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

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Table of Contents

HERBICIDE RESIDUE INJURY

FOLIAR HERBICIDE INJURY

Herbicide Residue

INTRODUCTION

Canola injury can occur from exposure to low soil concentrations of several Group 2 herbicides. In recent years, slower breakdown of residual herbicides due to drought has caused crop injury in subsequent crops. Herbicide carryover can cause crop injury ranging from minimal to complete crop loss. Injury problems have arisen where normal breakdown of herbicides has been affected by factors such as drought, low organic matter and pH.

OBJECTIVES AND METHODS

This section is intended to:

1) show canola injury symptoms associated with Group 2 herbicide residues, and

2) assist in differentiating between symptoms due to residue versus other problems.

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.

FACTORS AFFECTING HERBICIDE CARRYOVER

Field History

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

Soil Characteristics

Interactions between soil factors are complex and may either decrease herbicide decomposition or increase the herbicide residue available 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.

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. A general guideline to soil characteristics that increase carryover for Group 2 herbicides. For information on specific products, consult the herbicide label.

Chemical Family	pH	Organic Matter
Imizadolinone	< 6.0	low
Sulfonyurea	> 7.5	low
Sulfonyylaminocarbonyltriazolinones	> 7.5	low

Field Scouting

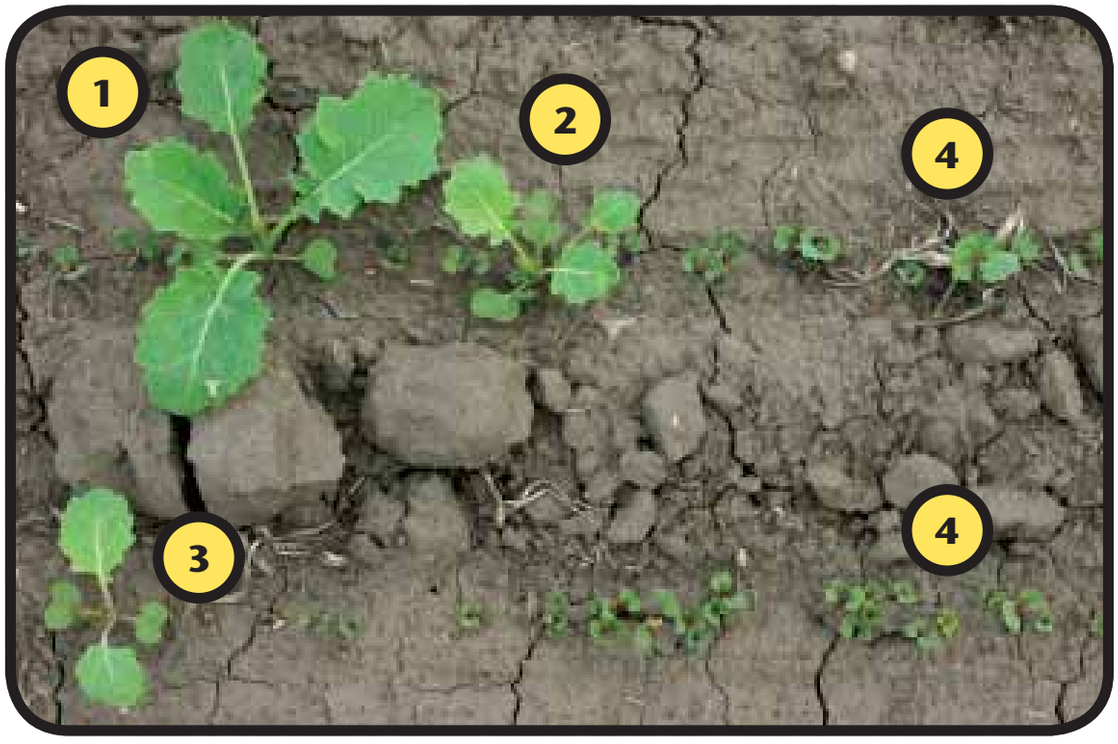
Injury can occur anywhere in the field and may be patchy. Patches that appear bare have normal emergence but there is considerable variation in plant development. Areas of low organic matter, headlands, corners or overspray may have more injury.

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 1st and 2nd leaves are of normal size, the purpling observed is not herbicide injury. The purpling is a result of anthocynin 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.

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.

