



RECOGNIZING
Herbicide Residue
& **Drift Injury**
IN CANOLA



Table of Contents

HERBICIDE RESIDUE INJURY

Introduction	4
Factors Affecting Herbicide Carryover	4
Field Scouting	10
Symptoms Similar to Herbicide Carryover Injury	12
Group 2 Residue Symptoms on Cotyledons	16
Group 2 Residue Symptoms on True Leaves	18
Group 2 Residue Symptoms on Mature Plants	28
Residual Effects of Group 4 Herbicides	30
Residual Effects of Group 5 and 14 Herbicides	32
Conclusion	33
Chemical vs. Plant Bioassay Testing	34

FOLIAR HERBICIDE INJURY

Introduction	36
Effects of Foliar-Applied Group 2 Herbicides	38
Sulfosulfuron (Sundance™)	40
Imazethapyr and Imazamox (Odyssey™).	48
Effects of Foliar-Applied Group 4 Herbicides	52
2,4-D Ester 600 and MCPA Amine 40	54
Effects of Foliar-Applied Group 5 Herbicides	58
Effects of Foliar-Applied Group 6 Herbicides	59
Effects of Foliar-Applied Group 7 Herbicides	60
Effects of Foliar-Applied Group 9 Glyphosate (Roundup Transorb™)	61
Effects of Foliar-Applied Group 10 Glufosinate Ammonium (Liberty™)	62
Effects of Foliar-Applied Group 14 Herbicides	63
Effects of Foliar-Applied Group 27 Herbicides	64

Herbicide Residue Injury

INTRODUCTION

Canola injury can occur from exposure to low soil concentrations of some herbicides, in particular several Group 2 herbicides, plus some Group 4, 5 and 14 herbicides. Herbicide carryover can cause crop injury ranging from minimal to complete crop loss. In recent years, increased acreage of canola and new herbicide options in other rotation crops have created more opportunities for residue injury. Injury problems have typically arisen where normal breakdown of herbicides has been inhibited by factors such as drought, low organic matter and pH, sometimes in conjunction with increased frequency of use of residual herbicides in the rotation.

This information is intended to:

- 1) show canola injury symptoms associated with herbicide residues, and
- 2) assist in differentiating between symptoms due to herbicide residue and due to other problems.

FACTORS AFFECTING HERBICIDE CARRYOVER

Field History

Residual herbicide injury can only occur in fields with a history of Group 2, 4, 5 or 14 herbicide applications. Not all of the Group 2, 4, 5 or 14 herbicides have residual action and only some affect canola. Refer to specific herbicide labels for restrictions on recropping to canola.

Recropping Restrictions for Residual Herbicides

Herbicide	Clearfield Canola	Non-Clearfield Canola
2,4-D*	1	1
Absolute*	1	2
Adrenalin, Solo, Viper	1	1
Altitude FX	1	1
Amitrol	1 day	1 day
Authority	2	2
Avadex	0	0
Barricade, Fluroxypyr + 2,4-D, Retain, Trophy	1	1
Benchmark	1	1
Curtail M, FlaxMax DLX, Prestige XC	1	1
Dicamba*	1*	1*
Eclipse III, Lontrel 360	1	1
Express Pro	10 months	10 months
Flucarbazone, Everest GBX, PrePare (Brown Soils)		

Herbicide	Clearfield Canola	Non-Clearfield Canola
Flucarbazone, Everest GBX, PrePare (Dark Brown, Black and Grey Wooded)	1*	1*
Flumioxazin	1	1
Frontline XL, Fronline 2,4-D, Spectrum	1	1
Imazamethabenz (Black and Grey Wooded Soils)	1	1
Imazamethabenz (Brown and Dark Brown)	1	2
Infinity	1	1
Kerb	1	1
Metesulfuron (pH less than 7, Brown and Dark Brown)		2
Metesulfuron (pH less than 7, other soils)		1
Metesulfuron (pH 7–7.9), Brown and Dark Brown)		3
Metesulfuron (pH 7–7.9, other soils)		2
Muster		2
Odyssey*, Odyssey DLX*	1	2
Option	1	1

Herbicide	Clearfield Canola	Non-Clearfield Canola
PrePass	1	1
Pulsar	1	1
Sencor	2	2
Simplicity	1	1
Stellar	1	1
Tandem	1	1
Triton C*	1	1
Velocity m3	1	1

Source: Guide to Crop Protection 2012. Saskatchewan.

Figures listed are the number of cropping seasons before each crop can be grown (“1” means that the crop can be grown the year following application). Products with preseeding restriction in months or days are labeled as such. A blank space means that there are no recommendations given on the product label and a field bioassay is recommended by many product manufacturers to determine if these crops are safe to plant.

*The minimum re-cropping intervals are listed. Safe intervals may be longer than those listed depending on the use rates, region, province, soil types, environment, time of application and crop variety. Refer to product label for more information.

Soil Characteristics

Interactions between soil factors are complex and may either slow the rate of herbicide breakdown or increase the availability of any remaining herbicide residue to the crop.

Organic Matter and Soil Texture

As organic matter decreases, microbial degradation of the herbicide decreases, increasing potential carryover. Soils with low clay content have decreased adsorption of residual herbicides, thereby increasing potential carryover. Therefore, potential for injury on subsequent canola crops increases as organic matter decreases, and clay content decreases (except where soluble herbicides are leached by lots of rainfall).

pH

Soil pH affects herbicide decomposition and availability to the subsequent canola crop (Table 1).

