

Herbicide resistance management in vegetable rotations

As of 2006, over 175 weed species worldwide have developed resistance to herbicides. Help preserve your control options!

Use this table to delay herbicide resistance in vegetable rotations

Resistance can be delayed or prevented by carefully evaluating herbicide options across rotational crops. The selection of feasible options should be balanced against factors such as herbicide cost, which weeds are present, and crop rotation restrictions.

Herbicide selection across rotational crops requires careful planning. The following questions can help with the planning process.

- Which herbicides are critical for each crop in the rotation?** Some crops, such as carrots, have extremely limited herbicide options and few cultural practices for weed control, and thus rely heavily on one or two herbicides for weed control. Selecting the "mandatory" herbicides in crops within the rotation will help prioritize modes of action available in other crops.
- Select herbicides for crops that have the fewest modes of action options first.** In this table, crops are grouped by number of available options going from carrots with the fewest to field corn with the most.
- Look for modes of action that are limited to one or two crops.** Unique modes of action offer an opportunity to reduce the reliance on common or high-risk herbicides in the rotation.
- Where possible, select herbicides with low or medium risks for developing resistance.** Some modes of action are more prone to selecting resistant weeds than others; avoiding herbicides from the high-risk category as often as possible will reduce the likelihood of resistance.
- What are the rotation restrictions for the selected herbicides?** Consult the herbicide label to ensure that your selections will allow rotation to the next crop. Herbicides with longer soil residual, such as atrazine, will require careful planning relative to crop rotations.

Weed resistance to herbicides worldwide

Mode of action	Herbicide group	Number of resistant species	Resistant weed species (examples)
Amino acid synthesis inhibitors (ALS)	2	95	common ragweed, common waterhemp, giant foxtail, kochia, redroot pigweed, wild oat
Auxin transport inhibitors	19	0	
Bleaching: inhibition of 4-HPPD	28	0	
Bleaching: inhibition of carotenoid synthesis	11	4	annual bluegrass, creeping bentgrass, prostrate knotweed, rigid ryegrass
Cell membrane disruptors (PPO)	14	3	common waterhemp, wild poinsettia
EPSP synthase inhibitors	9	8	common ragweed, horseweed, Italian ryegrass, Palmer amaranth, waterhemp
Glutamine synthetase	10	0	
Inhibition of VLCFAs	15	2	barnyardgrass, rigid ryegrass
Lipid synthesis inhibitors (not ACCase)	8	8	annual bluegrass, barnyardgrass, wild oat
Lipid synthesis inhibitors (ACCase)	1	35	barnyardgrass, giant foxtail, green foxtail, Italian ryegrass, wild oat
Microtubule assembly inhibitors	3	10	annual bluegrass, green foxtail, johnsongrass, wild oat
Photosynthesis (PS II) inhibitors: contact	6	1	common groundsel
Photosynthesis (PS II) inhibitors: systemic	5	65	black nightshade, common lambsquarters, kochia, redroot pigweed
	7	21	barnyardgrass, common purslane, horseweed, redroot pigweed
Synthetic auxins	4	24	common chickweed, field bindweed, kochia, wild carrot

Source: Heap, I. *The International Survey of Herbicide Resistant Weeds*, www.weedscience.com (accessed June 6, 2006).

Herbicide registrations vary by state and may have local restrictions. Always consult the label prior to use of any pesticide.

Herbicides by mode of action and crop rotation

Herbicides are listed trade name first, followed by the active ingredient(s). For premix products, only the active ingredient that corresponds to the listed mode of action is in black type, the other ingredients are gray. Products with multiple modes of action are cross-listed in each.

