GRAIN LEGUMES

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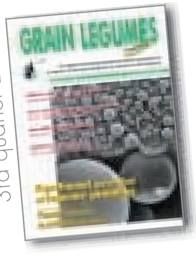

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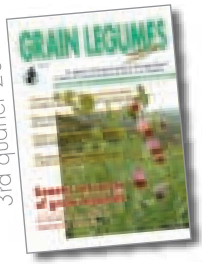

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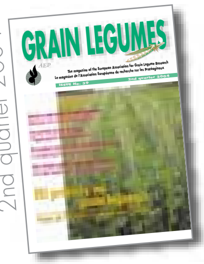

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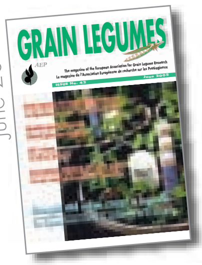

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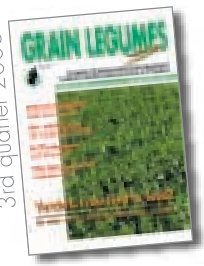

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Publishing Director/ ***Directeur de la publication***:
Álvaro Ramos Monreal
(Consejeria de Agricultura Ganadería, Spain)

Managing Editor/*Rédacteur en chef:*
Anne Schneider (AEP, FR)
Email: a.schneider-aep@prolea.com

Editorial Secretary/*Secrétaire de rédaction:*
Jill Craig (AEP, UK)
Email: jill.craig@zeronet.co.uk

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Carte blanche to...

Pierre Cuypers*

Available markets should be supplied – we need to encourage farmers to enlarge areas

In the past three years, grain legume areas in France have decreased significantly: 2007 areas are 50% less for peas and 30% less for faba beans compared with 2004 areas. In contrast to peas whose yield also decreased, faba beans benefited from a quite valuable average yield this 2007 harvest.

There has been a general trend in recent seasons for enhanced damage to arable crops caused by adverse climatic conditions during the crop cycle. However the decrease in grain legume area in France and in other EU countries is especially alarming for farming systems.

Indeed, as highlighted by Mr Christophe Terrain, President of Arvalis[1] at a French press conference this summer, it is vital to manage cropping decisions at the rotation level, and grain legumes bring a clear benefit in rotations. The Arvalis Acting Director, Gérard Morice pointed out that they enhance the yield of the following cereal by 0.7 to 1 t/ha, and have costs €50 to €70 lower than a wheat or oil crop.

We need to respect the cycle of crops on one field, by avoiding the return of similar crops too soon, and maintaining the diversity of cultivated species.

On the market side, UNIP was frustrated to see that there was a low offer of faba beans and peas for the attractive export outlets which have reached very high prices this commercial campaign!

Grain legumes compete indirectly with some other crops that benefit from a more positive image and from lucrative contracts, but we also identified some logistical difficulties at collection, storage and market levels that are linked to minor volumes. That is why we believe in demonstrating actions towards farmers and farmers' unions and in innovative partnerships at regional levels to reinforce stability of the crop chain from the grower to the market users.

In addition, we believe in collaboration with scientists to achieve genetic enhancement or agronomic solutions to overcome diseases and pests or soil and climatic variations, while maintaining high seed quality.

Grain legumes have benefits especially at agronomic and environmental levels, so we need to be creative to make them economically valuable! ■

*UNIP President, Paris, France.
(unip@prolea.com)

[1] The technical institute for cereals and several other crops in France.

Changes and challenges for AEP

Since autumn 2006, there have been some changes at AEP headquarters.

A lighter structure for AEP in Paris

One of AEP's main sponsors, UNIP, which hosts the AEP headquarters, has experienced difficulties associated with the strong decline in grain legume areas in recent years in France (as in other EU countries). UNIP has always supported AEP activities at financial and political levels and appreciates the successful networking and dissemination efforts that have been carried out by AEP in the past years. However, with the new situation, UNIP cannot continue to support AEP without reductions in the activities and finances that go through the AEP office in Paris hosted by UNIP. The consequence is that the Paris headquarters of AEP now have a lighter structure with only one half-time person and no more secretarial assistance.