Climate

Drought

Under drought conditions, microbial and hydrolytic breakdown of herbicides is decreased and adsorption of herbicide to soil particles is increased. The influence of drought on soil may override any previously favourable pH or organic matter conditions.

Temperature

When microbial decomposition is an important mechanism (e.g. imidazolinones), decomposition is reduced by cool soil temperatures.

Table 1: Soil factors that effect the degradation of some residual herbicides.

Group Name	Group No.	Herbicides	Mechanism of Degradtion	Rate of Degradation is slowed when:
Imidazolinone	2	Imazethapyr Imazamox Imazamethabenz	Microbial	Soil pH < 7.0 Drought
Sulfonylurea	2	Metsulfuron Ethametsulfuron	Chemical Hydrolysis	Soil pH > 7.0 Drought
	2	Sulfosulfuron	Hydrolysis Microbial	Soil organic matter < 4% Soil pH > 7.0, Drought
Sulfonylamino carbonyl-triazolinone	2	Flucarbazone	Microbial	Low soil organic matter Soil pH > 7.0, Drought
Triazolopyrimidine Sulfonylanilide	2	Florasulam	Microbial	Low soil temperature
Dinitroanilines	3	Trifluralin Ethafluralin	Microbial	Drought
Pyridinecarboxylic Acid	4	Clopyralid	Microbial	Drought Low organic matter
Protoporphyrinogen Oxidaze Inhibitors	14	Sulfentrazone	Microbial	Drought High soil pH, Low CEC

Source: Factors Affecting Herbicide Residue: Impact of a Dry Year. Eric Johnson, M.Sc., P.Ag., Agriculture and Agri-Food Canada, Scott Research Farm, Scott, SK. 2006

Field Scouting

Injury can occur anywhere in the field and may be patchy. Patches that appear bare have normal emergence but there is considerable variation in plant development. Areas of low organic matter, headlands, corners or overspray may have more injury.

A severely affected area (red arrow) and the effect of slope (yellow arrow) are shown.

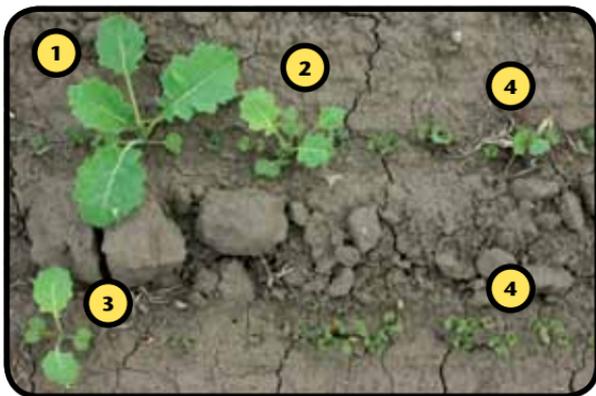


Carryover can have considerable field variation in acreage affected and severity of plant injury. Uneven plant stands can affect crop maturity and weed pressure.



Symptoms can vary in a small area. All plants in this picture emerged at the same time.

- 1) Unaffected
- 2) Mild injury
- 3) Moderate injury
- 4) Severe injury



Symptoms Similar to Herbicide Carryover Injury

Mild symptoms of herbicide injury may be confused with symptoms caused by cold temperatures or nutrient-deficient soil. Cold stress symptoms can arise only after a cold temperature event. Recovery will be rapid as temperatures increase. Nutrient stress symptoms are extremely unlikely to occur at the cotyledon stage as nutrient demands are low. A soil test can determine nutrient availability.

COLD TEMPERATURE SYMPTOMS

Since the first and second leaves are of normal size, the purpling observed is not herbicide injury. The purpling is a result of anthocyanin production caused by cold temperatures. Purpling may be towards the base, on the leaf margins or may cover entire young leaves of the plant. This symptom will diminish as temperatures increase.



In this case, cupping was caused by cold temperatures and symptoms quickly diminished as temperatures increased.



Cupping was caused by a low level herbicide residue. Variation in herbicide carryover means uninjured (red arrow) and injured (yellow arrow) plants may be found in close proximity. Cold stress generally causes more uniform damage.



NUTRIENT DEFICIENCY SYMPTOMS

These plants were grown under wet conditions from the 2-leaf stage and show classic purpling, cupping and chlorosis. Poor aeration to the roots has created nutrient deficiencies.



These plants were grown in severely sulphur deficient soil and have typical purpling and leaf cupping symptoms. Plants improved with the addition of magnesium sulphate.



These plants also exhibit symptoms of sulphur deficiency. Other symptoms include; interveinal chlorosis, purpling of the leaf margins, and necrosis.



Sulphur deficiency on older plants may result in purpling and cupping of axillary or sideshoot leaves. Herbicide carryover symptoms seldom appear at later leaf stages.



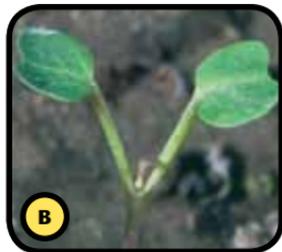
The information in this section shows canola injury symptoms associated with Group 2 herbicide residues. Photographs were generated from field plots and bioassays. Field plots were sprayed with reduced rates of Group 2 herbicides prior to planting the crop to simulate herbicide carryover.