Mode of action	Group	Carrots	Potato	Pea	Snap bean	Soybean	Sweet corn	Field corn		
LOW risk of resistance	Auxin transport inhibitors	19						Celebrity Plus (nicosulfuron + dicamba + diflufenzopyr) Distinct (dicamba + diflufenzopyr)		
	Glutamine synthetase	10						Liberty [†] (glufosinate) Liberty ATZ [†] (glufosinate + atrazine)		
	Inhibition of VLCFAs	15	Dual Magnum (s-metolachlor) Dual II Magnum (s-metolachlor) Outlook (dimethenamid-P)	Cinch (s-metolachlor) Dual II Magnum (s-metolachlor)	Dual Magnum (s-metolachlor) Dual II Magnum (s-metolachlor)	Boundary (s-metolachlor + metribuzin) Cinch (s-metolachlor) Define (flufenacet) Dual II Magnum (s-metolachlor) Intro (alachlor) Outlook (dimethenamid-P) Sequence ^{**} (s-metolachlor + glyphosate)	Bicep Lite II (s-metolachlor + atrazine) Bullet (alachlor + atrazine) Camix (s-metolachlor + mesotrione) Cinch (s-metolachlor) Cinch ATZ Lite (s-metolachlor + atrazine) Dual II Magnum (s-metolachlor)	G-Max Lite (dimethenamid-P + atrazine) Lariat (alachlor + atrazine) Lexar/Lumax (s-metolachlor + mesotrione) Micro-Tech (alachlor) Outlook (dimethenamid-P)	Bicep Lite II Magnum (s-metolachlor + atrazine) Bullet (alachlor + atrazine) Camix (s-metolachlor + mesotrione) Cinch (s-metolachlor) Cinch ATZ Lite (s-metolachlor + atrazine) Define (flufenacet) Degree (acetochlor)	Degree Xtra (acetochlor + atrazine) Dual II Magnum (s-metolachlor) Fulltime (acetochlor + atrazine) G-Max Lite (dimethenamid-P + atrazine) Harness Xtra (acetochlor) Keystone LA (acetochlor + atrazine) Lariat (alachlor + atrazine) Lexar/Lumax (s-metolachlor + atrazine + mesotrione) Micro-Tech (alachlor) Outlook (dimethenamid-P) Surpass (acetochlor) TopNotch (acetochlor)
	Lipid synthesis inhibitors (NOT ACCase)	8		Eptam (EPTC)		Eptam (EPTC)		Eradicane (EPTC)	Eradicane (EPTC)	
	Synthetic auxins	4			MCPA Thistrol (MCPB)			2,4-D Starane (fluroxypyr) Stinger (clopyralid)	2,4-D Accent Gold (clopyralid + flumetsulam + nicosulfuron + rimsulfuron) Banvel (dicamba) Celebrity Plus (nicosulfuron + dicamba + diflufenzopyr) Clarity (dicamba) Distinct (dicamba + diflufenzopyr) Hornet WDG (flumetsulam + clopyralid) Marksman (dicamba + atrazine)	NorthStar (primisulfuron + dicamba) Shotgun (atrazine + 2,4-D) Stinger (clopyralid) Yukon (halosulfuron + dicamba)
MEDIUM risk of resistance	Bleaching: inhibition of 4-HPPD	28					Callisto (mesotrione) Camix (s-metolachlor + mesotrione) Impact (topramezone)	Lexar/Lumax (s-metolachlor + atrazine + mesotrione) Callisto (mesotrione) Camix (s-metolachlor + mesotrione) Impact (topramezone)		
	Bleaching: inhibition of carotenoid synthesis	11		Command (clomazone)	Command (clomazone)	Command (clomazone)				
	Cell membrane disruptors (PPO)	14			Cobra (lactofen) Flexstar (fomesafen) Gangster (clorasulam + flumioxazin) Phoenix (lactofen) Resource (flumiclorac)	Spartan (sulfentrazone) Ultra Blazer (acifluorfen) Valor (flumioxazin)	Aim (carfentrazone + halosulfuron)	Aim (carfentrazone) Priority (carfentrazone + halosulfuron) Resource (flumiclorac)		
	EPSP synthase inhibitors	9				Extreme** (imazethapyr + glyphosate) glyphosate**	Sequence** (s-metolachlor + glyphosate)	glyphosate** Ready Master ATZ** (glyphosate + atrazine)		
	Microtubule assembly inhibitors	3	Treflan (trifluralin)	Pendimax (pendimethalin) Prowl (pendimethalin) Treflan (trifluralin)	Pendimax (pendimethalin) Prowl (pendimethalin) Pursuit Plus (imazethapyr + pendimethalin) Treflan (trifluralin)	Pendimax (pendimethalin) Prowl (pendimethalin) Treflan (trifluralin)	Pendimax (pendimethalin) Prowl (pendimethalin)	Pendimax (pendimethalin) Prowl (pendimethalin)		
	Photosynthesis (PS II) inhibitors: contact	6		Basagran (bentazon)	Basagran (bentazon)	Basagran (bentazon)	Basagran (bentazon) Laddok 5-12 (bentazon + atrazine)	Basagran (bentazon) Buctril (bromoxynil)	Buctril + atrazine (bromoxynil + atrazine)	
	Photosynthesis (PS II) inhibitors: systemic	5	Sencor (metribuzin)	Sencor (metribuzin)		Boundary (s-metolachlor + metribuzin) Sencor (metribuzin)	atrazine (s-metolachlor + atrazine) Bicep Lite II (s-metolachlor + atrazine) Bullet (alachlor + atrazine) Cinch ATZ Lite (s-metolachlor + atrazine) Evik (ametryne) G-Max Lite (dimethenamid-P + atrazine) Laddok 5-12 (bentazon + atrazine)	Lariat (alachlor + atrazine) Lexar/Lumax (s-metolachlor + atrazine + mesotrione) Princep (simazine)	atrazine (s-metolachlor + atrazine) Bicep Lite II Magnum (s-metolachlor + atrazine) Buctril + atrazine (bromoxynil + atrazine) Harness Xtra (acetochlor + atrazine) Keystone LA (acetochlor + atrazine) Lariat (alachlor + atrazine) Lexar/Lumax (s-metolachlor + atrazine + mesotrione) Fulltime (acetochlor + atrazine) G-Max Lite (dimethenamid-P + atrazine) Harness Xtra (acetochlor + atrazine) Keystone LA (acetochlor + atrazine) Liberty ATZ [†] (glufosinate + atrazine) Marksman (dicamba + atrazine) Princep (simazine) Ready Master ATZ** (glyphosate + atrazine) Sencor (metribuzin) Shotgun (atrazine + 2,4-D) Steadfast ATZ (rimsulfuron + nicosulfuron + atrazine)	
		7	Lorox (linuron)	Lorox (linuron) Linex (linuron)		Lorox (linuron)				
	Amino acid synthesis inhibitors (ALS)	2		Matrix (rimsulfuron)	Pursuit (imazethapyr) Pursuit Plus (imazethapyr + pendimethalin) Raptor (imazamox)	Pursuit (imazethapyr) Raptor (imazamox) Sanda (halosulfuron)	Classic (chlorimuron) Extreme** (imazethapyr + glyphosate) FirstRate (clorasulam) Gangster (clorasulam + flumioxazin) Harmony GT (thifensulfuron) Pursuit (imazethapyr) Pursuit Plus (imazethapyr + pendimethalin)	Python (flumetsulam) Raptor (imazamox) Synchro XP (chlorimuron + thifensulfuron)	Accent (nicosulfuron) Permit (halosulfuron) Priority (carfentrazone + halosulfuron) Sanda (halosulfuron)	Accent (nicosulfuron) Accent Gold (clopyralid + flumetsulam + nicosulfuron + rimsulfuron) Basis (rimsulfuron + thifensulfuron) Beacon (primisulfuron) Celebrity Plus (nicosulfuron + dicamba + diflufenzopyr) Hornet WDG (flumetsulam + clopyralid) Lightning [§] (imazethapyr + imazapyr) NorthStar (primisulfuron + dicamba) Option (foramsulfuron) Priority (carfentrazone + halosulfuron) Python (flumetsulam) Resolve (rimsulfuron) Steadfast (rimsulfuron + nicosulfuron) Steadfast ATZ (rimsulfuron + atrazine) Stout (nicosulfuron + thifensulfuron) Yukon (halosulfuron + dicamba)
	Lipid synthesis inhibitors (ACCase)	1	Fusilade (fluaizop) Poast (sethoxydim) Select (clethodim)	Poast (sethoxydim) Select (clethodim)	Assure II (quizalofop) Poast (sethoxydim)	Assure II (quizalofop) Poast (sethoxydim)	Assure II (quizalofop) Fusion (fluaizop + fenoxaprop) Poast Plus (sethoxydim) Select (clethodim)	Poast* (sethoxydim)		