In fact, UNIP proposes to take a greater part in AEP activities and decisions while ensuring the balance of AEP budgets. AEP has always wished to involve more representatives from the industry sector. It is expected that this involvement will be followed by similar involvement of other market-related organisations or economic partners.

Therefore today the AEP network needs to find the best way (i) to operate with a lighter permanent structure for its day-to-day running as well as (ii) to meet the needs and demands of all the different types of members within AEP.

New challenges for AEP after 15 years of successful development

Up to now AEP's priority has been to establish an active network in the legume scientific community, and AEP has been successful in raising interest and funds for legume research at EU and international levels.

Now a new challenge is to develop additional activities of greater interest to economic players who face short and medium term problems associated with the production and use of grain legumes; this means, identifying the technical issues to translate into questions for research for the short and medium terms, but also to prepare long term for the agriculture of the future.

At the same time, the activities of interest to scientists themselves should be maintained in AEP and the Executive Secretariat should find a new way to function with smaller resources. This should be discussed with any interested parties who wish to sustain such an informal and neutral platform for collaboration, a joint voice and the easiest dissemination of information. The joint activities will also be facilitated by the communication tools that have been developed by AEP in the recent years (web site, event cycles, GL magazine, etc).

Therefore facing the positive trends in R&D activities, the future AEP mandate will be an exciting and challenging period for legume enthusiasts!

Join AEP and apply for candidature to the Scientific Committee to contribute to these challenges, facilitated by the previous efforts and success. ■

Source: The AEP Executive Committee.

Lisbon-2007 – Integrating legume biology for sustainable agriculture – a coming milestone for legumes

We are delighted to announce that our Lisbon-event to be held from 12 to 16 November 2007 has received the patronage of Mr José Manuel Barroso, President of the European Commission.

Mr Timothy Hall, the Acting Director of Biotechnologies, Agriculture and Food of the European Commission Directorate-General for Research will officially open the conference and the Portuguese Minister of Agriculture and Rural Development, Jaime Silva, will give a welcome address on behalf of the Portuguese Government.

This event, the 6th European Conference on Grain Legumes features the final dissemination event of the EU FP6 Grain Legumes Integrated Project and promises to be a truly stimulating, scientifically rewarding and sociably enjoyable experience for the 400 participants.

The programme is composed of plenary sessions, workshops and poster displays, with presentations given by invited speakers and experts from a wide range of different fields, as well as plenty of opportunity for discussions.

This milestone will be the occasion to assess progress in grain legume research and to prepare future collaborative work on legumes.

More up-to-date information about the programme is available at: http://www.grainlegumes.com/index.php/aep/events/lisbon_2007/welcome_to_lisbon_2007 ■

First GL-TTP workshop in April 2007

The Grain Legumes Transfer Platform organised an exciting workshop entitled 'Targeting Science to Real Needs" which attracted 63 participants from 17 countries (five continents) to gather in Paris on 23–25 April 2007.

Reflecting the needs of grain legume breeders, the workshop focused on the exploitation of genetic resources, and on the concrete use and integration of molecular technologies in breeding. The main themes addressed were genetic diversity, disease resistance, abiotic stress tolerance and quality traits.

As a follow-up to the event, GL-TTP is currently working with GL-TTP members to complete the transfer of information and ready-to-use material presented at the workshop.

Finally, GL-TTP is building on the ideas that resulted from the brainstorming across professional sectors to set up Research & Development and Technology Transfer projects in partnership with research scientists and plant breeders.

More information at http://www.gl-ttp.com

5th Phaseomics meeting in Varenna, Italy, May 2007

The 5th Phaseomics meeting was held in the beautiful setting of Villa Monasteria, Varenna, Lake Como, Italy. 'Phaseomics' is a worldwide network of committed scientists that have ongoing research on beans. For more details visit www.phaseolus.net.

The highlights of the meeting were very diverse. There were sessions ranging from seed quality, to evolutionary genetics, genomics, genetic tools and resources, biotic and abiotic stresses, as well as the interaction with beneficial organisms. Abstracts from the meeting, and interesting links can be found at www.phaseomicsv.net.

