Weed Control in Canola: An integrated approach

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Outline

- Canada canola acres and productivity
  - HR varieties and hybrids
- Integrated approach to weed management
- Background on herbicides and resistance
- Herbicide intervention pre-seeding, in crop
- Avoiding herbicide resistance selection
- Is canola a weed? In fields and ruderal areas.
Canadian Canola Production

- In 1990, 2.5 million ha were seeded with a total production of 3.26 M tonnes
  - (1.3 tonnes ha\(^{-1}\))
- By 2012, 6.8 M ha and 3.26 M tonnes
  - (2.08 tonnes ha\(^{-1}\))
- Due to optimized fertilizer use, timely herbicides, enhanced HR hybrid varieties, enhanced management practices

Weed management is one of dozens of key management variables affecting canola establishment and yield

Weed management depends on
- rotational diversity and
- crop establishment
Adoption of herbicide resistant (HR) varieties in Canada
If you rely only on chemistry, it will fail
Crop health/vigor increases weed control and yield

- Factors affecting crop health
  - Fertility
  - Variety choice (G*E)
  - Weather/climate/soil
  - Direct seeding
  - Time of herbicide application
  - Seeding rate (but wait – there is more to it than seeds in the ground!)
  - Depth of seeding
  - Speed of seeding
  - Time of seeding
  - Precision seeding
  - Crop rotation

- Ask a simple question – get a simple answer

- Ask a complex question and experimental variability increases
  - Multiple sites, multiple years and multi-factorial experiments
  - (expensive and require consistency in research skills)

- Survey of grower practices (large scale) provide more complex responses
Early weed removal

- Two LL varieties, open pollinated Exceed and Hybrid InVigor
  - Non residual herbicide
- Seed rate (100, 150 and 200)
- Time of weed removal (2, 4 and 6 leaf)
- Early emerging weeds are the most competitive and have the largest effect on yield
- Combining cultivar, high seeding rate and early removal resulted in a 42% increase in yield

Timing is Everything!

Weeds Emerging Here Cause Crop Loss

Seeding

Crop Emergence

Leaf Stages

1 2 3 4 5 6

Week 1 Week 2 Week 3 Week 4

HIGH Yield Protection

Weeds Emerging Here Cause Crop Loss

Cosmetics, Weed Seed Prevention & LOW Yield Protection

HIGH Yield Protection
Time of intervention

Seeding
Crop Emergence

Leaf Stages

1              2                3             4         5     6
Week 1              Week 2             Week 3              Week 4

HIGH Yield Protection

Cosmetics, Weed Seed Prevention & LOW Yield Protection

Pre-seeding
In-crop
In-crop residual
Interactions of agronomic practices on wild oat populations in canola

- It may be possible to enhance the effectiveness of herbicides through agronomic practices
  - Reduce weed populations
  - Add cultural control to herbicide control
- Add and removal of treatments
Stand uniformity with precision seeding

Up to 32% yield increase with optimized spatial patterns of canola plant establishment in western Canada. 2014. Chao Yang & Yantai Gan & K. Neil Harker & H. Randy Kutcher & Rob Gulden & Byron Irvine & William E. May
DOI 10.1007/s13593-014-0218-5

Stand uniformity optimizes the use of available resources and increases weed competition
Influence of seeding rate and plant stand uniformity on yield

16 Site years in western Canada
Rotational benefits

- From farm survey, cumulative influence of rotations on canola yield
- Causal factors?
- Weeds, insect, disease? Loss of diversity?

<table>
<thead>
<tr>
<th>Alberta soil zone</th>
<th>Canola on canola</th>
<th>1 and 2 year break</th>
<th>3 year break</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark Brown</td>
<td>-</td>
<td>100%</td>
<td>107</td>
</tr>
<tr>
<td>Thin Black</td>
<td>89</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>Black</td>
<td>79*</td>
<td>100</td>
<td>105</td>
</tr>
<tr>
<td>Black Dark Grey East</td>
<td>83</td>
<td>100</td>
<td>108</td>
</tr>
<tr>
<td>Black Dark Grey West</td>
<td>86</td>
<td>100</td>
<td>97*</td>
</tr>
<tr>
<td>Peace region</td>
<td>82</td>
<td>100</td>
<td>-</td>
</tr>
</tbody>
</table>

*Limited data, only 3 of 6 years
Crop Rotations

- Crop rotation leads to reduced weed populations
  - Changes in herbicides
  - Changes in competition
  - Changes in time of application