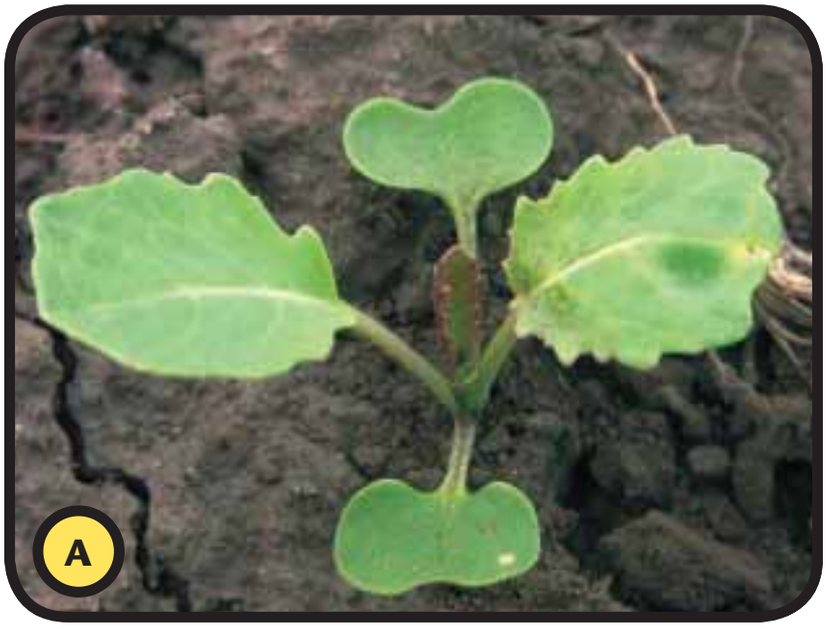
An unaffected (left) and severely affected cotyledon (right) (A). The affected plant had purpling on the back of the cotyledons, but no size reduction. Inspection of the true leaves of these same plants (B) reveals symptoms consistent with Group 2 herbicide injury. The injured plant (right) has reduced 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.

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 1st and 2nd leaves, reduced leaf area and mild cupping of the 3rd 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 1st and 2nd 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.