(Photo F. Sparvoli, IBBA-CNR, Milan, Italy)

Of particular interest were talks from Matthew Blair (CIAT, Cali, Colombia) describing work on the use of wild accessions to improve common bean varieties (1). This follows a trend set by work on rice (2) that uses wild accessions to improve crops. Despite plant breeders' initial reluctance, the data shows clearly that this is a process that also 'yields' in grain legumes!

Other interesting talks covered the food and feed qualities of bean (Francesca Sparvoli and Bruno Campion, Milano, Italy). They have developed and are now evaluating mutants with low phytic acid contents as well as beans that are lectin-free. Both could help improve the digestibility of beans. Nutritional work is in progress to verify this hypothesis.

As for genomics tools, a TILLING population in the variety BAT93 is being set up by collaboration between three teams (CIAT, University Geneva and USDA/ARS/TARS Puerto Rico). Part of the bean genome will be sequenced and different groups have contributed to the growing number of bean ESTs in Genbank.

In general the meeting was very successful, and the feeling was that the future for beans, as the most important food legume, looks very positive. ■

Source: Francesca Sparvoli (sparvoli@ibba.cnr.it), Nancy Terryn (nater@psb.ugent.be) and William Broughton (william.broughton@bioveg.unige.ch)

(1) Blair, M. W. *et al.* (2006). Theoretical Applied Genetics **112**, 1149–1163.

(2) McCouch, S. R. *et al* (2007). Euphytica **154** (3), 317–339.

Towards sustainability: eleventh Serbian forage crops symposium

The eleventh symposium on forage crops of the Republic of Serbia was held from 30 May to 1 June 2007 at the Faculty of Agriculture in Novi Sad under the auspices of the Serbian Ministries of Science and of Agriculture, Forestry and Water Management. The symposium was organised by the Forage Crops Society of Serbia, the Institute of Field and Vegetable Crops (IFVCNS) in Novi Sad and the Faculty of Agriculture of the University of Novi Sad (FANS).

With the title 'Systems of sustainable production and utilisation of forage crops', the meeting brought together more than 100 researchers, with about 70 from Serbia and more than 30 from 14 other countries. The three main sessions focused on (1) breeding, seed production and genetic resources, (2) field forage crops production and utilisation and (3) grassland production.

Half the papers were on legumes

About half of the one hundred papers presented were related to legumes, confirming the essential role that these crops, together with grasses and other forage crops, play in modern systems of feed production. Some papers focused on single species, and dealt mostly with lucerne, followed by vetches and red clover, while others focused on breeding and agronomy.

Following plenary talks on recent achievements and the future direction of breeding perennial and annual legumes in Serbia (Dragan Đukić , FANS, Serbia and Vojislav Mihailović, IFVCNS, Serbia) and also a review of the current status and prospects for annual forage and grain legumes in contemporary Serbian agriculture (Branko Ćupina, FANS, Serbia), other authors from Serbia presented numerous interesting contributions on the diversity of legume species and their utilisation. Among the highlights of the first two sessions were talks by foreign delegates: the genetics of agronomic characteristics in pea (Noel Ellis, JIC, UK), improving forage and seed yield in temperate legumes (Athole Marshall, IGER, UK), common vetch breeding (Rade Matić, SARDI, Australia), breeding sunn hemp (*Crotalaria juncea*) and sericea lespedeza (*Lespedeza cuneata*) (Jorge Mosjidis, Auburn University, USA), various cultivar evaluations (Fred Eickmeyer, Saatzucht Steinach, Germany and Piotr Stypiński, Warsaw Agricultural University, Poland), forage potential of a grain legume collection (Margarita Vishnyakova, VIR, Russia), lucerne management in irrigated areas (Jaume Lloveras, University of Lleida, Spain), the tripartite symbiotic system in legumes (Alexey Borisov, ARRIRAM, Russia), the role of legumes in sward management (Miluše Svobodová, Czech University of Agriculture) and red clover and other crops as alternatives to grasses for ensilage (Pádraig O'Kiely (Teagasc, Ireland).

All the symposium papers were published as Volume 44 of the journal, *A Periodical of Scientific Research on Field and Vegetable Crops*, issued by the Institute of Field and Vegetable Crops and freely available on a CD in pdf. format from Aleksandar Mikić. ■

Source: Aleksandar Mikić (mikic@ifvcns.ns.ac.yu).

