Redesigning cropping systems in three French regions

Gabriele Fortino, Laurence Guichard, Elise Lô-Pelzer, Raymond Reau, Muriel Valantin-Morison, INRA, France; Xavier Pinochet, CETIOM, France. The authors acknowledge the group of experts from the ‘ADAR – Systèmes de culture innovants’ and ‘CASDAR – Picoblé’ projects, in particular Nicolas Munier-Jolain (INRA, France)
Region one: Poitou-Charentes

Context and current cropping system
> Soil and climate: limestone plateau, shallow soils, oceanic climate.
> Crop sequence: winter oilseed rape - winter wheat – winter barley.
> Crop protection strategy: Pesticides (TFI 5.8), genetic.
> Main pest risk: autumn weeds, aphids & septoria (cereals); stem weevil, pollen beetle & sclerotinia (WOSR).
> Average expected yield (WWh: 5.3-6.9 t.ha-1; WOSR: 2.5-3.4 t.ha-1; WB: 5.8-7.4 t.ha-1).
> Region/farm specificities: intensive region; farm area > 100ha, tools for mechanical weeding.

Advanced cropping system

Main crop protection principles:
> Diversifying crop sequence and sowing periods by introducing spring crops and shifting sowing dates: non-specialized weed flora.
> Systematic intermediate catch crop when spring crops: competitiveness against autumn weeds.
> Mechanical weeding and stale seedbed, deep tillage when necessary.
> Diversifying sowing periods by shifting wheat sowing dates when possible: impact on weeds (allow stale seedbed on wheat sown later) and on insects (for example, autumn aphids). The delay in wheat sowing date is not systematic.
> Decrease in sowing density (against diseases) and double row spacing for WOSR (allows mechanical weeding).
> Use of resistant cultivars, wheat cultivar mixture.
> WOSR cultivar mixture with 10% early and taller WOSR cultivars (the hypothesis is that pollen beetles are attracted by this cultivar, the 90 % plants remaining might be less attacked; Valantin-Morison et al. 2006).
> Decrease N fertiliser amounts.
> Straws chopped and buried against slugs (favour soil C content).

Figure 1: Advanced system for Poitou-Charentes

<table>
<thead>
<tr>
<th>Crop</th>
<th>Disease control</th>
<th>Pest control</th>
<th>Weed control</th>
<th>Growth regulation</th>
<th>Fertilisation</th>
</tr>
</thead>
</table>
| **Winter oilseed rape (2.7t.ha-1)** | - Resistant cultivar  
- 0.75 dose of fungicide (spring) | - Straw chopped and buried (slugs)  
- No tillage (favour natural enemies)  
- Margin and early cultivars (mixture) to trap pollen beetle  
- Two doses of insecticide (weevils and aphids) plus one | - Stale seedbed  
- Drilling with combined tool  
- Double-row spacing to allow mechanical weeding  
- Two hoeings (autumn) and one (spring)  
- One dose of herbicide on row | - No problem | - N: 70 + 80kg/ha  
- P: 100kg/ha  
- K: 150kg/ha  
- S: 75kg/ha |
From Science to Field
Winter Crops Based Cropping Systems (WCCS) Case Study - Guide Number 2

