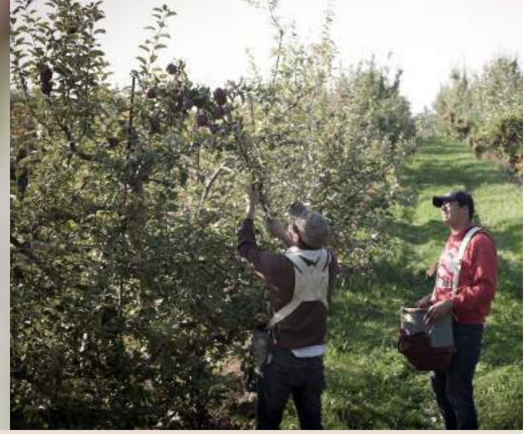

A Pesticide Decision-Making Guide to Protect Pollinators in *Tree Fruit Orchards*

2018 Edition

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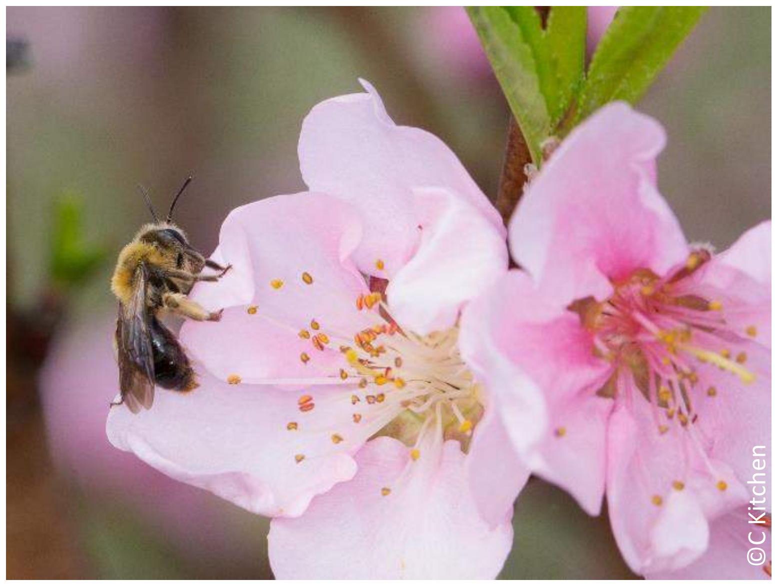
Acknowledgments

This research and development of this guide was supported by the New York State Environmental Protection Fund and New York Farm Viability Institute grant FOC 17-001. The expert advice and consultation provided by Dan Wixted of the Cornell Pesticide Management Education Program was supported by the Crop Protection and Pest Management Extension Implementation Program [grant no. 2017-70006-27142/project accession no. 1014000] from the USDA National Institute of Food and Agriculture.

Choosing lower-risk pesticides for pollinators in New York orchards

Growers recognize the vital role of pollination and understand that managing pests while protecting pollinators can be a balancing act. Both components are essential for a successful harvest, yet they can sometimes be in conflict with one another. Pollinators (mostly bees) are busy pollinating orchard blossoms at the same time growers need to be managing specific pests and diseases. The impact of pesticides on pollinator health has been an active area of research in recent years, including work conducted in New York orchards and elsewhere. The results from this research are clear: Pesticides can be a threat to pollinators, but there is variation in risk, due in part to grower management practices. This guide summarizes known impacts of pesticides on bees in a clear, concise, easy-to-use format. Our goal is to provide information to growers so they can develop an effective Integrated Pest *and* Pollinator Management program.

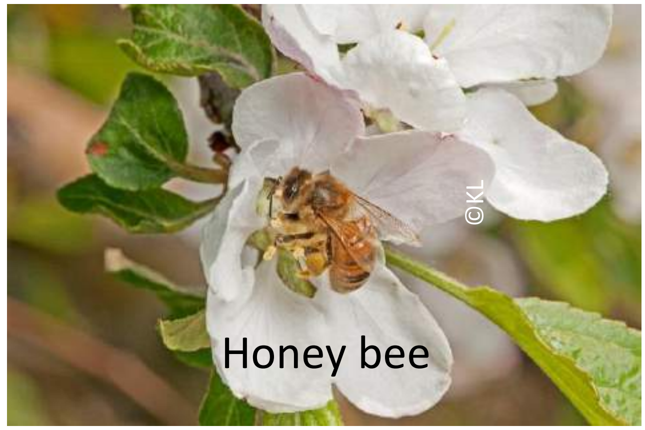


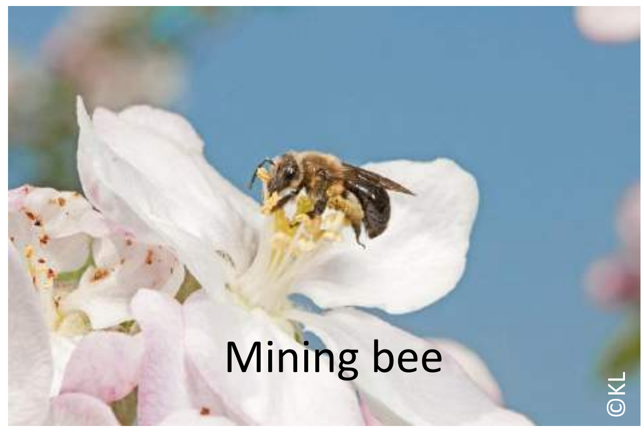
A native *Andrena* species grooming cherry pollen from its face.

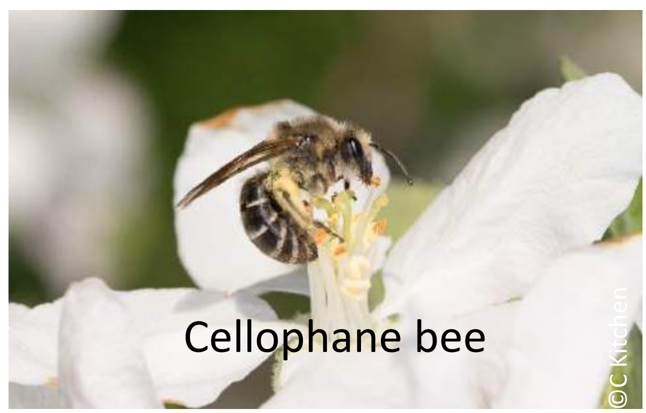
Pesticide risk to pollinators comes from a combination of ***exposure*** and ***effects***. Pollinators may be ***exposed*** to pesticides in several ways: through contact with direct sprays, puddle water, guttation droplets, extrafloral nectaries, pollen and nectar from treated crops and surrounding wildflowers, and residues in soil (for ground nesting bees). Pesticides have an ***effect*** on pollinators if exposure is sufficient to cause lethal or sub-lethal impacts. Recently, an understanding of the interactions between pesticides on bee health has brought focus on active ingredients that *synergize*, meaning that the combined toxicity is greater than the sum of the toxicity of each pesticide applied separately. Pesticide risk studies find that ***synergies*** among different pesticides can increase the toxicity of some pesticides up to 1000-fold. While some synergies are intentional and make a higher efficacy formulation, many synergies can lead to unintentional combined effects that can substantially increase pesticide risk to bees. These are beyond the scope of EPA label guidelines.

In summary, 48 of the 140 chemicals listed in this guide have been shown to synergize with other agrochemicals in tank mixes, formulations, or on plant or soil surfaces. These chemicals include some fungicides, neonicotinoids, pyrethroids, carbamates, organophosphates, piperonyl butoxide and some adjuvants. Synergisms are noted with a in **Table 2**, **'Synergies and acute, chronic, and sublethal toxicities for honey bees and other pollinators.'**

This guide summarizes reported pesticide effects as of October 2018. The guide presents the most up-to-date information about the impacts of fungicides, insecticides, microbicides, and growth regulators on bees that pollinate tree fruits. New York is home to 416 species of bees, and over 120 species are known to be important for NYS apple pollination, with several of those species also visiting other tree fruits. It is well documented that bee species can respond differently to active ingredients. However, there are so many bee species, each differing with respect to physiology, sociality, nesting habits, foraging habits, and ability to tolerate pesticides, that it is unrealistic to determine how every use of every pesticide will affect each species. Therefore, the Environmental Protection Agency (EPA) uses acute toxicity to honey bees (*Apis mellifera*) as a proxy for the potential adverse effects of a pesticide on bees in general, but will at times take studies on other bee species into account as appropriate. In addition to presenting these EPA toxicity ratings, this guide specifically highlights the chemical combinations that produce synergistic effects on bee pollinators. Furthermore, we expand on EPA standards to include reports of sublethal effects (e.g., reduced reproductive output) in honey bees as well as acute, chronic, and sublethal effects on bumble bee and solitary bee species that support agricultural pollination.







This guide is intended to be used as a decision-making tool. The primary goal of this guide is to help growers understand and compare the acute toxicity and synergistic effects of different pesticides on pollinators. The majority of registered products for New York orchard management are included and assigned a score of "highly toxic", "moderately toxic", or "practically non-toxic". Growers can easily compare the toxicity ratings of various pesticides to help them choose a product that is effective against target pests but poses minimal risk to bees. The Pollinator Network @ Cornell will update this guide as new research becomes available. This guide is intended to be a companion to the *Cornell Pest Management Guidelines for Commercial Tree Fruit Production*.

How to use this guide

This guide consists of a series of tables that summarize all the known products and their associated active ingredients used in orchard production. It also includes miticides that are used by beekeepers in New York. Growers and applicators can most effectively use this guide by following three steps:

1. Locate specific pesticide products in **Table 1** to determine the product's active ingredients.
2. Go to **Table 2** to find active ingredient toxicity ratings and known synergisms.
3. When possible, choose to apply products that are effective on target pests but least toxic to bees and do not synergize with other products used.