Manipulating flowering time

Changer la date de floraison du pois

by Bénédicte WENDEN*, Catherine RAMEAU* and Isabelle LEJEUNE-HÉNAUT**

Pea, the most representative European grain legume has limited development prospects mainly due to unstable yields within years or sites. Stabilising and improving the productivity of the dry pea crop could be achieved through the release of winter cultivars, as has been done, for example, for wheat and canola.

Towards an ideal winter pea

Escape from drought and heat stresses in the spring and through the earlier flowering period, together with a longer development cycle leading to higher global biomass production, would make the productivity of such winter grown cultivars more reliable (Figure 1).

For an autumn-sown pea however, it is essential to overcome frost which is another important abiotic stress. For the last 30 years, winter dry pea cultivars have been bred progressively for better frost tolerance, but until now they have never reached the level of tolerance expressed by some forage lines, like Champagne or Austrian Winter. Given that frost sensitivity rises after floral initiation, previous observations have shown that such frost tolerant peas are able to escape the main winter freezing periods by delaying their floral initiation under short days (3).

For the winter pea crop, the manipulation of the flowering genes appears to be a promising way to control the key developmental stages which are the dates of floral initiation and flowering. The ideal winter pea should initiate its flower primordia late enough to avoid winter frosts and should flower early enough to escape drought and heat stresses in late spring.

Regulating flowering time

Since the early 1950s, pea has been used as a model species for the study of the genetic control of flowering time through the physiological characterisation of mutants observed in different environmental conditions (long days, short days) and the use of grafting experiments. These studies resulted in a classical model which is currently being reconciled with the molecular genetic models developed in Arabidopsis by J. Weller's group at the University of Tasmania. The fact that most of the flowering genes identified in Arabidopsis are present in legume genome sequence databases (2) suggests that similar mechanisms are likely to occur between pea and Arabidopsis, and that already we have the tools to understand and to control flowering time in pea. In particular, the response to photoperiod in pea could, as for Arabidopsis, also involve the circadian clock and the precise cyclic regulation of photoperiodic genes (*CONSTANS*) (5).

The winter pea breeding strategy developed at INRA relies partly on the manipulation of two major genes controlling the natural variation for flowering time, namely *LF* and *HR*. These genes are promising targets because they are known to control, respectively, the intrinsic earliness for the beginning of flowering and the strength of the response to the photoperiod. More precisely, the dominant allele *HR* is known to delay the floral initiation of autumn-sown peas until a longer daylength is reached (approximately 13 h 30 min) in the following spring. This helps to escape the main winter freezing periods. The knowledge of the sequence of these genes will allow the development of molecular markers suitable for building optimal associations of the *HR* and *LF* alleles. A candidate gene approach has already led to the cloning of the *LF* gene as the homologue of the *TFL1* Arabidopsis gene (1), and molecular markers are being developed to follow the different alleles in crosses. For *HR* the same approach is being used, thanks to the microsynteny with *Medicago truncatula,* in order to clone the gene and/or develop molecular markers to backcross the high photoperiod response dominant *HR* allele in agronomic genetic backgrounds.

Developing integrative tools

To understand the biology of complex systems it is necessary to integrate at different scales the existing models, experimental data, and main hypotheses into new models that are able to describe, explain and predict biological phenomena. A PhD research project is ongoing at INRA Versailles to develop an integrative tool combining molecular, physiological and

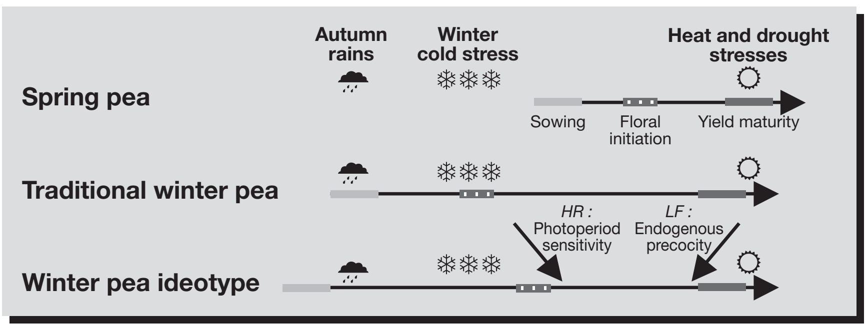


Figure 1. The winter pea strategy: manipulating the dates of floral initiation and flowering in order to escape winter frosts as well as drought and heat stresses in late spring.

