GRAIN LEGUMES

AEP

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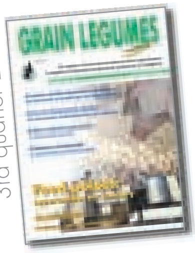

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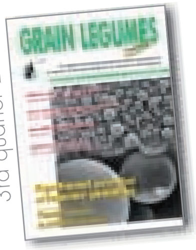

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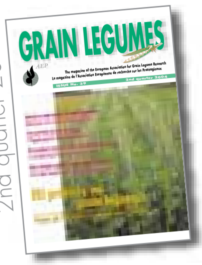

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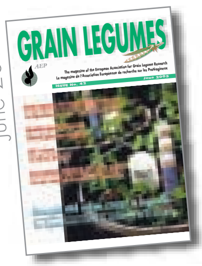

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EDITORIAL

Agriculture for renewable energy

Today most national authorities are looking to diversify their source of energy and, for instance, to increase the part of biomass in the production of heat and electricity.

Agriculture can provide renewable raw materials as alternative sources of energy and locally produced materials help to maintain environmental quality by reducing transport requirements and maintaining landscape and biodiversity.

In this context, especially because they do not need nitrogen fertilisers, grain legumes have the key advantages of a low fossil energy requirement for production, a high energy efficiency and a favourable environmental impact. Therefore, why not exploit grain legumes for bio-energy and other new services? This was discussed within a core group of AEP members last autumn and such ideas will be considered further in the working groups to be held on 4 May following the GL-Pro Dissemination Event on 3 May in Brussels[1].

Over the past three years the GL-Pro partnership has done much to explain and try to overcome the paradox, that grain legumes have only a minor role in EU crop production, and yet there is a great need for materials rich in protein for the feed industry and for environment-friendly crops for EU agriculture in general. The special report in this issue summarises some the findings of GL-Pro including some interesting and encouraging data from economic and environmental analyses of rotations with and without grain legumes.

Let's develop a new vision for the roles of grain legumes in agriculture.

Anne SCHNEIDER
Managing Editor

[1]The document (abstracts and slides) of the GL-Pro Dissemination Event (3 May 2006, where all results will be presented) will be available on request from the AEP office.

Le document de la journée de diffusion de l'ensemble des résultats de GL-Pro (3 mai 2006) sera disponible sur demande à siège de l'AEP.

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Carte blanche to...

Kofi Agblor*

Grain legumes: a value proposition for long-term sustainable production and increased utilisation

Grain legumes are receiving renewed attention. In Europe, the Grain Legumes Integrated Project (GLIP) will enhance grain legume production and utilisation; Canada's Pulse Innovation Project (PIP) seeks to develop new uses and markets for the North American food sector; Australia has increased investments in plant genetics and breeding for crop productivity; and in the United States, the Beans For Health Alliance is investigating the health benefits of bean consumption.

These efforts are occurring in spite of a steady decline in global per capita consumption over the past four decades. The efforts underway must incorporate a broader proposition to ensure a long-term adoption of grain legumes for increased consumption and utilisation – a viable and environmentally sustainable component of crop production; whole food and nutrition value of the seed; and total utilisation of seed components.

Agriculture recognises the value of grain legumes in crop rotation; their nitrogen-fixing capacity has contributed to increased production. As the price of nitrogen fertiliser increases with increasing energy costs, grain legumes will play a greater role in crop fertility. Significant agronomic research and practice exist to capture the value of grain legumes in rotation, but we must improve efforts to maximise their value in sustainable cropping systems.

Grain legumes are already known for their wholesomeness, providing a balanced nutrition of carbohydrate, protein, and fibre for humans. A coordinated approach involving genomics, genetics, breeding, and nutrition can further enhance their value by removing anti-nutritional factors while increasing targeted components, and demonstrating their health and nutrition benefits to humans, livestock, and aquaculture. This will position grain legumes as a vital component in the global food security basket.

Grain legumes have a competitive advantage over oilseeds in component fractionation, as separation can be accomplished without using solvents. Dry milling and air-classification are currently used to produce protein, starch and fibre fractions. Novel processing technologies, which are viable and environmentally sensitive, must be developed to further purify the components. We must also demonstrate the functionality of the various components to facilitate their use in foods, pet foods, and livestock and aquaculture nutrition. ■

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Progress highlighted at GLIP General Meeting

The participants of the GRAIN LEGUMES Integrated Project (GLIP) met for their annual meeting in Montpellier on 20–24 February 2006. Active discussions about progress, results and future plans were organised by workpackages within the consortium. In addition, some sessions, open to any interested parties, highlighted with examples the progress being made to integrate results and knowledge from different disciplines:

– the development of specific tools that facilitate research coordination and integration: for gene expression studies, comparison of model and crop genomes, or integration of heterogeneous databases into web services;
– unravelling metabolic and transcriptional seed development;
– modelling whole plant function to understand nitrogen flux and control;
– systems approaches for evaluating the environmental and economic impact of grain legumes.

The special report in the next issue of *Grain Legumes* magazine will provide an overview of these presentations.

On this occasion the newly created Grain Legumes Technology Transfer Platform (GL-TTP) held its first General Assembly bringing together the GLIP partners and the first GL-TTP members from outside the GLIP consortium, and open to all. ■

More about GL-TTP at: http://www.grainlegumes.com/gl-ttp/
More about GLIP at: http://www.eugrainlegumes.org/

FP7: research budget agreed

The EU budget for the term 2007–2013 was finally agreed in a lengthy evening session on 4 April. The total budget has gone up by €4 billion since the December proposals[1]. This includes a welcome €300 million extra for the Seventh Framework Programme (FP7). However, MEPs were quick to express disappointment at the level of funding for research.

Confusingly, the final figure for the FP7 budget has not yet been ironed out, although it will include the extra €300 million mentioned above. A Commission spokesperson said that the final details were in the "i-dotting and t-crossing" stage. The total extra going to research and education, including FP7 funding, is €2.1 billion over the 2007–2013 timeframe.

In a statement, EU Research Commissioner Janez Potocnik said he was pleased that the agreement on the budget for the framework programme for 2007–2013 had been reached and that additional funds had been found for programmes that are targeted at EU growth and competitiveness. "Now we have to get on with the important task of agreeing the programme that will implement this budgetary framework. The Commission, Parliament and Council will now work closely together to get this done as quickly as possible", he said.

Source: CORDIS 4 April 2006.

[1]European Commission's proposal in April 2005: €72,726 million (excluding Euratom budget).

EU Technology Platforms: to stimulate private investment in European research

The high quality of European research is recognised but the lower impact of this research and the less effective transfer of this knowledge to industry is noteworthy when compared with the trading competitors in North America and the Pacific Rim.

In order to address this so-called European paradox and strengthen the European-wide innovation process, the European Commission has introduced the concept of European Technology Platforms "to bring together companies, research institutions, the financial world and regulatory authorities, to define a common research agenda (for the next 10–30 years) which should mobilise a critical mass of national and European public and private resources" (June 2004).

Technology Platforms "should be seen as a challenge for industry itself", and help to develop "a joint vision", with "long term objectives which can affect the common competitive position [of the European given industry] with respect to other markets". The relevant stakeholders in key economic sectors should commit themselves to work together to identify the innovation challenge, develop the necessary research programme and implement results.

To define a vision led by industry

A Technology Platform should be a response to a major European Challenge, where a strategic European response is required; it should be politically highly visible, industry led and well planned and executed.

Recommendations from Technology Platforms will be taken into account for the research priorities in Framework Programme 7. Some of their ideas could also be developed through joint European Technology Initiatives (using Article 171), such as Global monitoring for environment and security, or Innovative medicines for the citizens of Europe, initiated in 2005.

Up to now, 29 Technology Platforms have been set up in relation to the Deployment of new technologies (Plant Genomics, Nanomedicine, Hydrogen, etc.), High Technology sectors (Nanoelectronics, etc.), Sustainable platforms (Photovoltaics, Water supply, etc.), New technologies-based public goods and services (Innovative medicines platform, Mobile and wireless communications), Restructuring the traditional industrial sectors (Forest, Construction, Textiles, etc.)

Several Platforms are related to our activities and concerns, for example:

– Plants for the future (coordinated by EPSO and EuropaBio) (draft Strategic Research Agenda at http://www.epsoweb.org/Catalog/TP/index.htm)
– Food for life (hosted by CIAA, Confederation of the food and drink industries) (http://etp.ciaa.be/asp/home.asp)
– Global animal health (related to the need for vaccines, pharmaceuticals and diagnostic tests).

AEP has had interactions with the first two Platforms where grain legumes are among the concerns. ■

AEP (Anne Schneider) from the following sources:
COM (2004) 333 final 16 June 2004; Spanish Conference on "European Technology Platforms: a road towards the future of European Competitiveness" March 2005; Winning at new products by Robert Cooper; Hyperion Ltd www.hyperion.ie; http://cordis.europa.eu.int/technology-platforms/

Conservation, management and regeneration of grain legumes genetic resources

22–23 September 2005 Valladolid, Spain

This *ad hoc* meeting was organised by a task force of members of the ECP/GR Working Group on Grain Legumes (WGGL) as part of an ongoing survey into the current status and methodologies employed in the regeneration of grain legume (GL) species. Twenty-six people attended the meeting including members of the WGGL and invited experts from Europe, Morocco, Canada and representatives from ICARDA and CIMMYT. The objectives of the meeting were to review and discuss the preliminary findings of the recent online questionnaire about current management practices for GL genetic resources, to exchange experiences and share expertise, and to plan strategies for acting on key issues.

The topics covered included mating systems, pollinators, multiplication methodologies, including statistical methods for monitoring genetic erosion during multiplication and complementary conservation strategies. Overviews of GL genebank activities from a number of institutions were also presented.

The online questionnaire achieved a 42% response from a targeted mailing to potential respondents. Replies were received from 23 countries and from both public and private sectors. Further analysis of the responses is required but the data represents an important compilation of the current status of knowledge, management practices and key issues associated with the maintenance of GL germplasm. A report of the preliminary results is available at: http://www.ecpgr.cgiar.org/Workgroups/grain_legumes/grain_legumes.htm.

Action on priority issues

Several priority issues emerged from the meeting and various plans of action were decided upon: information on mating systems of GL species was considered too general and often missing for some species. Working experiences relating to the mating behaviour of individual species were not universally shared. A further collation of specific data based on actual experiences for each species and location will be undertaken. Recent findings on the range and behaviour of pollinating insects show that the current guidelines for spatial isolation are very out of date and therefore create uncertainty. Again further evidence from research and experience should be built up by species and location. Those at the meeting recognised unanimously that pollinator agents and plant interactions have not been studied adequately and are still poorly understood. Pollinators should be managed as integral components in germplasm maintenance. This argues in favour of an approach at the habitat level rather than at the single species level for the management strategies of GL, and it advocates for coordinated actions at different locations and with different accessions involving complementary studies on plant and pollinator interaction.

Storage conditions in genebanks vary considerably. In a significant number of cases regeneration is being carried out every 5–9 years. With few studies evaluating the impact of the different regeneration methodologies and their influence on the genetic structure of germplasm, and the uncertainties associated with mating behaviour and isolation distances, a strong recommendation arising from the discussions was to promote the greater use of base collections and reduce the frequency of regeneration as ways to offset these problems.

There was support for the adoption of more holistic and multidisciplinary approaches, not limited to the classic three step approach (collection, characterisation and documentation), to ensure that the genetic integrity of germplasm accessions plays an increasing role in GL/GR management. The group was also interested to learn, and will seek to join with others, to evaluate different dynamic management practices. A CD-ROM of all the presentations given at the meeting is available from the ECP/GR Secretariat and WGGL web pages (http://www.ipgri.cgiar.org/ networks/ecpgr/meetings/allmeetingWG. asp?groupID=11). ■

Source: WGGL Task Force members: Maria José Suso, Margarita Vishnyakova, Álvaro Ramos, Mike Ambrose, Gérard Duc and Lorenzo Maggioni. The meeting and work of the WGGL is supported under the European Cooperative Programme for Crop Genetic Resources Networks (EC/PGR).

6th German Lupin Conference

On the invitation of the German Lupin Association the 6th German Lupin Conference (like the previous five conferences) was held in Heidelberg on 26 and 27 January 2006. The local organiser was Prof. Dr. Michael Wink (Institute of Pharmacy and Molecular Biotechnology of the University of Heidelberg).

The meeting was attended by 38 participants from different fields of activity: nutrition, science, plant production, breeding, processing, trade. Sixteen papers were presented, covering many aspects of lupin investigation, including animal and human nutrition, agronomy, diseases and plant protection, plant breeding, variety trials and seed quality. As in the previous conferences, much time was left for mutual exchange of experiences and for discussion. On the evening of the 26 January pictures and a video of the 11th International Lupin Conference (Mexico, May 2005) were presented by those who had attended.

The annual assembly of the German Lupin Association (Gesellschaft zur Foederung der Lupine e. V.) also took place during the conference.

More information about the papers presented will be made available on the AEP website. ■

Source and further information: P. Roemer (Roemer.GFL@t-online.de).

Grain legumes and the environment: how to assess benefits and impacts?

To determine the environmental impact of increasing the production and use of grain legumes in Europe, specific methods of measurement are required, some of which are not currently available. It was in this context that the international scientific workshop was organised in Zurich in November 2004 by AEP and Agroscope FAL Reckenholz, supported by the EU Concerted Action known as GL-Pro ('European Extension Network for the Development of Grain Legume Production in the EU', QLK5-CT-2002-02418).

The proceedings of this workshop have been recently published[1] and they include 40 articles (225 pages), issued from talks and posters presented in the four themed sessions of the workshop: 'Methodology for environmental assessment of grain legumes: state of the art'; 'Grain legumes in crop rotations'; 'Nitrogen cycle of grain legume crops'; and 'Grain legumes in animal feeding'. They also include syntheses of the sessions, including the expert discussions arising from the workshop.

The workshop objectives were: to gather and exchange expert knowledge, to define knowledge gaps and future research needs and to establish an inter-disciplinary expert network of scientists working on environmental aspects of grain legume production and use. The emphasis was on the methodology required and most suitable for assessing the environmental consequences of increasing grain legumes in European agriculture.

The questions posed are complex and the discussions emphasised the added-value of interdisciplinary approaches and of complementing models with agronomic and physiological know-how to improve tools and analyses. The real challenge is for research to be carried out on different temporal and spatial scales, and at different process and systems levels.

