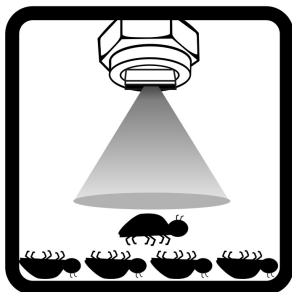

Section 7

Managing Pest Resistance

What is Pest Resistance?



A pest is described as being “resistant” to a pesticide when you apply the pesticide at a rate that used to control the pest, and it no longer works. When these resistant pests reproduce, the next generation of pests, like their parents, will not be controlled by the pesticide.

If you use the same pesticide season after season, or many times within a season, resistance may develop and you may find that the product no longer works effectively. You may also find this resistance happens when you use another pesticide that controls the pest in a similar way through the same Site of Action. **Site of Action** is the term that describes the way the pesticide works to control the pest. The term Mode of Action is also used to describe this.

Pesticide Groupings and Chemical Families

Pesticides are divided into Groups or Chemical Families according to their Site of Action.

The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) Publication, *Guide to Weed Control* includes a table that lists the “Herbicide Groupings for Ontario”. Other OMAFRA publications such as *Fruit Production Recommendations*, *Vegetable Production Recommendations* and *Nursery & Landscape Plant Production and IPM*, include tables that list pesticides by their product names and their chemical families. You can also find Herbicide, Insecticide and Fungicide Grouping tables later in this section. Use these tables when you make your pesticide decisions. Choose pesticides from different Groups so that you rotate the Sites of Action you use.

The Pest Management Regulatory Agency (PMRA) has introduced voluntary labelling of these numbered Groupings on the front panel of all Commercial and Restricted class products. PMRA has also developed guidelines so that manufacturers can give resistance management information in a consistent way under the “Use Directions” section of pesticide labels.

GROUP	1	HERBICIDE
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Resistance in Ontario

In Ontario, pests have developed resistance to herbicides, insecticides, and fungicides.

Weed resistance has been reported to herbicides from Groups 2, 4, 5, 7, 9 and 22. Resistance of pigweed, common ragweed and eastern black nightshade to Group 2 ALS inhibitor herbicides has been confirmed. Group 2 herbicides include imadazolinone products such as Pursuit, and sulfonyleurea products such as Pinnacle, Refine Extra, Accent, and Ultim.

Some insect pests have developed resistance to insecticides such as organophosphates (Guthion, Zolone, Imidan), carbamates (Sevin, Furadan, Lannate) and synthetic pyrethroids (Ripcord). Some mite populations have become resistant to dicofol (Kelthane) and clofentezine (Apollo).

Resistance to fungicides is also a concern. Apple scab is resistant to a number of fungicides, including dodine (Equal). Resistance to iprodione (Rovral) has been confirmed in Botrytis bunch rot of grapes. Fungi may also develop resistance to strobilurin (“strobic”) and sterol inhibitor (SI) fungicides.

How Can You Manage Resistance?

The best way to manage resistance is to prevent or delay it from occurring. Resistance management is a complex challenge. The specific methods you need to use will depend upon the crop you are growing and the pest you are trying to control. Researchers have shown that an Integrated Pest Management program that uses many different pest control methods will help you avoid resistance. Remember to use pesticides only when necessary. If you do need to use pesticides, plan to rotate pesticides from different Pesticide Groupings/Chemical Families.

All Types of Pesticides

Follow these general management strategies to prevent or delay pest resistance from developing to any pesticide.

1. **Scout regularly and identify the pests.** You must have this information to make informed pest management decisions.
2. **Use alternatives to pesticides when you can.** Use physical (mechanical), cultural, biological or genetic methods of pest control instead of pesticides if possible.
3. **Apply pesticides only when necessary.**
4. **Follow the pesticide label directions.** Use only the recommended:
 - ▶ rate
 - ▶ number of applications per season
 - ▶ number of consecutive applications
 - ▶ volume of water
 - ▶ tank mixes.
5. **Rotate crops** when possible. Some pest problems are more easily controlled in some crops than others. Crop rotation may help to control the pest without using pesticides or it may allow you to use pesticides from another pesticide Group.
6. **Know the Groups/Chemical Families of the pesticides you use and rotate them.** See the Groupings for Ontario, pages 76, 77, 78, 79 and 80. You can also find the “Herbicide Groupings for Ontario” in Ontario Ministry of Agriculture, Food and Rural Affairs Publication 75, *Guide to Weed Control* and chemical family listings in other OMAFRA Recommendation and Production publications.
7. **Keep records of crop rotations and the pesticides you use.** Records can help you to evaluate your control program and to plan long term Integrated Pest Management strategies.
8. **Learn about resistant pests in your area and how to manage them.** Communicate with grower organizations and crop management advisors and specialists. The OMAFRA web site offers commodity specific information which can help you to stay informed about pest resistance in the crops you grow. If you suspect that you may have a resistant pest, contact specialists in your area.