*SGAP INRA, Versailles, France. (benedicte.wenden@versailles.inra.fr, rameau@versailles.inra.fr)

**UMR INRA/USTL SADV, Estrées-Mons, Péronne, France. (lejeune@mons.inra.fr)

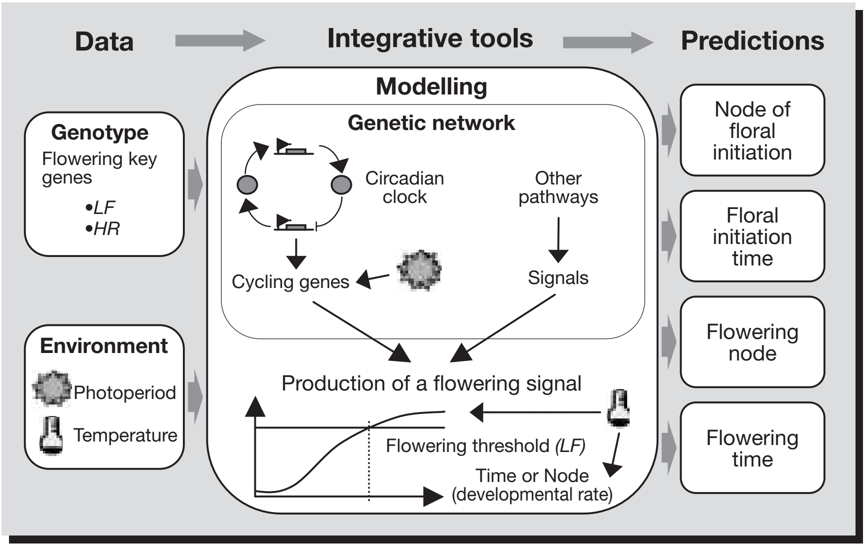


Figure 2. An integrative model to predict the flowering time in pea.

ecophysiological data into a computer model of flowering time in pea. This model will integrate the hypotheses that best represent our current understanding of the genetic and physiological regulation of flowering time from the genetic to the crop level.

Presently, two categories of flowering models can be described for pea. First, an agroecophysiological model has been established, primarily for two pea varieties, in which the time of flowering has been broken down into two component variables: the leaf appearance rate and the node of the first open flower (4). However, the response of flowering to the environment also depends on genotype and therefore extrapolation of these results to other environmental conditions or genotypes is limited. Secondly, genetic models of the control of flowering in pea have been based on the analyses of flowering mutants (see above) describing the interactions of signals that lead to the production of a flowering signal and thus to floral initiation (6), but these genetic models have no prediction capacity.

The aim of the PhD project is to gather all the sources of knowledge in the form of mathematical equations that will together allow the simulation of as many different environmental and genetic conditions as possible. In particular, this work should enable the effects of the different genes, and their interaction with environmental conditions, on flowering time to be quantified. The modelling approach is based on two sets of data (Figure 2): first the genotype of the key flowering genes (*LF, HR, SN, DNE, GI*) and second environmental data (photoperiod and mean temperature). For this model, we assume, as it was shown in Arabidopsis, that the production of the flowering signal is quantitatively controlled by an integrated network of pathways. The response of flowering to photoperiod is modelled through the effect of cycling genes controlled by the circadian clock and the coincidence between their level of expression and the daylength. The flowering signal accumulates over time until it reaches a flowering threshold, determined by the *LF* allele, and then triggers floral initiation at the apex. The main outputs of this integrative model are the node and time of floral initiation as well as the node and time of flowering. These variables could in turn be integrated as a prediction of flowering into a crop growth model.

How can this model be used?

Knowledge of the genetic and physiological basis of the interaction between flowering genes and the environment is essential to the selection of varieties closely adapted to a specific environment. This work will lead first to a better comprehension of the effects of the different flowering genes in pea, and their interaction with the environment.