The nitrogen cycle and underlying mechanisms need to be modelled in more detail. In crop production, the whole crop rotation or at least crop sequences must be considered. Investigating only an individual crop is certainly insufficient and may lead to wrong conclusions. Losses of nitrogen in the form of nitrate to ground water and nitrous oxide to the air related to the cultivation of grain legumes should be measured more accurately. To date, few data are available to quantify these emissions in relation to symbiotic nitrogen fixation. Long-term trials should be given high priority, so that all the effects can be measured and evaluated satisfactorily.

Further research is also required to improve the management of the nitrogen cycle, for instance, through optimisation of crop rotations, use of catch crops, intercropping or optimisation of fertilisation within the whole crop rotation.

When investigating the role of grain legumes in crop rotations, the effects of nitrogen that are specific to grain legumes, and non-nitrogen (or break crop) effects that also occur with non-legume crops should be distinguished. Often, these two types of effects are mixed up in discussion.

It is important that research takes into account the pedo-climatic effects in different countries and regions especially as there are close interactions between genetic background and environment. The challenge for genetic improvement of grain legumes by breeding lies in the creation of robust varieties with high and stable yields. There is potential for improvements in the composition of seed, changes in bioactive compounds and of protein degradability in the rumen.

Moreover, the workshop showed that plant and animal research should be linked more closely. Processes in the field can influence those in the barn, and vice versa: excreted nutrients should be returned to the field. It is a challenge for integrated systems research to optimise the nutrient cycles as far as possible.

Finally, for animal nutrition the workshop emphasised that the benefits of grain legumes could be increased by changing specific characteristics of the seed, either through plant breeding or through an appropriate treatment. The type of system used to evaluate the quality of feed was also highlighted as having a significant impact on the formulation. Optimising and unifying the different evaluation systems being used for grain legumes would help to get standardised values and clarify information for users.

This workshop was a first milestone. The analyses carried out should now be complemented and we hope that ongoing and future research projects will contribute to the knowledge base. Such multidisciplinary expertise is vital in order to exploit fully the potential of these low input crops for production and end use, avoid or reduce any negative effects and target more sustainable agriculture.

[1]Proceedings of the International Scientific Workshop 'Grain legumes and the environment: how to assess benefits and impacts', Zurich, 18–19 November 2004, (2006, Ed. AEP) cost €40 and can be ordered from the AEP office.

Source: Thomas Nemecek (thomas.nemecek@fal.admin.ch) and Anne Schneider (a.schneider-aep@prolea.com)

Jean Denarie is awarded the Grand Prix Charles-Léopold Mayer

Jean Dénarié (INRA, Toulouse), has been awarded the Grand Prix Charles-Léopold Mayer and is very happy to see his work on Rhizobium–legume symbiosis recognised this way.

Since 1960 the Grand Prix Charles-Léopold Mayer has been awarded each year in the field of cellular and molecular biology, and recently also in the field of genomics. It was awarded 20 times to researchers working in foreign labs (especially in the USA and in the UK) and 24 times to researchers working in France. It is the fourth time this prize has been awarded for work in the field of plant biology, and this time it is for legumes. It is also the first time to a researcher from INRA.

The prize, an amount of €38,000, was presented on 15 November 2005 at the Institut de France. Marion Guillou and Guy Riba were invited to attend the ceremony.

Source: AEP, Paris, France.

Professional body in Australia picks a pulse fellow

Kadambot Siddique, Director of the Centre for Legumes in Mediterranean Agriculture (CLIMA) and Professor of Crop Science at the University of Western Australia (UWA), has been elected a Fellow of the Australian Academy of Technological Sciences and Engineering (ATSE). The citation recognised his outstanding contribution to Australian and international agriculture, particularly his innovative research and leadership in production agronomy, crop physiology, germplasm development and breeding of grain legumes (pulses) and cereal crops of benefit to the grains industry in Australia and overseas. Professor Siddique, has developed and commercially released nine pulse varieties during the past eight years in Australia.

Source: CLIMA, Crawley, Western Australia (www.clima.uwa.edu.au)

Standardising the methodology for characterising *Medicago truncatula* phenotypes[1]

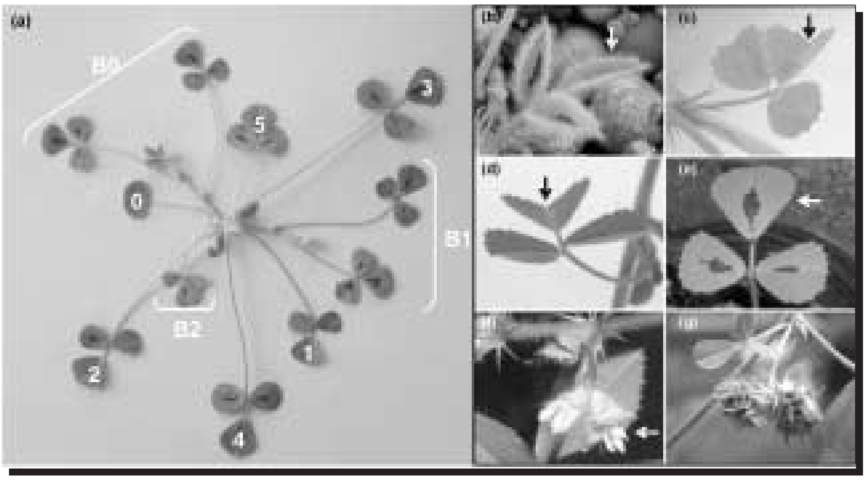
Standardiser la méthode de caractérisation phénotypique chez Medicago truncatula

by Delphine MOREAU*, Christophe SALON* and Nathalie MUNIER-JOLAIN*

Medicago truncatula has become a model of choice for studying legume genetics and genomics. A major challenge today is the large-scale determination of the function of its genes. Towards this goal, functional genomics has provided powerful tools for analysing metabolic and gene expression profiling. By contrast, there is little information about plant phenology which is an essential basis for functional genomics. Understanding plant development and its environmental control is crucial for two main reasons. First, gene expression can vary with plant developmental stage (4) and with the position of the analysed organ on the plant (5). It is therefore essential that tissues used for functional genomics are collected from plants whose development stage is precisely characterised and from organs with an unambiguously identified position on the plant. Second, the study of mutants has become a powerful means of analysing gene function. However, some mutations give rise only to subtle changes in plant phenology, such as slight morphological changes or altered timing of development, which are inconspicuous without a sensitive method for their detection (2).

Here, we describe different ecophysiological tools that have been developed for providing a standard method of characterisation of *M. truncatula* phenotypes. In this study, although the line A17 from Jemalong was taken as an example, the tools can be used for analysing any genotype. Both for facilitating functional genomics approaches and for making them more reproducible, different practical applications of the framework of analysis presented herein are discussed.

Figure 1. Phenotypic characterisation of *Medicago truncatula*. (a) Phyllotaxy of the main axis and arrangement of the primary branches. Main axis leaves are numbered according to their rank of appearance from 0 (i.e. the unifoliate leaf) to 5. The primary branches (B0, B1 and B2) are named according to the rank of the main axis leaf at the axil of which they develop. (b) to (e) Decimal code used for the notation of the vegetative development, and (g) Definition of the reproductive developmental stages.



Standard terminology

The rosette habit of the plant makes difficult the identification of the different organs (Figure 1a). Our primary aim was therefore to propose a standard method for identifying organs. A plant is made up of a rosette that is the main axis. A detailed analysis of the phyllotaxy revealed a constant arrangement of the leaves (Figure 1a). The first true leaf that develops is round and is called leaf 0. Then the other leaves always appear sequentially with the same arrangement, from leaf 1 to 5 and so on. During plant development, primary branches develop at the axil of the rosette leaves (Figure 1a). The first primary branch that appears is B0: it develops from the axil of leaf 0. Then the other primary branches always appear sequentially with the same arrangement: B1 develops from the axil of leaf 1; B2 develops from the axil of leaf 2; and so on.

In this way each leaf of the main axis and each primary branch is identified by its position on the plant and can be recognised easily throughout the plant cycle. Because this terminology is generic, it can also be used to identify the secondary and tertiary branches.

Standard system for characterising plant developmental stages

To accommodate the many vegetative–reproductive development relationships that can occur in indeterminate plants, our system of notation separates descriptions for vegetative and reproductive development. Vegetative stages are determined by counting the number of leaves per axis. Notations can be restricted to the two first branches (B0 and B1) which are the most representative for characterising genotypes. A leaf is counted when it is planar

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(Figure 1e). The system of notation includes a decimal code consisting of three intermediate stages (Figure 1b, c and d) corresponding to the degree of unfolding of the last leaf on each axis. Reproductive stages are determined for each axis by identifying the position of the first reproductive node and by counting the number of reproductive nodes. A node is considered as reproductive from the moment it bears at least one open flower (Figure 1f).

Requiring only a visual observation, this system of notation provides a simple and non-destructive method of describing both the vegetative and reproductive developmental stages.

A model of vegetative development in response to environment

Plant development is highly dependent upon environmental conditions. Temperature is the main factor affecting plant development but photoperiod can also have an impact to a lesser extent. Using the system of phenotypic characterisation previously presented, the timing of development was analysed in response to variations in the environment. The number of leaves on the first branch (B0) was observed in five experiments carried out under varied environmental conditions either in a glasshouse or in a growth chamber, with mean temperature and photoperiod ranging from 12 to 22 °C and from 10 to 16 h, respectively.

When the number of leaves was related to time expressed as the number of days (Figure 2a), the rate of leaf appearance was constant in a given experiment. However, the rate of leaf appearance varied strongly between experiments. Instead of analysing the timing of development as a function of the number of days, it was related to thermal time which is a means of expressing time by taking account of mean daily temperature (1). Thermal time was expressed in degree-days with a base temperature of 5 °C (Figure 2b). Interestingly, the use of thermal time unified the rate of development: the rate of leaf appearance became constant in spite of environmental differences among experiments.

Thus, analysing vegetative development using thermal time made it possible to identify a constant in plant development, valid in a wide range of environmental conditions. Because the rate of leaf appearance is stable, it can be considered as a reproducible genotypic trait of A17 plants (6).

Practical applications for functional genomics

- ***Standard framework for characterising plant material***

Probably due to the complex shoot phenology of *M. truncatula,* tissues used to perform functional genomics analyses are commonly harvested (i) at precise chronological ages rather than at precise developmental stages, (ii) from organs with an uncharacterised physiological age and (iii) from organs whose position on the plant is not precisely identified. This leads to difficult and sometimes inappropriate comparisons of data among experiments. In this context, both the standard terminology and the standard system of characterisation of plant developmental stages provide an effective method which could constitute a reference for characterising the plant material used for functional genomics. The rate of leaf appearance on the first branch (B0), expressed using thermal time, was shown to be stable in a wide range of environmental conditions. So, associated with temperature measurements, the use of the model of development presented herein should be helpful to schedule both plant observation and data collection better. Moreover, if temperature has been measured throughout the plant development, the model could be used *a posteriori* to evaluate the plant developmental stage and the physiological age of the organs that have been used for metabolic or gene expression analyses. Thus, this model can be of practical importance when checking if data produced with plants cultivated under different environments have been obtained using organs with similar physiological ages, making the comparison of data arising from different experiments more relevant.

- ***More accurate phenotyping***

Both the terminology and the system of notation appear to be relevant tools for highlighting morphological variations between lines. Besides, the model of vegetative development should be helpful for highlighting variations in the time course of plant development. Thus, the association of temperature measurements and observations of simple phenological traits could constitute a relevant framework for analysing plant phenotypic differences. Because some mutations are likely to induce fine disruptions in plant development, the methodology presented here should be of practical interest for reverse genetics approaches. It should also be relevant for studying the natural genetic variability or the effects of biotic and abiotic stresses.

Until now, there have been few ecophysiological studies conducted on model plants such as *M. truncatula*. However, a precise characterisation of plant functioning has become essential for conducting genomics analyses. Associating such a framework with analyses of metabolic and gene expression profiling could provide the opportunity to achieve a more detailed understanding of gene function. ■

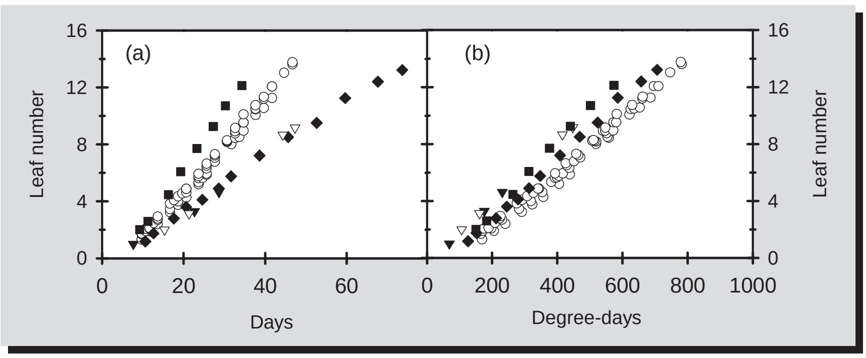

Figure 2. Changes over time in the number of appeared leaves on the first primary branch (B0), in five experiments identified by different symbols. (a) Time is expressed in calendar days from the date of appearance of the first trifoliate leaf on the main axis. (b) Time is thermal time expressed in degree-days (with a base temperature of 5 °C) from the date of appearance of the first trifoliate leaf on the main axis.

[1]This article is a short version of a complete study (3)

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Evaluation of the STICS crop model within the EU INTERCROP project

Evaluation du modèle de culture STICS dans le projet européen INTERCROP

by Nadine BRISSON*, Guenaëlle CORRE-HELLOU**, Audrey DIBET**, Marie LAUNAY* and Yves CROZAT**

Given the complexity of intercropping systems, models can be especially helpful to analyse them comprehensively and to test agronomic strategies. Hence a special investigation of modelling was included in the EU FP5 INTERCROP project (1) which aimed to promote pea–barley intercropping as a relevant cropping system for organic farming throughout several European countries (Denmark, France, England, Germany and Italy). The first phase of the work consisted of creating a tool from a first intercrop version of the STICS model (2) together with ecophysiological experiments conducted in conventional conditions in Angers (3). During this first phase a few new physiological concepts were introduced in the model and a thorough parameterisation of both species was performed in sole crop trials.