Herbicides

Use these added strategies to prevent weeds from becoming resistant to herbicides.

1. **Apply registered tank mixes or formulated mixtures of pesticides from more than one Group**, when it is possible. Make sure that the mixtures you choose include active ingredients that use different Sites of Action to kill the weed.
2. **Clean your tillage and harvesting equipment before you leave an affected field** to prevent spreading the seeds of resistant weeds to other locations.

Insecticides

Use these added strategies to prevent insects from becoming resistant to insecticides.

1. **Know the biology of the insect pest you want to control.** Plan to apply insecticides when the pest is at a susceptible stage of its life cycle.
2. **Rotate insecticide Chemical Families between each generation (one complete life cycle) of the pest, not within the generation.** When possible, rotate pesticides for each generation of the insect. If you use insecticides from more than one Chemical Family on the same generation, you may actually encourage resistance.
3. **Protect beneficial insects and mites.** Use insecticides and fungicides that cause the least damage to beneficial insects and mites. These beneficial organisms may help to control pest populations without further pesticide use. This will help to reduce the insecticide selection pressure applied to the pest, and that in turn will help to prevent resistance.
4. **If you plant Bt corn, maintain non-Bt corn refuges within 400 metres (1/4 mile) of your Bt crop.** Bt (*Bacillus thuringiensis*) corn contains a protein that kills corn borer caterpillars when they eat the corn. Insects may develop resistance to Bt if they are constantly exposed to it. Planting non-Bt corn nearby allows for genetic mixing of resistant and susceptible borers.

Fungicides and Bactericides

Use these added strategies to prevent fungal and bacterial pathogens from becoming resistant to fungicides.

1. Use cultural methods to reduce disease pressure.

Remove debris. Some pathogens survive in plant debris or wood from the previous year and can infect the next crop.

Help air to flow through the crop canopy so that it will dry quickly. Most fungi and bacteria prefer moist or wet conditions. If plant surfaces stay wet for a long time, disease may be more likely to develop. When you plant annual or perennial crops you may need to increase the spaces between and within the rows so that leaves, stems and fruits will dry quickly. Use pruning and training methods to manage the canopies of perennial crops such as tree fruits, cane fruits and grapes. In low-growing crops you may also need to control weeds that can add to relative humidity of the canopy and prevent drying. Schedule your irrigation so that the crop will not stay wet for hours at a time and so that it can dry out before nightfall.

2. Apply protectant fungicides when crop and weather conditions favour disease development.

Protectants can help to prevent infection and keep fungus populations low. Also, many protectant fungicides control the fungus in more than one way (Site of Action) and so resistance is less likely to develop.

3. Use fungicides from different Chemical Families in registered tank mixtures or as alternate sprays.

4. When possible, mix an eradicant fungicide with a protectant fungicide.

Researchers have found that combining these will help to prevent the development of resistance to the eradicant fungicide. Most eradicant fungicides have only one Site of Action and are at risk for resistance development. The protectant treatment will help to prevent disease infection. If less disease occurs, then this will help to reduce the amount of the fungus that is then exposed to the eradicant fungicide.

Do You Have a Resistant Pest?

If you see that a pest has survived a pesticide application, don't assume right away that you have a resistance problem. Rule out these other possible reasons first.

Could there have been an application error?

- ▶ Did you calibrate the sprayer correctly?
- ▶ Did you follow all the recommendations on the product label? Was the timing correct? Did you use the correct water volume? Was the pH of the water suitable for the product, or did the water have sediment in it?

Did the application equipment work correctly?

- ▶ Did a nozzle plug or was there another possible problem with the equipment?

What were the environmental conditions?

- ▶ Did it rain, or did overhead irrigation occur too soon after the application? Were there concerns with the temperature, humidity or wind? Was there a long period of drought conditions before the application?

Did you correctly identify the target pest?

- ▶ For example, it is very difficult to tell some weed species apart from each other when they are seedlings.

If you can't explain why the pest survived with one of the reasons above, then you may have a resistant pest. Check your records and answer the following questions:

Did the pesticide do a good job of controlling the other pests listed on the product label?