Then, with a better understanding and prediction of flowering time, new 'virtual' pea genotypes could be constructed and their flowering phenotypes predicted under different environmental conditions. By testing different *LF/HR* allele associations, under virtual winter conditions, we will be able to predict the best winter pea flowering genotype for a given environment and to provide precise targets to the breeders. ■

(1) Foucher, F. *et al.* (2003). Plant Cell **15**, 2742–2754.

(2) Hecht, V. *et al.* (2005). Plant Physiol **137**, 1420–1434.

(3) Lejeune-Henaut, I. *et al.* (1999). Euphytica **109 (3)**, 201–211.

(4) Truong, H. H. and Duthion, C. (1993). Ann Bot. **72(2)**, 133–142.

(5) Weller, J. (2005). Flowering Newsletter **40**, 39–42

(6) Weller, J. L. *et al.* (1997). Trends in Plant Science **2 (11)**, 412–418.

Insert

Digestibility of Hr winter peas

Pea breeders have started to breed varieties sensitive to photoperiod (length of the daylight) since they show an advantageous longer period of frost tolerance. This photoperiod sensitivity is controlled by the Hr gene.

In parallel, the nutritional value of these types of peas for pigs has been tested by UNIP and Arvalis Institut du Végétal in France, by comparing one classical spring pea (SP) to both one line sensitive to the photoperiod (HR1) and one line with a better agronomic value (HR2) issued from the cross between HR1 and a spring variety.

The two winter type varieties (HR1 and HR2) have a lower trypsin inhibitor activity compared with the one of spring type. The amino acid profiles of HR1 and HR2 are similar and slightly different from the one of SP but are very close to the usual value for peas.

The protein digestibility is 82% in HR2, slightly higher than for HR1 (80%) and SP (78%) but without significant difference.

The amino acid digestibility is high and similar in the three types.

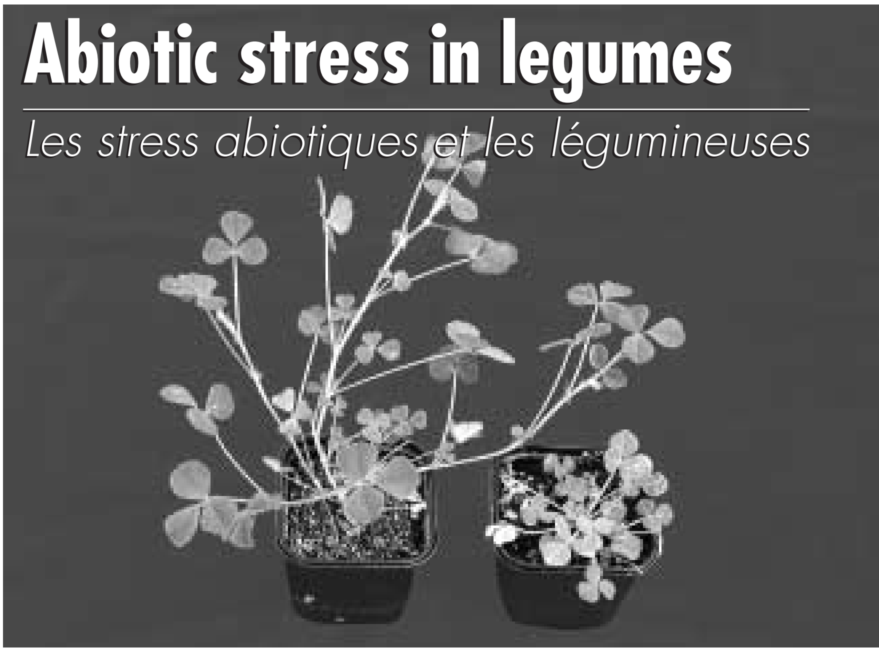
Therefore the genetic character which modifies the timing of the floral initiation does not modify the chemical composition or digestibility of the proteins and amino acids in pigs.

Source: Katell Crépon, UNIP, k.crepon@prolea.com

(Photo T. Huguet, INP-ENSAT, France)

Abiotic stress in legumes

Les stress abiotiques et les légumineuses



Salt effect on the growth of *Medicago truncatula* F83005.5 line. Left: no salt, right: 45 mM NaCl.

(Photo A. Schneider AEP)

Abiotic stress in field trial of faba beans at El-Sharkia in Egypt.