Model evaluation

The second phase focused on the model evaluation relying on the network of INTERCROP experiments. In this evaluation, results obtained with the model were analysed and compared with experimental results, either in terms of agricultural values (including yield and Land Equivalent Ratios) or in terms of intercropping management strategies (including choice of sowing dates and plant densities and position in the rotation). Here we aim to present some results from the second phase as a summary of how to handle such a crop model and what can be expected from it within the framework of intercropping in organic farming. Once the first phase was completed, the reliability of the model was estimated using sample simulations (Figure 1) corresponding to pea–barley intercrops grown under conventional conditions (with appropriate pesticides and herbicides) and under well watered conditions. Although the model is considered to be well adapted to intercropping, this is not the case for organic farming because it does not take account of biotic stress (pests, weeds and diseases).Therefore, since it is known that the conditions of simulation are different from the actual growing conditions within the organic intercropping network of the project, this modelling study cannot be considered a validation of the model. The main questions that need to be addressed are the following: Which of the growing conditions does the model apply to? How can the model help to interpret the experimental data? Can it be used to take decisions about the potential benefits of intercropping? Can it be used to test management strategies?

Simulation data set

The agronomic and physical framework consisted of nine pedoclimatic situations throughout Europe summarised in Table 1.

Analysis of the model results

Analysis of the agronomic results showed that STICS over estimates most of the plant variables and in particular pea nitrogen accumulation. This overestimation concerns the reproductive part of the cycle in particular and seems more critical for sole crops than for intercrops. As the model works satisfactorily in conventional

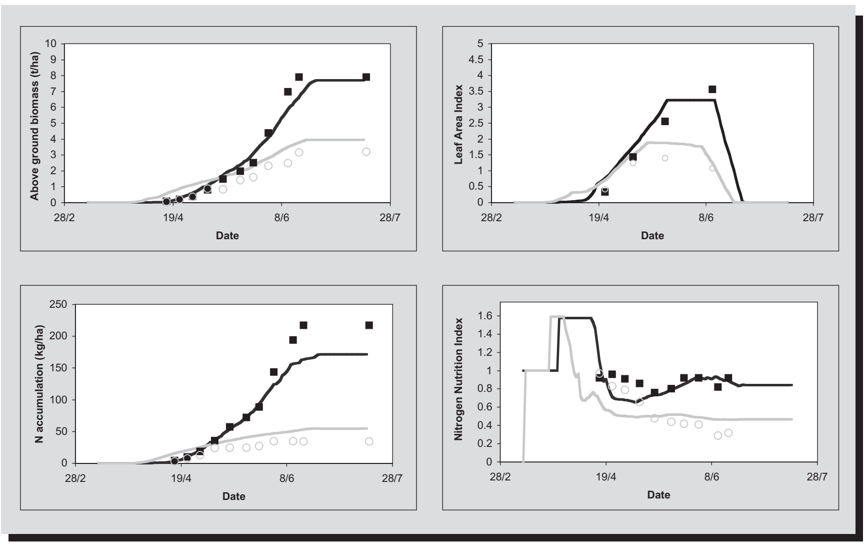

Figure 1. STICS intercrop model validation (Angers 2003, well-watered conditions, no fertiliser N, full plant protection) after species parameterisation in the sole crop trials. Pea measured values (■), pea simulated values (—), barley measured values (○), barley simulated values (grey line —).

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Table 1. Sowing dates and cycle durations for the nine pedoclimatic situations in five countries together with cumulative degree-days (0 °C as base temperature) and rainfall over the cycles.

Year	Cycle data	Denmark	England	France	Germany	Italy
2003	Sowing date	3 April	16 March	11 March	–	16 March
	Cycle duration	113 days	134 days	120 days	–	83 days
	Cumulative degree-days	1555	1843	1877	–	1269
	Cumulative rainfall (mm)	250	169	142	–	100
2004	Sowing date	16 April	17 March	10 March	31 March	14 March
	Cycle duration	112 days	131 days	123 days	129 days	102 days
	Cumulative degree-days	1616	1726	1696	1793	1716
	Cumulative rainfall (mm)	197	163	115	271	151

For each site, three cropping systems were studied
– sole crop of pea (100% pea[1]) – additive pea–barley intercrop: 100% pea and 50% barley
– sole crop of barley (100% barley) – substitutive pea–barley intercrop: 50% pea and 50% barley

conditions (3), we assume that this discrepancy is due mainly to biotic stresses. In order to analyse the discrepancy between measured and simulated values in relation to the cropping systems (sole crop, additive and substitutive intercrops), we proceeded to an ANOVA on the biomass variable, using the site x year variations as nine replicates. This confirmed that measured and simulated values were always significantly different while the differences between cropping systems (sole versus intercrops) are significantly different for barley only. Nevertheless, it did not reveal any interaction between the quality of the simulation and the cropping system, which shows that the modelling work dedicated to the development of an intercrop model from a sole crop model has no bias.

When comparing globally measured and simulated yields (Figure 2) the results appear more satisfactory despite a greater variability over years and sites for simulated values. Values for the Land Equivalent Ratio (see Insert) averaged over sites and years (Figure 3), are above 1 showing that intercrops are worthwhile in terms of yield and nitrogen contents. This shows that the model allows the appropriate agronomic conclusions to be drawn.

The measured values for nitrogen contents indicate that the intercrop does better than the values calculated by the model suggest. The lower LERs can also be explained by the fact that no account is taken of biotic stresses in STICS and this tends to overestimate to a larger extent for sole crops than for intercrops. This result is in agreement with the natural regulation of these stresses (in particular for weed pressure) in intercropping.

Testing agronomic strategies

The objective of this work is to use the model to investigate various technical intercropping strategies. The above conclusions do not impede such a prospective study focusing on the validity of the model, i.e. partitioning of light, water and nitrogen resources. In this work the relative results obtained for the various technical options will be of interest, rather than the absolute results. The aim is to clarify the potential use of certain methods of crop utilisation in relation to animal feeding or grain processing.

The approach was in three phases. The first consisted of identifying questions of interest with the project partners. The second focused on the translation of these questions into simulation designs and the last phase was devoted to the analysis of the results. In order to reach a general response through statistical analysis, we used a climatic series of about ten years.

To illustrate this approach we used as an example the question of sowing date effect on the intercrop performance at the French, English and Danish sites. Three sowing dates per site were analysed for both intercrop designs (additive and substitutive) in terms of level and stability of yield. The dates advised by the partners covering the largest sowing period were as follows:

- French site: 14/02, 28/02 and 14/03
- English site: 01/03, 20/03 and 15/04
- Danish site: 08/04, 15/04 and 22/04

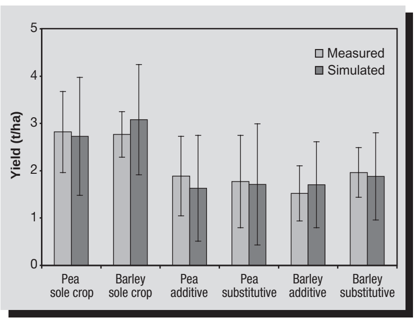

Figure 2. Comparison of measured and simulated yields and their variation with years and locations for pea and barley sole crops and pea–barley additive and substitutive intercrops.

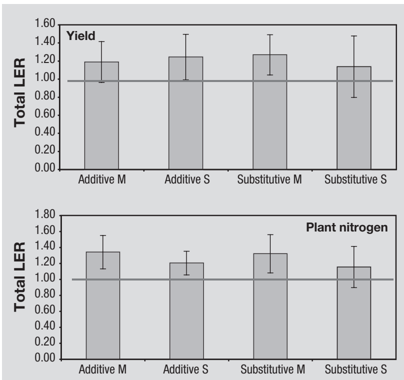

Figure 3. Comparison of measured (M) and simulated (S) LER for yield and plant nitrogen content of additive and substitutive pea–barley intercrops for two years and for five locations.

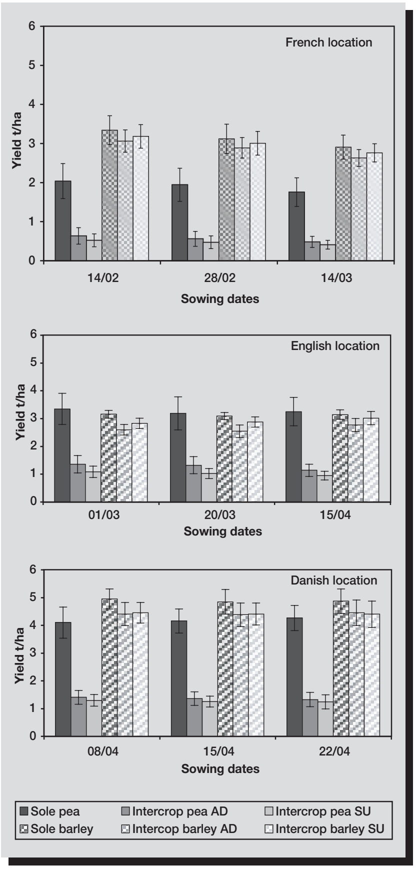

Figure 4. Influence of sowing dates on yields per hectare of sole crops and additive (AD) and substitutive (SU) pea–barley intercrops at three locations.

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The Land Equivalent Ratio (LER) allows the competitiveness of intercropping to be evaluated (4).

$$LER\_total(yield) = \frac{Intercrop\_yield(crop1)}{sole\_crop\_yield(crop1)} + \frac{Intercrop\_yield(crop2)}{sole\_crop\_yield(crop2)}$$

If total LER is <1, it means that the intercrop is less productive than the addition of both sole crops. A larger surface is required for the intercrop to reach the same yield as the sole crops. If total LER is >1 the intercrop is more productive than the two species as sole crops. For a given surface the intercrop gives a better yield than the two sole crops.

Yields per hectare (Figure 4) varied between sites and crops and this variation corresponds to 15% difference for the maximum. For intercropped pea the earlier the sowing dates, the better the yield. This is also the case for sole crops of pea at the French and English sites. On the contrary, at the Danish site higher yields were obtained with the later sowing date. For barley, the results were more erratic: in England the late sowing appears more favourable whereas it is the reverse for the French site. In Denmark there was no significant effect of sowing date.

From the above results, we could advise an early sowing for the French and Danish sites, but in England early sowing tended to favour pea relative to barley. The harvest quality was directly linked to the pea yield within the total amount, and is likely to be favoured by early sowing whatever the location.

Conclusions not entirely disappointing

This work was devoted to the evaluation and utilisation of the STICS intercrop/sole crop model taking into account the European environmental variability within an organic farming framework. Initially we experienced difficulty simulating appropriate absolute production values in spite of a satisfactory phase of parameterisation in Angers in conventional farming. We attributed most of the discrepancies between simulations and measurements to the effects of biotic stress which were not accounted for in the model. In spite of rather disappointing conclusions on the ability of the model to simulate correct absolute values, the relative values and in particular the Land Equivalent Ratios produced the same results for simulation and measurements, i.e. the global advantage of intercropping compared with sole crops. These conclusions cause us to think that the use of the model to test technical strategies was worthwhile. It showed that the technical strategies to obtain the most favourable agricultural outcome can be different according to locations and output objectives: favouring pea or barley, grain or forage utilisation. Some possible progress has been demonstrated, concerning for example the use of other genotypes, a sowing delay between the two crops or various inter-rows. ■

[1]This percentage refers to the sowing density that can vary in between sites.

(1) Bellostas, N. and Jensen, E. S. (2004). Grain Legumes **39**, 14–15.

(2) Brisson, N. *et al.* (2004). Agronomie **24**, 1–9.

(3) Corre-Hellou, G. (2005). Thèse de doctorat de l'Université d'Angers. 100 p.

(4) De Wit, C. T. and Van den Bergh, J. P. (1965). Neth. J. Agric. Sci. **13**, 212–221.

NEW BOOKS

[Diagnosis of diseases and disorders of spring and winter pea]

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December 2005, French, 152 pages

ARVALIS-Institut du végétal and UNIP

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EVENTS

A complete and up-to-date list of forthcoming events can be found on the AEP website at www.grainlegumes.com where new events are listed as soon as the details become available to AEP. The events below have been added to the website since the last issue of *Grain Legumes* was published.

April 25–27, 2006

2nd AEL Conference

Email : cuadra@inia.es

Web : http://www.uco.es/asociaciones/leguminosas/

May 30–31, 2006

Joint Organic Congress/Organic Farming and European Rural Development

Odense Congress Centre, Denmark

Email: ESS@landscentret.dk

Web: http://www.organic-congress.org

September 12–14, 2006

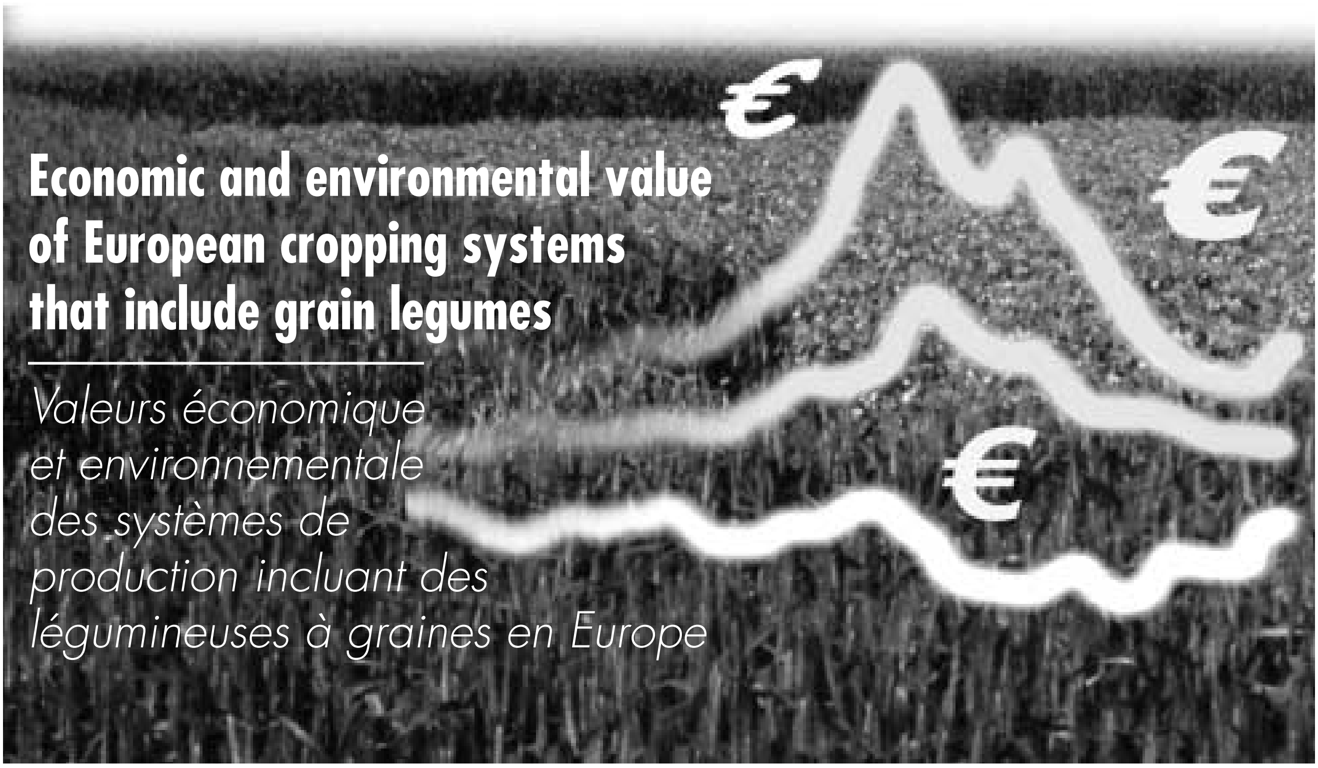
40th Nottingham Feed Conference

University of Nottingham, Sutton Bonnington Campus, UK

Email: Phil.Garnsworthy@nottingham.ac.uk

Economic and environmental value of European cropping systems that include grain legumes

Valeurs économique et environnementale des systèmes de production incluant des légumineuses à graines en Europe



(Photo composition A. Mauffret, photos UNIP, France)

Grain legume crops could offer many economic and environmental benefits if they were to be grown more widely in European crop rotations. The potential for increase would be great since grain legumes, such as peas, faba beans and lupins, represent only 1%–7% of the arable crops area in the EU, compared with 15%–25% outside Europe.