- ▶ You will usually first notice resistance with only one pest species. If the pesticide application also failed to control the other pests stated on the label, this is likely due to a problem other than resistance.

Did a pesticide from this Group/Chemical Family fail to control these pests last year?

Did you use pesticides from the same Group/Chemical Family frequently in this field year after year?

If you suspect that you have a resistant pest

If you think that you may have a resistant pest, contact a crop consultant or specialist in your area. You can reach Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) specialists through the OMAFRA Agricultural Information Contact Centre at **1-877-424-1300** or through the internet at **www.gov.on.ca/omafra**. These professionals will know which pests in your region are resistant to which Groups of pesticides. They can advise you on the best Integrated Pest Management strategy to use.

If you must apply a pesticide, be sure that you choose one from another Group/Chemical Family and be sure that the pesticide is labelled for that pest and crop.

Herbicide Groupings for Ontario

Products with two or more sites of action are followed by the group numbers involved.

¹ Group	Site of Action	Single Sites of Action	Two+ Sites of Action
1	Inhibitors of acetyl CoA carboxylase; ACCase	Acclaim Super, Achieve, Assure, Assure II, Excel Super, Poast Ultra, Select, Venture	
2	Inhibitors of acetolactate synthase (ALS) and also called acetohydroxyacid synthase (AHAS)	Accent, Arsenal, Classic, FirstRate, Muster, Option 35 DF, Option 2.25 OD, Pinnacle, Prism, Pursuit, Refine Extra, Telar, Ultim, Upbeet	Accent 1-Pass ³ (2,4), Accent Total ³ (2,4), Battalion (2,4,15) ³ , Broadstrike Dual Magnum (2,15), Cleansweep ³ (2,6), Conquest ³ (2,5), Fieldstar (2,4), Meridian Plus ³ (2,6), PeakPlus ³ (2,4), Summit (2,4), Summit Extra ³ (2,4), Ultim Total ³ (2,4), Valor (2,3), Viper ³ (2,14)
3	Microtubule assembly inhibitors	Bonanza, Dacthal W-75, Dimension, Prowl, Rival, Treflan	Valor (2,3)
4	Synthetic auxins	2, 4-D, Banvel II, Caliber, Cobutox, Compitox, Covitox Plus, Desormone, Diphenoprop, Dycleer, Dyvel, Embutox, Estaprop Plus, Garlon, IPCO Dichlorprop-D, IPCO Premium 2 Way, Killex, Lontrel, MCPA, Mecoprop, Mecocrop 2,4-D, Meco-D, Par III, Premium 3-Way, Release, Sword, Target, Topside, Tordon 101, Turf-Rite 2+2, Turboprop, Vanquish	Accent 1-Pass ³ (2,4), Accent Total ³ (2,4), Badge (4,6), Battalion (2,4,15) ³ , Buctril M (4,6), Distinct (4,19), Fieldstar (2,4), Marksman (4,5), Mextrol (4,6), PeakPlus ³ (2,4), Shotgun (4,5), Summit (2,4), Summit Extra ³ (2,4), Ultim Total ³ (2,4)
5	Inhibitors of photosynthesis at photosystem II, Site A	Aatrex, Atrazine, Gesagard, Hyvar X, Princep, Pronone, Pyramin FL, Sencor, Simadex, Simazine, Sinbar, Spin-Aid, Velpar	Axiom (5,15), Boundary ³ (5,15), Conquest ³ (2,5), Converge (5,28), Krovar (5,7), Laddok (5,6), LibertyPrime ³ (5,10,15), Marksman (4,5), Primextra II, Magnum (5,15), Shotgun (4,5)
6	Inhibitors of photosynthesis at photosystem II, Site A	Basagran, Basagran Forte, Koril, Pardner	Badge (4,6), Buctril M (4,6), Cleansweep ³ (2,6), Laddok (5,6), Meridian Plus ³ (2,6), Mextrol (4,6)
7	Inhibitors of photosynthesis at photosystem II, Site B	Diurex 80W, Herbec, Karmex, Linuron, Lorox	Krovar (5,7)
8	Conjugation of acetyl co-enzyme A	Betasan, Eptam, Eradicane, Ro-Neet	
9	Inhibitors of 5-enolpyruvylshikimate-3-phosphate synthase (EPSP)	Clear-It, Credit, Credit Plus, Expedite Grass & Weed, EZJect, Factor, Glyphos, Renegade, Roundup, Roundup Weathermax, Touchdown iQ, Vantage, Vision	
10	Inhibitors of glutamine synthase	Ignite, Liberty	LibertyPrime ³ (5,10,15)
11	Inhibitors of carotenoid biosynthesis	Amitrol	
14	Inhibitors of protoporphyrinogen oxidase (Protox)	Blazer, Goal, Reflex, Ronstar	Viper ³ (2,14)
15	Conjugation of acetyl co-enzyme A	Devrinol, Dual Magnum, Dual II Magnum, Frontier	Axiom (5,15), Battalion ³ (2,4,15) ³ , Boundary ³ (5,15), Broadstrike Dual Magnum (2,15), LibertyPrime ³ (5,10,15), Primextra II Magnum (5,15)
19	Inhibitors of auxin transport system	Alanap	Distinct (4,19)