<table>
<thead>
<tr>
<th>Winter wheat (6.5t.ha-1)</th>
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<td>dose (1/2 years)</td>
<td>(early September)</td>
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<td>(beetles) (spring)</td>
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<tr>
<td>- Cultivar mixture</td>
<td>- Late sowing</td>
<td>- Late sowing</td>
<td>- Late sowing, lower density</td>
<td>- N: 80 + 50kg/ha</td>
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<tr>
<td>- Low N fertilisation</td>
<td>(autumn, aphids,</td>
<td>(autumn, aphids,</td>
<td>lower density</td>
<td>- N: 80 + 50kg/ha</td>
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<td>- One dose of fungicide</td>
<td>slugs)</td>
<td>slugs)</td>
<td>- Low N fertilisation</td>
<td>- N: 80 + 50kg/ha</td>
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<tr>
<td>(April)</td>
<td>- One dose of</td>
<td>- Stale seedbed</td>
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<td></td>
<td>insecticide</td>
<td>- Two harrowings</td>
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<td></td>
<td>(3/5 yrs)</td>
<td>- 0.75 dose of</td>
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<td></td>
<td>(autumn)</td>
<td>herbicide (March)</td>
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<td></td>
<td>(spring)</td>
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<td>Winter barley (6.5t.ha-1)</td>
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<td>(Legumes) - sunflower</td>
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<tr>
<td>(2.3t.ha-1)</td>
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<tr>
<td>- Late sowing, lower</td>
<td>- Straw buried</td>
<td>- Late sowing</td>
<td>- Late sowing, lower density</td>
<td>- N: 70 + 70kg/ha</td>
</tr>
<tr>
<td>density - Resistant</td>
<td>(slugs)</td>
<td>(autumn, aphids)</td>
<td>lower density</td>
<td>- N: 70 + 70kg/ha</td>
</tr>
<tr>
<td>cultivar</td>
<td>- Seed treatment</td>
<td>- Stale seedbed</td>
<td>- Low N fertilisation</td>
<td>- N: 70 + 70kg/ha</td>
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<td>- Low N fertilisation</td>
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<td>- One harrowing</td>
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<tr>
<td>- 0.75 dose of fungicide</td>
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<td>(beginning of</td>
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<td>herbicide (end</td>
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<td>Other impacts</td>
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<td>Possible positive impacts:</td>
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<tr>
<td>&gt; Shifting sowing dates: effect on weeds, but also diseases, insects and slugs.</td>
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<td>&gt; Intermediate crop: less N on crops, reduced NO3 leaching.</td>
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<td>&gt; Straws buried: increase soil organic matter content (long term effect).</td>
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<td>Possible negative impacts:</td>
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<td>&gt; Mechanical weeding/superficial tillage between crops: energy and time cost.</td>
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<td>&gt; Late sowing (cereals): risk of unsuitable sowing conditions, yield reduction.</td>
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<tr>
<td>&gt; Extending and diversifying rotation: lower frequency of cash crops, delivery problems caused by lower volumes of product.</td>
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<td>&gt; Resistant cultivars: productivity.</td>
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<tr>
<td>&gt; Wheat cultivar mixtures: problems with delivery constraints and technological requirements.</td>
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<td>&gt; Intermediate crop: risk to increase slugs.</td>
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<td>&gt; Low fungicide doses: risk of inducing resistance (especially with strobilurin in cereals).</td>
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<td>&gt; No growth regulator: lodging problems (but N fertilisation is decreased).</td>
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</tbody>
</table>

**Region two: Paris Basin**

**Context and current cropping system**

> Soil and climate: loamy, deep soils, degraded oceanic climate.
> Crop sequence: sugarbeet - winter wheat - winter oilseed rape - winter wheat.
> Crop protection strategy: pesticides (TFI 7.2), genetic.
Main pest risk: spring weeds in sugar beet, autumn weeds in winter crops; aerial diseases on wheat.

High expected yield (WWh: 7.5-9.5 t.ha-1; WOSR: 3.3-4.5 t.ha-1; Sugarbeet: 80-105 t.ha-1).

Region/farm specificities: intensive region; food and industrial crops.

Innovative cropping system

Main crop protection principles:

- Extending and diversifying crop rotation: competitive crops are added (weeds), the frequency of a given crop is lowered (disease).
- Diversifying sowing periods by shifting sowing dates, impact on:
  - Weeds: allow stale seedbed on wheat sown later, competitiveness of WOSR sown earlier is increased against weeds.
  - Diseases: for example, WOSR sown earlier is less susceptible to phoma.
  - Insects: for example, autumn aphids on wheat sown later, winter flea beetle, tenthradinidae and slugs on WOSR sown early.
- Superficial tillage: mechanical weeding and stale seedbed.
- Systematic intermediate catch crop when spring crops: competitiveness against autumn weeds.
- Odd number of deep tillage between two successive cereals: the seedbank is buried when the cereal is sown.
- Use of resistant cultivars.
- WOSR cultivar mixture with 10% early and taller WOSR cultivars (the hypothesis is that pollen beetles are attracted by this cultivar, the 90% plants remaining might be less attacked; Valantin-Morison et al. 2006).
- Straws chopped and buried against slugs (favour soil C content).
- Decrease sowing density and N fertilizer amounts.