* Poast Protected sweet corn only.

** Glyphosate-resistant crops only, unless otherwise allowed on the product label.

+ Glufosinate-resistant crops only.

§ Clearfield field corn hybrids only.

Vegetable growers currently have few herbicide options available for managing weeds with even fewer new herbicides being registered. With so few choices, it's particularly critical to protect the usefulness of existing management tools. Likely the greatest threat to future weed management options in vegetable production will be the development of resistant weeds.

What is herbicide resistance?

Herbicide resistance describes the ability of a weed to survive exposure to a pesticide that would have previously controlled that species. Resistance typically develops following repeated applications of a specific chemical or chemical family or mode of action. Weeds that become resistant to a particular herbicide are often resistant to other herbicides with the same mode of action.

Recognizing herbicide resistance

Herbicide resistance in weeds is often confused with other factors that affect herbicide performance, such as misapplication (poor timing or rate) or weather conditions before, during, or after application. Consider the following questions if you suspect herbicide resistance:

- Is there an obvious pattern, such as a sprayer skip or poor herbicide coverage, that could explain the weed control failure? Resistant weeds often occur in irregular patches where seed spread from a plant that survived a previous herbicide application.
- Are there herbicide symptoms on the surviving plants? Resistant plants often, but not always, show no symptoms of herbicide damage.
- Is there a record of repeated use of the herbicide mode of action, and has the rate required for adequate control increased over time? Field notes and accurate record keeping are important tools in diagnosing the development of resistant weeds.
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Factors that increase the risk for herbicide resistance

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