Grain legumes are particularly relevant for sustainable cropping systems as shown by the results of economic and environmental studies undertaken within the scope of the Concerted Action GL-Pro[1] supported by the EU.

The first article of our special report describes the bottlenecks and prospects for grain legume cultivation and use in different European regions, discovered from questionnaire surveys with more than 500 farmers that do not grow grain legumes.

The economic and environmental benefits of grain legumes in crop rotations in some regions of France, Germany, Spain and Switzerland are presented in the following two papers. Crop rotations with and without grain legumes were compared in terms of their rotation gross margin in each region. Their impact on the environment in terms of energy consumption and greenhouse gas emissions has been evaluated by Life Cycle Assessment (LCA).

This distinctive twofold approach, comprising economic calculations and LCA, is based on the same data sets. It enables a comprehensive eco-environmental interpretation for a specific region and, in addition, the approach meets the increasing demand of society to evaluate cropping systems not only in terms of profitability but also sustainability and environmental impact. ■

[1]European extension network for the development of grain legume production in the EU (QLK-CT-2002-02418)

Les légumineuses à graines pourraient offrir plusieurs avantages économiques et environnementaux si ces cultures étaient plus importantes dans les rotations européennes. Le potentiel de développement est réel car les légumineuses telles que le pois, la féverole et le lupin ne représentent que 1%–7% des surfaces arables de l'UE, alors que la part des légumineuses à graines peut atteindre 15%–25% à l'extérieur de l'Europe.

Ces cultures sont particulièrement adaptées aux systèmes de production durables comme le montrent les résultats des analyses économiques et environnementales de l'Action Concertée européenne GL-Pro[1] financée par l'Union européenne.

Le premier article de notre dossier se base sur un questionnaire adressé à plus de 500 agriculteurs qui ne cultivent pas ou plus de protéagineux ou autres légumineuses à graines afin de décrire certains points critiques et prospectives pour la production et l'utilisation de légumineuses à graines.

Les deux articles suivants analysent les bénéfices économiques et environnementaux de l'inclusion des légumineuses à graines dans les rotations de cultures de plusieurs régions de France, Allemagne, Espagne et Suisse. La comparaison des rotations de cultures avec et sans légumineuses à graines est basée sur la marge brute de la rotation dans chaque région. L'impact sur l'environnement en terme de consommation d'énergie et d'émissions de gaz à effet de serre est évalué par l'Analyse du Cycle de Vie (Life Cycle Assessment, LCA).

Ces deux approches parallèles, calculs économiques et LCA, sont basées sur la même série de données de références. Cela permet une interprétation éco-environnementale globale pour une région donnée, et cela répond à la demande croissante de la société d'évaluer les systèmes de production non seulement en terme de profit économique mais aussi en terme de durabilité et d'impact environnemental. ■

[1]European extension network for the development of grain legume production in the EU (QLK-CT-2002-02418)

What do European farmers think about grain legumes?

Que pensent les agriculteurs européens des légumineuses à graines?

by Julia-Sophie VON RICHTHOFEN and GL-Pro partners*

About 1.4 million ha of field peas, faba beans and lupins were cultivated in 2005 throughout the EU, leading to a production of about 4 million tonnes (t). This amount contributes only 4% of the European consumption of protein for the feed industry.

Although grain legumes could offer many benefits in European crop rotations, they constitute only 1% to 7% of the arable crops area in the different European countries, compared with 15% to 25% outside Europe (data includes soyabeans) (1). Furthermore, in north-west Europe the cultivated area of grain legumes is decreasing (Table 1).

Compared with 2004, European farmers reduced the pea area by 62,000 ha (–7%) to 811,000 ha in 2005. Especially in France and Germany the area decreased to 311,000 ha (–12%) and 111,100 ha (–9%), respectively. In Denmark the reduction was particularly dramatic (about 40%): only 16,000 ha were grown in 2005 compared with 27,000 ha in 2004.

Against this trend in north-west Europe, Spanish farmers once again grew more field peas, increasing the area by 8% in 2005 to 147,000 ha. However, due to the long severe drought in spring and summer the national production was only about 120,000 t, which was 60% of the previous year's production.

In contrast with pea, the European faba bean areas continued to increase, reaching a total of 446,000 ha in 2005 (+11%). In France the acreage increased by 21,000 ha (+26%) to a total of 102,000 ha.

A survey of non-producers

To find out why European farmers do not grow more grain legumes and to determine the problems and prospects for grain legume production a questionnaire was sent to European farmers who had never grown grain legumes or who had stopped grain legume cultivation. This survey was supported by the European Commission within the framework of the Concerted Action GL-Pro.

In the winter of 2004/05, 553 farmers from Belgium, Denmark, France, Germany, Spain and Switzerland answered the questionnaire. The majority of farmers filled in a written questionnaire, but some interviews also took place based on the same questionnaire. Table 2 and Figure 1 on page 16 show the regions covered by the survey.

The French surveys were the end-study projects of students from three French agricultural schools (ISA Lilles, ESA Angers, ESITPA Rouen) and these were carried out in the regions of Barrois, Bretagne and Beauce-Gatinais using a modified questionnaire. For this reason the results were not integrated directly into the analysis.

The percentages of returned questionnaires and the sizes of the study areas covered by the survey differed from region to region. This has to be taken into consideration when the results are discussed. In Denmark only four non-producers answered the questionnaire and their answers were not included in the analysis.

Grain legumes are seen as less profitable

Farmers were asked their main reasons for not growing grain legumes and were offered a choice of answers to a series of different statements (Table 3).

In Belgium, Germany, Spain and Switzerland, farmers usually named the lack of competitiveness of grain legumes compared with potatoes, sugar beet and cereals as the main obstacle. The lack of ability to compete with an alternative break crop, namely oilseed rape, was also a sound reason for German and Swiss farmers. Market price, grain yield and the risk of yield fluctuations are therefore the major obstacles.

The same reasons are of concern for farmers surveyed in France. In contrast with their European colleagues, however, they stressed the high seed costs as an important constraint for grain legume production.

Table 1. Areas of field peas, faba beans and lupins in GL-Pro partner countries (1,000 ha).

	2000	2001	2002	2003	2004	2005
Belgium	1.7	1.9	1.6	2.1	2.1	1.9
Denmark	35.6	32.1	40.4	31.4	26.7	16.0
France	461.3	473.6	431.0	456.0	444.5	420.4
Germany	181.6	218.6	206.9	201.5	172.8	165.7
Spain	70.3	72.4	132.7	163.2	199.7	213.9
Switzerland	3.0	3.3	4.4	5.4	4.9	5.3

Source: UNIP, Paris, France; EUROSTAT; swiss granum (www.swissgranum.ch)

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Table 2. Participation of grain legume (GL) non-producers in the GL-Pro survey.

	Belgium	France*	Germany	Spain (Central) Castilla/Leon	Spain (North) Navarra	Switzerland (West)
Coordinating institution	APPO	ARVALIS/UNIP	proPlant/TUM	ITA	ITGA	Agroscope RAC Changins
Number of GL non-producers surveyed	62	170	159	36	38	84
Percentage of farmers who grew GL in the past	44%	64%	62%	75%	84%	64%

*Interviews in Barrois, Beauce-Gatinais and Bretagne in cooperation with agronomic schools based on a modified questionnaire.

Furthermore many farmers described the threshing of grain legumes as problematic. In particular, the farmers of Barrois in France emphasised harvesting problems.

Regional differences in opinion

The survey also revealed some regional differences in farmers' opinions about the specific reasons that limit the development of grain legume production. Farmers in Flanders, the north-western part of Belgium, argued against peas because of the serious pigeon damage that they experience every year in their fields. In Bretagne, owners of intensive pig farms with high livestock densities cannot expand grain legume production because of nitrate regulations.

In western Switzerland grain legumes compete with other break crops (sugar beet, potatoes, rapeseed) in rotations. Moreover, ley farming and temporary meadows play an important role in Swiss agriculture. Compared with many European cropping systems, the rotations are more varied: about 45% of the crop rotations mentioned by farmers are five years or longer.

Farmers know benefits for the following crop

In the GL-Pro surveys farmers were also asked to give their appraisal of grain legumes. Many of them had grown peas, faba beans or lupins in the past (Table 2) and had some experiences with these crops.

Table 3. Grain legume non-producers: reasons not to grow grain legumes.

Reasons[1]	Mean agreement/disagreement[2] Belgium	Germany	Spain (Central) Castilla/Leon	Spain (North) Navarra	Switzerland (West)
Not competitive with sugar beet/potatoes	3.5	3.1	3.6	1.0	3.1
Low/fluctuating producers' price	3.3	3.1	2.8	2.9	2.6
Not competitive with cereals	3.1	3.1	2.8	3.5	3.0
Unstable yields	3.1	3.2	3.0	3.7	3.0
Low yields	3.0	2.8	3.3	3.1	2.9
Harvesting problems	3.0	2.7	2.7	2.5	2.9
Insufficient CAP subsidies for protein crops	3.0	2.6	2.9	2.9	2.5
Damage by pigeons	3.0	2.1	2.3	1.0	1.5
Insufficient regional support	2.9	2.5	2.7	2.3	2.4
High seed costs	2.6	2.6	2.8	1.9	2.2
Not competitive with oilseeds	2.3	3.2	2.7	2.4	3.0
Lack of adapted varieties	2.2	2.1	2.2	2.3	2.4
Difficult to market	2.1	2.6	2.2	1.4	1.7
Problems with herbicides (availability/efficiency)	2.1	2.3	2.7	1.7	2.1
Not adapted to climate	2.1	1.7	1.7	1.8	2.2
Work organisation	2.0	2.0	2.1	1.8	1.8
Problems with pests	2.0	2.1	2.1	1.9	2.2
Nitrogen regulation	1.9	2.1	1.3	1.3	1.7
Problems with specific diseases	1.9	2.1	1.9	2.5	2.0
Not adapted to soils	1.7	1.7	2.2	1.6	1.9
Problem with root diseases in peas	1.7	1.9	1.7	1.6	1.9

[1]Sorted by agreement in Belgium (descending).
[2]Mean agreement/disagreement calculated from the possible answers: absolutely sure: 4, rather sure: 3, rather not: 2, surely not: 1.

Farmers agree on agronomic benefits

Most farmers interviewed were in agreement that grain legumes are precious feedstuffs, rich in protein and energy. However, many of them were not aware of their monetary value, i.e., that the on-farm feeding value of a farmer's own pulses is higher than the market price.

When asked about the impact of grain legumes in crop rotations, the farmers interviewed said that they regarded grain legumes as good break crops, improving soil fertility and leading to high additional grain yields of the following crop. On average they estimated, that wheat after grain legumes produces 0.6 to 0.9 t/ha more yield, compared with wheat after cereals (Belgium, central Spain and Switzerland +0.6 t/ha, Germany and northern Spain 0.9 t/ha, French farmers approved but did not quantify the yield gain of cereals after grain legumes).

Higher producers' prices and greater support for protein crops would be primary incentives for farmers to take up grain legume production, but this would interfere with CAP reform regulations. High yielding varieties, resistant to lodging associated with easier threshing are also classified as important.

For farms with dairy and suckler cows in Bretagne and Barrois an on-farm supply of protein feed is a substantial argument for grain legumes, providing the benefits of traceability, GMO-free feed.

According to some farmers, the reform of the sugar market regulations, with decreasing profitability for sugar beet cultivation, might provide a reason for replacing some sugar beet with grain legumes.

In conclusion, most of the farmers surveyed appreciated the agronomic advantages of grain legumes in crop rotations and their feeding value, but their choice of crops was determined mainly by yield and price. Compared with the gross margins of other important arable crops, especially rapeseed and wheat, grain legumes are seen as less profitable. In the following article we show that this is not the case when gross margins are compared at the rotation level; in fact economic analysis cannot be limited to the crop level in a cropping system. ■

(1) GL-Pro (2005). Guidelines for growing grain legumes in Europe. GL-Pro, UNIP, Paris.

