Adapting cropping system to delay herbicide resistance. A simulation study

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ALOMYSYS. Input variables

- Cropping system
- Weather
- Soil texture
- Initial weed population

ALOMYSYS. Output variables

Compare management techniques and farming systems

A. *myosuroides* plants/m² (per day/based simulations)
ALOMYSYS. Annual life-cycle

emerged
seedlings

tillering

dead

germinated
seeds

death

non-dormant
dormant

shallow

dead

... seed bank

deep

dead

Seed production

ALOMYSYS effect of management techniques

Uproots
Buries

Non-dormant
Shallow
Emerged seedlings
Tillering
Heading
Seeds production

ALOMYSYS. The genetic submodel

- **21 genotypes / Fop resistance**
  Sensitivity and resistance to different herbicides

- **Mutations occurring during reproduction**
  Occurrence

- **Fitness costs/benefits**
  Effect of genotype on life-stage processes
Mutated alleles and herbicide resistance

- **Genotypes result from the combination of:**
  - 1 wild (W) and 5 mutated alleles (Leucine-1781, Cystein-2027, Asparagine-2041, Glycine-2078, Alanine-2096)

<table>
<thead>
<tr>
<th>Mutation</th>
<th>Alanine-2096</th>
<th>Asparagine-2041</th>
<th>Cystein-2027</th>
<th>Glycine-2078</th>
<th>Leucine-1781</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ala</td>
<td>Asn</td>
<td>Cys</td>
<td>Gly</td>
<td>Leu</td>
</tr>
<tr>
<td>Cycloxydim</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>R</td>
<td>R</td>
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<tr>
<td>Clethodim</td>
<td>r</td>
<td>S</td>
<td>S</td>
<td>R</td>
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<tr>
<td>Fenoxaprop</td>
<td>R</td>
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<tr>
<td>Clodinafop</td>
<td>R</td>
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<tr>
<td>Haloxyfop</td>
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<tr>
<td>Diclofop</td>
<td>R</td>
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<tr>
<td>Pinoxaden</td>
<td>S</td>
<td>r</td>
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<table>
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<tr>
<th>Herbicide</th>
<th>Cycloxydim</th>
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<th>Fenoxaprop</th>
<th>Clodinafop</th>
<th>Haloxyfop</th>
<th>Diclofop</th>
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</table>

S = 95-90% mortality  
r = 0-70% mortality  
R = 0% mortality

(based on Délye et al., 2003; Délye et al., 2005; Délye et al., 2008; Petit et al., 2010)
Mutation during seed production

- **Number of mutated ovules and pollen grains depends on:**
  - Mutation rate = input variable chosen by user
  - Number of flowers producing pollen and ovules
  - Stochasticity

- **Genotype of mutated allele depends on:**
  - Stochasticity
  - Conversion rates
# Fitness costs/benefits

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<th>Cystein -2027</th>
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</tr>
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<td>Leu</td>
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</tr>
</tbody>
</table>

## Germination speed

<table>
<thead>
<tr>
<th></th>
<th>Fresh seeds</th>
<th>Old seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh seeds</td>
<td>No change</td>
<td>Slightly slower</td>
</tr>
<tr>
<td>Old seeds</td>
<td>No change</td>
<td>Slower</td>
</tr>
</tbody>
</table>

## Fatal germination

<table>
<thead>
<tr>
<th></th>
<th>Fresh seeds</th>
<th>Old seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh seeds</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>Old seeds</td>
<td>No change</td>
<td>Less</td>
</tr>
</tbody>
</table>

## Pre-emergent shoot length potential

<table>
<thead>
<tr>
<th></th>
<th>Fresh seeds</th>
<th>Old seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh seeds</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>Old seeds</td>
<td>No change</td>
<td>Longer</td>
</tr>
</tbody>
</table>

## Pre-emergent root length potential

<table>
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## Seed production

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(based on Menchari et al., 2008; Délye et al., 2013)
Simulation. Initialisation without selection pressure

No ACCase-inhibiting herbicides

Plants/m² at crop harvest

Wild N

B = fitness benefit
N = no fitness change
C = fitness cost

All mutants

Cys N

Leu B

Ala N

Asn B

Gly C

Herbicides were applied at the total regulatory rate. Applications were carried out in suboptimal conditions.
Simulation. Switching to selective herbicides

Many ACCCase-inhibiting herbicides

Plants/m² at crop harvest

ALL

Leu RR

Cys RR

Asn rR

Gly RRR

RRR = resistant to 3
RR = resistant to 2
rR = resistant to 1 and partially resistant to 1

applied herbicides
Simulation. Effect of cropping system

Plants/m²

- Mutant
- Wild

Relative herbiciderate  
Control  90%  80%  70%  60%  50%

Spraying conditions  
Optimal  Bad

- Every year
- Before oilseed rape
- Before wheat
- Before barley
- Mouldboard ploughing
- Delayed

Add pea to rotation
Conclusion: please feed the model with long term studies … and tests!

All models are wrong but some can be useful