Table 1: Product formulations and their active ingredients lists most but not all registered tree fruit pesticides alphabetically by product name so it's easy to find the associated active ingredient. If a product name is not in this product formulation list, please be aware that the active ingredient is always listed on the product label. Information on toxicity and synergy is organized by active ingredient in **Table 2**.

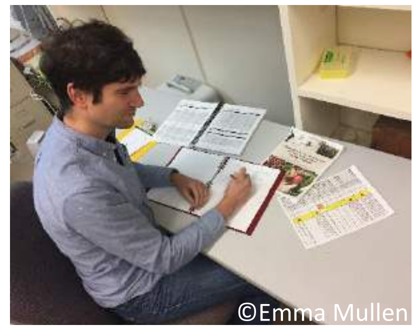


Table 2: Synergies and acute, chronic, and sublethal toxicities for honey bees and other pollinators lists all the active ingredients alphabetically, noting EPA honey bee acute toxicity ratings, ability to synergize, and sublethal effects or impacts to non-honey bee pollinators. Pesticides are grouped according to class: A) fungicides, antibiotics, and inert ingredients, and B) insecticides (including insect growth regulators) and adjuvants. In the 3rd to 5th columns of **Table 2**, the EPA's acute toxicity ratings for adult honey bees are reported with the symbol if a synergy has been documented. Notes on the active ingredients that cause synergistic interactions, as well as information on sublethal impacts or impacts to other bee species is outlined in the 6th column. Timing of spray is typically noted on the label, and we encourage applicators to use the most conservative timing when a potentially synergistic combination must be used.

While this guide has highlighted all laboratory and field experiments that have measured synergies beween active ingredients, and the sublethal, chronic, and developmental impacts of pesticides to honey bees (*Apis mellifera*) and other bee species, it is not an exhaustive list of all product formulations or all pesticides used in agriculture. The toxicity ratings in columns 3-5 of this guide refer to current registration standards set forth by the EPA based on acute toxicity of pesticides to adult honey bees. Where additional considerations for other bee species, chronic toxicity, sublethal toxicity, or larval or pupal toxicity are known from scientific literature, we have included these risks in the '**Pesticide synergies, sublethal effects, and toxicity to pollinators other than the honey bee'** column in **Table 2**.

Bombus impatiens on a cherry flower.

Understanding the terms in this guide

Pesticide toxicity (i.e. acute toxicity)

Acute toxicity is the dose or concentration of an active ingredient that it takes to kill 50% of bees that come into contact with it within 48 hours. The lethal dose of an ingredient is referred to as the LD_{50} value. Acute pesticide toxicity is grouped into three categories:

highly toxic (LD_{50} < 2 µg/bee),
moderately toxic (LD_{50} 2 - 10.99 µg/bee)
practically non-toxic (LD_{50} > 11 µg/bee)

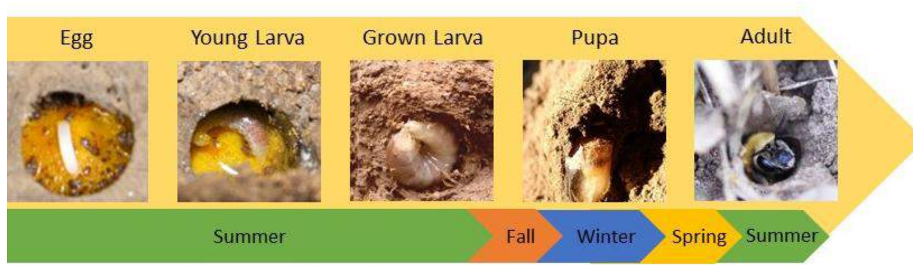
The EPA is currently working to adjust their registration standards to address risk, which consolidates toxicity data with exposure predicted from field application rates. These risk rankings will be available in a few years and, when they are, will be included or referenced in a future edition of this guide.

Synergistic Interactions

Traditionally, pesticide toxicity evaluates one active ingredient at a time. With our growing understanding of the multitude of pesticides bees come into contact with simultaneously, we now know that to understand the overall risk posed to bees in the environment, we need to measure how mixtures of pesticides interact with one another. Some pesticides commonly used in orchard management have been identified as synergists (see Table 2). Certain classes of fungicides and adjuvants are commonly reported to synergize with insecticides to create greater than expected effects on bees. For instance, the combination of DMI fungicides (e.g. myclobutanil, difenoconazole, propiconazole) with some pyrethroids or neonicotinoids have been found to create these effects. This guide highlights active ingredients that are known synergists and the mixtures that should be avoided whenever possible to mitigate risk to bees. This information is especially helpful when planning tank mixes and spray regimes. Keep in mind that the conditions for synergy can vary depending on formulation, weather, and time since application of an active ingredient. While we understand that tank mixing is a cost-effective and time-saving practice, we encourage pesticide applicators to identify and avoid certain pesticide combinations that are likely to cause synergisms, noted in Table 2.

Systemic Pesticides

"Systemic" pesticides are able to protect the entire plant instead of one isolated part of the plant. The pesticide is translocated within the plant from the point of soil uptake to the petals, leaves, stem, roots, pollen and nectar to protect the plant from a variety of pests. Unfortunately, this also means that these pesticides can be present in pollen, nectar, and guttation droplets for days or weeks, which can result in exposure to pollinators. The most common systemic pesticides are the



The life cycle of a solitary ground nesting bee. Bees can be exposed to pesticides in soil and in the pollen and nectar they consume as larvae. Photos by Laura Russo.

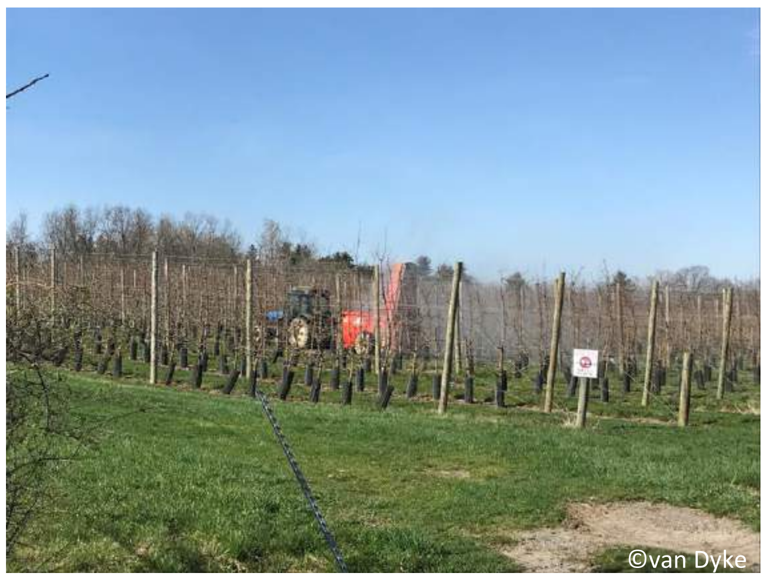
neonicotinoids (acetamiprid, clothianidin, dinotefuran, imidacloprid, nitenpyram, thiacloprid, thiamethoxam) and fipronil, a phenylpyrazole insecticide. A real conundrum we face is that some sytemics are only in NY because they are seed coatings on other crops planted in other fields that bees forage in at the same time as apple bloom, increasing the potential for synergy. Some neonicotinoids can persist in the soil for years and be taken up by nearby plants at any time creating a high likelihood for bee exposure and potential to synergize with other pesticides.

Adjuvants and/or inert ingredients

Adjuvants are chemicals added to a pesticide spray mix to improve performance. Inert ingredients are chemicals in a pesticide product formulation aside from the active ingredient(s). We have included some of these chemicals in Table 2 because recent findings have demonstrated that they are highly toxic to bees (for example, N-methyl-2-pyrrolidone and organosilicones). The literature on this topic is young, therefore we do not highlight it in this guide.

Tying it all together: adopting an Integrated Pest *and* Pollinator Management (IPPM) approach to protect pollinators

Growers and pesticide applicators have already made marked adjustments for the protection of bees by following pesticide label guidelines. Pesticide labels inform users about bee precautions in a "Bee Advisory Box", in the "Directions for Use" section, and/or in the "Environmental Hazards Statement" section of the product label. These precautions include information about the time, temperature, and wind speeds under which pesticides can be safely applied, and may specify additional requirements for reducing drift. Whether growers work closely with a county extension educator, a crop consultant, or a distributor, they must always read the pesticide label carefully.



Spraying in low-wind conditions can reduce drift, especially when using a typical airblast sprayer.

When reading the label, always note the crops for which the pesticide is registered, the proper mixing rate, the proper method of application, and the proper timing (e.g., weather conditions, time of day, stage of bloom) for minimizing negative impacts on non-target organisms and humans. Take note of the active ingredient name(s). Also note the compatibility of the pesticide with other products that will be applied at the same time or in the same tank mix. Applicators should verify that the product is currently registered in their region of New York by searching the products listed in the New York State Pesticide

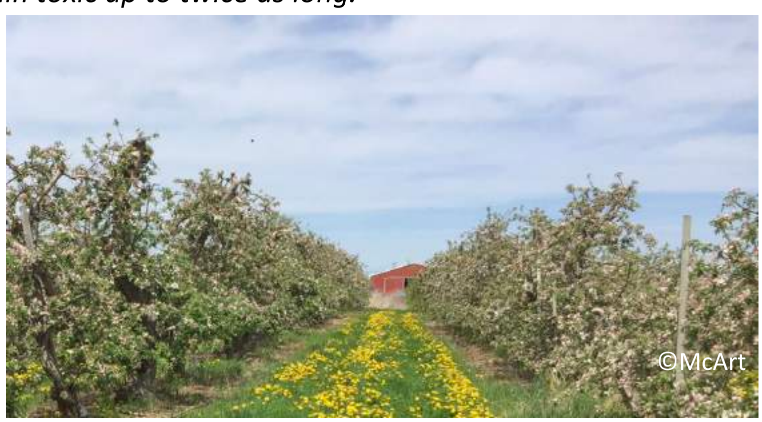
Administration Database (NYSPAD): http://www.dec.ny.gov/nyspad/. If applicators are using this guide in another state, they should check their state's pesticide registration database or the National Pesticide Information Retrieval System (NPIRS) to determine which pesticides are registered for their use: http://npirspublic.ceris.purdue.edu/state/.

