than most other neonicotinoids [4]. 1-2 days ERT for bumble bees [2].

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
Thiamethoxam *Neonicotinoid insecticide (nitro group)*	**X** 7-14 days ERT [1] *Can vary with formulation and application rate*			Actara, Adage, Agri-flex, Centric, Cruiser, Durivo, Endigo, Flagship, Helix XTra, Meridian, Platinum, Voliam	Thiamethoxam is often used as a systemic insecticide, and has been found in pollen and nectar of plants [4, 24]. Thiamethoxam may also be used in seed coatings. Whether these applications represent a hazard to bees is under scrutiny [16, 24]. Bumble bees may be more sensitive to neonicotinoids than honey bees [25]. Incompatible with bumble bees [2].
Thiodicarb *Carbamate insecticide*		**X** <2 hours RT [1] *Can vary with formulation and application rate*		Larvin	>8 hours ERT for alfalfa leafcutting bees and alkali bees.
Thiophanate-methyl *Thiophanate fungicide*			**X**	Incognito, Topsin	
Tolfenpyrad *Pyrazole insecticide, metabolic poison*			**X**	Hachi-hachi, Torac	Greenhouse use only, no PS on label. ERT to alfalfa leafcutting bees and alkali bees [3].
Triadimefon *Triazole fungicide*			**X**	Armada	
Triflumizole *Imidazole fungicide*			**X**	Procure	May increase toxicity of certain neonicotinoids [32].
Zeta-cypermethrin *Pyrethroid insecticide*	**X** >1 day ERT [1] *Can vary with formulation and application rate*			Mustang, Hero, Stallion, Mustang Maxx	
Ziram *Dithiocarbamate fungicide*			**X?**	Ziram	Laboratory studies suggest effects on honey bee larval development [12], field studies needed.

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Table 5. Trade names of commonly used pesticides and their active ingredients* in California, Idaho, Oregon, and Washington

Trade name	Active ingredient
Abacide	abamectin (avermectin)
Abacus	abamectin (avermectin)
Abba	abamectin (avermectin)
Abound	azoxystrobin
Acaritouch	propylene glycol monolaurate
Acelepryn	chlorantraniliprole
Acramite	bifenazate
Actara	thiamethoxam
Actino-Iron	*Streptomyces lydicus*
Actinovate	*Streptomyces lydicus*
Adage	thiamethoxam
Adament	tebuconazole
Admire	imidacloprid
Adorn	fluopicolide
Agmectin	abamectin (avermectin)
Agree	*Bacillus thuringiensis*
Agri-Flex	abamectin (avermectin) and thiamethoxam
Agri-Mek	abamectin (avermectin)
Akari	fenpyroximate
Alias	imidacloprid
Aliette	aluminum tris o-ethyl phosphonate
Allegiance	metalaxyl
Altacor	chlorantraniliprole
Amazin	azadirachtin
Ambush	permethrin
Amtide	tebuconazole
Apollo	clofentezine
Applaud	buprofezin
Apron	mefenoxam
Acquire	metalaxyl
Ardent	abamectin (avermectin)
Arena	clothianidin
Armada	triadimefon
Armicarb	potassium bicarbonate
Asana	esfenvalerate
Assail	acetamiprid
Assurity	spinetoram
Avaunt	indoxacarb
Avert	abamectin (avermectin)
Avicta	abamectin (avermectin)
Avid	abamectin (avermectin)
Aza	azadirachtin
Badge	copper hydroxide
Banner Maxx	propiconazole
Batallion	deltamethrin
Baythroid	beta-cyfluthrin (cyfluthrin)
Baythroid	cyfluthrin
Bee Gone	permethrin
Beethoven	etoxazole
Belay	clothianidin
Beleaf	flonicamid
Belmont	metalaxyl
Belt	flubendiamide
Benefit	imidacloprid
Biocover	petroleum/paraffinic oil
Bolton	gamma-cyhalothrin
Borax	sodium tetraborohydrate decahydrate
Bordeaux Mixture	copper sulfate + lime
Botaniguard	*Beauveria bassiana*
Botran	Dichloran
Bracket	acephate
Bravo	chlorothalonil
Brigade	bifenthrin
Brigadier	imidacloprid
BT	*Bacillus thuringiensis*
Bull's Eye	spinosad
Bumper	propiconazole
Buzz Ultra	tebuconazole
Cabrio	pyraclostrobin
Calypso	thiacloprid
Captan	captan
Captec	captan
Captevate	captan and fenhexamid
Capture	bifenthrin
Caramba	metconazole
Carbine	flonicamid
Carpovirusine	*Cydia pomonella granulosis* virus
Carzol	formetanate
Cease	*Bacillus subtilis*
Centric	thiamethoxam
Centaur	buprofezin
Champ	copper hydroxide
Chipco	aluminum tris o-ethyl phosphonate
Cinnacure	cinnamaldehyde
Closer	sulfoxaflor
Clutch	clothianidin
Cobalt	Chlorpyrifos and gamma-cyhalothrin
Comite	propargite
Companion	*Bacillus subtilis*
Condor	*Bacillus thuringiensis*
Confirm	tebufenozide
Coragen	chlorantraniliprole
Coronet	pyraclostrobin
Couraze	imidacloprid
Courier	buprofezin
Cruiser	thiamethoxam
Curzate	cymoxanil
Cyd-X	*Cydia pomonella granulosis* virus
Cygnus	kresoxim methyl
Cyzmic	lambda cyhalothrin
Daconil	chlorothalonil
Danitol	fenpropathrin
Deadline	metaldehyde bait
Declare	gamma-cyhalothrin
Decree	fenhexamid
Delegate	spinetoram
Demand	lambda cyhalothrin

