From Science to Field

Winter Crops Based Cropping Systems (WCCS) Case Study - Guide Number 2

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)

Landscape in the Paris Basin. © Adrien Rusch, INRA, France.

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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.

Above: Poitou-Charentes region and (below) proposed advanced winter crops based cropping system.

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).

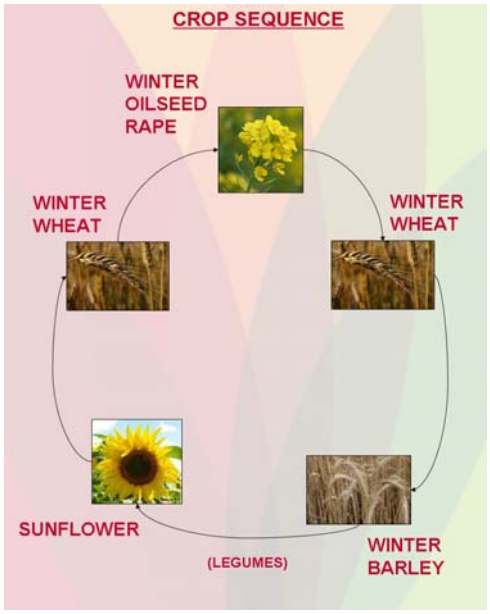


Figure 1: Advanced system for Poitou-Charente

Crop	Disease control	Pest control	Weed control	Growth regulation	Fertilisation
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

		dose (1/2 years) (beetles) (spring)	(early September)		
Winter wheat (6.5t.ha-1)	- Cultivar mixture - Low N fertilisation - One dose of fungicide (April)	- Late sowing (autumn, aphids, slugs) - One dose of insecticide (3/5 yrs) (autumn) and one dose (1/5 yrs) (spring)	- Stale seedbed - Two harrowings - 0.75 dose of herbicide (March)	- Late sowing, lower density - Low N fertilisation	- N: 80 + 50kg/ha
Winter barley (6.5t.ha-1)	- Late sowing, lower density - Resistant cultivar - Low N fertilisation - 0.75 dose of fungicide	- Straw buried (slugs) - Late sowing (autumn, aphids) - Seed treatment	- Late sowing (stale seedbed) - One harrowing (beginning of March) - One dose of herbicide (end of March)	- Late sowing, lower density - Low N fertilisation	- N: 70 + 70kg/ha
(Legumes) - sunflower (2.3t.ha-1)	- Resistant cultivar	- No problem	- Competitive intermediate crop - Inversion tillage - Three hoeings (May-June) - One dose of herbicide on row	- No problem	- P: 100kg/ha - K: 100kg/ha
Winter wheat (6.0t.ha-1)	- Late sowing, lower density - Resistant hardy cultivars - Low N fertilisation - 0.5 dose of fungicide (April)	- Late sowing (autumn, aphids and slugs) - Superficial tillage (slugs' eggs) - One dose of insecticide (1/5 yrs) (spring)	- Late sowing (stale seedbed) - One harrowing (1/2 yrs) (mid-February) - 0.75 dose of herbicide (May)	- Late sowing, lower density - Low N fertilisation	- N: 80 + 70kg/ha

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.

> Straws buried: increase soil organic matter content (long term effect).

System/TFI	Current	Advanced
TFI herbicide	2.1	0.7
TFI fungicide	1.5	0.8
TFI insecticide	1.6	0.6
Total TFI	**5.8**	**2.2**

Figure 2: Pesticide use in Poitou-Charente under current and advanced systems

Possible negative impacts:

> Mechanical weeding/superficial tillage between crops: energy and time cost.

> Late sowing (cereals): risk of unsuitable sowing conditions, yield reduction.

> Extending and diversifying rotation: lower frequency of cash crops, delivery problems caused by lower volumes of product.

> Resistant cultivars: productivity.

> Wheat cultivar mixtures: problems with delivery constraints and technological requirements.

> Intermediate crop: risk to increase slugs.

> Low fungicide doses: risk of inducing resistance (especially with strobilurin in cereals).

> No growth regulator: lodging problems (but N fertilisation is decreased).

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 flee beetle, tenthredinidae 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.

Above: Paris Basin and (below) proposed innovative winter crops based cropping system.