SPECIAL REPORT
ECONOMICS & ENVIRONMENT

Economic impact of grain legumes in European crop rotations

Impact économique des légumineuses à graines dans les rotations culturales en Europe

by Julia-Sophie von RICHTHOFEN and GL-Pro partners*

With technical progress in soil tillage, fertilisation and plant protection, the agronomic significance of crop rotation design and consequently the preceding crop effects of grain legumes have become less and less significant for farmers than in previous decades, while the competitiveness of the single crop has come to the fore. Very limited crop rotations have been developed, dominated by high yielding winter cereals, and this happened, even though the preceding value of grain legume crops seems to be well known. Their benefits for the following wheat compared with a preceding cereal crop can be summarised approximately as follows (1):

- Average additional grain yield: 0.5 – 1 t/ha,
- Reduction of N-fertilisers: –20% to –25%,
- Reduced pesticide costs: –20% to –25%,
- Reduced operation costs for tillage (no plough): –25% to –30%.

Decreasing proceeds (yield in t/ha x price in €/t) of cereals, increasing costs of N-fertiliser and fuel as well as the increasing size of farms and the increasing machine capacities required are weighty reasons supporting more diversified rotations. To study the economic feasibility of grain legumes in crop rotations was therefore the target of the GL-Pro network. The average crop rotation gross margin per hectare and year served as a key figure, since it is only the analysis of whole rotations that allows a correct and acceptable economic evaluation of grain legume cropping.

Figure 1. Regions chosen for the GL-Pro studies.

Figure 1 shows the regions that were chosen for this GL-Pro target. The main climatic and soil characteristics for some of these regions and the percentage of grain legumes in the arable land area are given in Table 1. This shows that grain legume cropping varies greatly in importance in these parts of Europe.

Rotation gross margin is crucial

For each region a typical arable rotation, including cereals and oilseeds, was identified. This rotation was then diversified with grain legumes. Using common methodology and hypotheses, all the data required to assess the gross margin of each crop in the rotations were compiled. A prospective approach was taken, considering reform of the Common Agricultural Policy (CAP), and taking only coupled payments into account. Based on these criteria, the rotation gross margins were calculated and compared. For more information about the methodology of this model see Inserts 1 and 2 on page 19. In the following sections some results are presented and discussed.

For Saxony-Anhalt in East Germany and the Barrois region in eastern France, the five-, four- and three-year rotations:

- oilseed rape–winter wheat–winter wheat–winter wheat–winter barley (80% cereals),
- oilseed rape–winter wheat–winter wheat–winter barley (75% cereals) and
- oilseed rape–winter wheat–winter barley (67% cereals)

were compared with the grain legume rotation oilseed rape–winter wheat–peas–winter wheat–winter barley (60% cereals).

The average grain yields of cereals and oilseed rape in the two regions obtained by farmers over the period 2000–04 were quite different: in Saxony-Anhalt rapeseed

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Table 1. Main characteristics of some study regions.

	South		Central			North	
	Navarra (North Spain)	Castilla y León (Central Spain)	Barrois (F)	Picardie (F)	Canton Vaud (CH)	Saxony-Anhalt (D)	Fyn (DK)
Annual average temperature (°C)	13	11	10	14	8	9	8
Annual average rainfall (mm)	600–800	400–500	730	600–700	850	400–500	450–600
Soil	Calcareous clay	Calcareous clay	Calcareous clay (+ stones)	Calcareous loam	Heterogeneous	Loam	Sandy loam
% of grain legumes in arable land (2004)	3*	4	1.4	6.4	3	3.3	1

* Non-irrigated areas. Source: GL-Pro partners.

yielded 3.5 t/ha and cereals yielded about 7.5 t/ha, compared with 3.0 t/ha and about 7.0 t/ha, respectively, in Barrois. There the advice is to produce winter peas, whereas in Saxony-Anhalt only spring peas are grown. In both regions pea yields were similar. Farmers obtained yields of about 4.0 t/ha on average with the respective pea types.

Diversifying the cereal rotations with peas had a favourable effect on the rotation margin. In Saxony-Anhalt its margin was €289/ha which is €29/ha (11%) higher than the margin for the five-year rotation with 80% cereals (Figure 2). Compared with the four-year rotation the advantage was still €11/ha (4%).

In Barrois farmers gained comparable economic benefits. The five-year rotation fell behind the pea rotation by 7% (–€25/ha). The four-year rotation, oilseed rape–winter wheat–winter wheat–winter barley, had a 5% lower gross margin (–€17/ha).

These results can be explained as follows: in Germany the market proceeds of the pea rotation fell below the proceeds of the five- and four-year cereal rotations by approximately 5% (about –€40/ha). Even the coupled premium for protein plants (€55.57/ha) did not compensate for this difference in the average of the rotation. In Barrois, however, the average market proceeds of the pea rotation were only about 2% lower. Here the greater competitiveness of winter peas compared with cereals and rapeseed in eastern France was evident: peas to cereal ratios for yield were about 1:1.7 in Barrois and 1:1.9 in East Germany, while peas to rapeseed ratios were 1:0.7 and 1:0.9, respectively.

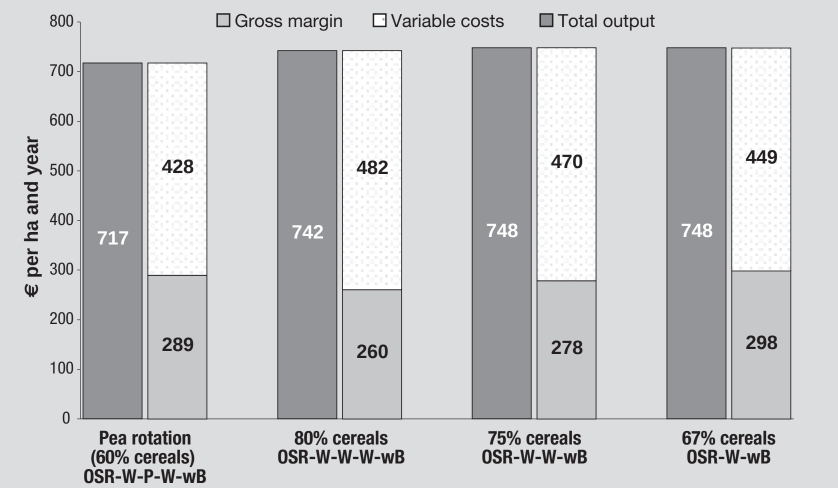
When considering also the coupled premium for peas and the re-coupled area payment, farmers in Barrois on average had an equivalent total output[1] when the percentage of cereals in the rotation was reduced to 60%.

An analysis of the production costs revealed that in Saxony-Anhalt more than €50/ha on average was saved when using the pea rotation compared with the five-year cereal rotation and about €40/ha was saved compared with the four-year rotation. Pea cropping was cost-efficient, although the seed was expensive and the costs of threshing were higher than for cereals. However, the following wheat was produced much more cheaply than when wheat followed wheat: a saving of 30 kg N fertiliser/ha, no extra treatments against grass weeds or special fungal diseases, and minimum tillage (without plough), amounting altogether to about €100/ha fewer variable costs.

In the German region it meant that on average, the lower proceeds of the pea rotation were more than compensated for by the saving on production costs.

In Barrois the cost savings were not so high, because winter peas are managed more intensively. For example three weed treatments and two fungicide and insecticide applications are usual, but costs of about €20/ha could be saved compared with the rotations with a high percentage of cereal.

When the more common three-year rotation of rapeseed–winter wheat–winter barley was compared with the diversified pea rotation, thereby reducing the percentage of cereals from 67% to 60%, the margin differences of the two rotations



OSR = oilseed rape, P = spring pea, W = winter wheat, wB = winter barley.

Components of the total output:
– Average yields and selling prices 2000–04 (OSR: 3.5 t/ha, €210/t; P: 3.8 t/ha, €123/t; W: 7.4 t/ha, €104/t; wB: 7.5 t/ha, €92/t).
– Coupled CAP payments from 2005 (€55.57/ha for protein crops).

Components of the variable costs:
– Seed, fertiliser, plant protection, hail insurance, grain drying, variable machine costs, calculatory interest.
– Crop management measures and prices for supplies according to crop season 2004.

Figure 2. Economic comparison of crop rotations in Saxony-Anhalt, Germany (CAP reform scenario 2005).

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were only minimal. The average annual margin for the pea rotation was €9/ha lower in Saxony-Anhalt and only €4/ha higher in Barrois than for the common three-year rotation.

Similar results were obtained when the same crop rotations were compared in Picardie (France) and the island Fyn (Denmark). Largely because of the high pea yield potential in these regions – an average of 5.2 t/ha in Picardie and 4.5 t/ha in Fyn for the period 2000–04, rotations with spring peas are competitive when compared with rotations dominated by cereals.

Spain: sustainable rotations with 17–25% grain legumes

In Spain the GL-Pro studies were in the more humid areas in the North (Navarra) and in the semi-arid areas of the Centre (Castilla y León).

In Navarra two scenarios were studied using the six-year standard rotation: *break crop*–winter wheat–winter barley–*break crop*–winter wheat–winter wheat:

a) on light soils with the break crops oilseed rape and peas (66% cereals) or oilseed rape and oats (83% cereals);
b) on deeper soils near the coast with the break crops sunflower and faba beans (66% cereals) and sunflower and oats (83% cereals), respectively.

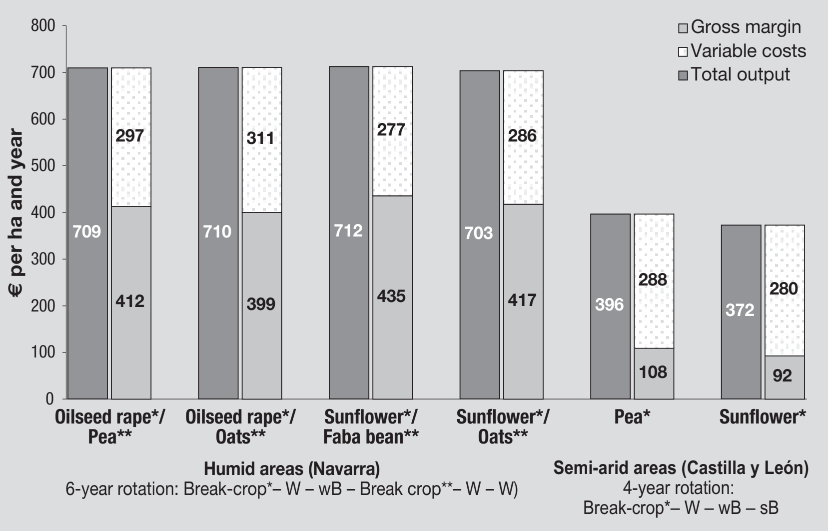
Replacing oats by peas or faba beans, thereby reducing the percentage of cereals by 17%, improved the gross margins of the rotations by €12–18/ha (3–4%) (Figure 3). Thanks to a higher yield increase of wheat after grain legumes (+16%) compared with wheat after oats (+8%) and the additional protein crops premium, more or less the same total output could be reached as with oilseeds.

Altogether up to 4% variable costs were saved although grain legumes lead to higher costs for plant protection than oats which are a relatively extensive crop.

In Castilla y León the first crop in the four-year rotation (sunflower–winter wheat–winter barley–spring barley) was replaced by pea. On average for the years 2000–04 peas yielded 1.2 t/ha and sunflower yielded 1.0 t/ha. The selling prices, however, were much higher for sunflowers (€228/t) than for peas (€169/t). Consequently pea growers had lower market proceeds averaged over the rotation.

However, according to Spanish experts and trial results (2), peas increase the yield of following wheat by about 0.6 t/ha, whereas sunflower has no effect on following wheat yield in this semi-arid zone. Taking into consideration the additional premium for protein crops, the total average output of the pea rotation exceeded that of the sunflower rotation by nearly 7% (Figure 3).

Even if the production costs were higher in the grain legume rotation, mainly because of the higher seed costs for pea, the pea rotation was highly competitive compared with the sunflower rotation: its average gross margin (€108/ha) was €16/ha (17%) higher.



OSR = oilseed rape, P = spring pea, SF = sunflower, FB = faba bean, W = winter wheat, wB = winter barley, sB = spring barley.

Components of the total output:
- Average yields and selling prices 2000–04:
  - Castilla y León: SF: 1.0 t/ha, €228/t; P: 1.2 t/ha, €169/t; W: 3.1 t/ha, €135/t; wB/sB: 2.8 t/ha, €123/t.
  - Navarra: OSR: 2.6 t/ha, €210/t; P: 2.5 t/ha, €156/t; Oats: 4.5 t/ha, €112/t; SF: 2.1 t/ha, €240/t; FB: 2.3 t/ha, €191/t; W: 5.1 t/ha, €134/t, wB: 4.9 t/ha, €120/t.
- Coupled CAP payments from 2006 (€15.75/t x reference yield + €55.57/ha for protein crops).

Components of the variable costs:
- Seed, fertiliser, plant protection, hail insurance, variable machine costs & contractor, calculatory interest.
- Crop management measures and prices for supplies according to crop season 2004.

Figure 3. Economic comparison of crop rotations with and without grain legumes in humid and semi-arid Spanish areas (CAP reform scenario 2006).

High subvention for oilseeds and grain legumes in Switzerland

In Switzerland farmers may only have 15% peas in the rotation. For the region of Canton Vaud, located in the western part of the country, an eight-year rotation was studied: two sequences of oilseed rape–winter wheat–grain maize (after a phacelia catch-crop)–winter wheat. High-yielding grain maize, yielding an average of 9.3 t/ha in 2000–04, was replaced by spring peas (3.7 t/ha) and soyabeans (3.2 t/ha), resulting in 14% lower average proceeds for the rotation (€2,058/ha). Although about 11% of the production costs were saved – mainly costs for grain drying of maize – these losses could not be compensated. The cultivation of grain legumes was profitable only when the area payments were taken into consideration. Then the margin of the grain legume rotation exceeded that of the maize rotation by €30/ha (2%).

Since 2002 farmers have received an area payment of €955/ha for grain legumes, which is the same as for rapeseed. For cereals and maize nothing is paid.

It must be stressed, that in Switzerland soyabeans are usually grown by contractors. The price is nearly 50% higher than for standard peas. Between 2000 and 2004 the average price for feed peas in Canton Vaud was about €310/t, and for soyabeans €462/t.

Insert 1

Common hypotheses for economic and environmental studies

In a twofold approach, the economic importance and the environmental impact of grain legumes were studied for cropping systems in Castilla y León (Central Spain), Barrois (France), Canton Vaud (Switzerland) and Saxony-Anhalt (Germany). The aim was to base the calculation of the rotation gross margins and the Life Cycle Assessment (LCA) on the same crop rotations. The data required for both approaches are largely congruent, even if the data for LCA are more extensive. Each measure needs to be defined in detail, for example, date, kind and amount of fertiliser or pesticide, the machines and equipment used, the number of field passages and the distance between different plots.