Residue Symptoms on True Leaves

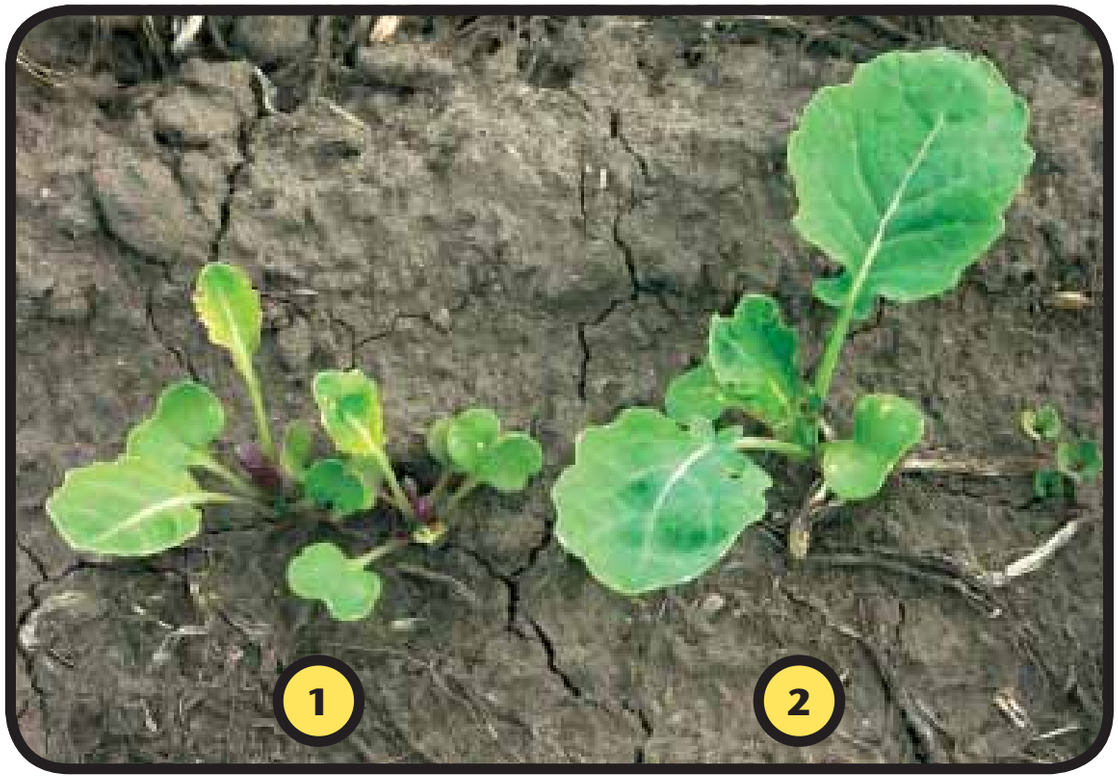
SEVERE SYMPTOMS

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 1st leaf growth.

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

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

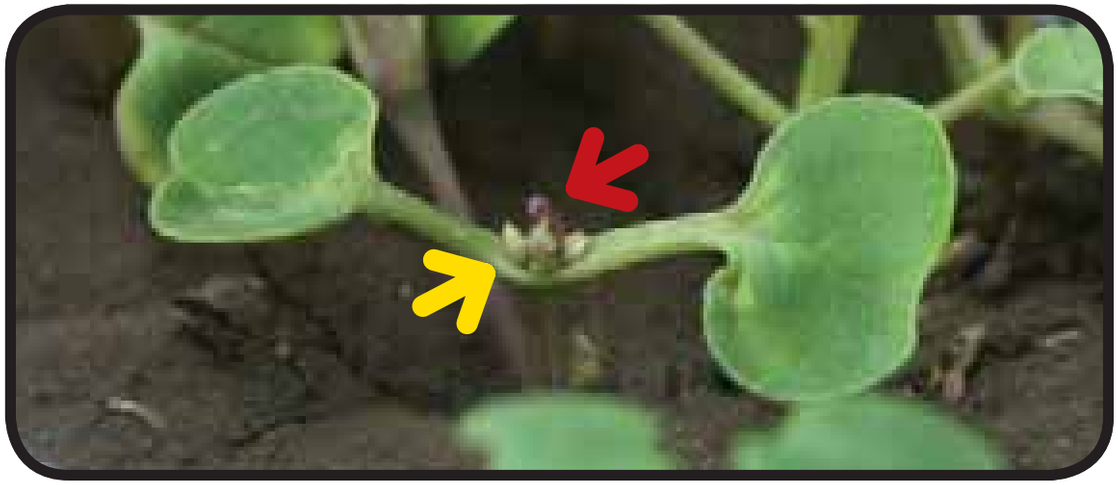
Leaf purpling and cupping on the 1st (yellow arrow) and 2nd leaf (red arrow) are classic injury symptoms. Although plants can recover, this level of injury slows plant development.

Another classic symptom is leaf chlorosis. Both the 1st and 2nd leaves have overall chlorosis. Chlorosis was observed through the 4-leaf stage.

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).

