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Increasing pea or fababean N\textsubscript{2} fixation by intercropping with durum wheat to improve the cereal grain protein concentration

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Improve agricultural systems efficiency

• Intensification of agriculture in the last 50 years sometimes leads to:
  - Environmental contamination (water, soil, air)
  - Resistance to chemicals (e.g. Griffon 2006)

• Input costs
• Limited resources
• Energy consumption

→ Efficiency of agricultural systems needs to be improved

→ One of the solutions: diversification of agro-systems (Malézieux et al. 2008)

• Intercropping = the simultaneous growing of two or more species in the same field for a significant period but without necessarily being sown and harvested at the same time (Willey 1979)
Advantages and Disadvantages of intercrops

Cereal – grain legume *spring intercrops* are known to **improve the use of available resources** (complementary use of light & N pools)


- Global yield
- Cereal grain protein content
- Chemicals inputs (*but* contradictory results in the literature)

Better stability over years


→ **Coherent with actual French agricultural policies:**

  “Increase organic farming production by 50% in 2012”
  “Reduce pesticides use by 50% in 2018”

→ **Interest for southern France and Mediterranean areas:**

  - Durum wheat *quality* in low N inputs systems
  - European *grain legume* production
  - Adapted to irregular and restrictive climates (particularly water)

But…

→ Lack of knowledge and references on winter intercrops
  → Technical difficulties
  → Necessity to sort grains (*for human consumption*)
  → Industry, cooperatives and farmers hesitation
Objectives and general hypotheses of our work

Hypotheses:
Intercrop efficiency depends on the balance between competition and complementarity for resource use

- Species:
  i) Growth, ii) Resource needs, iii) Aerial architecture

- Farming practices:
  i) N available, ii) Date and sowing densities, iii) Sowing pattern, iv) Pesticides...

- Weather and soil

→ Wide range of possibilities
→ Allowing efficient crop management systems design adapted to specific objectives

Objectives:
1. Analyse intercrops functioning in a wide range of competition in particular N availability (amount/dynamic)
2. Determine optimal management to improve IC efficiency
Choice of field experiments

- **Lack of knowledge → choice of field experiments**
- **1 main objective:** Evaluate a wide range of competition
- **3 years experiment = 3 complementary objectives:**
  
  **2005-2006:** Evaluate hypotheses & potentialities for winter crops
  **2006-2007:** Complete the understanding (functioning & mechanisms) in dynamics
  **2007-2008:** Design and evaluate prototypes of crop management systems according to specific objectives in low input & organic systems

<table>
<thead>
<tr>
<th>Height</th>
<th>Wheat Cultivars</th>
<th>Intrinsic grain protein content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tall</td>
<td>Orjaune</td>
<td>L1823</td>
</tr>
<tr>
<td>Intermediate</td>
<td>Nefer</td>
<td>Neodur</td>
</tr>
<tr>
<td>Short</td>
<td></td>
<td>Acalou</td>
</tr>
</tbody>
</table>

- **5 wheat cultivars**
- **2 “winter” legumes:** 1 pea (Lucy) & 1 faba bean (Castel)
- **Various N availabilities (Amount & Dynamics)**
IC efficiency for yield depends on N availability

- LER > 1 in low N systems
  → IC up to 19% more efficient than SC

- LER ≤ 1 with large amount of N available
  → IC efficiency depends on N-fertilization & IC more suited to low N

- N-fertilization slightly increased wheat yield
- Pea yield strongly reduced by N-fertilization
Intercropping increases legume $N_2$ fixation

- Pea $N_2$ fixation in IC > SC
  - The more wheat N acquisition the more pea $N_2$ fixation
  - Complementarity for N pools use
- High pea $N_2$ fixation in IC (80-85 %Ndfa)
  - 14 kg N/ha up taken from soil (only 15% of N available)

$\delta^{15}N_{\text{ref}} = IC$ wheat
$\beta = -1‰$
(Voisin et al. 2002)

$%\text{Ndfa} = \frac{\delta^{15}N_{\text{ref}} - \delta^{15}N_{\text{pea}}}{\delta^{15}N_{\text{ref}} - \beta} \times 100$

(Shearer and Kohl 1986)
Intercropping improves light absorption

- Wheat growth earlier than that of pea and then slower
  - The whole IC absorbed more PAR than the SC
  - Species complementarities
  - ≠ in time & height growth

BUT
IC less efficient than SC wheat with large amount of N

Nefer – Lucy 2006-2007

Materials & methods
Results: IC efficiency & dynamic; higher wheat protein
Conclusion
Perspectives

07/11
IC improves wheat grain protein content

IC GPC higher than in SC

The lower SC Wheat GPC the larger the increase

IC more adapted to low N input systems

Why larger amount of N available per grain in IC?
### Why more N available per grain in IC?

Wheat (mean of Nefer, Neodur, Acalou & Orjaune) – Pea (Lucy) in 2006-2007 (N0)

<table>
<thead>
<tr>
<th></th>
<th>Yield</th>
<th>N available</th>
<th>N available /yield unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC (reference)</td>
<td>100%</td>
<td>100%</td>
<td>100% (34 kg N/tonne)</td>
</tr>
<tr>
<td>SC1/2 (% SC)</td>
<td>92%</td>
<td>100%</td>
<td>109% (37 kg N/tonne)</td>
</tr>
<tr>
<td>IC (% SC)</td>
<td>58%</td>
<td>85%</td>
<td>147% (49 kg N/tonne)</td>
</tr>
</tbody>
</table>
Conclusions

• IC improves the use of available resources (LER>1) in low N input
  - Complementary use of N pools
  - Complementary light absorption
  - Intercrop efficiency reduced with N fertilization

• IC improves durum wheat grain protein content (GPC) in low N input

• IC efficiency reduced with N fertilization
  - Early N fertilization ↑ wheat growth & ↓ available light for pea

• IC functioning & efficiency is function of:
  - Dynamic competition & complementarity
  - N fertilization, cultivar, species & densities

→ Design crop management systems adapted to specific objectives
Perspectives

• Knowledge needs for designing cropping management systems
  - Which are the best-adapted legume cultivars and species?
  - Effect of sowing densities and sowing pattern?

• Knowledge needs for pests, diseases and weeds in IC

• Technical feasibility, Interannual stability and Effect of phosphorus?

• Intercrop modelling for designing management systems

• Next question to resolve:

  How to introduce Durum wheat-Grain legumes IC in the cropping systems and in agrofood chain?
Thank you for your attention

For more details:
http://wwagir.toulouse.inra.fr/agir

Plant and Soil (2010)
Vol. 330, 19:35
Vol. 330, 37:54
Additional results related to IC design

IC-F efficiency depends on plant densities

98 W / 23 F  
112 W / 13 F

IC could ↓ green aphids but not weevils

IC could ↓ weeds compared to Pea SC

IC could ↓ wheat septoria and pea ascochyta