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Agroecology and arable crops: the system needs to be redesigned!

Maintaining the yields of cereal and oilseed crops through the inclusion of grain legumes in rotations can enable a reduction in N fertiliser inputs. However, it is necessary to adapt the crop rotation in order to sustain economic margins and mitigate losses of soil organic matter.

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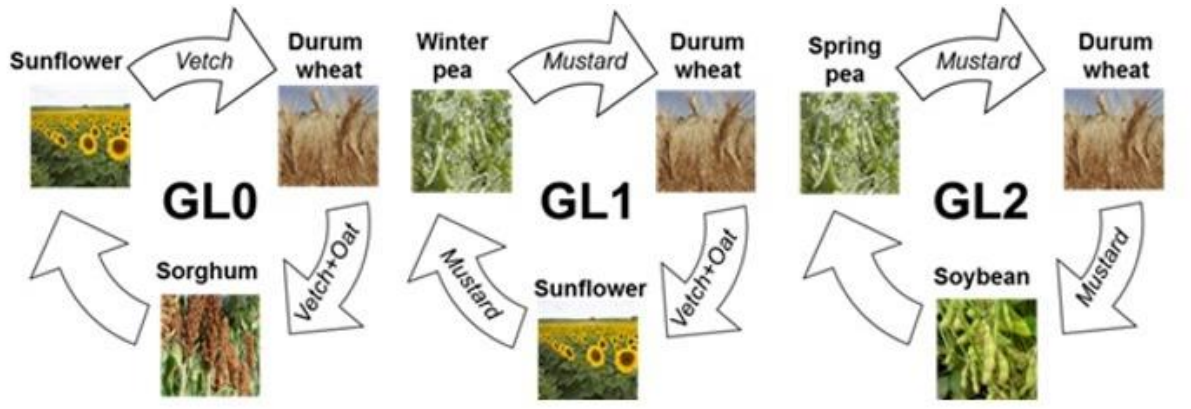

Scientists in Toulouse have been working to define the conditions that would enable the introduction of different grain legume species in cereal and oilseed rotations. Various prototype cropping systems have been experimented (with or without cover crops) in the rotations, and several crop management sequences applied. These field trials took place between 2003 and 2010 at INRA's Experimental Farm in Auzeville.

Adapting the design of crop rotations

To optimise the cultivation of cereals or oilseeds with the objective of reducing the use of synthetic inputs, and to sustain the yields of commercial crops, three types of rotation were tested: a rotation without introducing a grain legume and rotations including one or two grain legumes (winter pea, spring pea or soybean). Cover crops were included all three rotations in order to provide different services (nitrogen recycling, soil carbon storage).
Table summarising the three types of rotation:

	year 1						year 2
Rotation	Main crop	Cover crop	Main crop	Cover crop	Main crop	Cover crop	
without grain legume	Sunflower	Vetch	Durum wheat	Vetch + oat	Sorghum	---	Sunflower…
with 1 grain legume	Winter pea	Mustard	Durum wheat	Vetch + oat	Sunflower	Mustard	Winter pea…
with 2 grain legumes	Spring pea	Mustard	Durum wheat	Mustard	Soybean	---	Spring pea…

- Taking account of the dominant roles of both cover crops and grain legumes

The species used as cover crops were chosen for the services they can provide to the soil: nitrate trapping by mustard and nitrogen input from the vetch-oat mixture, thus enriching soil carbon levels.
The experiments enabled measurement of the beneficial effects of inserting cover crops and grain legumes:

- Over three years, nitrate leaching was reduced 1.6-fold under rotations including a grain legume (winter pea) and 2.9-fold under rotations with two legumes (spring pea and soybean).
- Organic carbon levels were sustained in the soil: rotations with grain legumes prevented the loss of 8-11% carbon over two cycles, or over six years;
- The use of nitrate fertilisers was reduced by 13%-30% for durum wheat crops and 40%-60% throughout the rotation.
- Using an approach that combines experimentation and modelling

Based on these trials and on studies of the bibliography, the scientists then modelled these complex crop rotation systems. Very good agreement was demonstrated between the experimental results and those simulated using the STICS crop model (the study model used by scientists and engineers). The use of modelling was found to be highly relevant when representing the effects of climatic variability on the functioning of the cropping system. The design of the rotation, type of cover crop, quantity of nitrate fertiliser and adjustments to irrigation could be prototyped using the STICS model, thus enabling an *in silico* experiment. The pertinence of the proposals obtained was thus proved experimentally.

Supporting agroecology in arable crops throughout Europe

This work demonstrated that it is possible to maintain the yields and quality of end products (protein content in durum wheat, oil content in sunflower) while markedly reducing inputs of nitrate fertilisers, maintaining soil carbon levels and ensuring that farmers will sustain their economic margins. These initial results were obtained under the climatic conditions of south-western France.
The scientists are now involved in European projects that will allow them to achieve proof of concept of the prototype cropping systems in other regions (FP7 LEGATO and H2020 ReMIX projects; see Insert). Modelling of the agroecological management of arable crops will be proposed for the diversity of conditions which prevail in different European regions.
Generating the ecosystem services anticipated without there being a negative effect on soil carbon and organic nitrogen stocks in the medium term will thus soon be a reality for European farmers!

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Find out more

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- The French National Research Agency (ANR): Add Systerra Agrobiosphère programmes: Legitimes and MicMac design projects;
- The French Environment and Energy Management Agency (ADEME): EFEMAIR-N20 and CiCC projects;
- The European FP6 programme: Grain Legumes Integrated Project.

It gave rise to the publication of four articles:

- Plaza-Bonilla D., Nolot J-M, Raffaillac D., **Justes E**. (2015). Cover crops mitigate nitrate leaching in cropping systems including grain legumes: field evidence and model simulations. *Agriculture, Ecosystem and Environment*. 212, 1-12. http://dx.doi.org/10.1016/j.agee.2015.06.014

- Plaza-Bonilla D., Nolot J-M, Passot S., Raffaillac D., **Justes E**. (2016). Grain legume-based rotations managed under conventional tillage need cover crops to mitigate soil organic matter losses. *Soil & Tillage Research*. 156, 33-43. http://dx.doi.org/10.1016/j.still.2015.09.021

- Plaza-Bonilla D., Léonard J., Peyrard C., Mary B., **Justes E**. (2017). Precipitation gradient and crop management affect N2O emissions: simulation of mitigation strategies in rainfed Mediterranean conditions. *Agriculture, Ecosystem and Environment*, 238, 89-103. http://dx.doi.org/10.1016/j.agee.2016.06.003

- Plaza-Bonilla D., Nolot J-M, Raffaillac D., **Justes E**. (2017). Innovative cropping systems to reduce N inputs and maintain wheat yields by inserting grain legumes and cover crops in southwestern France. *European Journal of Agronomy*, 82, 331-341. http://dx.doi.org/10.1016/j.eja.2016.05.010

ReMIX

Species mixtures for redesigning European cropping systems

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ReMIX

ReMIX: Redesigning European cropping systems based on species Mixtures

This project was launched officially in May 2017. It is being funded under H2020 and follows on from the FP7 LEGATO project. It involves 23 partners from 13 different countries. ReMIX focuses on associated crops corresponding to the cultivation of species mixtures (e.g. cereal–grain legume). The principal working groups are being managed by INRA (scientific and technical coordinator of the project), the University of Kassel (Germany), Wageningen University (Netherlands), the Swedish University of Agricultural Sciences, Scotland's Rural College (UK) and Roskilde University (Denmark). Management support is assured by INRA-Transfert with respect to administrative and financial coordination.

http://www.remix-intercrops.eu

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