Residue Symptoms on True Leaves

SEVERE SYMPTOMS

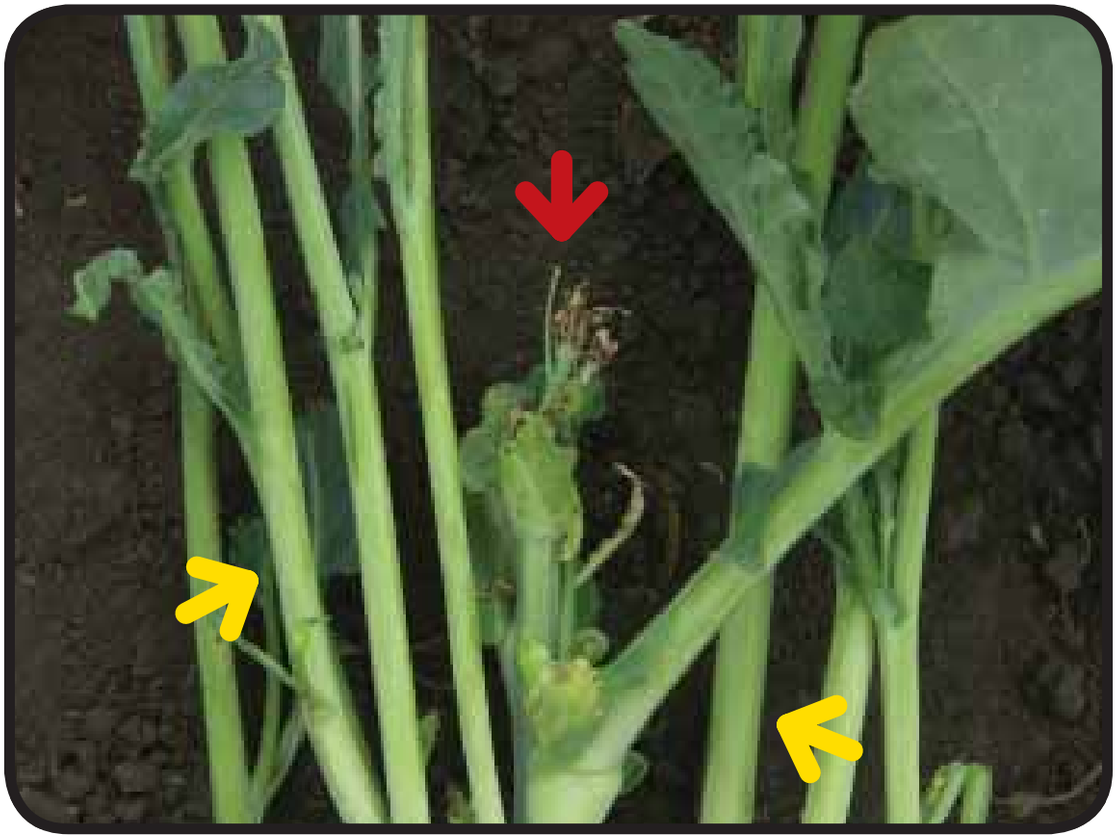
This level of meristem damage causes premature growth of side branches (A). Inset: an unaffected plant the same age.

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

Residue Symptoms on Mature Plants

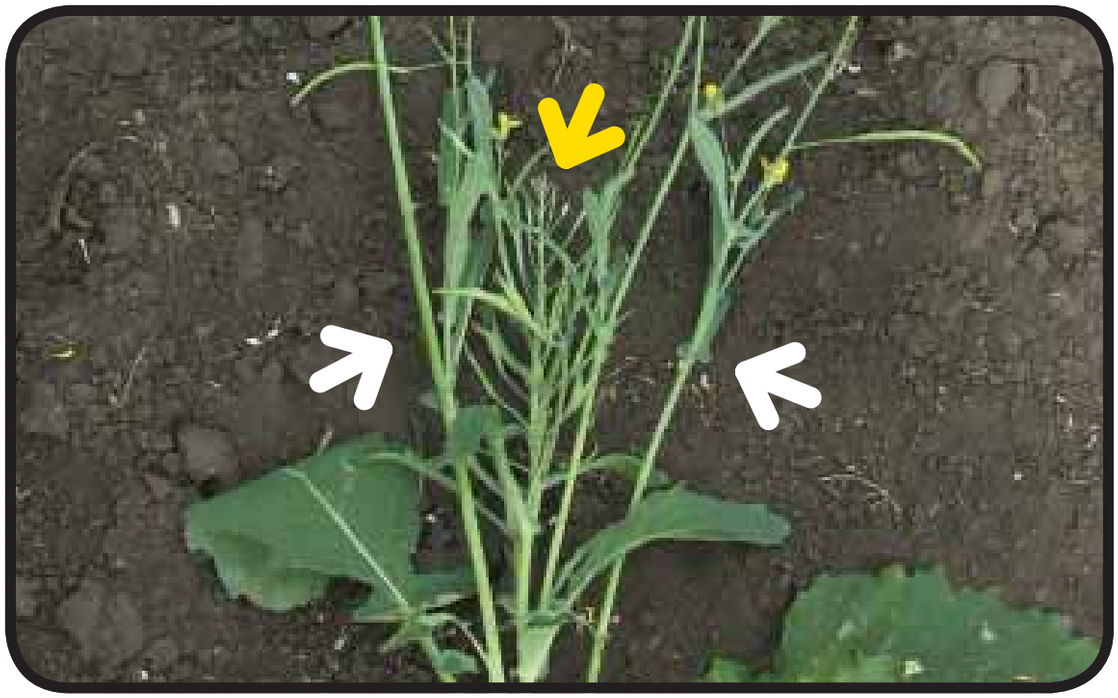
Injury symptoms should be detected before maturity, as these symptoms also mimic those caused by herbicide drift. Severe injury symptoms are long lasting and significantly affect plant development. Significant meristem damage effectively “prunes” plants and they respond with either production of damaged 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).