*This table lists only the most common trade names; these active ingredients also are used in products with other trade names not listed here. Some products contain multiple active ingredients, which may vary in their toxicity to bees. The Oregon State University Extension Service does not endorse these products nor intend to discriminate against products not mentioned.

Trade name	Active ingredient
Denim	emamectin benzoate
Diamond	novaluron
Di-Syston	Disulfoton
Diazinon	diazinon
Dibrom	naled
Dimate	dimethoate
Dimilin	diflubenzuron
Discipline	bifenthrin
Distance	pyriproxyfen
Dithane	mancozeb
Dividend	difenoconazole
Dominion	imidacloprid
Dorado	propiconazole
Dormant	horticultural oil
Dovetail	iprodione
Durivo	Chlorantraniliprole and thiamethoxam
Dursban	chlorpyrifos
Dynasty	azoxystrobin
Echo	chlorothalonil
Ecozin	azadirachtin
Elevate	fenhexamid
Eminent	tetraconazole
Enable	fenbuconazole
Endeavor	pymetrozine
Endigo	thiamethoxam
Endorse	polyoxin D zinc salt
Endura	boscalid
Entrust	spinosad
Envidor	spirodiclofen
Epi-Mek	abamectin (avermectin)
Equus	chlorothalonil
Esteem	pyriproxyfen
Exponent	piperonyl butoxide
Fastac	alpha-cypermethrin
Flagship	thiamethoxam
Flanker	aluminum tris o-ethyl phosphonate
Floramite	bifenazate
Fontelis	penthiopyrad

Trade name	Active ingredient
Forbid	spiromesifen
Fore	mancozeb
Fosetyl-Al	aluminum tris o-ethyl phosphonate
Fosphite	phosphorous acid, mono and di-potassium salts
Fujimite	fenpyroximate
Fulfill	pymetrozine
Fyfanon	malathion
Gaucho	imidacloprid
Gavel	mancozeb
GC-mite	oil: cottonseed, clove, garlic
Graduate	fludioxonil
Grandevo	*Chromobacterium subtsugae*
Greencure	potassium bicarbonate
Grim Reaper	deltamethrin
Grubex	chlorantraniliprole
Guthion	azinphos-methyl
Hachi-hachi	tolfenpyrad
Headline	pyraclostrobin
HelixXTra	thiamethoxam
Heritage	azoxystrobin
Hero	zeta-cypermethrin
Hot pepper wax	capsaicin
Imidan	phosmet
Incognito	thiophanate-methyl
Indar	fenbuconazole
Insignia	pyraclostrobin
Inspire	Cyprodinil and difenoconazole
Intrepid	methoxyfenozide
Jackpot	*Bacillus thuringiensis*
JMS	petroleum/paraffinic oil
Judge	fenhexamid
Judo	spiromesifen
Kaligreen	potassium bicarbonate
Kanemite	acequinocyl
Kestrel	propiconazole
Knack	pyriproxyfen
Kocide	copper hydroxide
Kodiak	*Bacillus subtilis*