Group 2 Residue Symptoms on Cotyledons

Severe injury symptoms such as purpling or chlorosis, severe size reduction or thickening of cotyledon leaves and petioles often appear at the cotyledon stage. However, cotyledon symptoms must be verified by damage to true leaves and/or meristems to eliminate cold stress as a cause for symptoms. Plants with mild injury to true leaves do not show injury to cotyledons.

Plants with this severity of cotyledon injury are unlikely to form true leaves, mature and flower.

A 2-leaf seedling with normal cotyledons (A) and a severely affected seedling (B) at the same age.



An unaffected (left) and severely affected cotyledon (right) (A). The affected plant had purpling on the back of the cotyledons, but no size reduction. Inspection of the true leaves of these same plants (B) reveals symptoms consistent with Group 2 herbicide injury. The injured plant (right) has reduced leaf area, is chlorotic and is more cupped than the check plant (left). While short term cold events produce cotyledon injury, they do not reduce true leaf area.



Group 2 Residue Symptoms on True Leaves

MILD SYMPTOMS

Mild injury involves minimal or no damage to the meristem, but can interfere with early leaf development. Mild injury may not produce sufficient symptoms for definite diagnosis until the 3-leaf stage since symptoms may mimic nutrient deficiency or cold stress. Maturity delay can occur with mild injury.

Mild symptoms (A) can include mild chlorosis noticeable on the first and second leaves, reduced leaf area and mild cupping of the third leaf. After two weeks, (B) leaf size was normal and no other symptoms were evident. Plant development was delayed by two leaf stages relative to nearby plants.



An unaffected plant (left) and one with chlorosis and reduced leaf size (right). The first and second leaves show the initial injury through reduced leaf area and elongated petioles. Petiole elongation is typical of mild injury.



Differences between uninjured (left) and injured (right) plants could not be seen until the 3-leaf stage.



Group 2 Residue Symptoms on True Leaves

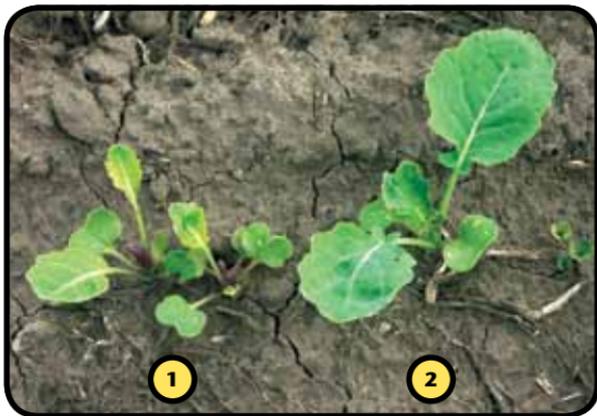
SEVERE SYMPTOMS

Severe symptoms are characterized by meristematic damage which may result in;

- 1) poor recovery and subsequent maturity delay,
- 2) yield loss, or
- 3) plant death

Other symptoms may include early and long lasting purpling or chlorosis, cupping, reduction in leaf area and very slow growth. Severe injury is not mimicked by nutrient, insect or disease injury symptoms.

Severe chlorosis, purpling and cupping (1) and a normal plant (2).



SEVERE SYMPTOMS

At the 3-leaf stage (A), unaffected (left) and severely affected (right) plants. Affected plants have chlorotic cotyledons with minimal first leaf growth.



After four weeks of growth (B), there was minimal leaf recovery.



Group 2 Residue Symptoms on True Leaves

SEVERE SYMPTOMS

At the 2-leaf stage (A), severe symptoms include growth reduction, purpling and cupping. After three weeks (B), symptoms were still present.



After six weeks (C), symptoms have diminished, but leaves are chlorotic and small.



SEVERE SYMPTOMS

Leaf purpling and cupping on the first (yellow arrow) and second leaf (red arrow) are classic injury symptoms. Although plants can recover, this level of injury slows plant development.



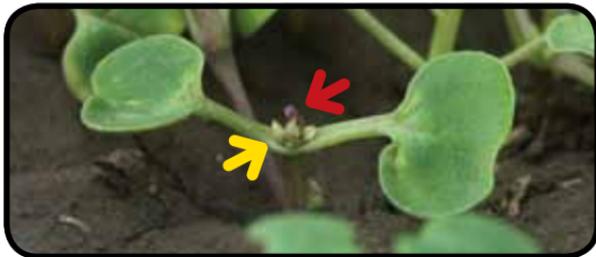
Another classic symptom is leaf chlorosis. Both the first and second leaves have overall chlorosis. Chlorosis was observed through the 4-leaf stage.



Group 2 Residue Symptoms on True Leaves

SEVERE SYMPTOMS

The first leaf is almost unrecognizable (red arrow). The production of the colorless leaf buds (yellow arrow) indicates a residue effect. This plant is unlikely to flower.



An example of severe chlorosis. Leaves can appear almost transparent.



SEVERE SYMPTOMS

The combination of severe chlorosis and significant leaf area reduction indicates substantial herbicide carryover (A). Inset: an unaffected plant the same age.



After six weeks, plants still exhibit symptoms: elongation and thickening of leaf petioles, mottled leaf chlorosis and reduced leaf area (B).



Group 2 Residue Symptoms on True Leaves

SEVERE SYMPTOMS

This level of meristem damage causes premature growth of side branches (A). Inset: an unaffected plant the same age.



After five weeks, these plants are still chlorotic and stunted (B).





Group 2 Residue Symptoms on Mature Plants

Injury symptoms should be detected before maturity, as these symptoms also mimic those caused by herbicide drift. Severe injury symptoms are long lasting and significantly affect plant development. Significant meristem damage effectively “prunes” plants and they respond with either production of damaged leaves and weak side shoots, or no growth at all.

