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Origins of the performance gaps in the innovative cropping systems under experimental assessment

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Context and Objectives

To meet new agricultural issues and make agriculture more sustainable, innovative cropping systems (ICSs) targeting a multiplicity of purposes need to be designed. Four ICSs were designed by prototyping (Reau and Doré, 2008[1]) and assessed in a long-term field system experiment.

Our objective was to analyze the results after the first complete rotation, particularly the bad performances compared to the targeted aims.

Materials and Methods

Multiple goals of the four designed ICSs (Colnenne-David and Doré, 2014[2])

The PHEP ICS goals:

1. **To satisfy multiple environmental criteria:**

*low pesticide use → high crop diversity, highly resistant varieties

*low direct energy consumption → only 1 ploughing within the rotation

*low indirect energy consumption → legumes in the rotation

*low nitrogen leaching → catch crop (CC) before spring crops and no N fertilization during autumn and winter

*stabilization and/or to enrich soil organic matter → burying residues of all crops

2. **To reach yield targets** matching the Ile-de-France yields

Crop sequence: winter faba bean, winter wheat, winter oilseed rape, winter wheat, mustard as CC and spring barley

The L-GHG ICS goals:

1. **50% GHG emissions compared to the PHEP ICS**
   - **(i) increase soil C sequestration** → many cereals, continuous soil cover, high yield targets, no ploughing
   - **(ii) decrease N_2O emissions** → high number of legume crops in the rotation, improvement of N fertilization management, crops with taproots in order to reduce soil compaction
2. **To satisfy multiple environmental criteria: idem PHEP ICS**
3. **To reach yield targets** matching the Ile-de-France yields

Crop sequence: catch crop (CC), maize, triticale, CC, spring faba bean, winter oilseed rape, winter wheat, CC, winter barley

The L-EN ICS goals:

1. **50% fossil energy consumption compared to the PHEP ICS**
   - **(i) Low direct energy consumption** → no ploughing and using direct sowing machine
   - **(ii) Low indirect energy consumption** → high number of legume species in the rotation, species with high N efficiency use, decrease N fertilization by reducing yield objectives
2. **To satisfy multiple environmental criteria: idem PHEP ICS**
3. **To reach yield targets:** 20% lower than the Ile-de-France yields

Crop sequence: winter faba bean, winter wheat, winter flax, winter wheat–*trifolium* mixture, *Trifolium* as CC, spring oat

The No-Pest ICS goals:

1. **No pesticide is allowed**

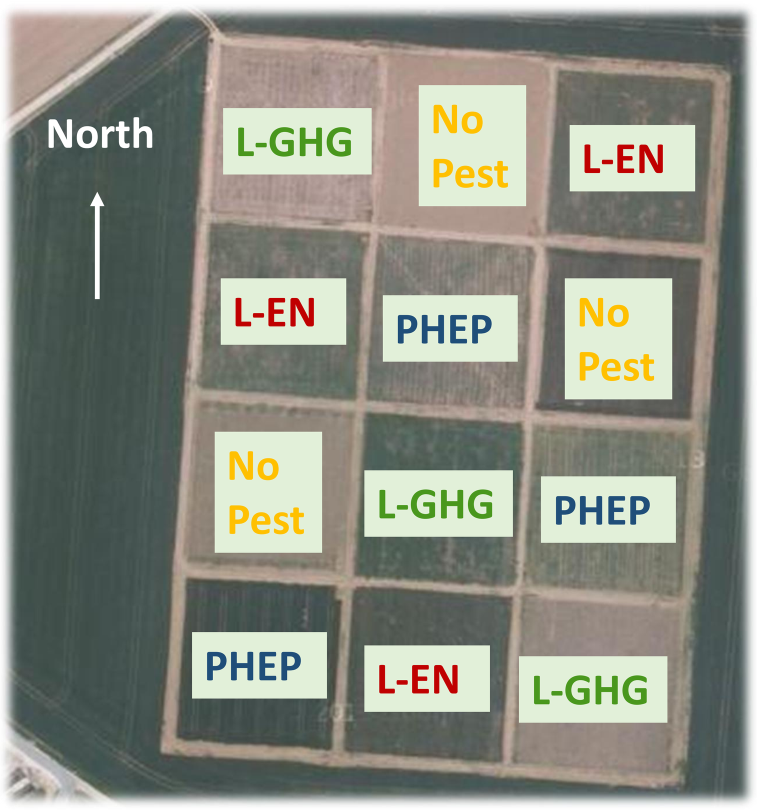
→ long rotation including a wide diversity of species (e.g. hemp), alternate sowing dates, different dates and densities of sowing, highly resistant varieties or mixtures, ploughing and mechanical weeding

2. **To satisfy multiple environmental criteria: idem PHEP ICS**
3. **To reach yield targets:** higher than organic systems in the Ile-de-France

Crop sequence: triticale, CC, maize, winter wheat, CC, spring faba bean, winter wheat, CC, hemp

Main characteristics of the field trial

✓located in Grignon (78, France)
✓6.2 ha (surface plot: ≈ 4000 m²)
✓3 blocks
✓deep loamy soil
✓Beginning of field assessment: 2008



Results: Classification of the major disparities

Classification	Examples collected in the ICSs
Some agronomical strategies were no suitable to reach the goals	In the L-GHG ICS: No ploughing → No increase of C sequestration as expected. C sequestration evolution = -149kgCO_2 ha^{-1}year^{-1} (+87kgCO_2 ha^{-1}year^{-1} expected)
Some practices were not adapted to satisfy a multiplicity of objectives	In the No-Pest ICS: No possible to satisfy both the pesticide constraint and the S.O.M. criteria. Restitution of small organic matter amounts **+** regular ploughings → Few weeds but adverse effect on C sequestration (C sequestration evolution = -560kgCO_2 ha^{-1}year^{-1})
Some practices were not appropriate in the context of the field-trial conditions	In the L-GHG ICS: Very dry conditions in summer 3 years / 6 → Low amount of aerial biomass of cover crops
An unpredicted evolution of the agrosystem occurred	In both the L-EN and the L-GHG ICSs: High weed development → to mow oilseed rape plots in 2014

Discussions – Conclusion

- **After the first complete rotation the major sources of disparities were classified**
- **Nevertheless, a more complete agronomic diagnosis is necessary to identify and to rank all the causes of bad performances**
- **This knowledge allowed us to improve the innovative cropping systems through a new design step**
- **This experiment contributes to the learning design processes and cropping system management**

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