Trade name	Active ingredient
Kontos	spirotetramat
Kphos	phosphorous acid, mono and di-potassium salts
Kryocide	cryolite
Lannate	methomyl
Laredo	myclobutanil
Larvin	thiodicarb
Legend	chlorothalonil
Legion	aluminum tris o-ethyl phosphonate
Leverage	beta-cyfluthrin (cyfluthrin) and imidacloprid
Lime Sulfur	calcium polysulfide
Linebacker	aluminum tris o-ethyl phosphonate
Lorsban	chlorpyrifos
Luna	fluopyram, pyrimethanil, and/or tebuconazole
Macho	imidacloprid
Malathion	malathion
Mankocide	mancozeb
Manzate	mancozeb
Mavrik	fluvalinate
Maxim	fludioxonil and mefenoxam
Mayhem	novaluron
Meridian	thiamethoxam
Merit	imidacloprid
Merpan	captan
Met52	*Metarhizium anisopliae*
Metastar	metalaxyl
MSR	oxydemeton-methyl
Mettle	tetraconazole
Micora	mandipropamid
Miltrex	cyflufenamid
Mimic	tebufenozide
Mocap	ethoprop
Monsoon	tebuconazole
Movento	spirotetramat
M-Pede	potassium salts of fatty acids
Mustang	zeta-cypermethrin
Mustang Maxx	zeta-cypermethrin
Mycotrol	*Beauveria bassiana*
Natria	pyrethrin

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Trade name	Active ingredient
Natular	spinosad
Neemix	azadirachtin
Nevado	iprodione
Nexter	pyridaben
Nu-Cop	copper hydroxide
Nudrin	methomyl
Nuprid	imidacloprid
Nyguard	pyriproxyfen
Oberon	spiromesifen
Omite	propargite
Onager	hexythiazox
Optiva	*Bacillus subtilis*
Organocide	phosphorous acid, mono and di-potassium salts
Orius	tebuconazole
Ornazin	azadirachtin
Orthene	acephate
Orthonex	acephate
Oso	polyoxin D zinc salt
Palladium	cyprodinil
Pasada	imidacloprid
Pedestal	novaluron
Penbotec	pyrimethanil
Penncozeb	mancozeb
Permastar	permethrin
Pest Out	oil: cottonseed, clove, garlic
Phantom	chlorfenapyr
Ph-D	polyoxin D zinc salt
Philabuster	pyrimethanil
Pirimor	pirimicarb
Pitch	pyriproxyfen
Platinum	thiamethoxam
Poncho	clothianidin
Pounce	permethrin
Premise	imidacloprid
Presidio	fluopicolide
Prev-am	sodium tetraborohydrate decahydrate
Pristine	boscalid and pyraclostrobin
Proaxis	gamma-cyhalothrin

Trade name	Active ingredient
Proclaim	emamectin benzoate
Procure	triflumizole
Prokil	cryolite
Prophyt	phosphorous acid, mono and di-potassium salts
Propicure	propiconazole
Propulse	fluopyram
Protector Pro	spinosad
Protocol	propiconazole and thiophanate-methyl
Provado	imidacloprid
Pyganic	pyrethrin
Pylon	chlorfenapyr
Pyramite	pyridaben
Pyrenone	pyrethrin
Pyrocide	pyrethrin
Quadris	azoxystrobin
Quadrus	difenoconazole
Quash	metconazole
Quilt	azoxystrobin and propiconazole
Quintec	quinoxyfen
Radiant	spinetoram
Rally	myclobutanil
Reaper	abamectin (avermectin)
Regalia	*Reynoutria sachaliensis*
Regent	fipronil
Requiem	*Chenopodium ambrosioides* extract
Revus	difenoconazole and mandipropamid
Rhapsody	*Bacillus subtilis*
Ridomil	mancozeb and mefenoxam
Rimon	novaluron
Rotenone	rotenone
Rovral	iprodione
Rubigan	fenarimol
Safari	dinotefuran
Safer's Soap	potassium salts of fatty acids
Sanmite	pyridaben
Savey	hexythiazox
Scala	pyrimethanil
Scholar	fludioxonil