Herbicide Groupings for Ontario

Products with two or more sites of action are followed by the group numbers involved.

¹ Group	Site of Action	Single Sites of Action	Two+ Sites of Action
20	Inhibits cell wall synthesis Site A	Casoron	
22	Photo system I - electron diverters	Gramoxone, Reglone, Reward, Weed & Grass Killer	
23	Inhibitors of mitosis	CIPC	
27	others	Basamid, Krenite, Vapam	
28	Inhibitors of p-hydroxyphenyl pyruvate dioxygenase (HPPD)	Callisto	Converge (5,28)

¹ Herbicide groupings for Ontario follow the Weed Science Society of America's nationally accepted grouping. Groups 12, 13, 16, 17, 18, 21, 24, 25 and 26 are not available in Ontario.

² Products with two or more sites of action are followed by the group numbers involved.

³ Indicates herbicides sold as a co-pack under this trade name.

Insecticide and Acaricide Groups Based on Sites of Action

The classification scheme was developed in consultation with the Insecticide Resistance Action Committee (IRAC).

Group	Chemical Family/Group	Product Name	Active Ingredient
1	Carbamate	Carzol SP Furadan 480F Lannate Pirimor 50 DF Sevin XLR Plus Vydate	formetanate hydrochloride carbofuran methomyl pirmicarb carbaryl oxamyl
	Organophosphate	Agrox B-2 Agrox CD APM 50W Instapak Counter 15 G Cygon 480 Diazinon 50 W Diazinon 500E Dibrom EC DZN 600 EW Guthion Solupak, 240SC Imidan 50 WP Lagon 480 E Lorsban 50 W, 4E Malathion 25 W, 500 E Monitor 480 Orthene 75 SP Pyrifos 15 G Pyrinex 480 EC Sniper 240 E Thimet 15 G Zolone Flo	diazinon diazinon azinphosmethyl terbufos dimethoate diazinon diazinon naled diazinon azinphosmethyl phosmet dimethoate chlorpyrifos malathion methoamidophos acephate chlorpyrifos chlorpyrifos azinphosmethyl phorate phosalone
2A ¹	Chlorinated cyclodiene	Endosulfan 50 W Thiodan 4 EC Thiodan 50 WP Thionex 50 WP, 400 EC	endosulfan endosulfan endosulfan endosulfan

Insecticide and Acaricide Groups Based on Sites of Action

The classification scheme was developed in consultation with the Insecticide Resistance Action Committee (IRAC).

Group	Chemical Family/Group	Product Name	Active Ingredient
3	Diphenylethane	Kelthane 50 W Methoxychlor 240	dicofol methoxychlor
	Pyrethroid	Cymbush 250 EC Force 3.0 G Decis 5 EC Matador 120 EC Pounce 384 EC Ripcord 400 EC	cypermethrin tefluthrin deltamethrin cyhalothrin lambda permethrin cypermethrin
4	Chloronicotines	Admire Assail Gaucho	imidacloprid acetamiprid imidacloprid
5	Naturalyte	Success 480 SC	clofentenzine
6	Avermectin	Agri-Mek 1.9 EC	abamectin
9B	Pyridines	Fulfill 50 WG	pymetrozine
10	Mite Growth Inhibitor	Apollo SC	clofentenzine
11	Bt Microbial	Bioprotec CAF Dipel 2XDF Foray 48BA Novodor Thuricide HPC	<i>Bacillus thuringiensis</i> <i>Bacillus thuringiensis</i> <i>Bacillus thuringiensis</i> <i>Bacillus thuringiensis</i> <i>Bacillus thuringiensis</i>
17	Cyromazine	Citation 75 WP, Govenor 75 WP	cyromazine
18	Ecdysone disruptor	Confirm 240 F	tebufenozide
19	Trizapentadiene	Mitac W	amitraz
21	Pyridazinone Botanical	Pyridamite Rotenone 5 WP, 1% WP	pyridaben rotenone

¹ Other resistance mechanisms that are not linked to site of action, such as enhanced metabolism, are common for this group of chemicals. All members of this class may not have developed significant cross-resistance.