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 tests for the presence of herbicide residue by bioassay, chemical analysis (Appendix 1) or both.

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

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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.

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. To generate photographs and descriptions, 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.

Effects of Foliar-Applied Sulfosulfuron (Sundance™)

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

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

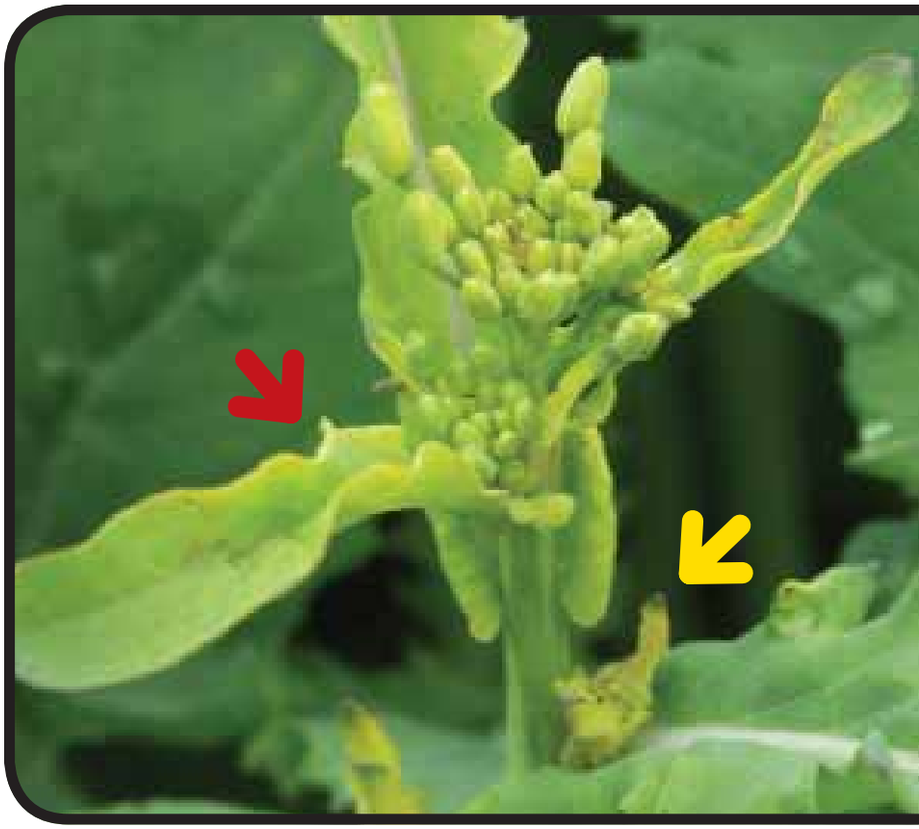
SULFOSULFURON SYMPTOMS: 2% OF AN 11 G/ACRE RATE

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).