Effect of agronomic inputs and crop rotation on biodiesel quality and fatty acid profiles of direct-seeded canola

K. N. Harker¹, J. T. O'Donovan¹, R. E. Blackshaw², L. M. Hall³, C. J. Willenborg⁴, H. R. Kutcher⁵, Y. Gan⁶, G. P. Lafond⁷, W. E. May⁸, C. A. Grant⁹, V. Barthe⁹, T. McDonald⁹, D. Wisinski¹⁰, and M. Hartman¹¹
imazamethabenz-methyl

imizethapyr
Entry into the plant (foliar or root)

Entry into the cell

Entry into subcellar organelle

Translocation via xylem or phloem

Metabolism – activation or degradation

Interaction at the target site

Sequestration

Whole plant response

Physio-chemical Properties
Pka and K<sub>ow</sub>
ALS (or AHAS) Acetolactate synthase

Mixed inhibition by four families of herbicides

Enzyme is a key in the synthesis of branched chain amino acids

Catalyzes two reactions
# Imidazolinone herbicides

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Product name</th>
<th>Residual (half life days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imazapyr</td>
<td></td>
<td>25-122</td>
</tr>
<tr>
<td>Imazapic</td>
<td></td>
<td>120</td>
</tr>
<tr>
<td>Imazethapyr</td>
<td></td>
<td>60-90</td>
</tr>
<tr>
<td>Imazamox</td>
<td></td>
<td>20-30</td>
</tr>
<tr>
<td>Imazaquin</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>Imazamethabenz</td>
<td></td>
<td>25-36</td>
</tr>
</tbody>
</table>

Herbicide Handbook WSSA 2007
<table>
<thead>
<tr>
<th>Class</th>
<th>Active Ingredient</th>
<th>Trade Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfonylurea</td>
<td>thifensulfuron</td>
<td>RefineExtra*</td>
</tr>
<tr>
<td></td>
<td>tribenuron</td>
<td>RefineExtra*</td>
</tr>
<tr>
<td></td>
<td>metsulfuron</td>
<td>Express</td>
</tr>
<tr>
<td></td>
<td>sulfosulfuron</td>
<td>Ally</td>
</tr>
<tr>
<td>Imidazolinone</td>
<td>imazamethabenz</td>
<td>Assert</td>
</tr>
<tr>
<td></td>
<td>imazapyr</td>
<td>Pursuit</td>
</tr>
<tr>
<td></td>
<td>imazamox</td>
<td>Odyssey*</td>
</tr>
<tr>
<td>Triazolprimidine</td>
<td>florasulam</td>
<td>Spectrum,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frontline</td>
</tr>
<tr>
<td></td>
<td>pyroxsulam</td>
<td>Simplicity</td>
</tr>
<tr>
<td>Sulfonyl amino carbonyl triazolinones</td>
<td>flucarbazone-sodium</td>
<td>Everest</td>
</tr>
</tbody>
</table>
Binding of sulfonylurea and imidazolinone to the ALS site of action

The ALS binding site is very susceptible to genetic changes without reductions in fitness.
Clearfield crops

- Selected for a modified ALS which binds with low affinity to imidazolinone herbicides
- Wheat, sunflower, lentils, canola, others
Group 2 - Symptoms

Slow to appear

- Inhibition of plant growth
- **chlorosis**
- **terminal bud death**
- purple coloration
- death is slow
- **ALS in young meristematic regions**
Imidazolinone – soil interactions

- Imidazolinones are adsorbed to soil and adsorption effects the activity and persistence of these products
- Adsorption is influenced by pH, organic matter and time
- The weak acid nature of these products plays an important role in soil activity
- At soil pH, the negatively charged anionic form predominates and this form is repelled from the negative charge of the soil colloids, resulting in low adsorption to neutral and high pH soils
- As soil pH decreases (pH < 6) herbicide adsorption increases and so does persistence
- This is moderated by both organic matter and water, more organic matter increases adsorption
Soil persistence and microbial degradation

- Soil degradation is through microbial degradation and any factor that influences microbial activity affects degradation
  - Temperature, moisture, pH
- Soil residual is measured in herbicide half life ($T_{0.5}$) days
- For long residual herbicides (imazapyr, sulfometuron) the half lives can be significant

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Half life (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imazapyr</td>
<td>25-142</td>
</tr>
<tr>
<td>Sulfometuron methyl</td>
<td>20-28</td>
</tr>
<tr>
<td>Florasulam</td>
<td>2-8</td>
</tr>
</tbody>
</table>
# Relative Toxicity Categories