An integrated pest and pollinator management approach requires growers to be aware of their pest populations through scouting early and often, to use non-chemical methods to delay the need for chemical applications, and when pesticides are warranted, to choose products that are effective and pose the lowest risk to bees and other non-target organisms.

Bees visit plants in field edges even when a crop is not in bloom

IPPM: Putting the "Pollinator" in IPM:

1) Read the entire product label to find pollinator protection guidelines during application, and follow label directions.
2) Select pesticides that are effective against target pests, but least toxic to bees.
3) Avoid using pesticides or tank mixing pesticides and adjuvants that are noted in this guide to synergize with each other.
4) Choose sprayer nozzles and settings that reduce drift. Follow label directions regarding wind speed and temperature inversions to avoid drift to areas of potential bee habitat at field edges.
5) Unless the product label notes otherwise, avoid applying insecticides when high humidity at low temperatures are forecasted following application. *Dew is common under these conditions, which allows residues to remain toxic up to twice as long.*
6) Prevent bees from visiting the orchard floor while pesticides are being applied by frequently mowing broadleaf weeds (e.g., dandelions). Leaving flowers on the orchard floor can expose bees to pesticides.
7) Follow label directions to reduce contamination of surface waters (e.g., irrigation ditches, retention ponds, creeks, etc). Bees actively collect water and mud from these sources.
8) Develop a communication strategy to alert nearby beekeepers at least 24 hours in advance of applying a highly toxic pesticide. Consider using a written pollination contract with beekeepers who provide pollination services to discuss an IPPM plan in advance. An example template can be found in Appendix A of this guide.



Mowing dandelions and other flowering weeds in orchard lanes can protect bees from pesticides exposure.

Table 1. Product formulations and their active ingredients

Product Name	Active ingredient
Fungicides, antibiotics and inert ingredients	
Abamectin *(ingredient in)*	N-methyl-2-pyrrolidone (NMP)
Abound	azoxystrobin
Academy	difenoconazole + fludioxonil
Acadia	azoxystrobin
Actigard	acibenzolar-s-methyl
Aframe	azoxystrobin
Agricure	potassium bicarbonate
Agri-mycin	streptomycin
AgriTin*	triphenyltin hydroxide*
Alamo	propiconazole
Aliette	fosetyl-al
Alsa*	propiconazole
Amistar	difenoconazole
Aprovia	benzovindiflupyr
AproviaTop	benzovindiflupyr + difenoconazole
Ardent *(ingredient in)*	N-methyl-2-pyrrolidone (NMP)
Azoxystar	azoxystrobin
Badge SC & X2§	copper oxychloride + copper hydroxide
Banner Maxx	propiconazole
Biocover	mineral oil
Bonide complete fruit tree spray	captan
Bonide Fruit Tree & Plant Guard	boscalid+pyraclostrobin+ lambda-cyhalothrin
Bordeaux§	copper sulfate
BravoUltrex	chlorothalonil
Bromazil	imazalil
Bumper 250 EC*	propiconazole
BVA	mineral oil
C.O.C.S.	copper oxychloride + copper sulfate
Cabrio EG	pyraclostrobin
Camelot O§	copper octanoate
Cannonball	fludioxonil
Captan 50 WP	captan
Captan 80 WDG	captan
Captec 4L	captan
CaptEvate	fenhexamid + captan
Catamaran	chlorothalonil + potassium phosphite
Cease§	*Bacillus subtilis*
Champ§	copper hydroxide
Cherokee	propiconazole
Civitas Turf	mineral oil
Contans	*Coniothyrium minitans*
Crystalline BASF* products	pyraclostrobin
Cueva§	copper octanoate
Cuprofix Ultra§	copper sulfate
Cuproxat§	copper sulfate
Curzate 60 DF	cymoxanil
Damoil	mineral oil
Decco Pyr. 400 SC	pyrimethanil
Deccozil	imazalil
Decree	fenhexamid
Dithane	mancozeb
Double Nickel§	*Bacillus amyloliquefaciens*
Echo 90 DF & Lite	chlorothalonil
Eclipse Turf	iprodione
EFOG-160-PYR storage	pyrimethanil
Elatus	benzovindiflupyr
Elevate	fenhexamid
Empress Intrinsic	pyraclostrobin
Encartis	boscalid + chlorothalonil
Endura	boscalid
Equus products	chlorothalonil
Ethos§	*Bacillus amyloliquefaciens*
Exilis plus	N-methyl-2-pyrrolidone
Exponent	piperonyl butoxide
Ferbam	ferbam
Fireline	oxytetracycline
Firewall	streptomycin
Flint	trifloxystrobin
Flint Extra	trifloxystrobin
Fontelis	penthiopyrad
Fortix	flutriafol
Fortuna	mancozeb
Freshgard	imazalil
Fungaflor	imazalil
Fungazil	imazalil
Fungisol	debacarb
Gem 500 SC	trifloxystrobin
Glacial Spray	mineral oil
Heritage	azoxystrobin
Incognito 4.5F	thiophanate-methyl
Indar2F	fenbuconazole
Initiate	chlorothalonil
InspireSuper	difenoconazole + cyprodinil
Iprodione2F Select*	iprodione
Kaligreen	potassium bicarbonate
Kasumin 2L	kasugamycin
Kestrel Mex*	propiconazole
Kocide§	copper hydroxide
Kodiak§	*Bacillus subtilis*
Liquid Copper Products§	copper octanoate
Luna Sensation†	fluopyram + trifloxystrobin
Luna Tranquility†	fluopyram + pyrimethanil
ManKocide	mancozeb + copper hydroxide
Mantis	propiconazole
Manzate Flowable*	mancozeb
Manzate Max T&O	mancozeb
Manzate ProStick	mancozeb
Marazo	propiconazole
Mastercop§	copper sulfate
Menara	propiconazole
Merivon Xemium*†	fluxapyroxad + pyraclostrobin
Meteor*	iprodione
MilStop	potassium bicarbonate
MoncoatMZ	flutolanil + mancozeb
Monterey§	*Bacillus amyloliquefaciens*
Mural	benzovindiflupyr
MycoShield	oxytetracycline
Natria§	*Bacillus subtilis*
Nevado*	iprodione
Omni	mineral oil
Oreon	PCNB (quintozene or pentachloronitrobenzene)
Ortho Elements Garden§	copper octanoate
PBO-8	piperonyl butoxide
Penbotec 400 SC	pyrimethanil
Penncozeb	mancozeb
Polyram 80 DF	metiram
Presidio*	fluopicolide
Pristine fungicide	boscalid + pyraclostrobin
Procure*	triflumizole*
Propi Max	propiconazole
Pure Spray	mineral oil
Quadris Ridomil Gold SL	azoxystrobin + mefenoxam
Quadris F	azoxystrobin
Quadris Opti	azoxystrobin + chlorothalonil
Quadris Top	azoxystrobin + difenoconazole
Quali-Pro	mefenoxam
Quash	metconazole
Quilt	azoxystrobin + propiconazole
QuiltXcel	azoxystrobin + propiconazole
Quintec	quinoxyfen
Rally 40 WSP	myclobutanil
Ranman 400SC	cyazofamid
Regalia	reynoutria
Revitalize§	*Bacillus amyloliquefaciens*
Rhyme	flutriafol
Rovral 4 F*	iprodione
Scala	pyrimethanil
Scholar	fludioxonil
Serenade§	*Bacillus subtilis*
Sonata§	*Bacillus subtilis*
Sonoma 20 EW AG	myclobutanil
Sonoma 40 WSP	myclobutanil
Sovran	kresoxim-methyl
Streptrol	streptomycin
SubdueGR	mefenoxam- nonbearing
Sulfur	sulfur
SuperTin*	triphenyltin hydroxide*
Syllit FL	dodine
Tartan	trifloxystrobin
Temprano *(ingredient in)*	N-methyl-2-pyrrolidone (NMP)
Terraguard*	triflumizole*
Tilt	propiconazole
Topguard†	flutriafol
Topguard EQ†	azoxystrobin+flutriafol
Topsin M	thiophanate-methyl
Tourney	metconazole
Triathlon§	*Bacillus amyloliquefaciens*
Ultra Flourish	mefenoxam
Vanguard WG	cyprodinil
Vault§	*Bacillus amyloliquefaciens*
Velum Prime*†	fluopyram
Vivando	metrafenone
Warden RTA	mefenoxam + fludioxanil
Ziram	ziram
Zoro (*ingredient in*)	N-methyl-2-pyrrolidone (NMP)
Products with insecticide and fungicide mixtures	
Bonide fruit tree & plant guard	Boscalid + Pyraclostrobin + Lambda-cyhalothrin
Insecticides, Insect growth regulators and adjuvants	
Abamex	abamectin
Aceto*†	bifenthrin
Acramite	bifenazate