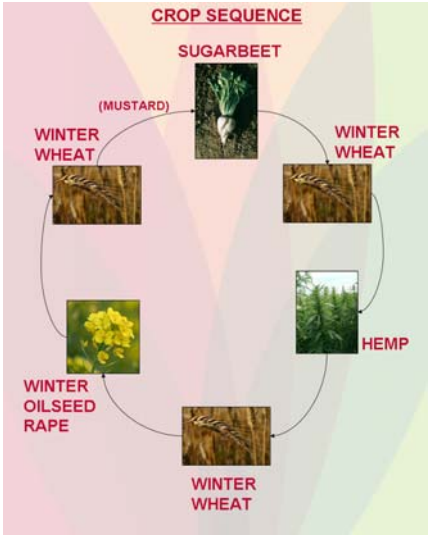


Figure 3: Innovative system for Paris Basin

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

(8.0t.ha-1)		- No problem	management - Inversion tillage - Competitive crop		- P: 200kg/ha - K: 300kg/ha
Winter wheat (7.5t.ha-1)	- Late sowing, lower density - Resistant, hardy cultivars - Low N fertilisation - 0.75 dose of fungicide (April)	- Late sowing (autumn, aphids, slugs) - Superficial tillage (slugs' eggs) - 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
Winter oilseed rape (3.8t.ha-1)	- Resistant cultivar - Early sowing - 0.8 dose of fungicide (April)	- Straw chopped and buried (slugs) - Favour natural enemies - Margin and early cultivars (mixture) to trap pollen beetle - Two doses of insecticide (weevils)	- Inversion tillage - Competitive crop - Drilling with combined tool - Early sowing - 0.8 dose of herbicide (end of August) and one dose (1/3 years)	- No problem	- N: 70 + 60 + 80kg/ha - P: 100kg/ha - K: 150kg/ha - S: 75kg/ha
Winter wheat (7.5t.ha-1)	- Late sowing, lower density - Resistant, hardy cultivars - Low N fertilisation - 0.75 dose of fungicide (April)	- Late sowing (autumn, aphids, slugs) - Superficial tillage (slugs' eggs) - One dose of insecticide (1/5 yrs) (spring)	- Preceeding crop stubble breaking - 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

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).

System/TFI	Current	Innovative
TFI herbicide	2.4	0.8
TFI fungicide	2.1	0.7
TFI insecticide	1.9	0.4
Total TFI	**7.2**	**1.9**

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

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*.

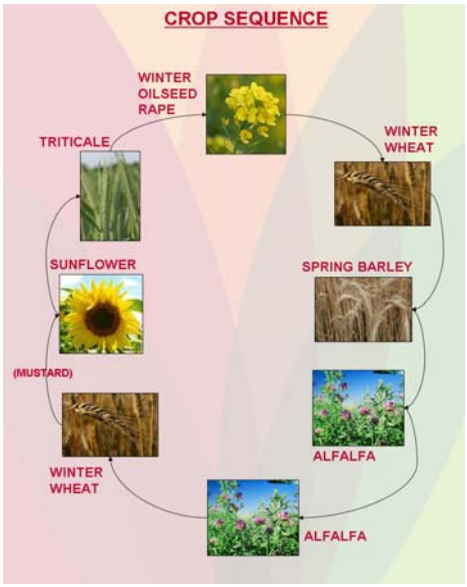
Above : France's Burgundy region

Region three: Burgundy

Context and current cropping system

> Soil and climate: limestone plateau, shallow soils, degraded oceanic climate.

> 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.



Above: Proposed innovative winter crops based cropping system.

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 flee beetle, *tenthredinidae* 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

Crop	Disease control	Pest control	Weed control	Growth regulation	Fertilisation
Winter oilseed rape (2.5t.ha-1)	- Early sowing - Resistant cultivar - Contans©: 1kg/ha (at sowing of all crops)	- 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)	- 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)	- No problem	- N: 100 + 70 + 80kg/ha - P: 100kg/ha - K: 150kg/ha - S: 75kg/ha
Winter wheat (5.5t.ha-1)	- Cultivar mixture (more resistant) - Late sowing, lower density	- Late sowing (autumn, aphids) plus stale seedbed (slugs) - One dose of	- Stale seedbed - Two harrowings (autumn) - One dose of herbicide (1/2	- Late sowing, lower density - Low N fertilisation	- N: 70 + 50kg/ha

		insecticide (1/10 yrs) (May)	yrs) (March)		
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
Alfalfa (9.0t.ha-1)	- No problem	- No problem	- Stale seedbed and early sowing - Mowing not too frequent and early (avoid seedbank)	- No problem	- P: 100kg/ha - K: 300kg/ha
Alfalfa (9.0t.ha-1)	- No problem	- No problem	- Stale seedbed and early sowing - Mowing not too frequent and early (avoid seedbank)	- No problem	- K: 300kg/ha
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 (landscpae management) - One dose of insecticide (1/10 yrs) (May)	- Inversion tillage plus one harrowing and stale seedbed - 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)	- Straw exported (slugs)	- Competitive intermediate crop plus mechanical breaking - Two hoeings (May and June)	- No problem	- P: 100kg/ha - K: 150kg/ha
Triticale (5.2t.ha-1)	- Resistant cultivar - Late sowing - Low N fertilisation	- Late sowing (autumn, aphids) and stale seedbed (slugs) - Natural enemies (landscape management)	- Stale seedbed plus high sowing density - Two harrowings (autumn) - One dose of herbicide (1/2 yrs) (March)	- Late sowing - Low N fertilisation	- N: 70 + 80kg/ha

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.

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

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.

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