Severe early injury caused disruption of the meristem (red arrow) and increased production of immature side shoots (yellow arrow).



Symptoms observed at this stage are:

- 1) significant disruption of the meristem (yellow arrow) as well as production of immature and numerous side branches (white arrow), and



- 2) abortion of inflorescences (red arrow).



Residual Effects of Group 4 Herbicides

Group 4 herbicides are synthetic auxins or hormone mimics, which affect the growth in the newest stems and leaves by affecting protein synthesis and normal cell division.

Group 4 Herbicides

Chemical Family	Active Ingredient	Found In:
Benzoic Acids	Dicamba	Banvel II, Banvel VM, Battalion, DyVel, DyVel DSp, Harmony K, Hawkeye Power, Oracle, Overdrive, Pulsar, Rustler, Sword, Takkle, Target, Tracker XP, Triton K, Vanquish, VMD 480 Dicamba
Carboxylic Acids	Clopyralid	Absolute, Curtail M, Eclipse III, Lontrel 360, FlaxMax DLX, Momentum, Prestige, Prestige XC, Spectrum, Tensile
	Aminopyralid	Milestone, Restore, Reclaim
	Fluroxypyr	Altitude FX, Attain XC, Barricade II, Everest GBX, Flurox 2,4, Harmony Max, Momentum, OcTTain XL, Prestige XC, Pulsar, Retain, Stellar, Tandem, Trophy 600
	Picloram	Grazon, Tordon 22K
Phenoxy	2,4-D	2,4-D, Adrenalin SC, Approve, Attain XC, Desormone, Dichlorprop-D, Dichlorprop-DX, DyVel DSp, Estaprop Plus, Estaprop XT, Flurox 2,4, Frontline 2,4-D, Frontline 2,4-D XC, Grazon, Leader, OcTTain XL, Reclaim, Restore, Retain, Salvo, Signal D, Thrasher, Thumper, Titanium, Triton K, Turboprop

Chemical Family	Active Ingredient	Found In:
Phenoxy	Dichlorprop (2,4-DP)	Desormone, Dichlorprop-D, Dichlorprop-DX, Estaprop Plus, Estaprop XT, Optica Trio, Turboprop
	2,4-DB	2,4-DB, Caliber 625, Cobutox 625, Embutox 625
	MCPA	Achieve Liquid Gold, Altitude FX, Assert FL, Badge, Broadside, Buctril M, Clovitox Plus, Curtail M, DyVel, FlaxMax DLX, Frontline, Frontline XL, Horizon BTM, Logic M, MCPA, Mextrol 450, Optica Trio, Prestige XC, Refine M, Signal M, Spectrum, Stellar, Sword, Target, Topside, Tracker XP, Trophy 600, Tropotox Plus
	MCPB	Clovitox Plus, Topside, Tropotox Plus
	Mecoprop (MCP)	Compitox, DyVel DSp, Mecoprop-P, Optica Trio, Sword, Target, Tracker XP
	Quinclorac	Triton C

Always confirm active ingredients and recropping restrictions on product labels prior to use.

- Seedlings can be stunted and malformed.
- Abnormal growth, including twisting of stems, cupping and deformation of leaves.
- Uncontrolled cell growth in the lower stem and upper root area can lead to the development of abnormal tissues and secondary roots.
- Calluses can also form on the stems.

Residual Effects of Group 5 and 14 Herbicides

Group 5 herbicides include the triazine type photosynthetic inhibitors of which Sencor is the product most likely of concern for residue issues in canola crops. Symptoms can include wilting and yellowing of oldest leaves, followed by plant death in severe cases. For a list of Group 5 actives and products and more details on mode of action, see page 58 under foliar injury symptoms.

Group 14 herbicides may be soil active (Authority) or foliar active (Cleanstart) or both (Heat), and result in membrane disruption and desiccation.

Group 14 Herbicides

Chemical Family	Active Ingredient	Found In:
Aryl Triazone	Carfentrazone	Cleanstart
	Flumioxazin	Payload, Valtera
	Saflufenacil	Eragon, Heat WG
	Sulfentrazone	Authority

Always confirm active ingredients and recropping restrictions on product labels prior to use.

- Symptoms include yellow and desiccated leaves.
- Seedlings can show bleaching and yellowing symptoms.
- Seedlings usually die prior to or shortly following emergence.

Conclusion

Herbicide carryover can cause significant yield loss and maturity delay. Carryover symptoms can be confused with symptoms caused by nutrient deficiency or cold stress.

However, causes for symptoms can be differentiated by:

- 1) soil tests (nutrients),
- 2) climatic observation (cold temperature), and
- 3) soil chemical analysis for the presence of herbicide residue (see Appendix 1 on page 34).

When carryover is possible or suspected, check fields at early leaf stages and record (e.g., photographs) symptoms and recovery.

Labs that offer soil test for herbicide residue:

A&L Laboratories

London, Ontario

Toll-free: 1-855-837-8347

Website: www.alcanada.com

AGAT Labs

Calgary, Alberta

Toll-free: 1-800-661-7174

Website: www.agatlabs.com/agri-foods/agricultural-analysis/index.cfm

ALS Centre of Excellence

Edmonton, Alberta

Phone: 780-391-2300

Website: <http://alsglobal.com/environmental/services/north-america-environmental-services/canada.aspx>

Exova

Edmonton, Alberta

Phone: 780-438-5522

Website: www.exova.ca

Appendix 1

CHEMICAL TESTING VS. PLANT BIOASSAY

Determining if residues are present is important for pre-plant risk assessment and confirmation of herbicide injury already observed in the field. This can be accomplished with a plant bioassay, chemical analysis or both. Both methods rely on appropriate soil sampling and have advantages and disadvantages. While bioassay is the most accurate method for confirming that a field is safe for growing sensitive crops like canola, currently we are unaware of any commercial labs offering the service.