Table 1. Product formulations and their active ingredients *(continued)*

Product Name	Active ingredient
Actara*†	thiamethoxam
Activator90	polyethoxylated nonylphenol (N-90)
Admire Pro*	imidacloprid
Advise 4*	imidacloprid
Agree WG§	*Bacillus thuringiensis*
Agri-Flex*†	abamectin + thiamethoxam
Agri-Mek*	abamectin
Altacor*†	chlorantraniliprole
Ammo	cypermethrin
Annihilate*	methomyl
Apistan	*tau*-fluvalinate
Apollo	clofentezine
Applaud IGR	buprofezin
Aquaflow	*tau*-fluvalinate
Arvida	acetamiprid
Asana XL*	esfenvalerate
Assail	acetamiprid
Avaunt	indoxacarb
Aza-Direct§	azadirachtin
AzaGuard§	azadirachtin
Azatin§	azadirachtin
Azomar	acetamiprid
Banter	bifenazate
Baythroid XL*	beta-cyfluthrin
Baythroid*	cyfluthrin
Beleaf products	flonicamid
Belt SC*†	Flubendiamide
Besiege*†	chlorantraniliprole + lambda-cyhalothrin
Bifenture*	bifenthrin
BioBit§	Bacillus thuringiensis subspecies and proteins
Bonideoil§	horticultural oil
Brigade 10WSB*	bifenthrin
Brigade 2EC*	bifenthrin
Buprofezin 65% WP	buprofezin
Butacide	piperonyl butoxide
Calypso 4 Flowable*†	thiacloprid
Carbaryl 4L	carbaryl
Cease	*Bacillus subtillis*
Centaur*†	buprofezin
Collate*	ethephon
Companion	*Bacillus subtillis*
Confirm*†	tebufenozide
Corrida 29SL*	methomyl
Counter Lock-n-Load*	terbufos
Counter 15G Smartbox*	terbufos
Crossfire	polyethoxylated nonylphenol (N-90)
Damoil	horticultural oil
Danitol*	fenpropathrin
Delegate WG	spinetoram
Demand SC, EZ & G	lambda-cyhalothrin
Des-X§	insecticidal soap
Diazinon*	diazinon
Dimethoate*	dimethoate
Dimilin*†	diflubenzuron
DiPel DF§	Bacillus thuringiensis subspecies and proteins
Drexel carbaryl	carbaryl
Durivo*†	thiamethoxam + chlorantraniliprole
Endigo*†	thiamethoxam + lambda-cyhalothrin
Entrust SC§	spinosad
Envidor*†	spirodiclofen
Epi-Mek	abamectin
Esteem	pyriproxyfen
Exirel*† (Dupont)	cyantraniliprole
Falgro	gibberellic acid
Fanfare*	bifenthrin
Fascination	benzyladenine + gibberellins
Flagship*†	thiamethoxam
Flonicamid 50WG	flonicamid
Floramite	bifenazate
Fyfanon	malathion
GameStop§	kaolin
Gaucho 480	imidacloprid
Gaucho 600	imidacloprid
Gaucho XT	imidacloprid
GibGro	gibberellic acid
Gladiator*	zeta-cypermethrin + avermectin
Gnatrol§	*Bacillus thuringiensis* subspecies and proteins
Hero*	bifenthrin + piperonyl butoxide
Imidan*	phosmet
Induce	non-ionic surfactant
Intrepid*†	methoxyfenozide
IntruderMax	acetamiprid
Javelin§	*Bacillus thuringiensis* subspecies and proteins
JMS Stylet§	horticultural oil
Justice	acetamiprid
Kanemite	acequinocyl
Kopa§	insecticidal soap
Lannate products*	methomyl
Leverage 360*	beta-cyfluthrin + imidacloprid
Leverage 2.7*	cyfluthrin + imidacloprid*
Leverage products	imidacloprid
LI-700	non-ionic surfactant
Lorsban*	chlorpyrifos
M1-LV*	methomyl
Macho 2 & 4	imidacloprid
Magister	fenazaquin
Magus	fenazaquin
Mavrik	*tau*-fluvalinate
Molt-X§	azadirachtin
Movento*	spirotetramat
M-pede§	insecticidal soap
Mustang & Mustang MAXX*	piperonyl butoxide & zeta-cypermethrin
N-90	polyethoxylated nonylphenol (N-90)
Nealta	cyflumetofen
Neemix§	azadirachtin
Nexter†	pyridaben
N-Large	gibberellic acid
Novagib	gibberellic acid
Nudrin*	methomyl
NuFarm Abamectin	abamectin
Omni	acetamiprid
Onager	hexythiazox
Pedestal*	novaluron
Perimeter	*tau*-fluvalinate
Perlan	benzyladenine + gibberellins
Phase	organosilicone surfactant
Platinum 75 SG*†	thiamethoxam
Portal	fenpyroximate
Pounce 25 WP*	permethrin
Proclaim*	emamectin benzoate
Pro-Gibb	gibberellic acid
ProGibb 4%	gibberellic acid
Promalin	benzyladenine + gibberellins
Provide 10% SG	gibberellic acid
Provoke*	imidacloprid
Pure Spray§	horticultural oil
Pybuthrin	piperonyl butoxide
Pycana	pyrethrin
PyGanic§	pyrethrin
Pyrenone	pyrethrin
Radiant SC	spinetoram
Regent	fipronil
Regulaid	non-ionic surfactant
Return*†	oxamyl
Rimon*	novaluron
Safer§	*Bacillus thuringiensis* subspecies and proteins
Safer§	insecticidal soap
Savey	hexythiazox
Seduce Insect Bait§	spinosad
Serenade	*Bacillus subtillis*
Sevin	carbaryl
ShuttleO	acequinocyl
Silencer*	lambda-cyhalothrin
Silicone	organosilicone surfactant
Silkin	organosilicone surfactant
Silt	organosilicone surfactant
SpinTor 2SC§	spinosad
Spirotetramat 240SC*	spirotetramat
Steward	indoxacarb
Subtilex NG	*Bacillus subtillis*
SuffOil-X§	horticultural oil
Sultrus*	beta-cyfluthrin
Sunspray	horticultural oil
Supracide	methidathion
Surround 95 WP§	kaolin
Talus 70DF*†	buprofezin
Thuricide§	*Bacillus thuringiensis* subspecies and proteins
Tombstone*	cyfluthrin
Tourismo*†	flubendiamide
Triact 70§	azadirachtin
Trilogy§	azadirachtin
Tundra*	bifenthrin
Typy	benzyladenine + gibberellins
Ultra-Fine	horticultural oil
Vendex*	fenbutatin-oxide
Ventas*†	oxamyl
Verve*	ethephon
Voliam Flexi*†	thiamethoxam + chlorantraniliprole
Warrior II Zeon*†Δ	lambda-cyhalothrin
Xentari§	Bacillus thuringiensis subspecies and proteins
Zeal	etoxazole
ZetaGuard LBT	zeta-cypermethrin + PBO
Zoro	abamectin

Table 2. Pesticide synergies and acute, chronic, and sublethal toxicities for honey bees and other pollinators

Key to table abbreviation, symbols, and colors

- * - Restricted-use pesticide
- † - Not for use in Nassau and Suffolk counties of New York
- § - Meets USDA organic standards
-  - Identifies a chemical that at least one study has shown synergy with other active ingredients or products.
-  - Identifies a formulation containing more than one active ingredient, at least one of which has been shown to synergize with other chemicals

EPA standard toxicity ratings: acute oral and/or contact toxicity to the honey bee *(Apis mellifera)*

- ***Highly toxic*** (acute LD_{50} < 2µg/bee)
- ***Moderately toxic*** (acute LD_{50} 2 - 10.99µg/bee)
- ***Practically non-toxic*** (acute LD_{50} >11 µg/bee)

Fungicides, antibiotics and inert ingredients

Active Ingredient *Chemical group* *[Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
acibenzolar-S-methyl *benzothiadiazole [P01]*	Actigard				
azoxystrobin *QoI-methoxy-acrylate fungicide [11]*	Quadris F, Abound, Acadia, Aframe, Heritage				azoxystrobin (Quadris) synergizes with iprodione (2SE Select)[1]. No synergy detected with thiacloprid[2].
azoxystrobin + difenoconazole *QoI-methoxy-acrylate + DMI-triazole fungicide [11+3]*	Quadris Top				See azoxystrobin and difenoconazole separately for synergy information.
azoxystrobin + flutriafol *QoI-methoxy-acrylate + DMI-triazole fungicide [11+3]*	TopguardEQ				
azoxystrobin + propiconazole *QoI-methoxy-acrylate + DMI-triazole fungicides [11+3]*	Quilt, Quilt Xcel				See azoxystrobin and propiconazole separately for synergy information.

