A trait-based approach to understand and predict the performance of arable annual mixed crops

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Agronomic context: towards a more sustainable agriculture

**Intensive agriculture**

Environment optimized through **external inputs**

**Agroecological transition**
System diversification (field, rotation, landscape)

**Sustainable agriculture**

Less or no inputs $\rightarrow$ limiting conditions
Use of **plant diversification**
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**Sole crops**

**Intercrops**
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Maximize complementarities and positive interactions
**Conceptual framework**: Recipes of ecology to make efficient mixtures

**Divergence between species** Complementarity or competition

Metrics = distance for target functional traits between the two species

*Brooker et al. (2015)*
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**Phenotypic plasticity**

1 genotype ↔ $n$ phenotypes = Adaptation to the environment

Metrics = variance of a target trait between environments

Trends Plant Sci 15:684-692
What about the transposability of these concepts to agroecosystems?
- Low diversity compared to natural communities
- Artificial selection for sole crops rather than natural selection
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Can we gather relevant data to add experimental points on theoretical curves?

Litrico I, Violle C (2015)
Trends Plant Sci. 20:604–613

Trends in Ecology & Evolution 27:244–252
Objective

- Agronomic interest of intercrops experimentally demonstrated
- High variability of results according to environmental conditions
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Interest of *predictive approaches* to generalize (and profusion of data)

**Objective:** develop statistical models to predict intercrops performance based on environmental conditions (soil, climate, practices), species intrinsic differences (trait values) and species plasticity (trait variance).
Approach: existing data (being acquired) → statistical models

- France, Germany, UK, Denmark, Netherlands, Italy
- 42 field experimentations, in 15 sites and 16 years
- 153 intercrops combinations and ~ 10,000 plots
- Measured traits: biomass, height, LAI, N...dynamically

Data-driven models (empirical)
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“intelligent”: driven by ecological concepts
= mobilize agronomic and ecological knowledge to define integrative variables that are considered important for the performance of the modeled system

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Preliminary results on a data subset

**Data subset:**

- 10 experiments in France (two sites: INRA AGIR, ESA Angers)
- 6 years
- 40 intercrops combinations of wheat and pea
Preliminary results on a data subset

Successful but variable performance of intercrops in low input contexts

\[ LER_{trait} = \frac{\text{trait}_{ICi}}{\text{trait}_{SCI}} + \frac{\text{trait}_{ICj}}{\text{trait}_{SCj}} \]

SC, sole crop
IC, intercrop
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Effect of mixtures on species characteristics (plasticity)

Species adapt strongly when growing in intercrop (illustration for wheat)

\[ \Delta \text{trait}_{(\text{intercrop}, \text{sole crop})} = \text{trait}_{\text{intercrop}} - \text{trait}_{\text{sole crop}} \]
Preliminary results on a data subset

Differences between species within intercrops (inter-specific divergence)

pea > wheat

pea < wheat
Preliminary results on a data subset

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pea > wheat

\[ \Delta t_{\text{trait}} = \text{trait}_{\text{wheat}} - \text{trait}_{\text{pea}} \]
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Performance of a species according to the difference between species

In intercrop, pea performance is linked to growth strategies (predictors)

\[
\text{Yield}_{\text{pea}} = f(\text{growth rate}_{\text{wheat}} - \text{growth rate}_{\text{pea}})
\]
Perspectives

Still a lot of work

Identify other variables linked to the cover functioning + other mixtures

→ Develop the models, from multiple regression to machine learning (decision tree, random forests, deep learning)

Difficulties identified

- The traits measured in agronomic experiments do not systematically reflect niche complementarity (height, biomass)
- Take into account phenotypic plasticity to build generic assembly rules for different cropping conditions
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