Results should be interpreted in conjunction with:

- 1) Label recommendations
- 2) Soil pH and organic matter
- 3) Herbicide field history
- 4) Precipitation

	Chemical Analysis	Plant Bioassay
What it does	Detects concentration of extractable herbicide in soil (ng/g, ppm, ppb).	Determines potential level of biological activity.
Pros	Fast results.	Detects herbicide residues at lower concentrations than chemical analysis. Less expensive than chemical analysis.
Cons	No indication of biological activity.	Takes three to five weeks to get results.
	Need to know which herbicide to test for.	Does not test for specific herbicides, only herbicide group.
	Expensive.	Results take experience or expert advice to interpret.



Foliar Herbicide Injury

INTRODUCTION

Canola injury from foliar-applied herbicides may be caused by drift from adjacent fields or from spray tank contamination.

Drift injury generally occurs at field edges or at shelterbelts. However, highly volatile herbicides such as 2,4-D ester, may drift further into the field. In young plants (1–4 leaf stage), drift injury is easily distinguished from residue injury, since drift causes injury on a larger leaf area. In older plants, drift injury cannot be visually distinguished from residue injury. However, a bioassay can provide information to distinguish between injury types.

Injury due to spray tank contamination occurs when spray tanks, booms, filters or sump pumps are improperly cleaned between herbicide applications. Residue in the tank, sumps or filters may affect a larger area compared to residue in the booms or spray jets. Boom and spray jet contamination may dissipate after a few passes with the sprayer, and injury patterns should match the application.

OBJECTIVES AND METHODS

This section is intended to show injury levels and symptoms for different herbicides at various rates, and includes results of trials on specific herbicides at varying rates. Other herbicide Group symptoms included in this booklet are based on general herbicide activity and were not specifically tested for drift symptoms.

To generate photographs and descriptions of injury from Sundance, Odyssey, 2,4-D, MCPA, glyphosate and Liberty, canola was grown in field plots and sprayed at the 3- and 5-leaf stages. Herbicides were applied at 1, 2, 5, 10 and 20% of selected rates to simulate injury due to drift and/or tank contamination. Glyphosate was applied at 30% of the selected rate. Glyphosate-tolerant canola was used in all plots except plots receiving glyphosate herbicide.

OBSERVATIONS

For the products included in the trials, canola sensitivity to simulated drift was greatest with Group 2 herbicides, followed by Groups 4 and 11 and then Group 9. Within Group 2 herbicides, foliar application of sulfonylurea herbicides caused damage at lower rates than imidazolinones. At low rates, apparently mild symptoms resulted in floral disruption and reduced pod fill. Canola was relatively tolerant to glyphosate and plants were unaffected until the 30% rate was applied.

In general, increasing the herbicide rate resulted in earlier appearance of symptoms and increased symptom severity.

Effects of Group 2 Herbicides

Group 2 herbicides are ALS/AHAS inhibitors that include five different chemical families.

Group 2 Herbicides

Chemical Family	Active Ingredient	Found In:
Imidazolinones	Imazamethabenz	Assert 300 SC, Assert FL, Avert
	Imazamox	Adrenalin SC, Altitude FX, Ares, Solo, Tensile, Viper
	Imazamox + Imazethapyr	Absolute, Odyssey, Odyssey DLX
	Imazapyr	Ares, Arsenal
	Imazethapyr	Guardman Gladiator, MPower Kamikazi, Multistar, Phantom, Pursuit
Sulfonylamino-carbonyltriazolinones	Flucarbazone Sodium	Everest, Everest GBX, Pace, Prepare, Prepare Complete, Sierra
Sulfonylureas	Chlorsulfuron	Glean, Telar
	Ethametsulfuron Methyl	Muster, Muster Toss-N-Go
	Metsulfuron-methyl	Accurate, Ally Toss-N-Go, Clearview, Escort, Express Pro, Reclaim

Chemical Family	Active Ingredient	Found In:
Sulfonylureas	Nicosulfuron	Accent, Ultim
	Rimsulfuron	Elim, Prism, Ultim
	Thifensulfuron-methyl	Barricade II, Broadside, Deploy, Harmony K, Harmony Max, Harmony SG, Nimble, Pinnacle, Pinnacle SG, Refine M, Refine SG, Retain, Triton C
	Tribenuron-methyl	Barricade II, Broadside, Deploy, Express Pro, Express SG, FirstStep Complete, Harmony K, Harmony Max, Harmony SG, Nimble, Nuance, Refine SG, Refine M, Retain, Spike-Up, Triton C, Triton K
	Triflurosulfuron methyl	UpBeet
Triazolpyrimidines	Florasulam	Assert FL, Benchmark, Broadband, Frontline, Frontline XL, Frontline 2,4-D, PrePass, PrePass XC, Spectrum, Stellar
	Pyroxulam	Simplicity, Tandem
Triazolones	Thiencarbazone-methyl	Thumper Total 1, Varro, Velocity m3

Always confirm active ingredients and recropping restrictions on product labels prior to use.