Active Ingredient *Chemical group* *[Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
Bacillus amyloliquefaciens *Microbial disruptor of pathogen produced by natural bacterium [44]*	Double Nickel§, Ethos§, Monterey§, Revitalize§, Triathlon§, Vault§				
Bacillus subtilis *Microbial disruptor of pathogen, toxin produced by natural bacterium [44]*	Cease§, Kodiak§, Natria§, Serenade§, Sonata§, etc.				The **wet** application of *B. subtilis* strain QST713 (Serenade) reduced honey bee brood production and was highly toxic to the bumble bee (*Bombus terrestris*)[3]. Tests on the **dry** application of *B. subtilis* strain QST713 (Serenade) and strain QRD132 (Serenade) did not significantly impact *Bombus impatiens*[4] or honey bees[5].
benzovindiflupyr *SDHI-pyrazole-4-carboxamide fungicide [7]*	Aprovia*, Elatus*, Mural*				A new product for bitterrot.
boscalid *SDHI-pyridine-carboxamide fungicide [7]*	Endura (grape)				Synergizes with clothianidin and thiamethoxam[6].
boscalid + pyraclostrobin *SDHI-pyridine-carboxamide + QoI- methoxy-carboxamide fungicides [7+11]*	Coronet, Pristine				boscalid+pyraclostrobin (Pristine) synergizes with chlorpyrifos[7] reducing queen emergence, with iprodione (2SE Select) increasing honey bee mortality[1], and with iprodione (Rovral) negatively impacting solitary bee species nesting behavior[8].
boscalid + pyraclostrobin + lambda-cyhalothrin *SDHI-pyridine-carboxamide + QoI-methoxy-carboxamide fungicides + a pyrethroid insecticide [7+11+3A]*	Bonide Fruit Tree and Plant Guard				See boscalid, pyraclostrobin and lambda-cyhalothrin separately for synergy information.
captan *phthalimide fungicide [M4]*	Captan 50 WP, Captan, 80 WDG, Captec 4L				Studies have found captan to increase honey bee brood mortality at a **moderately** toxic level[9,10] and alter larval feeding capacity[11]. A study conducted by the USDA Bee Lab in Weslaco, TX found that the inert ingredients mixed with captan make it **highly** toxic[12]. Other laboratory studies report captan to be **highly toxic** to mason bees[13] and leafcutter bees [14,15] but **practically non-toxic** to bumble bees at recommended field rates[16].

Active Ingredient *Chemical group* *[Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
chlorothalonil *chloronitrile fungicide [M5]*	Bravo ZN, Bravo Ultrex, Echo Products, Equus, Initiate				Synergizes with alpha-cypermethrin and lambda-cyhalothrin[17] and the beekeeping miticides *tau*-fluvalinate, coumaphos[18,19], and Thymol[18]. Also synergizes with the thiophanate-methyl product Cerconil®. Chlorothalonil exhibits cumulative oral toxicity in honey bee larvae reared on field relevant doses for 6 days[19] and increases honey bee and bumble bee susceptibility to *Nosema* infection[20,21] & entombed pollen inside the honey bee hive[20].
copper hydroxide *inorganic fungicide/bacteriacide [M1]*	Kocide§, Champ§				
copper octanoate *inorganic fungicide/bacteriacide [M1]*	Camelot O§, Cueva§, Liquid copper Products§, Ortho Elements Garden§				
copper oxychloride/ copper hydroxide *inorganic fungicide/bacteriacide [M1]*	Badge SC & X2§				copper oxychloride synergizes with imidacloprid[22].
copper oxychloride/copper sulfate *inorganic fungicide/bacteriacide [M1]*	C.O.C.S.				copper oxychloride synergizes with imidacloprid[22].
copper sulfate *inorganic fungicide/bacteriacide [M1]*	Bordeaux§, Cuprofix Ultra§, Cuproxat§, Mastercop§				**Highly** toxic to a stingless bee species via oral exposure[23].
cyprodinil *anilino-pyrimidine fungicide, [9]*	Vanguard WG				**Moderate** toxicity when it synergizes with thiacloprid[2].
difenoconazole *DMI-triazole fungicide [3]*	Quadris-Top, Amistar, etc.				Synergizes with deltamethrin[24] and the *tau*-fluvalinate[25] product MAVRIK inducing hypothermia in honey bees.
difenoconazole + fludioxonil *DMI-triazole + phenylpyrroles fungicides [3+12]*	Academy				See difenoconazole and fludioxonil separately for synergy information.

Active Ingredient *Chemical group* *[Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
difenoconazole + cyprodinil *DMI-triazole + anilino-pyrimidine fungicides [3+9]*	Inspire Super				See difenoconazole and cyprodinil separately for synergy information.
dodine *guanidine fungicide [U12]*	Syllit FL				
fenbuconazole *DMI-triazole fungicide [3]*	Indar 2F				Synergizes with *tau*-fluvalinate[18] making it **highly** toxic to honey bees. At a field relevant dose the fenbuconazole product, Indar 2F, synergizes with acetamiprid[27] in a solitary bee, doubling the toxicity of acetamiprid, making it borderline **highly** toxic (LD_{50} 2.1).
fenhexamid *SBI-KRI hydroxyanilide fungicide [17]*	Decree, Elevate				
fenhexamid + captan *SBI-KRI hydroxyanilides + phthalimide [17+M4]*	CaptEvate				See captan separately for toxicity notes.
ferbam *dithiocarbamate fungicide [M3]*	Ferbam granuflo				
fludioxonil *phenylpyrroles fungicide [12]*	Cannonball, Scholar				Impacts honey bee learning behavior[28].
fluopicolide *acylpicolide fungicide [U]*	Presidio* *for landscape fruit trees*				
fluopyram *pyridinyl-ethyl-benzamide fungicide [7]*	Velum Prime*†, Broadform*†				
fluopyram + pyrimethanil *Pyridinyl-ethyl-benzamide + anilino-pyrimidine fungicides [7+9]*	Luna Tranquility*†				
flutriafol *DMI-triazole fungicide [3]*	Rhyme†				Synergizes with lambda-cyhalothrin[29,30] making lambda-cyhalothring 3 times more toxic. Although EPA classifies this pesticide as low toxicity to honey bees, the European Food Safety Authority has determined it exhibits **moderate** toxicity when the a.i. is consumed by bees[31].

Active Ingredient *Chemical group* *[Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
fluxapyroxad + pyraclostrobin *SDHI-pyrazole-4-carboxamide + methoxy-carboxamide fungicides [7+11]*	Merivon Xemium*†				See pyraclostrobin separately for synergy information.
fosetyl-Al *Aluminum tris (O-ethylphosphonate) fungicide [P07(33)]*	Aliette WDG				
imazalil *DMI-imidazole fungicide [3]*	Fungaflor, Freshgard, Fungazil				Synergizes with cypermethrin, fipronil, and thiamethoxam in bumble bees[32] and lambda-cyhalothrin in honey bees[30].
iprodione *dicarboxamide fungicide [2]*	Meteor*, 26GT*, Nevado*, Rovral 4 F*, Iprodione 2F Select*				Synergizes with the product Pristine (pyraclostrobin+boscalid)[8]. A product formulation, Compass SC (iprodione + thiophanate methyl), was found to synergize with the varroacide, Mavrik (*tau*-fluvalinate)[33] and decrease the repellency of honey bees to cypermethrin[17] thereby increasing their exposure. One study reports high toxicity to honey bee larvae[10] and another study reports sublethal effects on some solitary bees[8].
kasugamycin *antibiotic [24]*	Kasumin 2L				
kresoxim-methyl *QoI-oximino-acetate fungicide [11]*	Sovran*†				
mandipropamid + difenoconazole *CAA mandelic acid amides + DMI- triazole fungicides [40+3]*	Revus Top				See difenoconazole separately for synergy information.
mancozeb *dithiocarbamate fungicide [M3]*	Dithane*, Koverall*, Manzate, Penncozeb*				When combined with alpha-cypermethrin or lambda-cyhalothrin studies found a 2-4 fold decrease in the contact toxicities[17] of these two insecticides. Synergy not detected with thiacloprid[2].
mancozeb + copper hydroxide *dithiocarbamate fungicide + inorganic fungicide/bactericide [M3+M1]*	ManKocide*				See mancozeb separately for synergy information.

Active Ingredient *Chemical group* *[Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
mefenoxam (metalaxyl-M) *phenylamide acylalanine insect growth regulator [4]*	Quali-Pro Mefenoxam, Ultra Flourish				
metconazole *DMI- triazole[3]*	Quash, Tourney				Synergy with *Tau*-fluvalinate[18] causing a 3-4 fold increase in contact toxicity of this miticide.
metiram *dithiocarbamate fungicide [M3]*	Polyram 80DF				
metrafenone *benzophenone fungicide [50]*	Vivando				
myclobutanil *DMI-triazole fungicide [3]*	Rally 40 WSP, Sonoma 20 EW AG, Sonoma 40 WSP				Synergizes with clothianidin, imidacloprid, thiamethoxam[34], lambda-cyahalothrin[30,35], *Tau*-fluvalinate[18] via oral and/or contact exposure in honey bees. Synergy with lambda-cyhalothrin also affects bumble bees feeding on pollen[35]. Synergy is not detected with thiacloprid[34].
mineral oil *Horticultural Spray*	Biocover, BVA, Damoil, Civitas Turf, Glacial Spray, PureSpray, Omni				
N-methyl-2-pyrrolidone (NMP) inert ingredient often used in pesticide formulations as a co-solvent	NMP is in abamectin 0.15EC, Ardent 0.15, Exilis plus, Temprano, Zoro				This inert ingredient is highly toxic to honey bee larvae[19].
oxytetracycline *tetracycline antibiotic*	Fireline, MycoShield				One study found a synergy with *Tau*-fluvlinate[36]while another study did not show synergy with *tau*-fluvalinate[18].
penthiopyrad *pyrazole-4-carboxamide fungicide [7]*	Fontelis				
piperonyl butoxide *synergist*	Exponent, PBO-8, *and various pyrethrum products*				Synergizes with acetamiprid[37], coumaphos[38,18], Cyfluthrin[39], fenpyroximate[18], lambda cyhalothrin[29,39], permethrin[40], *tau*-fluvalinate[38,18], and thiacloprid[37] as well as imidacloprid and the product Advise[37,41].