Trade name	Active ingredient
Scorpion	dinotefuran
Sebring	metalaxyl
Sepresto	clothianidin and imidacloprid
Serenade	*Bacillus subtilis*
Sevin	carbaryl
Shackle	novaluron
Shuttle	acequinocyl
Seize	pyriproxyfen
Slug-fest	metaldehyde bait
Snail & Slug Killer	metaldehyde bait
Sniper	bifenthrin
Solera	abamectin (avermectin)
Solero	abamectin (avermectin)
Sonoma	myclobutanil
Sovran	kresoxim methyl
Spera	myclobutanil
Stallion	zeta-cypermethrin
Stamina	pyraclostrobin
Steward	indoxacarb
Stride	myclobutanil
Success	spinosad
Sucrashield	sucrose octanoate esters
Sucrocide	sucrose octanoate esters
Sulforix	calcium polysulfide
Sulfur	sulfur
Summer	horticultural oil
SunSpray	petroleum/paraffinic oil
Superior	horticultural oil
Supracide	methidathion
Supreme	horticultural oil
Surround	kaolin clay
Switch	Cyprodinil and fludioxonil
Syllit	dodine
Synapse	flubendiamide
Systhane	myclobutanil
Talstar	bifenthrin
Talus	buprofezin
Tame	fenpropathrin

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Trade name	Active ingredient
Tanos	Famoxadone and cymoxanil
Tavano	polyoxin D zinc salt
Tazz	iprodione
Temik	aldicarb
Tempo	beta-cyfluthrin (cyfluthrin)
Temprano	abamectin (avermectin)
Tenkoz	cypermethrin
Terva	pyriproxyfen
Tetrasan	etoxazole
Thimet	phorate
Thionex	*Endosulfan*
Thuricide	*Bacillus thuringiensis*
Tilt	propiconazole
Timectin	abamectin (avermectin)
Topguard	flutriafol
Topsin	thiophanate-methyl
Torac	Tolfenpyrad

Trade name	Active ingredient
Torino	cyflufenamid
Tourismo	buprofezin and flubendiamide
Transform	sulfoxaflor
Transport	acetamiprid
Trigard	cyromazine
Trilogy	neem oil
Tristar	acetamiprid
Trumpet	naled
Turbo	neem oil
Ultiflora	milbemectin
UltraFlourish	mefenoxam
Unicorn	tebuconazole
Up-Cyde	cypermethrin
Vangard	cyprodinil
Vault	*Bacillus thuringiensis*
Veggieturbo	polyoxin D zinc salt
Velista	penthiopyrad

Trade name	Active ingredient
Vendex	fenbutatin-oxide
Venom	dinotefuran
Veratran-D	sabadilla
Vetica	buprofezin and flubendiamide
Vigilant	bifenazate
Vintage	fenarimol
Vireo	metalaxyl
Vivando	metrafenone
Voliam	chlorantraniliprole and thiamethoxam
Vydate	oxamyl
Warrior	Lambda-cyhalothrin
Widow	imidacloprid
Zeal	etoxazole
Ziram	ziram
Zoecon	fluvalinate
Zoro	abamectin (avermectin)

Photo: Melissa Scherr

Shaking bees after almond pollination for sale as bulk bees.

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Photo: Ramesh Sagili

Bees need a source of clean water.

For more information

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Photo: Louisa Hooven

In addition to cultivated crops, bees visit blooming weeds in adjacent areas.

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