Effects of Foliar-Applied Group 2 Sulfosulfuron (Sundance™)

Sulfosulfuron, tradenamed Sundance, was removed from the marketplace and is no longer available to western Canadian farmers. However, as a Group 2 sulfonylurea product, these sulfosulfuron symptoms of drift are similar to those found in other currently registered sulfonylureas such as Telar, Ally, Express Pro, Harmony, and many of the DuPont PrecisionPac herbicides.



GROUP 2 SYMPTOMS: 1% OF AN 11 G/ACRE RATE OF SULFOSULFURON

At this rate, the only symptom observed was temporary purpling of side shoot leaves, which occurred at flowering time.

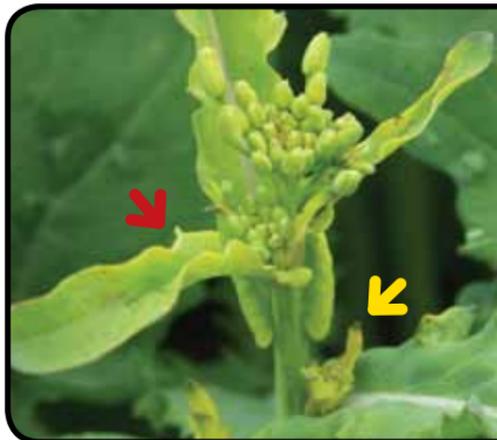
GROUP 2 SYMPTOMS: 2% OF AN 11 G/ACRE RATE OF SULFOSULFURON

At this rate, symptoms first appeared at early flowering. Symptoms included:

- 1) chlorosis on the newest leaves,
- 2) chlorosis and purpling of side shoot leaves,
- 3) chlorosis of axillary flowers and the main flower stem,
- 4) injury to the meristem, and
- 5) delayed maturity of axillary flowers.

SULFOSULFURON SYMPTOMS: 2% OF AN 11 G/ACRE RATE

Chlorosis of true leaves (red arrow) and side shoot leaves (yellow arrow). Leaf chlorosis diminished over time.



Chlorosis of main flower head (red arrow) and an unaffected flower (yellow arrow).



SULFOSULFURON SYMPTOMS: 2% OF AN 11 G/ACRE RATE

Early symptoms (A) include purpling of side shoot leaves and chlorosis in the flower head.



Purpling and flower chlorosis may become more severe (B) over time.



SULFOSULFURON SYMPTOMS: 2% OF AN 11 G/ACRE RATE

An unaffected (A) versus an injured (B) canola at maturity. Meristem damage has resulted in reduced main shoot production and a maturity delay in the side shoots (B).



SULFOSULFURON SYMPTOMS: 5% OF 11 G/ACRE RATE

At this rate, symptoms first appeared four to five days after spraying. Symptoms included chlorosis, immediate cessation of growth on new leaves, growth proliferation at the crown and a lack of flower production.

SULFOSULFURON SYMPTOMS: 5% OF AN 11 G/ACRE RATE

Unsprayed (A) and sprayed
(B) plants. Chlorosis appeared
four days after spraying.



The insert (B) is a close-up
of the chlorotic plants.



SULFOSULFURON SYMPTOMS: 5% OF AN 11 G/ACRE RATE

Classic early (A) symptoms include chlorosis of new leaves and minor necrotic spots on older leaves (yellow arrow).



Four weeks after application (B) herbicide injury caused crown growth proliferation (red arrow).



SULFOSULFURON SYMPTOMS: 10% OF AN 11 G/ACRE RATE

At this rate, symptoms appeared four to five days after spraying. Early symptoms (A) include chlorosis and reddening, cessation of new growth and crown growth proliferation.



Necrotic leaf spotting became more pronounced over time (B).



SULFOSULFURON SYMPTOMS: 10% OF AN 11 G/ACRE

Severe injury (A) occurred at this rate (left) compared to an unsprayed check (right).



A close-up of an injured plant (B) shows recovery of older leaves (red arrow) and crown growth proliferation (yellow arrow).



Effects of Foliar-Applied Group 2 Imazethapyr and Imazamox (Odyssey™)

Odyssey is registered for use on Clearfield canola as a foliar application. The symptoms presented here are for non-Clearfield type canola varieties.

IMAZETHAPYR AND IMAZAMOX SYMPTOMS: 2% OF A 17 G/ACRE RATE

Symptoms were not observed at lower rates. Injury symptoms first appeared at flowering time at the 2% rate.

Symptoms included:

- 1) purpling of side shoot leaves,
- 2) chlorosis on the newest leaves, main stem and side shoots, and
- 3) delayed maturity and poor pod fill.



Unsprayed (A) versus sprayed (B) canola, and a close-up of chlorosis on new leaves (C).

IMAZETHAPYR AND IMAZAMOX SYMPTOMS: 2% OF A 17 G/ACRE RATE

Unsprayed plants (A) have normal axis development compared to sprayed (B) plants, which have purpling and chlorosis of side shoot leaves.



IMAZETHAPYR AND IMAZAMOX SYMPTOMS: 2% OF A 17 G/ACRE RATE

Unsprayed plants (A) with normal maturity and pod fill compared to sprayed plants (B).



IMAZETHAPYR AND IMAZAMOX SYMPTOMS: 5% OF 17 G/ACRE RATE

Symptoms first appeared four days after spraying. Symptoms included chlorosis of new leaves, cessation of leaf growth, crown growth proliferation and a lack of flower production.