Figure 3: Innovative system for Paris Basin

<table>
<thead>
<tr>
<th>Crop</th>
<th>Disease control</th>
<th>Pest control</th>
<th>Weed control</th>
<th>Growth regulation</th>
<th>Fertilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Mustard) – Sugarbeet (95t.ha-1)</td>
<td>- Resistant cultivar</td>
<td>- Seed treatment</td>
<td>- Preceeding intermediate crop management</td>
<td>- Low N fertilisation</td>
<td>- Vinassee on preceeding intermediate crop</td>
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<td></td>
<td>- Low N fertilisation</td>
<td>- One dose of molluscicide (1/10 yrs) (end of March)</td>
<td>- Inversion tillage</td>
<td>- Lower density</td>
<td>- N: 100kg/ha</td>
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<td></td>
<td>- One dose of fungicide (spring) and one more if problems (1/5 yrs)</td>
<td>- Drilling with combined tool</td>
<td>- 0.5 dose of herbicide localised on row (end of March)</td>
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<td>- P: 200kg/ha</td>
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<td></td>
<td></td>
<td>- Two hoeings (spring)</td>
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<td>- K: 300kg/ha</td>
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</tbody>
</table>

Winter wheat (8.0t.ha-1)

- Late sowing, lower density
  - Resistant, hardy cultivars
  - Low N fertilisation
  - 0.5 dose of fungicide (April)

- Late sowing (autumn, aphids, slugs)
  - One dose of insecticide (1/5 yrs) (spring)

- Late sowing (stale seedbed)
  - One harrowing (1/2 yrs) (beginning of March)
  - One dose of herbicide (May)

- Late sowing, lower density
- Low N fertilisation

- N: 90 + 70kg/ha

(Mustard) - hemp

- No problem
- Straw chopped and buried (slugs)
- Preceeding intermediate crop

- N: 100kg/ha
Other impacts

Possible positive impacts:
> Intermediate crop: less N on crops, reduction of NO3 leaching.
> Straws buried: increase in soil organic matter content (long term effect).

Possible negative impacts:
> Mechanical weeding/superficial tillage between crops: energy and time cost.
> Late sowing (cereals): risk of unsuitable sowing conditions, yield reduction.
> Extending rotations: lower frequency of cash crops, delivery constraints for some crops (hemp).
> Intermediate crop: risk of increased slugs.
> Low fungicide doses: risk of inducing resistance (especially with strobilurin in cereals).
> No growth regulator: lodging problems (but N fertilisation is decreased).
> Introduction of hemp: risk of broom rape and sclerotinia.

Region three: Burgundy

Context and current cropping system
> Soil and climate: limestone plateau, shallow soils, degraded oceanic climate.