Legumes are sensitive to abiotic stresses such as water deficit and soil salinity. Tolerance and susceptibility to these stresses are very complex traits and plants show complex cell signalling pathways activating metabolic functions and developmental switches to cope with environmental stresses.

Hence, international experts working on the analysis of plant tolerance were gathered at a scientific workshop 'Abiotic stresses in legumes' (Tunis, 22–24 March 2007, supported by GLIP[1]). Basic scientists, molecular biologists, genomicists, physiologists and agronomists involved in several ongoing EU projects were present together with representatives of international agricultural organisations. Legume experts and their colleagues working on non-legume plants came together so as to learn from a variety of stress response models: agronomic, eco-physiological and genomic models. In the latter case, the well known Arabidopsis model has allowed tremendous progress in the genomic analysis of abiotic stresses even though several physiological characteristics of legumes are not found in this plant. More recently *Medicago truncatula*, an annual, diploid and autogamous legume, has been adopted as a model legume in various European and USA laboratories and diverse genetic, genomic and reverse genetic tools are being developed for the analysis of physiological responses at genomic level.

This special report[2] brings together some highlights of this workshop and presents current perspectives of the way plants cope with abiotic stresses with particular emphasis on the implications for grain legume crops. The data discussed deal with whole-plant approaches and crop management as well as genetic and genomic analysis of abiotic stress responses. ■

[1]the EU Grain Legumes Integrated Project www.eugrainlegumes.org

[2]a previous dossier dealt with the same topic: Special report (2005) Drought and saline stress in legumes, *Grain Legumes* **42**, 13–22.

Les légumineuses sont sensibles aux stresses abiotiques comme le déficit hydrique et la salinité du sol. La tolérance et la susceptibilité à ce type de contraintes sont des caractères complexes et les plantes présentent des processus d'échanges cellulaires élaborées, activant des fonctions métaboliques et des changements de développement pour gérer les stresses environnementaux.

Il a été décidé de rassembler plusieurs experts internationaux travaillant sur l'analyse de la tolérance végétale à un séminaire scientifique 'Les stress abiotiques et les légumineuses' (Tunis, 22–24 mars 2007, co-organisé par GLIP[1]), avec des scientifiques plus fondamentaux, des génomiciens, des physiologistes et des agronomes. Les experts légumineuses et leurs collègues spécialistes des plantes modèles ont partagé leurs différents schémas d'analyse de la réponse végétale au stress : agronomiques, éco-physiologiques ou génomiques. La plante modèle Arabidopsis a notamment permis des avancées considérables sur la génomique de la réponse au stress même si cette plante n'a pas certaines fonctionnalités des légumineuses. Plus récemment, Medicago truncatula*, une légumineuse annuelle, diploïde et autogame, a été adoptée comme modèle des légumineuses par différents laboratoires européens et américains, et des outils génétiques et de génomie fonctionnelle ont été développés pour l'analyse des réponses physiologiques.*

Le dossier de ce numéro[2] rapporte quelques informations saillantes du séminaire de Tunis, analysant les différentes façons dont les plantes gèrent les stress abiotiques, en insistant sur les conséquences sur les cultures de légumineuses. Sont traités à la fois les approches intégrant la gestion de la culture, la compréhension de la physiologie de la plante dans son ensemble et les analyses génomiques des réponses de la plante au stress. ■

[1]*le projet intégré européen sur les légumineuses à graines www.eugrainlegumes.org*

[2]*un dossier précédent traitait aussi de ce sujet: Special report (2005) Drought and saline stress in legumes,* Grain Legumes ***42****, 13–22.*

Growth and functioning of legumes under drought: a whole plant perspective

Croissance et fonctionnement des légumineuses sous déficit hydrique : une approche à l'échelle de la plante

by Bill DAVIES*

All crop plant species are highly sensitive to soil drying, with reductions in productivity occurring before the amount of water available to the plant has changed significantly. Sensing involves both reduced uptake of water from the soil and/or the modified production and transport of a range of chemical signals in roots in contact with drying soil. Both of these responses can provide information to the shoots on soil water availability. These changes in chemical and hydraulic signalling allow plants to regulate growth and development as a function of resource availability to the roots.