Unaffected (A) and affected plants (B) four days after application.



IMAZETHAPYR AND IMAZAMOX SYMPTOMS: 5% OF A 17 G/ACRE RATE

This close-up shows chlorosis of the third and fourth leaves. These plants did not produce any further growth.



IMAZETHAPYR AND IMAZAMOX SYMPTOMS: 10% OF A 17 G/ACRE RATE

Symptoms first appeared four to five days after spraying and included chlorosis of new leaves, cessation of leaf growth, crown growth proliferation and a lack of flower production.

This close-up shows crown growth proliferation.



Effects of Foliar-Applied Group 4 Herbicides

Group 4 herbicides are synthetic auxins, which disrupt plant cell growth leading to malformed growth and tumors.

Chemical Family	Active Ingredient	Found In:
Benzoic Acids	Dicamba	Banvel II, Banvel VM, Battalion, DyVel, DyVel DSp, Harmony K, Hawkeye Power, Oracle, Overdrive, Pulsar, Rustler, Sword, Takkle, Target, Tracker XP, Triton K, Vanquish, VMD 480 Dicamba
Carboxylic Acids	Clopyralid	Absolute, Curtail M, Eclipse III, Lontrel 360, FlaxMax DLX, Momentum, Prestige, Prestige XC, Spectrum, Tensile
	Aminopyralid	Milestone, Restore, Reclaim
	Fluroxypyr	Altitude FX, Attain XC, Barricade II, Everest GBX, Flurox 2,4, Harmony Max, Momentum, OcTTain XL, Prestige XC, Pulsar, Retain, Stellar, Tandem, Trophy 600
	Picloram	Grazon, Tordon 22K

Chemical Family	Active Ingredient	Found In:
Phenoxy	2,4-D	2,4-D, Adrenalin SC, Approve, Attain XC, Desormone, Dichlorprop-D, Dichlorprop-DX, DyVel DSp, Estaprop Plus, Estaprop XT, Flurox 2,4, Frontline 2,4-D, Frontline 2,4-D XC, Grazon, Leader, OctTain XL, Reclaim, Restore, Retain, Salvo, Signal D, Thrasher, Thumper, Titanium, Triton K, Turboprop
	Dichlorprop (2,4-DP)	Desormone, Dichlorprop-D, Dichlorprop-DX, Estaprop Plus, Estaprop XT, Optica Trio, Turboprop
	2,4-DB	2,4-DB, Caliber 625, Cobutox 625, Embutox 625
	MCPA	Achieve Liquid Gold, Altitude FX, Assert FL, Badge, Broadside, Buctril M, Clovitox Plus, Curtail M, DyVel, FlaxMax DLX, Frontline, Frontline XL, Horizon BTM, Logic M, MCPA, Mextrol 450, Optica Trio, Prestige XC, Refine M, Signal M, Spectrum, Stellar, Sword, Target, Topside, Tracker XP, Trophy 600, Tropotox Plus
	MCPB	Clovitox Plus, Topside, Tropotox Plus
	Mecoprop (MCP)	Compitox, DyVel DSp, Mecoprop-P, Optica Trio, Sword, Target, Tracker XP
	Quinclorac	Triton C

Always confirm active ingredients and recropping restrictions on product labels prior to use.

Effects of Foliar-Applied 2,4-D Ester 600 and MCPA Amine 40

Reduced rates selected for 2,4-D and MCPA were based on full rates of 285 ml/acre and 444 ml/acre respectively. Symptoms were similar for both herbicides and included swelling (stems, petioles and at the crown area), resulting in stem cracking and epinasty (downward curvature of a leaf or stem). Chlorosis on new leaves was produced when swelling or stem cracking was severe enough to interrupt the water and sugar transport within the plant. Stem cracking at the base was more pronounced with 2,4-D than MCPA, whereas stem epinasty was more pronounced with MCPA compared to 2,4-D.

2,4-D ESTER 600 SYMPTOMS: 5% OF 285 ML/ACRE RATE

Symptoms were not observed at lower rates for either herbicide. Symptoms appeared six days after spraying and included swelling and epinasty of the stems and/or crown area.

This plant is showing swelling above the crown and is starting to crack below the crown area.



2,4-D ESTER 600 SYMPTOMS: 5% OF A 285 ML/ACRE RATE

An unaffected plant (left) and sprayed plant (right). Note the lack of leaf symptoms. Epinasty is present only in the crown area.



A close-up of the above plants.



MCPA SYMPTOMS: 5% OF A 444 ML/ ACRE RATE

Severe epinasty on the main stem (A).



An unsprayed plant (B) developed normally whereas epinasty in sprayed plants (C) persisted through maturity.



2,4-D ESTER 600 SYMPTOMS: 10% OF A 285 ML/ACRE RATE

At this rate, symptoms first appeared three to five days after spraying. Symptoms included severe swelling at crown area or on main stem, cracking of swollen areas, callus formation and subsequent chlorosis of new leaves due to physical injury.

Swelling of the crown area seven days after application.

Crown swelling has resulted in cracking and callus formation. Subsequent growth was chlorotic.



Effects of Foliar-Applied Group 5 Herbicides

The most common Group 5 herbicide that may cause herbicide injury to canola through drift is Sencor, a metribuzin. This group also includes the atrazine family.