## Mammals (people)

<table>
<thead>
<tr>
<th>Relative Toxicity Category</th>
<th>Oral LD&lt;sub&gt;50&lt;/sub&gt; (mg/kg)</th>
<th>Dermal LD&lt;sub&gt;50&lt;/sub&gt; (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slightly Toxic</td>
<td>&gt; 500</td>
<td>&gt; 1000</td>
</tr>
<tr>
<td>Moderately Toxic</td>
<td>51 - 500</td>
<td>201 - 1000</td>
</tr>
<tr>
<td>Very Toxic</td>
<td>0 - 50</td>
<td>0 – 200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product</th>
<th>Oral LD&lt;sub&gt;50&lt;/sub&gt; (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refine</td>
<td>&gt;5000 mg/kg</td>
</tr>
<tr>
<td>Odyssey</td>
<td>&gt;5000 mg/kg</td>
</tr>
</tbody>
</table>
Herbicide Risk Triangle

Beckie et al 2006
ALS (Group B) herbicides are the products most prone to select for resistance.

Glyphosate/Glufoxinate resistant canola decrease the concern with Group A and B herbicides when introduced.
Herbicide resistant weeds reported in Brazil and Canada
Potential Mechanisms of Resistance

Anything that works!

1. Changes to the target site
   - Changes the binding of herbicide to target site

2. Gene amplification that increases the amount of the target site

3. Changes in the rate or pathway of herbicide metabolism

4. Changes in the translocation of herbicides

5. Ability to withstand toxic effects of the herbicide

6. Altered herbicide uptake

7. Sequestration of the herbicide away from the target site
All Selective Management Practices Change the Nature of a Weed Population

- Weed populations are genetically variable
- Variation via mutation or pre-existing in a population
- Weed populations are dynamic, they respond to shifts in climate, management (like tillage), crop choice, time of seeding, and selection by herbicides

“Make it look like natural selection.”
Factors Effecting the Rate of Selection

- Number of weeds selected
- Frequency of use (↑ applications = more selection)
  - duration of selection (residual herbicides)
- Selection pressure
  - herbicide efficacy (↑ control = more selection)
- Genetic nature of the resistance mechanism
- Weeds biology
  - Longevity of weed seeds in soil (buffers selection)
  - Number of weed seeds in the soil
- Fitness
Survival of the fittest?

- Any individual that can survive the application of an ALS inhibitor may reproduce and the genes increase in the population.
Herbicide Use Patterns

- Not all chemicals are alike in their ability to select for resistance.
- After many years of Group 4 herbicides, resistant individuals are just beginning to be examined.
- Resistance to ALS inhibitors can be selected in a field by 5-7 years application.
Intervention Options with Herbicides

✔ Pre-harvest glyphosate in the preceding crop year (perennials)
✔ Pre-seeding control (winter annuals and early germinating spring annuals)
✔ Use of pre-emergence herbicides (annuals)
✔ Early applied post-emergence herbicides (s&w annuals)
✔ Apply an early post-emergence herbicide with soil residual activity (s&w annuals)
✔ Split application of post-emergence herbicides (s&w annuals)
Is canola a weed?

- Canola is the 14th most abundant weed in Western Canadian cropping systems.
- Average seed loss pre and post harvest is >8,000 plant m⁻².
- Secondary seed dormancy from seed burial (absence of light, cooler temperatures).
- Limited seed persistence.
- At the end of the first winter, only 1/3 remain, 0.5% emerge and in the second year the seed bank is reduced to 0.3%.
Canola volunteer control

- Not other Group B products
- Mixtures of Group O products
  - 2,4-D, MCPA, fluroxypyr
- With glyphosate
- Bentazon, bromoxynil (C)
- Pyrasulfotole (Group F)
- Carfentrazone (Group E)
- Saflufenacil (Group E)
Canola in ruderal areas

- Seed spillage along roadways and railroads is common
- Canola is common ruderal (disturbed) areas, especially along rural roads, in ports and collection areas
- Often seed in Canadian cities where soil has been moved
- Ruderal populations are ephemeral but are maintained by reintroduction
- Not found where environments are undisturbed (natural areas)
Reliance on a few herbicides has lead to resistance all over the world

- Your options for use of imidazolinone herbicides in the same field are limited
  - How many hits before you hit the wall?
- Use the power of competitive hybrids backed by herbicides
- Diversity in rotation, herbicides (by group), time of intervention
- Use them carefully and with additional products if possible
  - Herbicide mixes, herbicides in sequence