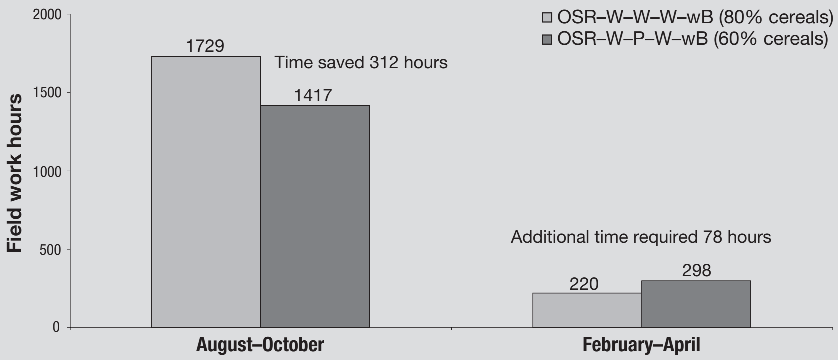
It was not possible to carry out surveys on farms to obtain the data required. Therefore cash crop farms representative of each region were described as examples. In brief, the analyses were based on the regional average yields and prices for the period 2000–04. Official statistics and market reports were the main sources to calculate the market proceeds of the crops in the rotations. The effects of the preceding crop were considered by taking into account results of rotational trials in conventional cropping systems.

To compile all input data (fertilisation, plant protection etc.) for a representative cropping year and according to up-to-date crop management recommendations, close collaboration with local extension services was necessary. Data collection, treatment and calculation were realised by a common tool based on Microsoft Excel.

To summarise: all the case studies show that in the short-term grain legume rotations can compete with the dominating cereal rotations in the regions. However, in addition to the rotation gross margin, labour requirements are important criteria for farmers choosing to grow grain legumes.

Better partitioning of farm labour

Cropping only winter rapeseed and winter cereals causes a labour peak in autumn (tillage, seedbed preparation and sowing of winter crops). To manage this peak, powerful and expensive mechanisation is required. That this work load can be reduced by integrating grain legumes into the rotation is shown in the following example from Saxony-Anhalt (Figure 4). When a 500-ha farm with an average plot size of 20 ha introduces spring peas into a five-year rotation of rapeseed–wheat–wheat–wheat–barley (resulting in rapeseed–wheat–pea–wheat– barley) more than 300 tractor hours can be saved between August and October. On the other hand only about 80 additional hours are required in the spring.



OSR = oilseed rape, P = spring pea, W = winter wheat, wB = winter barley
Source: KTBL machine data collection 2003/04.

Figure 4. Labour time required in spring and autumn (including harvest) depending on rotation on a 500-ha farm in Sachsen-Anhalt.

Machines and manpower can be used more efficiently, with the grain legume rotation allowing a greater acreage to be managed. Alternatively, the same acreage can be managed with reduced (cheaper) mechanisation.

Furthermore, it must be stressed that integrating grain legumes in the rotation allows a reduction in tillage. Minimum or non-tillage, saving labour and machine costs, may be realised also in cereal rich rotations. However, this can lead to increasing problems, for example, with straw management, grass weed regulation and certain diseases (3).

Insert 2

Methodology of economic analyses

The economic comparisons of regional crop rotations were based on one hectare. They were not implemented on the farm level, i.e. different crop or set-a-side ratios or changes in mechanisation due to restructured rotations were not taken into account. Only data on farm size and plot size were specified to determine appropriately the variable machine costs and the field working hours needed.

Total output and variable costs were taken into account to calculate the crop gross margins. Besides the market proceeds, coupled payments are part of the total output in the prospective scenario of the reform of the Common Agricultural Policy (CAP). The variable costs cover costs for seed, fertiliser, plant protection, hail insurance, grain drying, variable machine costs (maintenance, supplies) and contractor work. For a given rotation the average gross margin per hectare and year was calculated.

Grain legume rotations can be advantageous

To quantify the economic benefits of grain legumes, the entire crop rotation must be considered. The isolated comparison of crop gross margins does not reveal the monetary value of grain legumes for the following crop. Higher yields for the following crop, cost savings because of nitrogen fixation and for tillage due to improved soil structure, as well as a better management of the high demand for labour in early autumn are some of the advantages of grain legumes.

The model calculations of rotation gross margins demonstrate that diversifying tight cereal rotations with grain legumes does not cause a drop in farmers' income. On the contrary in most cases the grain legume rotation offers slightly higher gross margins than tight rotations with 75% or more cereals. At the same time the work load is managed better. ■

[1]Total output = average proceeds of selling the harvest (yield x price) + CAP payments (coupled); gross margin = total output – variable production costs (fertilisers, seed etc).

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SPECIAL REPORT
ECONOMICS & ENVIRONMENT

Environmental impact of grain legumes in regional crop rotations

Impacts environnementaux des rotations de cultures incluant les légumineuses à graines

by Thomas Nemecek and GL-Pro partners*

As shown in the previous paper (1) the introduction of a grain legume in a crop rotation does not reduce the gross margin of the rotation, and may even increase it slightly in some cases. Additionally, what are the consequences for the environment of introducing grain legumes in crop rotations? This question is dealt with in this article using life cycle assessment (see Insert). Comparing a grain legume with a non-legume crop reveals some advantages of the legume (2), but does not demonstrate all of its effects on the following crops in the rotation. The impact of farming systems on the environment needs to be analysed at the rotational level (3), especially for potential problems like nitrate leaching that occur mainly in the inter-crop periods.

The same crop rotations as those used for the economic analysis (1), assessed in four study regions (Table 1), were subjected to life cycle assessment (see Insert 1 on page 19). The environmental impacts were expressed in relation to a reference unit, the so-called functional unit, and in this study two functional units were used: cultivated area (hectare per year) as a measure of the land management function and gross energy (upper heating value) of harvested products (GJ) as a measure of the productive function. The presentation of the results follows the three management areas: resource management, nutrient management and pollutant management (according to (4)).

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Table 1. Overview of the crop rotations compared in the four study regions. GL = grain legumes, OSR = oilseed rape, W = winter wheat, wB = winter barley, sB = spring barley, P = spring pea, wP = winter pea, M = grain maize, SB = soyabean, SF = sunflower, (cc) = catch crop (*Phacelia*). The replaced crops are printed bold.

Region	Crop rotation 1 (without GL)	Crop rotation 2 (with GL)
Saxony-Anhalt (D)	OSR–W–**W**–W–wB	OSR–W–**P**–W–wB
Barrois (F)	OSR–W–W–wB	OSR–W–**wP**–W–wB
Canton Vaud (CH)	OSR–W–(cc)**M**–W- OSR–W–(cc)**M**–W	OSR–W–(cc)**P**–W- OSR–W–(cc)**SB**–W
Castilla y León (E)	**SF**–W–wB–sB	**P**–W–wB–sB

Lower energy demand

Including a grain legume in a crop rotation generally led to a substantially lower energy demand per cultivated area (Table 2). There are three reasons for this: a reduction in the quantity of N fertiliser (no N applied to grain legumes and less fertiliser required for the following crop (Figure 1), reduced tillage after pea in Saxony-Anhalt (Figure 1) and no energy demand for maize drying in Vaud (grain maize is replaced by a grain legume). As for the energy demand, the global warming potential and the ozone formation were also reduced in Saxony-Anhalt and Barrois, two regions with a high proportion of cereals.

Table 2. Environmental impacts per hectare times year (ha*year) for crop rotations without grain legumes (CR1) and crop rotations with grain legumes (CR2). The impacts of CR2 relative to CR1 are judged to be: ++ = very favourable, + = favourable, 0 = similar, - = unfavourable, -- = very unfavourable.

		Sachsen-Anhalt (D)			Barrois (F)			Vaud (CH)			Castilla y León (E)		
		CR1	CR2		CR1	CR2		CR1	CR2		CR1	CR2	
Resource management	Energy demand (MJ-equivalents)	24501	21066	++	22491	19921	++	31548	21856	++	10348	10749	0
Resource management	Global warming potential (kg CO_2-equivalents)	3762	3331	++	3974	3666	+	4003	3653	+	1920	2168	--
Resource management	Ozone formation (g C_2H_4-equivalents)	790	709	+	669	629	+	854	728	++	335	354	-
Nutrient management	Eutrophication (kg N-equivalents)	48.2	47.4	0	100.9	94.7	0	58.8	64.4	-	63.4	72.8	-
Nutrient management	Acidification (kg SO_2-equivalents)	21.4	17.7	+	44.4	36.3	+	20.4	17.5	+	9.4	9.8	0
Pollutant management	Terrestrial ecotoxicity (points)	50929	32293	++	11413	10603	0	731	862	-	387	401	0
Pollutant management	Aquatic ecotoxicity (points)	3846	3904	0	4701	4088	+	2708	2611	0	3332	2471	+
Pollutant management	Human toxicity (points)	747	636	+	990	856	+	1334	1261	0	328	342	0

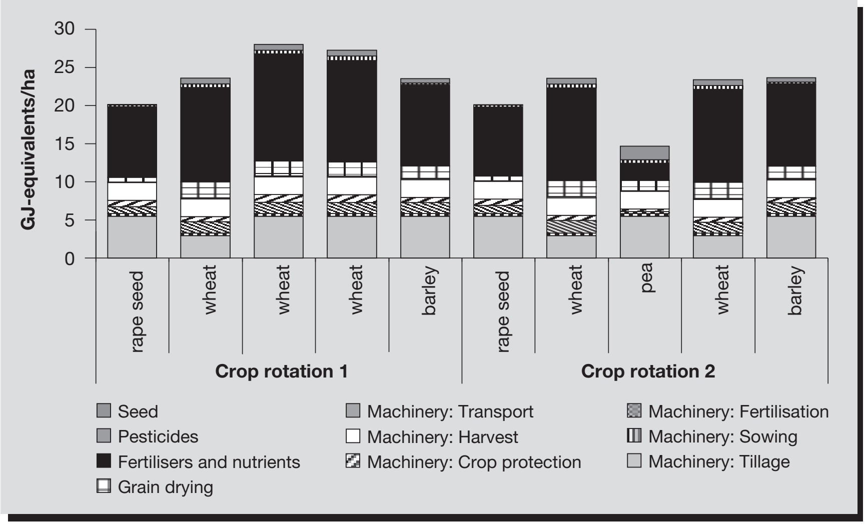

Figure 1. Demand for non-renewable energy resources for the two crop rotations in Saxony-Anhalt (D).

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Life cycle assessment

Life Cycle Assessment (LCA) is a management method used to quantify and evaluate the potential impacts on the environment of a product or process during its whole life cycle. The goal is to include all relevant impacts on the environment in order to detect shifts from one environmental problem to another. An analysis of the life cycle aims to include all steps from the extraction of the raw materials to the disposal or recycling of waste. The method is defined in the ISO standards 14040 to 14043. The SALCA method (Swiss Agricultural Life Cycle Assessment, as used in (4)) includes also methods to assess impacts on soil quality and biodiversity, in addition to the usual impact categories.

The crop rotation in Spain (Castilla y León) gave less favourable results compared with the other three rotations. This is because peas replaced sunflower in Spain (Table 1), whereas grain legumes were sown instead of wheat in Germany and France or grain maize in Switzerland. In Spain, sunflower is produced extensively as an unfertilised break crop with a low yield. Replacing an extensive crop by a grain legume did not have a favourable effect on the environment. The energy demand was slightly higher with pea, due to its high seed quantity.

Sometimes higher nitrate leaching

Although nitrate leaching is generally higher after pea, crop rotation 2 (CR2) did not always have a higher eutrophication potential (Table 2), since higher nitrate losses could be compensated for by lower ammonia volatilisation. Ammonia is also responsible for the acidification potential, which was generally lower for CR2, since the total N-fertilisation, the main source of ammonia emissions, was also lower. Although the level of nitrate leaching was estimated to be higher in Barrois compared with the other regions due to the higher rainfall, CR2 performed slightly better than CR1 for the eutrophication potential, since the winter pea has a lower risk of nitrate leaching than spring pea in Saxony-Anhalt. A catch crop was included before pea in the crop rotation in Saxony-Anhalt for a sensitivity analysis (results not shown). Instead of a 4% increase in nitrate leaching a reduction of 7% resulted. In Switzerland both crop rotations included catch crops grown before the crops sown in spring (maize, pea and soyabean). In this situation the crop rotation with grain legumes had a higher eutrophication potential, which is explained by a higher risk of nitrate leaching.

Advantageous pollutant management

In terms of pollutant management (ecotoxicity and human toxicity potentials), equal or lower impacts were observed for CR2 compared with CR1. For intensive crop rotations rich in cereals (Germany and France), more favourable results were obtained for CR2 because a break crop reduced the number of pesticide treatments required for the cereals. Only for the crop rotation in Switzerland was terrestrial ecotoxicity increased, because insecticide treatment was required for pea but not for maize. However, it should be noted that the terrestrial ecotoxicity potential is much lower in Vaud than in Saxony-Anhalt or Barrois. The results depended heavily on the choice of pesticide active ingredients.

No effect on soil quality and biodiversity

The potential impacts on soil quality and biodiversity were only assessed for Vaud. Soil quality indicators were not changed significantly by the inclusion of grain legumes, but the Swiss crop rotation is already quite diverse.

Table 3. Environmental impacts per GJ gross energy of the harvested products for crop rotations without grain legumes (CR1) and with grain legumes (CR2). The impacts of CR2 relative to CR1 are judged to be: ++ = very favourable, + = favourable, 0 = similar, - = unfavourable, -- = very unfavourable.