<table>
<thead>
<tr>
<th>Winter wheat (7.5t/ha-1)</th>
<th>Winter oilseed rape (3.8t/ha-1)</th>
<th>Winter wheat (7.5t/ha-1)</th>
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<tbody>
<tr>
<td>Late sowing, lower density</td>
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<tr>
<td>Resistant, hardy cultivars</td>
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<td>Low N fertilisation</td>
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<td>0.75 dose of fungicide (April)</td>
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<td>Late sowing (autumn, aphids, slugs)</td>
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<tr>
<td>Superficial tillage (slugs’ eggs)</td>
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<tr>
<td>One dose of insecticide (1/5 yrs) (spring)</td>
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<tr>
<td>Late sowing, lower density</td>
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<tr>
<td>- No problem management</td>
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<tr>
<td>- Inversion tillage</td>
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<td>- Competitive crop</td>
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<td>- P: 200kg/ha</td>
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<td>- K: 300kg/ha</td>
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<tr>
<td>- N: 90 + 70kg/ha</td>
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<tr>
<td>Resistant cultivar</td>
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<td>Early sowing</td>
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<td>0.8 dose of fungicide (April)</td>
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<td>Straw chopped and buried (slugs)</td>
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<td>Favour natural enemies</td>
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<td>Margin and early cultivars (mixture) to trap pollen beetle</td>
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<td>Two doses of insecticide (weevils)</td>
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<td>No problem</td>
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<td>- Inversion tillage</td>
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<td>- Competitive crop</td>
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<td>- Drilling with combined tool</td>
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<td>- Early sowing</td>
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<td>- 0.8 dose of herbicide (end of August) and one dose (1/3 years)</td>
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<td>- N: 70 + 60 + 80kg/ha</td>
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<td>- P: 100kg/ha</td>
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<td>- K: 150kg/ha</td>
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<td>- S: 75kg/ha</td>
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<td>Late sowing, lower density</td>
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<td>Resistant, hardy cultivars</td>
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<td>Low N fertilisation</td>
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<td>0.75 dose of fungicide (April)</td>
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<td>Late sowing (autumn, aphids, slugs)</td>
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<td>Superficial tillage (slugs’ eggs)</td>
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<td>One dose of insecticide (1/5 yrs) (spring)</td>
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<td>Preceding crop stubble breaking</td>
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<td>Late sowing (stale seedbed)</td>
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<td>One harrowing (1/2 yrs) (beginning of March)</td>
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<td>One dose of herbicide (May)</td>
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<td>Late sowing, lower density</td>
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<td>- No problem</td>
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<td>- Inversion tillage</td>
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<td>- Competitive crop</td>
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<td>- Drilling with combined tool</td>
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<tr>
<td>- Early sowing</td>
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<tr>
<td>- 0.8 dose of herbicide (end of August) and one dose (1/3 years)</td>
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<td>- N: 90 + 70kg/ha</td>
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</tbody>
</table>

Figure 4: Pesticide use in Paris Basin under current and innovative systems

Above: France’s Burgundy region
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> Crop sequence: winter oilseed rape - winter wheat - winter barley.
> Crop protection strategy: pesticides (TFI 7.1), genetic.
> Main pest risk: autumn weeds, aphids & septoria (cereals); stem weevil, pollen beetle & sclerotinia (WOSR).
> Average expected yield (WWh: 5.3-6.9 t.ha-1; WOSR: 2.5-3.4 t.ha-1; WB: 5.8-7.4 t.ha-1).
> Region/farm specificities: intensive region, livestock farming; minimum tillage, tools for mechanical weeding.

Innovative cropping system

Main crop protection principles:
> Extending and diversifying crop rotation introducing: (i) spring crops and shifting sowing dates: non-specialized weed flora; (ii) competitive crops (including alfalfa perennial crop).
> Mechanical weeding and stale seedbed, deep tillage only after alfalfa (favour natural enemies).
> Diversifying sowing periods by shifting sowing dates, impacts:
> Weeds: allow stale seedbed on wheat sown later, competitiveness of WOSR and barley sown earlier is increased against weeds.
> Diseases: for example, WOSR sown earlier is less susceptible to phoma.
> Insects: for example, autumn aphids on wheat sown later (systematic); winter flea beetle, tenthriddenae and slugs on WOSR sown early.
> Use of resistant cultivars.
> WOSR cultivar mixture with 10% early and taller WOSR cultivars (the hypothesis is that pollen beetles are attracted by this cultivar, the 90% plants remaining might be less attacked; Valantin-Morison et al. 2006).
> Landscape management (if possible): small fields (<10 ha), settlement of hedges or other non-productive areas, flowering strips for pollinators, refuges for natural enemies, turnip rape (Brassica rapa) on WOSR margins to trap pollen beetle.
> Use of Contans© (biological control) each year against sclerotinia.
> Decrease sowing density and N fertilizer amounts.
> Straws exported against slugs.

