Design and assessment of innovative cropping systems for winter crop-based crop successions, with limited use of pesticides

approach and point of view from three north-European countries in the EU project ENDURE

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Context

Arable crop protection: relied greatly on pesticides

Pesticides are efficient but:
- Potential impacts on the environment (e.g. water quality) (e.g. Connel, 2005)
- Potential impacts on human health (e.g. Tron et al., 2001)
- Loss of efficiency due to adaptation of pest populations (e.g. McCartney et al., 2007)

Current European political agenda: reducing impacts of agricultural practices
- Integrated crop management (ICM) systems with a more limited use of pesticides
Context

ENDURE European project (FP6, www.endure-network.eu)
“European Network for the Durable Exploitation of Crop Protection Strategies” (2007-2010)

ENDURE RA2.6a: winter crop system case study
- Main objectives:
  - Describing widespread current systems
  - Design and assessment of theoretical innovative cropping systems with reduced pesticide inputs
- Working group with researchers and advisors from three north-European countries: France, Denmark and United Kingdom
- A multidisciplinary approach (weed science, pathology, agronomy landscape ecology)
Methodology

Current cropping systems in each country

- limit pesticide use

Theoretical innovative cropping systems

- According to expert opinion
- Exploring a wide range of protection strategies and different time and space scales

Assessment of cropping systems

- Predicted consequences for pesticide use (TFI)
- Overall sustainability
  (DEXiPM, Poster 281, session 3.2.3)

From Vereijken, 1997; Lançon et al. 2006

Diagnosis: objectives, constraints

GUIDE LINES

Cropping system design

PROTOTYPE

Multi-criteria assessment

INNOVATIVE CROPPING SYSTEMS

Test in fields

Context

Prototypes Adaptation

Context
Description of current cropping systems

Local contexts accounted for

France: Poitou-Charentes region
Denmark: most Danish regions, characterized by production of winter cereals for feedstuff
UK: predominant arable area of England.

Description of current cropping systems

Typical crop sequences

- France: winter oilseed rape (WOSR)-winter wheat-winter barley
- Denmark: winter barley-WOSR-winter wheat-winter wheat
- UK: winter wheat-winter wheat-WOSR

Crop management practices: intensive agriculture
- e.g. high sowing density, intensive use of mineral fertilizers

Crop protection strategies mainly based on pesticides and on genetic or cultural control (e.g. resistant cultivars, cultivations)

Source: GNIS, INRA, Bayer
Innovative cropping system design

Example of theoretical innovative cropping systems proposed

Crop sequence

- Diversification of crops and sowing periods
- Crops with high competitiveness against weeds, catch crops, or a fallow period for grass weed management

  - France (ADAR, Reau and Landé, 2006): WOSR-winter wheat-spring barley-alfalfa-alfalfa-winter wheat-(mustard)-sunflower-triticale
  
  - Denmark: winter barley-WOSR-winter wheat-winter wheat-(catch crop)-spring barley-(undersown ley)-spring barley
  
  - UK: winter wheat-spring beans-optional winter wheat-fallow/spring barley/spring wheat-WOSR

Source: INRA
Innovative cropping system design

Theoretical innovative cropping systems proposed:

→ Examples of crop management choices (not exhaustive)

Cultivars: resistant (Fr, Dk, UK), cultivar mixtures (Dk)

Cereal seed rate: Decreased for mechanical weeding (Fr),
Increased to improve competitiveness against weeds (Dk, UK)

Tillage:
- Stale seedbeds (Fr, Dk; already a standard technique in the UK),
- Minimised ploughing (Fr, UK; conservation of natural enemies), ploughing each year (Dk, weed management)

Landscape management: Non-crop habitats (natural enemies and pollinators), turnip rape sown at WOSR margins (trap pollen beetle) (UK, Fr)

Hi-tech practices: DSS, precision spray application (UK, Dk)

Biological control: against sclerotinia (Fr)

Source: Rothamsted research, GNIS
Innovative cropping system design: Discussion

Two approaches were chosen for the design of the innovative CS

Efficiency-substitution (Hill & MacRae, 1995)
- Innovative cropping systems are devised by modifying the current CS
- Pesticide use reduction through the introduction of
  - low-tech practices (e.g. optimized/adjusted dosages, sowing densities and dates, cultivars, crop sequences, tillage etc.)
  - hi-tech practices (e.g. GPS-guided applications, pesticide targeting, decision support systems)

- Mix of preventative and curative pest management (UK and Denmark)

Redesign (Hill & MacRae, 1995)
- Innovative CS are designed based on a CS with no pesticide
  - all possible low technology means to control pests (including crop sequence)
  - pesticides only added when alternative practices would possibly fail

- Firmly emphasises preventative measures (France)
Innovative cropping system design: Discussion

Two approaches for the design of innovative CS: efficiency-substitution and redesign (Hill & MacRae, 1995)

- Arise from the main priorities chosen by the authors and from the contexts
  - Maintain profitability and yield (UK)
  - Support pig production, already low TFI levels (Denmark)
  - Some options for pesticide reduction are limited, and a less radical redesign of the CS is preferred
  - High priority given to reducing TFI, and suitability of the local context chosen for a wider range of crops (France)
  - More complete redesign of the CS, including radical modification of the crop sequence
## Cropping system assessment

### Predicted consequences for pesticide use

Treatment Frequency Index (TFI) based on expert opinion

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<th>France (ADAR)</th>
<th>UK</th>
<th>Denmark</th>
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<td>6.2</td>
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- **Big difference in current levels of TFI between countries**
  - Differences in pest prevalence, climate, national priorities and policy, extension services

- **Consequences in terms of the performance of innovative systems in comparison with current systems**
  - According to authors’ hypotheses, TFI may potentially be reduced by 93 % and by 56 % with the French and UK innovative CS described
  - Despite low level of current TFI, it may potentially be reduced by 36 % in Dk
Overall sustainability assessment

Environmental sustainability (resource use, environmental quality, biodiversity)
- Significantly improved with the French and English innovative CS described
- Slightly improved with the Danish innovative CS described (changes are shallower)

Economic sustainability (profitability, medium and long term viability)
- Reduced in each country:
  - new rotations may be associated with more risk and variability, even if the production cost can be reduced due to less chemical inputs.
  - smaller volumes for collecting firms when crop successions are diversified

Social sustainability (market access, farmer health, society)
- Either improved (re-design, France) or little changed (efficiency-substitution approach, England and Denmark)
Assessment of innovative cropping systems

TFI estimation
- Good indicator to assess the pesticide reduction
- But a low level of TFI does not mean a sustainable cropping system

The multicriteria assessment of the sustainability of cropping system is fundamental
- Differed according to approaches
  - Redesign: more environmentally sustainable
  - Efficiency-substitution: more economically sustainable in the current economical context

The ex ante multicriteria assessment is a prerequisite to increase the efficiency of the innovation process (reducing the number of solutions to be tested in field experiments)