Active Ingredient *Chemical group* *[Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
potassium bicarbonate *Inorganic salt*	Agricure, Kaligreen, MilStop				
propiconazole *DMI-triazole fungicide [3]*	Alamo*, Alsa*, Propi Max, Bumper 250EC*, Cherokee, Kestrel Mex*, Menara, Marazo, Tilt, Mantis, Banner Maxx				Synergizes with alpha-cypermethrin[30], acetamiprid, imidacloprid, thiacloprid[37,34], lambda cyhalothrin[30,17], *Tau*-fluvalinate[18], and thiamethoxam[34] in honey bees. One study determined that propiconazole reduced the toxicity of thiacloprid[34]. Synergizes with clothianidin in honey bees, bumble bees and some solitary bees[42] however another study demonstrated only additive effects of clothianidin[43]. propiconazole alone decreases bumble bee reproduction[44].
pyraclostrobin *QoI-methoxy-carboxamide fungicide [11]*	Crystalline BASF* products, Cabrio EG, Empress Intrinsic				Synergizes with fenpyroximate and the beekeeping miticide *Tau*-fluvalinate[18]. The pyraclostrobin+boscalid product Pristine synergizes with iprodione (2SE Select)[1] and negatively impacts nesting success of some solitary bees[8] and reproductive success[45] and immunity in honey bees[7]. When combined with fipronil honey bee larval feeding decreases[46].
pyrimethanil *anilino-pyrimidine fungicide [9]*	Decco Pyr. 400 SC, Scala, Penbotec 400 SC, EFOG-160				
quinoxyfen *azanaphthalene aryloxyquinoline fungicide [13]*	Quintec				
reynoutria Botanical extract of *Reynoutria sacchalinensis*	Regalia				
streptomycin *antibiotic [25]*	Agri-mycin*, Streptrol, Firewall				
sulfur *Inorganic natural element [M2]*	Sulfur, *Some products* **§**				Moderate oral toxicity can remain up to 7 days[47].
thiophanate-methyl *thiophanate fungicide [1]*	Topsin M, Incognito 4.5F				Synergizes with *tau*-fluvalinate[17,18], flumethrin, and lambda-cyhalothrin[17] becoming **highly** toxic to honey bees. Synergizes with product formulations containing the single active ingredients imidacloprid, deltamethrin and chlorothalonil[48] to become **highly** toxic to honey bees and other bees when consumed.

Active Ingredient *Chemical group [Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
trifloxystrobin *methoxy-carboxamide fungicide [11]*	Flint, Flint Extra, Gem 500SC,				
triflumizole *imidazole fungicide [3]*	Procure*, Terraguard*				Synergizes with acetamiprid, imidacloprid, and thiacloprid[37].
ziram *dithio-carbamate fungicide [M3]*	Ziram				Larval mortality in laboratory studies[10].

Mixtures of fungicides and insecticides

Active Ingredient *Chemical group [Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
boscalid + pyraclostrobin + lambda-cyhalothrin *SDHI-pyridine-carboxamide + QoI-methoxy-carboxamide fungicides + a pyrethroid insecticide [7+11+3A]*	Bonide Fruit Tree and Plant Guard				See boscalid, pyraclostrobin and lambda-cyhalothrin separately for synergy information.

Insecticides (including insect growth regulators) and adjuvants

Active Ingredient *Chemical group [Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
abamectin /avermectin *avermectin insecticide [6]*	Agri-Mek*, Abamex, Epi-Mek*, NuFarm abamectin*, Zoro*				The abamectin formulation (Vertimec®) which includes unknown inert ingredients produces a synergistic response that was 709 times/1870 times more toxic to honey bees/Melipona bees than the active ingredient, abamectin alone[49]. **Highly** toxic both topically and orally to honey bees[50] and arrests reproduction in bumble bees[51]. Other non-honey bee species exhibits **moderate to high** toxicity via contact and oral exposure, respectively[52].
abamectin + thiamethoxam *avermectin + nitro-neonicotinoid insecticide [6+4A]*	Agri-Flex*†				See abamectin separately for toxicity information and thiamethoxam separately for synergy information.
acequinocyl *quinolone insecticide [20B]*	Kanemite, Shuttle O				Topical and oral exposure arrests bumble bee reproduction[51].

Active Ingredient *Chemical group* *[Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
acetamiprid *cyano-neonicotinoid insecticide [4A]*	Assail, Arvida, Azomar, Justice, Omni, Intruder Max,				Synergizes with piperonyl butoxide (PBO), S,S,S-tributylphosphorotrithioate (DEF), triflumizole[37], propiconazole[37,35], and the fenbuconazole product (Indar2)[27] making these **highly** toxic mixtures. Synergy with propiconazole[35] and fenbuconazole (Indar2)[27] is also present in bumble bees and mason bees respectively.
azadirachtin *Naturally occurring tetranortriterpenoid Insect growth regulator [UN]*	Aza-Direct§, AzaGuard§, Molt-X§, Neemix§, Azatin§, Triact 70§, Trilogy§				Oral exposure at field relevant dose causes honey bee larval mortality and sublethal effects on adult body size[53–55]. Oral exposure below, at, and above a field relevant does causes bumble bee worker mortality and sublethal effects on reproduction and body mass[56].
Bacillus subtillis *Microbial disruptor of insect midgut membranes [11A]*	Cease, Companion, Serenade (Max, Opti, ASO, Soil), Subtilex NG				*B. subtilis* is toxic to bumble bee species (*B. terrestris*)[3] and exhibits sublethal effects on reproduction in *Bombus impatiens*[4].
Bacillus thuringiensis subspecies and proteins *Microbial disruptor of insect midgut membranes [11A]*	BioBit§, DiPel DF§, Gnatrol§, Javelin§, Monterey§, Safer§, Thuricide§, Xentari§				Negative sublethal impacts on honey bee physiology[57].
benzyladenine + gibberellins *Insect growth regulators*	Perlan, Promalin, Fascination				
beta-Cyfluthrin *pyrethroid insecticide [3A]*	Baythroid XL*, Sultrus*, Tempo SC*				The parent chemical, cyfluthrin synergizes with piperonyl butoxide[39] becoming 30 times more toxic to honey bees. It also impacts honey bee behavior[39] and is **highly** toxic topically and orally to bumble bees[35,58]
beta-Cyfluthrin + imidacloprid *pyrethroid + cyano-neonicotinoid insecticide [3A+4A]*	Leverage 360*				See cyfluthrin and imidacloprid separately for synergy and toxicity information.
bifenazate *Insect growth regulator [20D]*	Acramite, Banter, Floramite				**Moderate** and **High** toxicity, topically and orally, relatively to bumble bees including sublethal effects at just $^1/_{10}$ - $^1/_2$ MFRC[51]. Honey bee mortality increased 5 times, 10 days after exposure[59].

Active Ingredient *Chemical group* *[Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
bifenthrin *pyrethroid insecticide [3A]*	Aceto*†, Bifenture*, Brigade WSB*†, Brigade EC*†, Fanfare*, Tundra EC*				Synergizes with the miticide Apistan (Tau-fluvalinate)[60]. **Highly** toxic to bumble bees[60,35] however typically bifenthrin residue not frequently found in pollen and nectar[35].
***bifenthrin + zeta-cypermethrin* w/ piperonyl butoxide** *pyrethroid insecticide + synergist [3A+synergist]*	Hero*				See bifenthrin, zeta-cypermethrin and piperonyl butoxide separately for other synergy information. Piperonyl butoxide is a well known synergist with pyrethroids like bifenthrin. **Highly** toxic to bumble bees[60,35].
buprofezin *Insect growth regulator [16]*	Applaud IGR*†, buprofezin 65% WP*†, Centaur*†,				The product formulation *buprofezin 65% WP* exhibits **moderate** toxicity[49].
carbaryl *carbamate insecticide [1A]*	Sevin Carbaryl, Drexel Carbaryl, Carbaryl 4L				Toxic to bee species other than the honey bee[61]. Used as a thinner at petal fall it impacts the bee community that typically are still visiting petal-less flowers.
chlorantraniliprole *anthranilic diamide insecticide [28]*	Altacor*†				Suppresses reproduction in worker bumble bees[62]. Synergy not detected with propiconazole in honey bees[63].
chlorantraniliprole + lambda-cyhalothrin *anthranilic diamide + pyrethroid insecticide [28+3A]*	Besiege*†				See chlorantraniliprole and lambda-cyhalothrin separately for synergy and toxicity information.
chlorpyrifos *organophosphate insecticide [1B]*	Lorsban*				Synergizes with propiconazole[64] doubling the toxicity. When combined with the product formulation Pristine (pyraclostrobin + boscalid) it reduces honey bee queen emergence[7]. **Highly** toxic to bumble bees[65,66,35], solitary bees[52] and chronically lethal to honey bee larvae[19].
chlorpyrifos + bifenthrin *organophosphate + pyrethroid insecticide [1B+3A]*	Tundra Supreme*†				See bifenthrin and chlorpyrifos separately for synergy information.
clofentezine *tetrazine ovicide/miticide, an insect growth inhibitor [10A]*	Apollo				
cyantraniliprole *anthranilic diamide insecticide [28]*	Dupont Exirel*†				