Figure 5: Innovative system for Burgundy

<table>
<thead>
<tr>
<th>Crop</th>
<th>Disease control</th>
<th>Pest control</th>
<th>Weed control</th>
<th>Growth regulation</th>
<th>Fertilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter oilseed rape (2.5t.ha-1)</td>
<td>- Early sowing - Resistant cultivar - Contans©: 1kg/ha (at sowing of all crops)</td>
<td>- Stale seedbed and straw exported (slugs) - Natural enemies (no tillage and landscape) - Margin and early cultivars (mixture) to trap pollen beetle - 1-2 doses of insecticide (weevils) (spring)</td>
<td>- Stale seedbed - Drilling with combined tool and N fertilisation on the row - Double row spacing to allow mechanical weeding - Two harrowings (autumn) plus three hoeings (two autumn and one in spring)</td>
<td>- No problem</td>
<td>- N: 100 + 70 + 80kg/ha - P: 100kg/ha - K: 150kg/ha - S: 75kg/ha</td>
</tr>
<tr>
<td>Winter wheat (5.5t.ha-1)</td>
<td>- Cultivar mixture (more resistant) - Late sowing, lower density</td>
<td>- Late sowing (autumn, aphids) plus stale seedbed (slugs) - One dose of</td>
<td>- Stale seedbed - Two harrowings (autumn) - One dose of herbicide (1/2)</td>
<td>- Late sowing, lower density - Low N fertilisation</td>
<td>- N: 70 + 50kg/ha</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Varieties/Management Notes</th>
<th>Pesticide Use</th>
<th>Fertilisation Notes</th>
<th>Other Management Notes</th>
</tr>
</thead>
</table>
| **Spring barley (4.0t ha⁻¹)** | - Resistant cultivar  
- Low N fertilisation  
- Straw exported and stale seedbed (slugs)  
- Early sowing (differentiate weed flora/sunflower)  
- Two harrowings (early March and April)  
- Low N fertilisation  
- N: 70kg/ha | insecticide (1/10 yrs) (May)  
- Early sowing (March) | — | — |
| **Alfalfa (9.0t ha⁻¹)** | - No problem  
- Low N fertilisation  
- Mowing not too frequent and early (avoid seedbank)  
- Straw exported (slugs)  
- Early sowing (March and April)  
- One dose of insecticide (1/10 yrs) (May)  
- N: 70kg/ha | insecticide (1/10 yrs) (May)  
- Mowing not too frequent and early (avoid seedbank) | — | — |
| **Winter wheat (5.5t ha⁻¹)** | - Cultivar mixture (more resistant)  
- Late sowing, lower density  
- Low N fertilisation  
- Late sowing (autumn, aphids) plus stale seedbed (slugs)  
- Bearded cultivars  
- Natural enemies (landscape management)  
- One dose of insecticide (1/10 yrs) (May)  
- Inversion tillage plus one harrowing and stale seedbed (slugs)  
- Low row spacing  
- Two harrowings (autumn)  
- One dose of herbicide (1/4 yrs) (March)  
- Late sowing, lower density  
- Low N fertilisation  
- N: 60 + 50kg/ha | insecticide (1/10 yrs) (May)  
- Late sowing (autumn, aphids) plus stale seedbed (slugs)  
- Bearded cultivars  
- Natural enemies (landscape management)  
- One dose of insecticide (1/10 yrs) (May)  
- Inversion tillage plus one harrowing and stale seedbed (slugs)  
- Low row spacing  
- Two harrowings (autumn)  
- One dose of herbicide (1/4 yrs) (March)  
- Late sowing, lower density  
- Low N fertilisation  
- N: 60 + 50kg/ha | — | — |
| **(Mustard) – sunflower (2.5t ha⁻¹)** | - Multi-resistant cultivar  
- Contans©: 1kg/ha (at sowing of all crops)  
- Competitive intermediate crop plus mechanical breaking  
- Two hoeings (May and June) | insecticide (1/10 yrs) (May)  
- Competitive intermediate crop plus mechanical breaking  
- Two hoeings (May and June) | — | — |
| **Triticale (5.2t ha⁻¹)** | - Resistant cultivar  
- Late sowing  
- Low N fertilisation  
- Late sowing (autumn, aphids) and stale seedbed (slugs)  
- Natural enemies (landscape management)  
- One dose of herbicide (1/2 yrs) (March)  
- Late sowing  
- Low N fertilisation  
- N: 70 + 80kg/ha | insecticide (1/10 yrs) (May)  
- Late sowing (autumn, aphids) and stale seedbed (slugs)  
- Natural enemies (landscape management)  
- One dose of herbicide (1/2 yrs) (March)  
- Late sowing  
- Low N fertilisation  
- N: 70 + 80kg/ha | — | — |