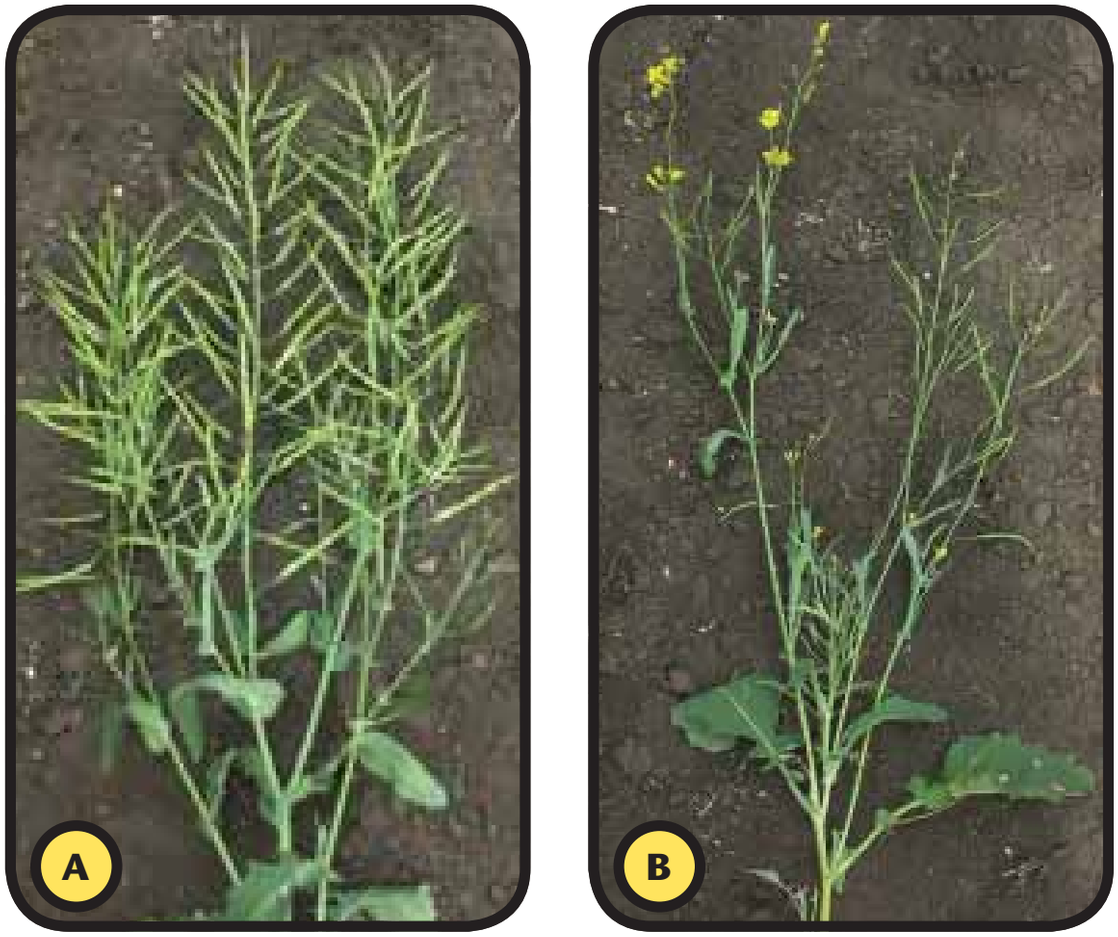
SULFOSULFURON SYMPTOMS: 2% OF AN 11 G/ACRE RATE

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

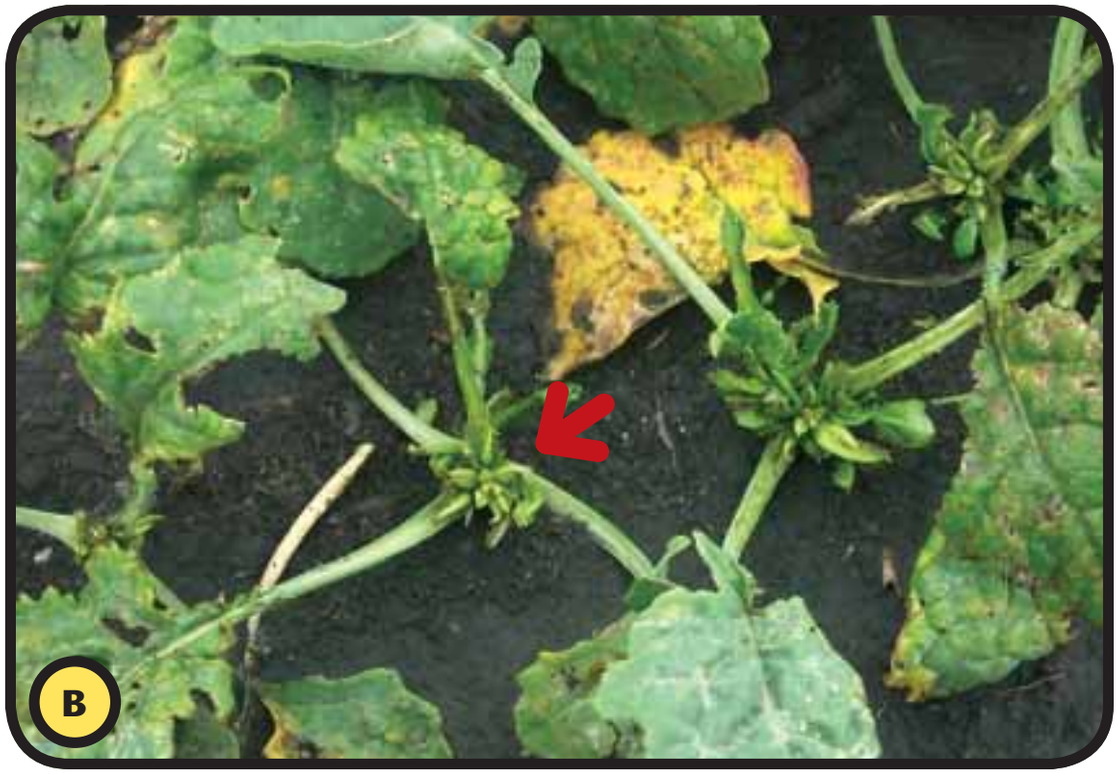
Unsprayed (A) and sprayed (B) plants. Chlorosis appeared four days after spraying.