		Sachsen-Anhalt (D)			Barrois (F)			Vaud (CH)			Castilla y León (E)		
		CR1	CR2		CR1	CR2		CR1	CR2		CR1	CR2	
Resource management	Energy demand (MJ-equivalents)	227	210	+	233	217	+	294	251	++	256	268	-
	Global warming potential (kg CO_2-equivalents)	35	33	+	41	40	0	37	42	--	47	54	--
	Ozone formation (g C_2H_4-equivalents)	7.3	7.1	0	6.9	6.8	0	8.0	8.4	-	8.3	8.8	-
Nutrient management	Eutrophication (g N-equivalents)	446	471	0	1046	1030	0	547	740	--	1568	1817	-
	Acidification (g SO_2-equivalents)	199	176	+	460	395	+	190	201	0	232	244	0
Pollutant management	Terrestrial ecotoxicity (points)	472	321	++	118	115	0	7	10	--	10	10	0
	Aquatic ecotoxicity (points)	36	39	0	49	44	0	25	30	-	82	62	+
	Human toxicity (points)	6.9	6.3	0	10.3	9.3	0	12.4	14.5	-	8.1	8.5	0
	Gross energy production GJ/(ha*year)	108	101		97	92		107	87		40	40	

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Biodiversity was slightly higher for CR2 compared with CR1 (7.3 versus 7.1 biodiversity points) because maize was replaced by a grain legume. Maize had a particularly low biodiversity potential because of the application of unselective herbicides. Replacing another crop would not have had the same effect.

Less favourable results for the productive function

When the environmental impacts were evaluated in relation to the second chosen functional unit (gross energy of the harvested products in GJ as a measure of the productive function, Table 3), the results for CR2 relative to CR1 were less favourable than when the evaluation was done using cultivated area (a measure of the land management function) as the functional unit. This was because the energy production was lower with grain legumes than with wheat or grain maize. The difference in gross energy production was especially large in Switzerland, where the highly productive grain maize was replaced in the rotation by pea. Despite the lower energy production with grain legumes, the energy efficiency (energy demand per GJ produced) is better with the exception of Spain.

Positive effects in intensive rotations

From these four case studies in Germany, France, Switzerland and Spain it can be concluded that the introduction of grain legumes in intensive crop rotations with a high proportion of cereals and intensive N-fertilisation is likely to reduce energy use, global warming potential, ozone formation and acidification as well as eco- and human toxicity per unit of cultivated area. Nitrate leaching tends to be higher in general, but can in many cases be reduced by including catch crops or sowing winter grain legumes, where possible. No differences were found for soil quality and biodiversity. In low-input crop rotations like the one in Spain, no significant changes in environmental impacts are to be expected. Due to the lower yields of grain legumes compared with cereals, the advantages of grain legumes are smaller when considered per GJ gross energy of the harvested products.

Therefore introducing grain legumes in European crop rotations offers interesting options to reduce environmental burdens, especially in a context of depleted fossil energy resources. ■

This research was supported by the European Commission (grant no QLK5-CT-2002-02418) and by the Swiss State Secretariat for Education and Research.

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Grain legumes are shown to contribute to a sustainable and environment-friendly European agriculture

by Julia-Sophie von Richthofen, Hubert Pahl and Thomas Nemecek

The preceding value of grain legumes is well known by European farmers. This was demonstrated more clearly by a survey of more than 500 grain legume non-producers carried out within the scope of the Concerted Action GL-Pro (European extension network for the development of grain legume production in the EU, QLK-CT-2002-02418). Farmers consider grain legumes to be good break crops, resulting in an increase in the yield of the following crop. However, this contribution to the profitability of the following crop is not credited to the grain legume crop's account. Grain legumes are therefore often seen as less profitable compared with arable crops like oilseed rape or wheat, because farmers make cropping decisions using the crop gross margin or even the crop proceeds.

However, from an economic viewpoint the numerous preceding effects of grain legumes can only be assessed correctly, when the whole rotation is taken into account. Case studies to calculate the average gross margins per hectare and per year of rotations with and without grain legumes were made in regions of France, Germany, Spain and Switzerland. The results show that diversified rotations with grain legumes compare well with tight cereal rotations. If grain legumes are integrated in cropping systems with 75% and more cereals, the rotation margin is actually increased. In addition the work-load in early autumn can be reduced.

Furthermore, the environmental consequences of diversifying rotations with grain legumes were studied by means of Life Cycle Assessment. In intensive cropping systems, with a high proportion of cereals and high N-fertiliser input, the incorporation of grain legumes has especially beneficial effects on the environment. The use of fossil energy resources is reduced and so is the emission of greenhouse gases. In addition, ammonia volatilisation causing acidification is lower in grain legume rotations. These benefits result primarily from the lower level of industrial N-fertiliser use because of the symbiotic fixation of atmospheric nitrogen by the grain legume crop. The risk of nitrate leaching, however, is often increased by the inclusion of a grain legume crop. It can be reduced by efficient catch-crop management, inter-cropping or sowing winter grain legumes, where possible.

With respect to pollutant management, introducing grain legumes in the crop rotation contributes to lower eco and human toxicity. Less herbicides and fungicides are used because grass weed infestation and certain diseases in cereal-rich rotations are reduced by the break-crop effect of grain legumes.

Economic and environmental results are largely congruent: introducing grain legumes in intensive crop rotations with a high proportion of cereals leads to a slightly higher gross margin and simultaneously to more favourable effects on the environment. ■

Cultivar registration in Europe: grain legume breeders and breeding programmes

Inscription variétale en Europe: obtenteurs et programmes de sélection de légumineuses à graines

by Gaëtan DUBOIS* and Frédéric MUEL** on behalf of GL-Pro partners and associated experts***

The common catalogue of varieties of agricultural plant species is put together from the national lists of varieties produced by national authorities in EU Member States. Although varieties registered in the common catalogue can be marketed and used within the EU, it is still difficult for farmers and experts to find data on varieties registered in other EU countries.

DUS and VCU

In order to establish their national list, Member States have to verify that each added variety is *distinct* from the others, *uniform* in its characteristics and *stable* in the long term (DUS). DUS tests have a minimum duration of two vegetation cycles and have been harmonised at the European level with the Community Plant Variety Office, but they are still implemented through the national offices.

In addition to basic characteristics, arable crop varieties must also have satisfactory *value* for *cultivation* and *use* (VCU). The VCU trials are also implemented by the official organisations over two vegetation cycles. In order to be added to the national list a variety has to show a clear improvement either in its cultivation or in the quality of its products, compared with other already registered varieties when cultivated in a determined region. The procedures and the defined agronomic and technological characteristics used in these VCU trials are still very variable at the EU level.

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***Overview compiled within the scope of the concerted action GL-Pro (QLK5-CT-2002-02418: European extension network for the development of grain legumes production in the EU) with the collaboration of the official partners of the project and associate experts: www.grainlegumes.com/gl-pro/

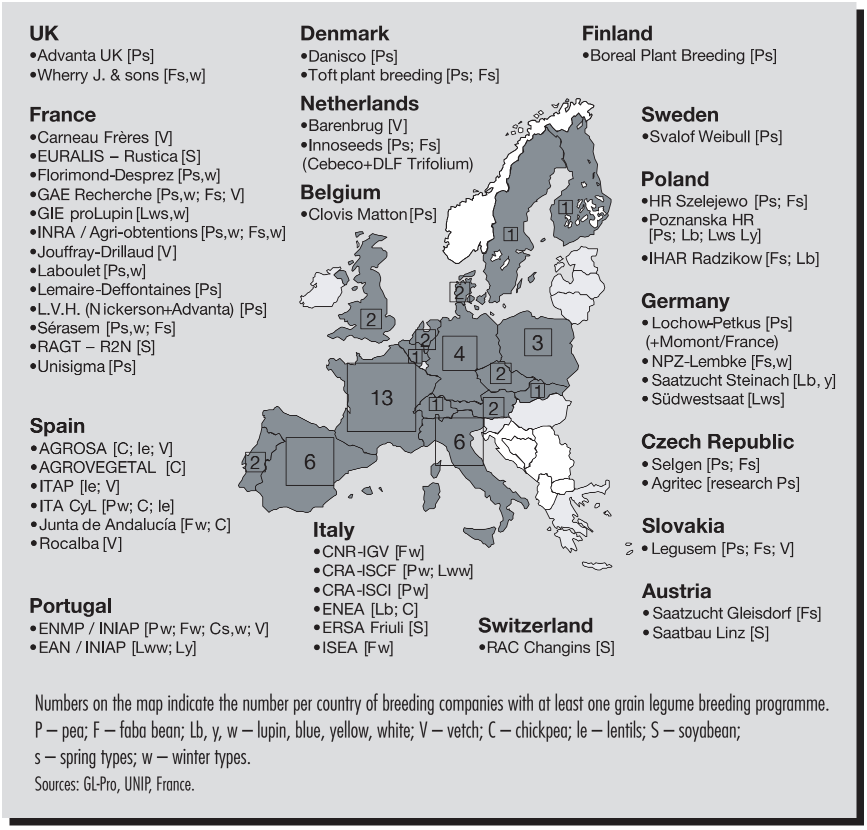


Figure 1. Grain legume breeders and programmes in European countries.

Pea, faba beans, lupins

Within the framework of the GL-Pro project, European data on grain legumes have been gathered in one database that will soon be available on the www.grainlegumes.com/gl-pro/ website. Here the focus will be on the protein crops (pea, faba bean and lupins) since chickpeas and lentils are not in the common catalogue and neither are vetches and soyabeans. The data in Table 1 show the numbers of new varieties registered each year. They were defined through the common EU catalogue with additional data from the national lists.

Between 25 and 30 new varieties of peas, mainly spring peas, are registered each year at the European level. For faba beans and lupins the number of new registrations averaged about 5.5 and 7 varieties per year respectively in 2000–05. It is worth noticing the close relationship between the number of new registrations and the area of cultivation and importance of a crop in a particular country. For example in France, the main pea grower in the EU (40% of the area), the number of new pea registrations is highest with about 10 new varieties each year. The same happens in

New registration per year in the EU

	Mean 2000–05	2006 (provisional)
Pea	27	23
Faba bean	5.5	5
Lupins	7	0
TOTAL	40	28

New registrations per year in France

	Mean 2000–05	2006 (provisional)
Pea	10	12
Faba bean	1.8	2
Lupins	1.7	0
TOTAL	13.5	14

New registrations per year in Germany

	Mean 2000–05	2006 (provisional)
Pea	2.3	5
Faba bean	1	2
Lupins	2.2	0
TOTAL	5.5	7

New registrations per year in the UK

	Mean 2000–05	2006 (provisional)
Pea	7.8	7
Faba bean	2.2	1
Lupins	0.8	0
TOTAL	10.8	8

Sources: GL-Pro/Common and national catalogues.

Table 1. Number of new registered varieties per year in the EU, France, Germany and the UK.

the UK for faba beans and in Germany for lupins, the main growers of those respective crops.

Concerning species and types, it is interesting to notice that registrations of faba beans and winter peas, almost non-existent around 2000 have grown to 2–3 varieties per year in recent years in France. Lupin registrations in Germany are mainly narrow-leaved or blue lupin but in France they are mainly white lupin.

Breeders and breeding programmes

Figure 1 shows the different identified European breeders with their respective grain legume breeding programmes.

Of the 186 varieties of pea registered since 2000, 27 have been registered by the group Innoseeds/Cebeco + DLF Trifolium whose cultivars occupy 20% of the areas entered for certified seed production for the three years 2003–05. These multiplying areas [m.a.] are indicators of seed production and market share. These three years of data are based on the official data from five European countries whose cumulative m.a. represent more than 80% of the EU m.a. (Czech Republic/UKZUZ, Denmark/DAAS, France/GNIS, Germany/BSA, UK/DEFRA). The breeder Sérasem with 10 registrations since 2000 represents around 15% of pea m.a. The cultivars of the L.V.H. group (Advanta-Nickerson) and Selgen occupy about 10% of the pea m.a. each. Then come the companies Toft, Lochow-Petkus, Florimond-Desprez and GAE Recherche with 6–7% of the m.a. and finally Danisco and Clovis-Matton, with close to 5% and more than 3%, respectively.

With close to 40 new varieties of faba bean registered since 2000, NPZ-Lembke has registered 10 and their varieties cover about 30% of the faba bean m.a. Another main faba bean breeder is J. Wherry & sons/PBI with 25% of the m.a. for the period 2003–05, followed by Innoseeds with 11%, Selgen with 7.5%, Sérasem and INRA with 6% each and Gleisdorf with close to 5% of area entered for certified seed production.

Lupin breeding is more concentrated, Steinach and INRA have each registered about 1/5 of the 42 varieties since 2000. Steinach is the main narrow-leaved or blue lupin breeder with 87% of their m.a., followed by Poznan HR, Nordseed, HR Smolice and Dr. Späth/Südwestsaat. For the m.a. of white lupins, which represents less than 20% of that for blue lupins, INRA and E. von Baer/Florimond Desprez have respectively 45% and 35% followed by the GIE proLupin and Südwestsaat. ■

NEWS

Australian harvest

The 2005/06 harvest is likely to be better than forecasted because of higher yields following welcome rains in some regions in September and October 2005. For five years, Australian production has been erratic with record production in 2001/02 and 2005/06 and poor results in 2002/03 and 2004/05.

Source: UNIP, France.

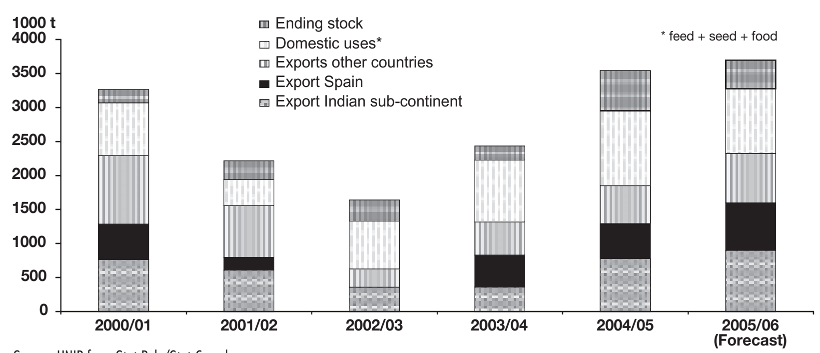
2005/2006 (winter crops excluding vetches and *Phaseolus* or *Vigna* beans)	Areas (ha)	Production (t)
Lupin	754,000	1,075,000
Pea	280,000	438,000
Faba bean	183,000	329,000
Lentil	113,000	185,000
Chickpea	98,000	116,000
Total	1,428,000	2,143,000

Source: UNIP, France; ABARE, Australia.