Fungicide/Bactericide Groupings Based on Sites of Action			
This list is based on the fungicide listing compiled by the Fungicide Resistance Action Committee (FRAC).			
Group	Chemical Family or Group	Product Name	Active Ingredient
1	Benzimidazole (MBC)	Benlate T-N-G Mertec SC Senator 75 DF	benomyl thiabendazole thiophanate-methyl
2	Dicarboximide	Ronilan EG Rovral WP	vinclozolin iprodione
3	Piperazine Triazoles (DMI)	Funginex 190 EC Indar 75WP Nova 40 W Nustar Topas 250 E Tilt 250 E	triforine fenbuconazole myclobutanil flusilazole propiconazole propiconazole
4	Acylamine (PA)	Apron XL LS Ridomil/Copper Ridomil Gold MZ Ridomil Gold 480 EC	metalaxyl-m metalaxyl + copper metalaxyl + mancozeb metalaxyl
5	Morpholine	Acrobat MZ	dimethomorph + mancozeb
7	Anilide carboxamide	Lance WDG	boscalid
9	Anilinopyrimidine	Vanguard 75 WG	cyprodinil
11	Strobilurin	Cabrio EG Flint 50 WG Sovran	pyraclostrobin trifloxystrobin kresoxim-methyl
14	Chlorophenyl	Botran 75 W Quintozene 75 WP	dicloran quintozene
17	Hydroxyaniline	Elevate 50 WDG	fenhexamid
22	Benzamides	Gavel 75 DF	zoxamide + mancozeb
27	Acetamide	Curzate 60 DF	cymoxanil
33	Phosphonate	Aliette	fosetyl-Al
M1	Inorganic	Copper 53W Copper Spray 50 W Kocide 101 WP Kumulus DF Lime Sulphur Microscopic sulphur Parasol Ridomil/Copper	tri-basic copper sulphate copper oxychloride copper hydroxide sulphur lime sulphur sulphur copper hydroxide copper + metalaxyl
M2	Dithiocarbamate	Acrobat MZ Dikar Dithane DG Dithane M45 Ferbam WDG Gavel 75 DF Manzate DF No Damp Pennocozeb 75DF Polyram DF Ridomil Gold MZ Thiram Zineb 80W	mancozeb + dimethomorph mancozeb + karathane mancozeb mancozeb ferbam mancozeb + zoxamide mancozeb oxine benzoate mancozeb metiram mancozeb + metalaxyl thiram zineb
M3	Phthalimide	Captan 80 WDG Folpan 50 WP Maestro 80DF	captan folpet captan

Fungicide/Bactericide Groupings Based on Sites of Action			
This list is based on the fungicide listing compiled by the Fungicide Resistance Action Committee (FRAC).			
Group	Chemical Family or Group	Product Name	Active Ingredient
M4	Chloronitrile	Bravo 500 Tatoo C	<u>chlorothalonil</u> <u>chlorothalonil</u> + propamocarb hydrochloride
M6	Guanidines	Equal 65WP	dodine

M = Multisite Inhibitors

If the product in the table above has two or more active ingredients, the underlined active ingredient is the one that places it in that group.

Review Questions



1. The best way to manage resistance is to:
 - a) spray on a weekly basis.
 - b) rotate the pesticide Groups you use.
 - c) wear the proper protective clothing.
 - d) use the lowest label rate of the pesticide.

2. What are three management strategies you can use to prevent or delay pest resistance from developing?
 - 1.
 - 2.
 - 3.

3. Fill in the chart using the “Herbicide Groupings for Ontario” table.

Herbicide	Herbicide Group Number
Basagran Forte	
Frontier	
Poast Ultra	
Roundup	
Gramoxone	

4. What weeds in Ontario have become resistant to Group 2 herbicides?

5. Define Site of Action.

6. How can you delay pest resistance?
 - a) Plant the same crop year after year so you can use the same pesticides.
 - b) Use pesticides instead of cultural, physical or genetic methods of pest control.
 - c) Be aware of the resistant pests in your area and scout for them regularly.
 - d) Use the same pesticide group each year.