Active Ingredient *Chemical group* *[Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
cyflumetofen *beta-ketonitrile miticide [25A]*	Nealta				
cyfluthrin *pyrethroid insecticide [3A]*	Baythroid*, Tombstone*				Synergizes with piperonyl butoxide[39] becoming 30 times more toxic to honey bees. It also impacts honey bee behavior[39] and is **highly** toxic topically and orally to bumble bees[35,58]
cyfluthrin + imidacloprid* *pyrethroid + nitro-neonicotinoid insecticide [3A+4A]*	Leverage2.7*, Leverage 360*				See cyfluthrin and imidacloprid separately for synergy information.
cypermethrin *pyrethroid insecticide [3A]*	Ammo, Fastac				Synergizes with imazalil in at least one bumble bee species[32]. *Alpha*-cypermethrin, an isomer of cypermethrin, synergizes with chlorothalonil (Bravo SC®, 500g/l), propiconazole (Tilt EC, 250g/l), and prochloraz (Sportak EW®, 450 g/l), and increases toxicity of carbendazim (Derosal WG® 80%), iprodione + thiophanate methyl (Compass SC® 15.5%/15.5%) and other triazoles including Tebuconazole (Folicur EW®, 250 g/l) and difenoconazole (Plover EC®, 250 g/l). Both cypermethrin and Zeta-cypermethrin are **highly** toxic to solitary bees[67]. cypermethrin increases Chronic Paralysis Virus (CPV) infection[68].
diazinon *organophosphate insecticide [1B]*	Diazinon*				**Highly** toxic to bumble bees and some solitary bees as well as honey bees[69,61].
diflubenzuron *Insect growth regulator [7C]*	Dimilin*†				Has shown sublethal effects on larvae and fertility of adult honey bees[70–75]; but see[76].
dimethoate *organophosphate insecticide [1B]*	Drexel Dimethoate*				**Highly** toxic to bumble bees and some solitary bees [77,13].
emamectin benzoate *avermectin insecticide [6]*	Proclaim*Δ				
esfenvalerate *pyrethroid insecticide [3A]*	Asana XL*				**Highly** toxic to bumble bees[52,35] and exhibits sublethal effects on megachilid bees[78].
ethephon *Insect growth regulator*	Collate*, Verve*				
etoxazole *etoxazole insecticide [10B]*	Zeal				**Highly** toxic to bumble bees when consumed[51,57].
fenazaquin *pyridazine insecticide [21A]*	Magister, Magus				**Low** toxicity to bumble bees[58]

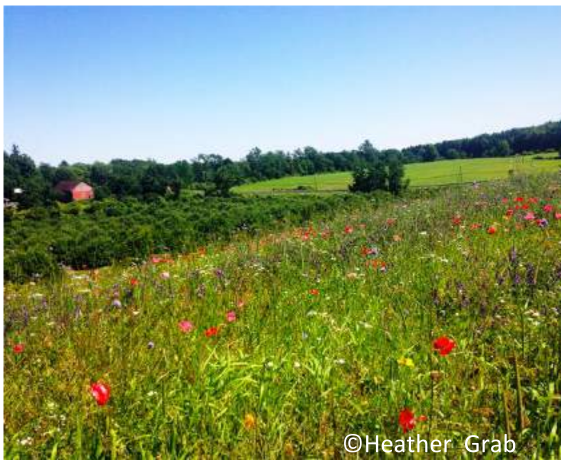
Active Ingredient *Chemical group* *[Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
Fenbutatin-oxide *organotin insecticide [12B]*	Vendex*				
fenoxycarb (EXPIRED) *Insect growth regulator [7B]*					Reduces reproduction and the size of winter honey bee colonies[74].
fenpropathrin *pyrethroid insecticide [3A]*	Danitol 2.4*†				**Highly** toxic to bumble bees and some solitary bees[79].
fenpyroximate *pyridazine insecticide [21A]*	Portal				Synergizes with enzyme inhibitors piperonyl butoxide (PBO) and S,S,S-tributylphosphorotrithioate (DEF), fungicides including prochloraz, pyraclostrobin and beekeeping miticides amitraz[18], and Oxalic acid making these mixes **highly** toxic. And in the cases of the beekeeping miticides *tau*-fluvalinate and coumaphos[18] borderline **high** toxicity (LD_{50} 2.04-2.4). Although EPA has reported that this active ingredient is practically non-toxic, one study measured **moderate** toxicity to honey bees[18].
fipronil *phenylpyrazoles [2B]*	Regent				Synergizes with imazalil to be lethal to bumble bees at 24 hrs but the toxicity subsides by 48 hrs[32]. fipronil is associated with increased *Nosema* infection[80]
flonicamid *flonicamid insecticide [29]*	Beleaf 50SG, Flonicamid 50WG				
flubendiamide *anthranilic diamide insecticide [28]*	Belt SC*†, Tourismo*†				M**oderate** toxicity when applied topically to honey bees has been reported in laboratory and semi-field conditions[81]. *Megachile rotundata*[82] and *Bombus impatiens*[83] were not impacted by the flubendiamide product formulation, Belt SC®.
gibberellic acid *Insect growth regulator*	Falgro, Novagib, GibGro, N-Large, Pro-Gibb 4%§, Pro-Vide 10%SG				Also used as a supplement in the honey bee diet[84].
hexythiazox *thiazolidine insecticide [10A]*	Hexygon, Savey, Onager				
horticultural oil	Damoil, PureSpray§, Sunspray, JMS Stylet§, SuffOil-X§, Ultra-Fine, Bonide oil§				Products with Thymol, Menthol, and Rosemary can be **highly** toxic, especially when bees are already stressed[85–88]). Bees are temporarily inactivated by direct contact with oil sprays; death may occur[89].

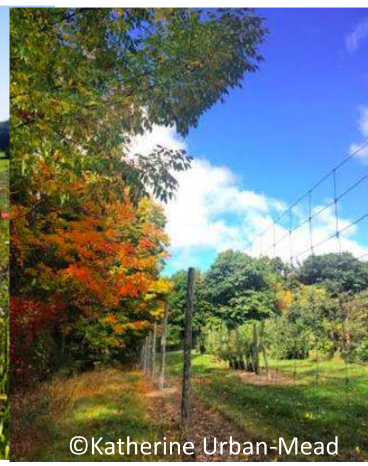
Active Ingredient *Chemical group* *[Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
imidacloprid *neonicotinoid insecticide [4A]*	Advise 4*, Admire Pro Protectant*, Leverage products, Macho 2* & 4*, Provoke*				Synergizes with piperonyl butoxide[37,41], propiconazole[37], triflumizole[37], The imidacloprid product Advise 2FL® synergized with Vydate 3.77 CLV® (oxamyl), Transform 5G® (Sulfloxaflor), and Domark ME® (Tetraconazole)[41]. **Highly** toxic to bumble bees[90]. May impact groundnesting bees in general[91].
indoxacarb *oxadiazine insecticide [22A]*	Avaunt				**High** toxicity even at field-realistic doses[81,92].
insecticidal Soap *Repellant*	M-pede§, Des-X§, Kopa§, Safer§				
kaolin *Repellant*	Surround WP§				
lambda-cyhalothrin *pyrethroid insecticide [3A]*	Demand SC* & EZ* & G*, Silencer*, Warrior II with Zeon*				Synergizes with flutriafol[29], imazalil, myclobutanil, propiconazole[30], prochloraz[29,30,93], and piperonyl butoxide[29,39] making them 16x. **Highly** toxic to bumble bees[79] and some solitary bees[79,94].
malathion *organosphosphate insecticide [1B]*	Fyfanon				**Highly** toxic to bumble bees and some solitary bees[95].
methidathion *organosphosphate insecticide [1B]*	Supracide				Realistic field exposure **moderately** toxic[35].
methomyl *carbamate insecticide [1A]*	Annihilate*, Corrida 29SL*, Lannate*, Lannate LV, M1-LV*, Nudrin*				**Moderately to Highly** toxic to bumble bees[96,58].
methoxyfenozide *diacylhydrazine insecticide [18] an insect growth regulator*	Intrepid*†				Acute and chronic effects to honey bee larvae and adults over time[59].
non-ionic surfactant	Regulaid, LI-700, Induce				
novaluron *benzoylureas insecticide [15]*	Pedestal*, Rimon*				Sublethal impacts on egg and larvae of honey bees[97], some bumble bees[91,98] and leafcutter bees[91,99].

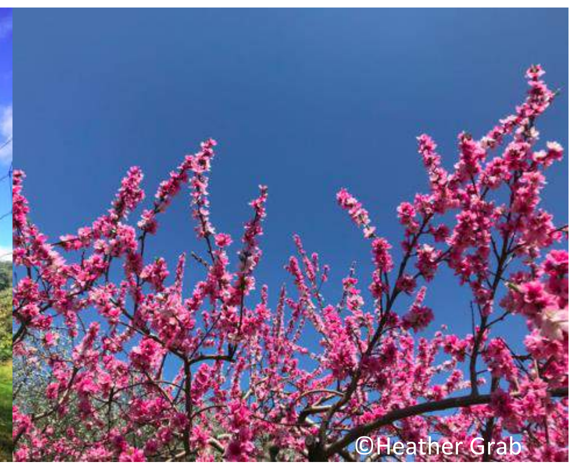
Active Ingredient *Chemical group [Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
organosilicone surfactant *adjuvant*	Phase, Silt, Silkin, Silicone				Increases susceptibility of bees to disease, resulting in exponentially increased mortality[70,100].
oxamyl *carbamate insecticide [1A]*	Return*†, Ventas*†				The oxamyl product Vydate 3.7CLV® synergizes with imidacloprid product (Advise2FL®) [41]. No effects on bumble bees[57].
permethrin *pyrethroid insecticide [3A]*	Pounce 25 WP*				Synergizes with piperonyl butoxide[40]. **Highly** toxic to bumble bees[79,101] and solitary bees[79,102].
phosmet *organophosphate insecticide [1B]*	Imidan*				**Highly** toxic to some solitary bees[79]. Often high residues in pollen samples[35].
piperonyl butoxide (PBO) *synergist*	*Ingredient in* Mustang MAXX*, Butacide, Pybuthrin, *and* Ambush				Synergizes with acetamiprid[37], coumaphos[18], cyfluthrin[39], fenpyroximate[18], lambda cyhalothrin[29,93], permethrin[40,29,38], prochloraz[29,93], *tau*-fluvalinate[18,39], and thiacloprid[37] making **highly** or **more highly** toxic including coumaphos[18] which became **moderately** toxic with PBO. While PBO synergizes with imidacloprid to be just 1.7x more toxic, its combination with the *imidacloprid product* Advise® increased toxicity 5.2 -fold[41].
polyethoxylated Nonylphenol (N-90) *adjuvant*	N-90, Activator 90, Crossfire				Sublethal effects on behavior of the honey bee in response to the product Activator-90[70] as well as to managed solitary bee species when used alone and in the case of Grow-More® N-90, in combination with Rovral 4F® (iprodione) and Pristine® (pyraclostrobin + boscalid) which ultimately decreases reproductive output[8].
pyrethrin *pyrethrin insecticide [3A]*	PyGanic§, Pycana, Pyrenone				Synthetic forms synergize with multiple pesticide ingredients. See pyrethroids. Some formulations found to decrease honey bee body temperature[103].
pyridaben *pyridazine insecticide [21A]*	Nexter†				
pyriproxyfen *Insect growth regulator [7C]*	Esteem				Exhibits sublethal impacts on honey bee larvae, adult behavior, and survival[59,104] as well as bumble bee larvae[105].
spinetoram *spynosin insecticide [5]*	Delegate WG, Radiant SC				
spinosad *spynosin insecticide [5]*	Entrust SC§, Seduce§, SpinTor 2SC§, Conserve SC Turf Ornamental				**Moderate contact and high** oral acute toxicity to bumble bees[106,91] as well as sublethal foraging effects[107] on bumble bees. One non-*Apis* bee species experienced **moderate contact toxicity**[91] while three other species experienced **high contact toxicity**[91,108,23].