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 Imazethapyr and Imazamox (Odyssey™)

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

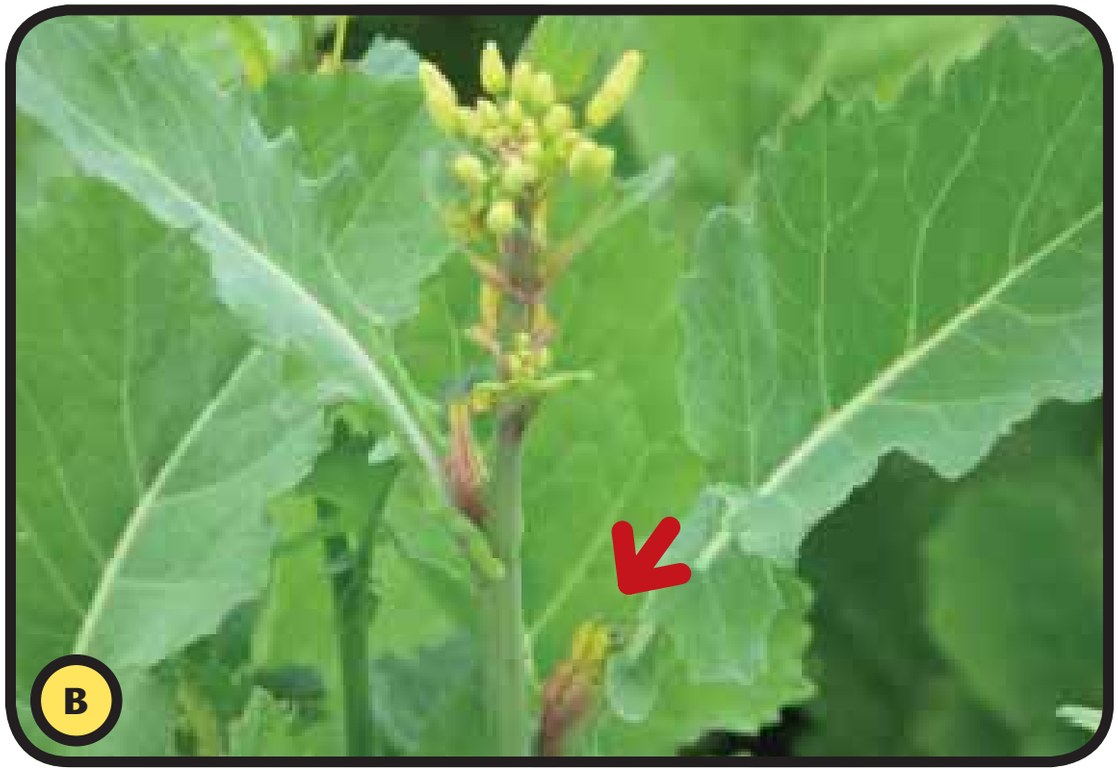
Symptoms were not observed at lower rates. Injury symptoms first appeared at flowering time at the 2% rate. Symptoms included:

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 3rd and 4th 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 2,4-D Ester 600 and MCPA Amine

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 Glufosinate Ammonium (Liberty ™)

GULFOSINATE 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.

GULFOSINATE 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 Glyphosate (Roundup Transorb™)

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 3rd leaf and developed on subsequent leaves.

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

Conclusion

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.

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