Group 5 Herbicides

Chemical Family	Active Ingredient	Found In*
Phenyl-carbamates	Desmedipham	Betamix, Betamix β
	Phenmedipham	Betamix, Betamix β
Triazines	Atrazine	AAtrex Liquid 480, Atrazine, Converge 480, Frontier Max Plus, Laddok, Liberty AT, Lumax, Marksman, Primextra II Magnum, Prospero
	Simazine	Princip Nine-T, Simazine 480
Triazinones	Hexazinone	Velpar DF, Velpar L
	Metribuzin	Axiom DF, Lexone DF, Sencor, Tricor 75 DF
	Pyrazon	Pyramin DF, Pyramin FL
Uracils	Bromacil	Calmix Pellets, Hyvar X/X-L, Krovar I

Always confirm active ingredients and recropping restrictions on product labels prior to use.

- Initial symptoms of Group 5 activity include rapid chlorosis and necrosis at the leaf edges, and inter-veinal chlorosis.
- The leaves rapidly desiccate and develop a burned-off appearance.

Effects of Foliar-Applied Group 6 Herbicides

Common Group 6 herbicides that may cause drift damage to canola include Viper, and any of the pre-formulated herbicides containing bromoxynil.

Group 6 Herbicides

Chemical Family	Active Ingredient	Found In:
Benzthiadiazoles	Bentazon	Basagran, Basagran Forte, Laddok, Viper
Nitriles	Bromoxynil	Achieve Liquid Gold, Approve, Axial iPak, Badge, Benchmark, Bromotril, Brotex 240, Buctril M, Horizon BTM, Infinity, Koril 235, Leader, Logic M, Mextrol 450, Pardner, Signal D, Signal M, Thrasher, Thumper, Titanium, Tundra, Velocity m3

Always confirm active ingredients and recropping restrictions on product labels prior to use.

- Typical symptoms include a general discoloration and yellowing in two to four days.
- The plants brown completely and shrivel and die in one to two weeks.



Photos by F.A. Holm

Effects of Foliar-Applied Group 7 Herbicides

The most common Group 7 herbicide that may cause drift damage to canola is Linuron.

Chemical Family	Active Ingredient	Found In:
Ureas	Diuron	Diurex 80W, Karmex XP, Krovar I DF
	Linuron	Linuron, Lorox

Always confirm active ingredients and recropping restrictions on product labels prior to use.

- High concentrations of drift cause interveinal yellowing of the oldest leaves with death occurring within a few days.
- Lower drift concentrations result in wilting of leaves and the development of grey blotches and yellowing of leaves. Interveinal yellowing may occur if concentration is high enough.



Photo by F.A. Holm

Effects of Foliar-Applied Group 9 Glyphosate (Roundup Transorb™)

Glyphosate was applied to non-Roundup Ready canola at 30% of the 1 L/acre rate to simulate herbicide drift.

ROUNDUP TRANSORB SYMPTOMS: 30% OF 1 L/AC RATE

In field studies, no damage was observed at any rate. In greenhouse studies, symptoms were not observed at rates lower than 30% of a 1L/AC rate. Symptoms started with chlorosis at the base of the third leaf and developed on subsequent leaves.

Close-ups showing chlorosis 10 (A) and 15 (B) days after application.



Effects of Foliar-Applied Group 10 Glufosinate Ammonium (Liberty™)

Liberty herbicide was applied at various rates to non-Liberty Link canola to simulate drift onto susceptible canola varieties.

GLUFOSINATE AMMONIUM SYMPTOMS: 5% OF A 1.08 L/ ACRE RATE

Symptoms were not observed at lower rates. Symptoms first appeared six days after herbicide application. Symptoms included mottling and/or marginal chlorosis of contacted leaves. No effect was observed on new leaves emerging after application.

GLUFOSINATE AMMONIUM SYMPTOMS: 10% OF A 1.08 L/ ACRE RATE

Symptoms appeared four days after application and included chlorosis and necrosis on contacted leaves. Leaves emerging after application were chlorotic and no further plant development occurred.



Effects of Foliar-Applied Group 14 Herbicides

The Group 14 herbicides are used in both pre-seed and post-emergent applications, and may cause canola injury due to drift.

Group 14 Herbicides

Chemical Family	Active Ingredient	Found In:
Aryl Triazone	Carfentrazone	Aim, Cleanstart
	Flumioxazin	Payload, Valtera
	Saflufenacil	Eragon, Heat WG
	Sulfentrazone	Authority

Always confirm active ingredients and recropping restrictions on product labels prior to use.

- Symptoms include yellow and desiccated leaves. At high concentrations, death is within one to three days.
- As a contact herbicide, low drift concentrations may cause leaf spotting.



Photo by Nasir Shaikh

Effects of Foliar-Applied Group 27 Herbicides

Group 27 herbicides are commonly used in post-emergent control in cereals.

Group 27 Herbicides

Chemical Family	Active Ingredient	Found In:
Pyrazole	Pyrasulfotole	Infinity, Tundra, Velocity m3

Always confirm active ingredients and recropping restrictions on product labels prior to use.

- Activity symptoms include bleached and whitened leaves in two to 10 days.
- High concentrations can result in death in seven to 10 days.





Canola Council of Canada

400–167 Lombard Avenue
Winnipeg, Manitoba, Canada
R3B 0T6

Phone: (204) 982-2100

Fax: (204) 942-1841

Toll-free: 1-866-834-4378

www.canolacouncil.org

Thanks to Sandi Scott and Dr. Paul Watson from the Alberta Research Council (now Alberta Innovates) for their contribution to the original publication, and to all those involved in the updates to this revised version.