Uses of Canadian peas

After three years of poor yields in 2001, 2002 and 2003, Canadian production of peas reached a peak in 2004 (3.34 Mt) and maintained a good level in 2005 (3.10 Mt), leading to a resumption in exports (Figure 1). The exports of yellow peas to the Indian sub-continent for human consumption increased strongly, as did the exports to Spain, the major European importer of peas for animal feed: 600,000 t and 530,000 t in August 2005 and January 2006, respectively. China is also an expanding market (190,000 t during the same period). Green peas are exported mainly to Latin America. At the same time, Canadian home consumption of peas is increasing mainly for feeding fattening pigs.

Figure 1. Trends in the different uses of Canadian peas.



Source: UNIP from Stat Pub/Stat Canada.

Genome specific packages for pulses in Australia

Des conduites de culture spécifiques au génotype pour les légumineuses à graines en Australie

by David L. McNeil*, Jason Brand, Michael Materne and Ben Jones

Pulses offer a substantial opportunity for expansion and improvement of grains industry sustainability and productivity in Australia. This will occur both through the high value of pulses in their own right and their rotational benefits. October 2005 estimates by Pulse Australia (7) indicated planted areas of 699,000 ha for peas, chickpeas, lupins and faba beans with a further 755,000 ha of lupins. Estimated yields are 995,000 and 952,000 tonnes respectively. These figures represent about 8% of the average production figures of 18,000,000 ha and 25,000,000 tonnes for winter cereals.

Enhancements in agronomy and variety development have led to increased yields for Australian pulses. Table 1 below indicates the benefits that have occurred as a result of breeding new peas for the Australian climate. Estimates for yield benefits of agronomy changes on national pulse yields are difficult to find. For cereals in Australia increases of about 1% per year have been claimed (4). However, while the value of management improvements is unclear what is clear is that pulse agronomy has changed over the last 20 years (1). These shifts in agronomy could only be in response to benefits arising. Most shifts have been as a consequence of the needs of the pulse crop. Examples of this include later planting of peas to avoid ascochyta blight (*Ascochyta rabei*) and the use of new herbicides and new weed management techniques, such as wick wiping[1] and crop topping, to control problematic and herbicide resistant weeds. Other new agronomic practices include rolling of paddocks post sowing to enable easier harvesting of short lentil and field pea crops, and the use of specially formulated fertilisers to meet the specific nutritional needs of pulses. Agronomic changes have also occurred in the total farming system, for example, the use of minimum or no tillage practices in combination with increased stubble retention. These provide ongoing challenges for pulse production, which will be met through development of new varieties and management techniques.

Further progress in increasing pulse yields in Australia is likely to require increased concurrent development of genetics and agronomy. In this concurrent development paradigm for pulses (which are frequently used as rotation crops in Australia) the agronomy must take into account both the individual crop requirements and the agronomic needs of the cropping system. In reality this approach is an attempt to maximise an additional component (grower intervention or management) of the genotype by environment interaction by simultaneously developing the genotype and the environment in tandem.

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Variety specific agronomy

Pulse varieties vary significantly in their response to changes in agronomic management. For example, the lentil variety Northfield is more sensitive to the herbicide Brodal® than other varieties; the field pea variety Kaspa requires 10%–20% higher seeding rates to achieve optimum grain yields compared with older commonly grown varieties. In addition, the new Genesis varieties of chickpeas with their improved levels of ascochyta blight resistance require significantly fewer fungicide sprays. Thus, Jason Brand is leading a national project (Grains Research and Development Corporation, Pulse Australia, Victorian Department of Primary Industries, NSW Department of Primary Industries, South Australian Research and Development Institute) which is developing and delivering variety specific management packages. These packages contain the type of information outlined above to optimise grain yield and quality benefits of new varieties in a range of environments. The research concentrates on agronomic management aspects of new varieties for which we have limited knowledge. For example, the faba bean variety Nura has improved resistance to chocolate spot (*Botrytis fabae*) and rust (*Uromyces vicia-fabae*) but resistance to ascochyta blight (*Ascochyta fabae)* similar to Farah and no resistance to cercospora (*Cercospora zonata*). However, growers have limited specific information on fungicide management regimes required to control disease in this variety. Growers have asked the question: Can we reduce the number of sprays applied and, if so, which sprays do we remove? Alternatively, is this just a lower risk variety to grow under our current fungicide management regimes?

To maximise efficiencies and minimise time to release of the management package, research runs in parallel with the last stage of breeding, commercialisation of varieties. This provides a minimum of two to three years of data prior to large-scale availability of seed to growers. The major aim of the variety specific management packages

Table 1. Effect of year of release on mean yields of peas[1] grown in trials in South Australian and Victorian variety yield evaluation trials.

Commodity	Time period of release years	% increase	% increase per annum	Number of releases
Dun pea[2]	1970–1992	0	0	3
	1992–2002	18	1.8	6
White pea	1992–2003	11	1.0	7
Blue pea	1993–2001	8	1.0	3
Wheat[3]	1870–2000		0.9	

[1] The names refer to the cotyledon colour. Dun peas are a dull greyish brown to brownish grey colour with more tannins and a sharpish taste. They are Australia's main export pea for human consumption on the Indian subcontinent. White peas are white to yellow in cotyledon colour and used principally for stock feed in Australia though worldwide they are a major dried pea for stock and human use. Green or blue peas are frequently used for feed as well as canning and freezing.

[2] Data collated from the Australian Coordinated Field Pea Improvement Program yield trials.

[3] Data from (4).

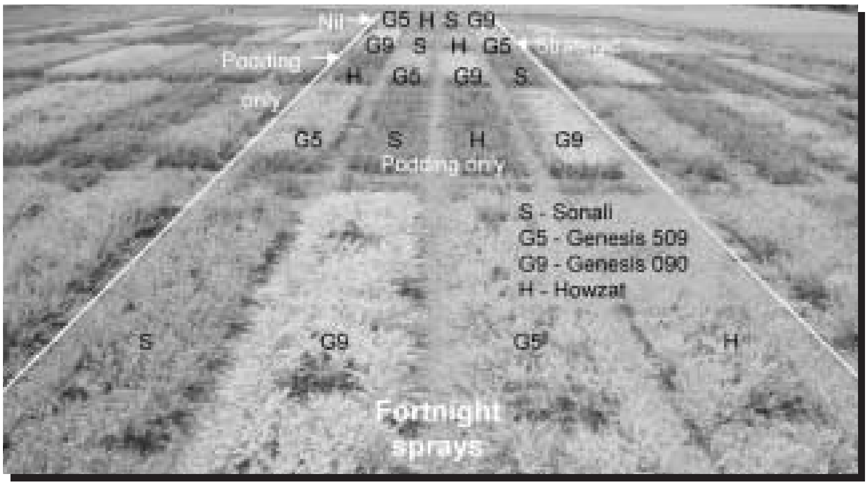
produced is to optimise the yield potential and stability of new varieties (approximately 5%–10% increase in profitability) and minimise major yield and quality losses, such as could occur with herbicide intolerance or poor disease control (Figure 1).

Germplasm specific agronomy

Development of variety specific packages involves interaction of breeders and agronomists late in the breeding cycle. However, substantial benefits may also occur from much earlier collaborations during germplasm development phases of breeding. Two major opportunities exist, and are being taken up, for this collaboration. Firstly when new agronomy systems become plausible development is needed of lines for screening that are optimally matched to the new agronomy. Secondly when new genes become available (for example, altered boron membrane transporters) providing possible improvements in traits of interest (either through GM, non-GM biotechnology or traditional selection approaches) their specific interactions with the environment, environmental requirements for desired trait expression and opportunities for agronomic application need elucidation. Examples of developments for both of these opportunities are provided below for present interactions between pulse agronomy and breeding programmes in southern Australia.

1. Breeding of lines for variable agronomic systems

In the Mallee region of Victoria research on cereals has indicated that 2-cm precision agriculture can allow placement of rows relative to the previous season's rows and consequently this may assist with direct stubble planting (3). To maximise the benefits of standing stubble and guidance systems, wider rows are commonly used. Advanced varieties of different species exhibit marked differences in their response to wide row spacing and stubble retention. Some drastically reduce yield whereas others are virtually unaffected. In South Australian lentil growing areas tall, herbicide resistant or difficult to control broadleaf weeds are presently being controlled in rotation systems by wick wiping over the top of the lentil crop. The need in this situation is for a lentil crop with a dense, even canopy. Breeding and agronomic screening for these characteristics needs to be part of the variety development programme to maximise the incorporation of beneficial genes in these



(Photo J. Brand, VDPI, Horsham, Australia)

Beulah Research Site (Victoria, Australia) 2005, showing four chickpea variety releases with differential maturity and responses to ascochyta blight and thus requiring variety specific disease management. Note the later maturity and low plant numbers for Sonali and Howzat with less than total disease control.

circumstances. If lines are tested only after final variety release, opportunities will be lost.

2. Development of agronomy for new hostile soil tolerance genes

Boron and salinity tolerances (5, 6) have now been located among lentils, peas and chickpeas. Lines carrying these tolerances have been included as germplasm parents in the Australian National Pulse Breeding Program. However, agronomic specification of the potential benefits and real world situations where these benefits may be achieved are now needed for these genes. Do they carry adverse consequences either by linkage or pleiotropic effects in non-hostile soils? Can they give benefits to subsequent crops and environment through increased soil dewatering? Can they give yield increases if used individually or are they only economically beneficial when combined? Development of answers to these questions is proceeding via on-going collaboration between those working in early stage breeding and those working on agronomic optimisation of the early lines prior to varietal development.

It is clear that to benefit from 'genome specific agronomy' approaches require the concurrent input of agronomy and breeding research in collaboration with extension and farming systems experts to ensure maximal development for 'real world' situations. The concept is not new (for example, dwarfing genes led to wheats benefiting from high N applications; North American maize breeding benefits have arisen from ability to capture gains in increasing maize populations (2). What is new is that scientific advancements are leading to the more rapid discovery of new genes, and new agronomic and breeding technologies. These offer many previously unavailable opportunities for synergistic developments. However, it is also clear that with the introduction of specialised breeding businesses and more molecular breeding approaches there are risks of disassociating breeding and agronomy programmes. A challenge therefore exists to capture the benefits of genome specific agronomic approaches. Pulse breeders and agronomists in southern Australia are currently embracing this challenge. ■

[1]A long strip of material (e.g. a rope wick) continuously wetted with non-specific herbicide (e.g. glyphosate) and supported by a bar is passed over the crop (e.g. short dense lentil crop) above the crop height but below the weed height to kill all weeds taller than the crop.

(1) Brand, J. D. *et al.* (2001). In: Proc. 10th Australian Agronomy Conference, Hobart, Tasmania, 29 Jan.–1 Feb. 2001. Available online at: www.regional.org.au/au/asa/2001/

(2) Duvick, D. N. and Cassman, K. G. (1999). Crop Science **39**, 1630–1635.

(3) Jones, B. and O'Halloran, N. (2006). In: Farming the Mallee with GPS Guidance, Chapter 1, 5–35. Department of Primary Industries Victoria, Australia.

(4) Hamblin, J. (2000). GRDC Ground Cover **31**, 23.

(5) Hobson, K. B. *et al.* (2004). In: Proc. 4th International Crop Science Congress, Brisbane Australia, 26 Sep.–1 Oct. 2004 (Eds T. Fischer *et al.*). Available online at: www.cropscience.org.au

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(7) Slatter, J. *et al.* (2005). Pulse Market Overview October 2005. Pulse Australia.

GRAIN LEGUMES

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Le magazine de l'Association Européenne de Recherche sur les Protéagineux

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COVER PHOTO:
Photocomposition of a field pea at the emergence stage, pea flowers, legume nodules, a mixture of legume grains, and white lupin flowers
(Photos: UNIP, France)

PHOTO DE COUVERTURE :
Montage photographique d'un champ de pois à la levée, fleurs de pois, nodules de légumineuses, mélange de graines de légumineuses, et fleurs de lupin blanc
(Photos: UNIP, France)

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Integrated activities in the European Grain Legumes Project

Dossier

Vers l'intégration des résultats dans le projet européen GLIP

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The AEP is an associative network of persons with interests in grain legume research (peas, faba beans, lupins, chickpeas, lentils, dry beans, etc.) to favour the exchange of information and multidisciplinary collaborations (Conferences, publications, workshops, joint projects). It aims both to strengthen the research works and to enhance the application of research into the integrated chain of grain legumes.

UNIP

French Interprofessional Organisation of Protein Crops

Union Nationale Interprofessionnelle des plantes riches en Protéines

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The UNIP is the representative organisation of all the French professional branches of the economic integrated chain of grain legumes. It provides information about pulse production, utilisation, and the market and it coordinates research works related to grain legumes in France, especially peas, faba beans and lupins for animal feeding.

Processors and Growers Research Organisation

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The PGRO provides technical support for producers and users of all types of peas and beans. Advice is based on data from trials sited from Scotland to the South West of England and passed to growers and processors through technical bulletins and articles in the farming press.

APPO

Belgian Association for Oilseeds and Protein Crops

Association pour la promotion des protéagineux et des oléagineux

Faculté universitaire des sciences agronomiques
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The APPO is the representative organisation of Belgian growers of oilseeds and protein crops, especially rapeseed, peas and faba beans. The main tasks are experimentation, giving advice to producers, providing technical and economic information through meetings and mailings and encouraging non-food uses of vegetable oil.

Technical Institute for Cereals and Forage

Arvalis – Institut du végétal

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Run and financed by French farmers, Arvalis-Institut du végétal carries out and disseminates applied research on the production, storage and utilisation of cereals, grain legumes, potatoes, and forage.

UFOP

Union zu Förderung von Oel- und Proteinpflanzen

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UFOP is the representative organisation for German producers of oil and protein crops. It encourages professional communication, supports the dissemination of technical information on these crops and also supports research programmes to improve their production and use.

CRA-W

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A broad research topic of the Animal Production and Nutrition Department deals with the utilisation of lupin and pea seeds in animal feeding (ruminant, monogastric and poultry) in terms of nutritional value, environmental benefits, protein utilisation and economic aspects. The research is also concerned with the development of legume silages, seed treatments prior to feeding and seed processing for non-food uses.

Pulse Canada

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Pulse Canada is a national industry association. This organisation represents provincial pulse grower groups from Alberta, Saskatchewan, Manitoba, Ontario and the pulse trade from across Canada who are members of the Canadian Special Crops Association. Pulse crops include peas, lentils, beans and chickpeas.

To be added to this sponsorship list, do not hesitate to contact the AEP Office.