Active Ingredient *Chemical group [Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
spirodiclofen *tetronic acid insecticide [23]*	Envidor*†				Although EPA classifies spirodiclofen as low toxicity, one study finds **moderate** toxicity to adult honey bees[109]. Chronic exposure significantly reduced honey bee[110] and bumble bee reproduction and colony strength[51].
spirotetramat *tetramic acid insecticide [23]*	Movento*, Spirotetramat 240 SC*				**Moderate** acute toxicity and **High** chronic oral toxicity and sublethal reproductive effects to bumble bees[111,4]. **Moderately** toxic to honey bee larvae in laboratory studies with does above field recommendations[112].
tau-fluvalinate (beekeeping) *pyrethroid insecticide [3A] a beekeeping miticide.*	Apistan, Aquaflow, Perimeter, Mavrik				Synergizes with boscalid[18], chlorothalonil[19,18], fenbuconazole, metconazole, myclobutanil, prochloraz, propiconazole[18], piperonyl butoxide[39,18] as well as beekeeping miticides coumaphos[38,18], Thymol, amitraz, fenpyroximate, and oxalic acid[18]. **Highly** toxic to honey bee larvae[19]. One study on the *tau*-fluvalinate product Mavrik® and the difenoconazole+carbendazim product ERIA® resulted in no lethal nor sublethal effects on bees[25].
tebufenozide *Insect growth regulator[7c]*	Confirm*†				Exhibits sublethal effects on honey bee behavior and learning[73,70].
thiacloprid **This product is suspended, please dispose. cyano-neonicotinoid insecticide [4A]*	Calypso 4 Flowable*†				Synergizes with cyprodinil[2], piperonyl butoxide[37], triflumizole and propiconazole[39,noted in 29] and is associated with increased *Nosema* infection in honey bees[80]. However one study found no synergy when mixed with tebuconazole, propiconazole or myclobutanil[34]. Field relevant exposure is lethal to bumble bee colonies[113].
thiamethoxam *nitro-neonicotinoid insecticide [4A]*	Actara*†, Flagship*†, Platinum 75 SG*†, Cruiser FS				Synergizes with boscalid[6], propiconazole[33,34], myclobutanil[34], and tebuconazole[34]. Synergizes with imazalil in both honey bees and bumble bees[32]. **Highly** toxic to bumble bees[114,115] and some solitary bees[116]. Synergistic effect on honeybee mortality when co-exposed to thiamethoxam and Chronic Bee Paralysis Virus[117].
thiamethoxam + fludioxonil + mefenoxam	Adage ST, Cruiser MAXX				
thiamethoxam + chlorantraniliprole *nitro-neonicotinoid + anthranilic diamide insecticide [4A+28]*	Voliam Flexi*†, Durivo*†				See thiamethoxam and chlorantraniliprole separately for synergy and toxicity information.
thiamethoxam + lambda-cyhalothrin *nitro-neonicotinoid + pyrethroid insecticide [4A+3A]*	Endigo*†				See thiamethoxam and lambda-cyhalothrin separately for synergy information.

Active Ingredient *Chemical group [Resistance code]*	**New York Trade Name Examples**	**High toxicity**	**Moderate toxicity**	**Practically non-toxic**	**Synergies, sublethal effects, and toxicity to bee species other than the honey bee**
zeta-cypermethrin *pyrethroid insecticide [3A]*	Mustang MAXX*				See cypermethrin separately for synergy information. *Zeta*-cypermethrin is **highly** toxic to solitary bees[67].
zeta-cypermethrin + avermectin *pyrethroid + avermectin insecticides [3+6]*	Gladiator*				See (*zeta*)-cypermethrin and avermectin separately for synergy and toxicity information.







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Sample Pollination Services Contract

This sample contract is provided as a service and is not a substitute for legal advice.

This agreement dated ___________________ is made between the following parties:

Beekeeper's name: **Grower's name:**

__________________________________ ___________________________________

CONTACT INFORMATION		
	Beekeeper	Grower
Mailing address:		
Phone number(s):		
Emergency phone number:		
Email address:		

The parties agree to the following terms

CROP AND COLONY OVERVIEW			
This agreement involves the 20___ growing season			
Crop to be pollinated by honey bee colonies. This agreement is for crop varieties that are in flower.			
Address and/or GPS coordinates of orchard/field where the hives will be placed			
Date of colony placement*		Date of colony removal*	
* If actual flowering dates differ from dates above, the grower will provide __ hours notice to the beekeeper regarding when colonies should be placed and removed			
No. of hives rented		Price of a standard hive rental	$
Total anticipated rental price	$	Date(s) on which the rental fee is payable to the beekeeper	
Describe in detail or illustrate the colony placement in the orchard			
The grower will provide right of entry at all times to beekeepers visiting the property so that s/he can manage colonies	☐ Yes ☐ No		
Before services are provided, the beekeeper will locate a holding yard to place colonies in the event that they require movement to avoid a pesticide spray	☐ Yes ☐ No		
A water source will be provided to the honey bee colonies by the following party	☐ Beekeeper ☐ Grower ☐ No water will be provided		
The grower and beekeeper agree to comply with all applicable federal, state and local laws, including pesticide label restrictions designed to protect bees.			

The **beekeeper** agrees to provide colonies of the following standards:

COLONY STATUS OF A STANDARD HIVE	
Colony configuration (2 deeps, 1 deep, etc.)	
Minimum frames of bees in each hive	
Minimum frames of brood in each hive	
Pounds of food stores	lbs
Presence of a laying queen	
Colonies are free of American Foulbrood	
The beekeeper agrees to open and demonstrate the health and status of colonies randomly selected by the grower at least one (1) time following placement of the hives and thereafter as reasonably requested by the grower.	
The beekeeper will maintain colonies in good pollinating condition by providing feed, medication, and mite treatments as needed	

The **grower** agrees to the following responsibilities:

GENERAL RESPONSIBILITIES
The grower will provide a suitable place(s) for the hives that are accessible by truck or other vehicles
The grower will hold the beekeeper harmless from any and all claims of injury or property damage arising from beekeeper's performance of this contract, including but not limited to, claims arising from bee stings to animals or people, and claims for field or crop damage or loss resulting from the use of beekeepers vehicle(s).

MINIMIZING RISK OF PESTICIDE EXPOSURE		
The following pesticides or agricultural chemicals are mutually agreed to be used while the bees are on the crop:		
1.	2.	
3.	4.	
5.	6.	
7.	8.	
9.	10.	
The beekeeper will be notified of an application of a pesticide in this above list	☐ Yes	☐ No
The beekeeper will be notified at the emergency contact (number/email address) provided above of an application of a pesticide that is not included in this above list	☐ Yes	☐ No
The number of hours notice the grower agrees to give the beekeeper before a pesticide is applied to a crop (e.g., 48 hrs)		hrs
If a pesticide not included in the above list will be applied during pollination, the grower shall assume the costs to move the colonies away from and back to the crop. State the cost of moving colonies	$	
The grower will compensate the beekeeper for any colonies that died from acute pesticide poisoning events while present or within one month of pollinating this crop. Cause of death must be verified by the state apiculturist, state inspector, or Department of Environmental Conservation. State the cost of compensation per colony	$	
The grower will dispose of all pesticide products in a manner that bees will not be able to contact it while searching for a source of water		

Additional agreements:

____
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ADDITIONAL CONSIDERATIONS
Prior to placing colonies for pollination, either party can terminate this contract should events occur beyond his/her control that prevent him or her from fulfilling the obligations as outlined (e.g., unexpected colony deaths, unexpected damage or disease of crops, etc.).
If disputes arise that cannot be resolved through communication or small claims court, they will be settled by arbitration. Either party may request arbitration by providing written notice to the other at the contact information provided above by certified mail, return receipt requested. Within 10 days of receipt of such written request, each party will select one arbitrator and the two arbitrators will select a third. After reviewing the case, the decision of any two arbitrators will be binding. Cost of arbitration will be equally divided between the two parties. This contract shall be governed by New York law.

Signature of beekeeper: ______________________________ Date: _____________

Signature of grower: _________________________________ Date: _____________