**System/TFI** | **Current** | **Innovative**
--- | --- | ---
TFI herbicide | 2.2 | 0.2
TFI fungicide | 2.1 | 0
TFI insecticide | 1.7 | 0.2
**Total TFI** | **7.1** | **0.4**

*Figure 6: Pesticide use in Burgundy under current and innovative systems*

### Other impacts

**Possible positive impacts:**
- Shifting sowing dates: effect on weeds, but also diseases, insects and slugs.
- Intermediate crop: less N on crops, reduced NO3 leaching.
- Landscape perception: society.

**Possible negative impacts:**
- Mechanical weeding/superficial tillage between crops: energy and time cost.
- Late sowing (cereals): risk of unsuitable sowing conditions, yield reduction.
- Extending rotations: lower frequency of cash crops and delivery constraints (alfalfa, triticale).
- Biological control: cost.
- Resistant cultivars: productivity.
- Straws exported: decrease soil organic matter content; Intermediate crop: risk of increase in slugs.
- No growth regulator: lodging problems (but N fertilisation is decreased).
- Landscape management: loss of productive area, crop mosaic reorganisation.
Redesigning cropping systems in three French regions

Summary
Current cropping systems with a high proportion of winter cereals are pesticide demanding and match poorly with the current political goals to reduce pesticide inputs. Three cropping systems with reduced pesticide inputs, each one related to a specific French region, are presented here. They are classed as: (i) advanced systems, which are based on current solid knowledge, and (ii) innovative systems, which are more experimental.

These systems are designed starting from a system with no pesticide (for example, an organic system), based on all possible non-chemical measures to control pests (crop sequence, sowing densities and dates, etc.). Then, pesticides are added when it is necessary (when the no-pesticide system fails to control one pest). This can explain the consistent reductions of TFI observed in the three cases.

TFI of current systems are based on real data from the French expert study ECOPHYTO R&D, while the TFI of advanced and innovative theoretical systems have been estimated using the expert knowledge of the authors. The examples of the advanced and innovative cropping systems presented in this leaflet show that, given these hypotheses, a significant decrease in pesticide use could be reached in the French context.

For further information please contact:
Elise Lô-Pelzer
UMR211 Agronomie, INRA-AgroParisTech, BP 01,78850 Thiverval-Grignon, France.
Telephone: +33 (0)1 30 81 45 84
E-mail: elise.pelzer@grignon.inra.fr

About ENDURE
ENDURE is the European Network for the Durable Exploitation of Crop Protection Strategies. ENDURE is a Network of Excellence (NoE) with two key objectives: restructuring European research and development on the use of plant protection products, and establishing ENDURE as a world leader in the development and implementation of sustainable pest control strategies through:
> Building a lasting crop protection research community
> Providing end-users with a broader range of short-term solutions
> Developing a holistic approach to sustainable pest management
> Taking stock of and informing plant protection policy changes.

Eighteen organisations in 10 European countries are committed to ENDURE for four years (2007-2010), with financial support from the European Commission’s Sixth Framework Programme, priority 5: Food Quality and Security.

Website and ENDURE Information Centre:
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