Plant breeders believe that characteristics important for yield in resource-poor environments have more to do with growth under favourable conditions than with resistance to stress *per se*. As there is little growth by plants once stress develops, overall productivity is best improved by maximising growth in favourable times (10). Processes that help the plant survive severe cellular dehydration may be important in perennial crops but to sustain yields of annuals we need to understand the regulation of growth and development under moderate drought stress, rather than focussing on survival and tolerance of low plant water content.

Drought regulates a variety of plant processes

The sensitivity of different aspects of the plant's physiology and biochemistry to drought can vary substantially; lesions in most processes will contribute to reduced yields and/or crop quality. Nitrogen (N) fixation, vegetative growth and development and aspects of reproductive development are most sensitive to soil drying.

A high leaf area index is vital to maximise the interception of radiation for photosynthate production. Restrictions in canopy development under drought, and limitation in vegetative growth before a plant community has covered the ground can be very damaging for carbon (C) accumulation and yielding. Furthermore, covering the soil early in the growing season can restrict soil water loss significantly and thereby enhance the transpiration (T) component of evapotranspiration (ET), resulting in more productive use of water (16). Only water taken up by the plant can contribute to C gain (*W* in Equation 1 below).

Turgor

Cellular water status (turgor) provides the driving force for organ growth and usually leaf growth becomes restricted as the soil dries because leaf turgor falls below a threshold value for leaf expansion. Some genotypes accumulate solute in cells as shoot water potential falls, thereby maintaining turgor and the potential for growth. However, the maintenance of leaf turgor does not usually result in maintenance of shoot growth as the soil dries. A good correlation between restricted shoot growth and high solute accumulation in shoots indicates that some variable other than cell turgor can restrict cell growth under drought. In this situation solutes accumulate as a result of restricted leaf growth, rather than providing the driving force for cell expansion as the soil dries (7). Solute accumulation can prolong the period before cells die and in some dryland legumes, postponing cell death by this method is adaptive (5).

> **What is water stress?**
>
> Successful growth and development of land plants requires maintenance of a favourable cellular water status in even the most challenging of climates. The dry air surrounding the above-ground parts of the plant promotes rates of water loss (transpiration) from the shoots that potentially can be very high. Plants must protect themselves against excessive water loss (using water-proofing of aerial plant surfaces and stomatal pores of variable aperture). This will help avoid the damaging effects of stress which will inevitably limit all aspects of growth and development and ultimately result in cell death. These stresses may be low cell water contents (low water potential) and also the build-up of growth-inhibiting chemicals. Sustained water uptake from soil and transport of this water to leaves is also required to replace water lost via transpiration and avoid the development of damaging deficits.

There is often some root growth in drying soil, even when shoot growth is entirely restricted. As a result the plant root:shoot ratio is increased. The development of water and nutrient depletion zones in soil surrounding slowly growing roots (particularly when roots clump in compacted soil) restricts resource uptake from drying soil. In these circumstances sustained root growth sustains water and nutrient uptake.

Selection for solute regulation capacity in roots may be a way of developing crops for dryland regions (11) and many have shown the positive impact of root turgor maintenance on growth (3). Sustained root growth in drying soil may also require accumulation of the plant hormone abscisic acid (ABA) which prevents run-away ethylene production at low water potentials

*Lancaster Environment Centre, Lancaster University, UK. (w.davies@lancaster.ac.uk)

(15). In many circumstances ethylene is a powerful growth inhibitor (13) and, as the soil dries, increased soil strength may also limit shoot growth through up-regulation of ethylene synthesis. Ethylene accumulation can also restrict nodulation significantly. Low ethylene transgenics show reduced leaf growth sensitivity to compacted soil and to soil at low water potential (14).

Three key cropping variables

An analysis by Passioura (9) highlights three key cropping variables that will contribute to sustained crop yield (*Y*) under drought:

$Y = WUE \times W \times HI$ (Equation 1)

WUE = plant biomass produced per unit of water used, *W* = water available, and *HI* = harvest index (proportion of biomass produced as grain). We have seen above how *W* can be manipulated to sustain *Y*. *WUE* can be enhanced, for example, by selecting for or manipulating particular aspects of photsynthesis or stomatal behaviour. Crop yield can also be sustained by ensuring that water is available at key developmental periods so that a greater proportion of crop biomass is yield (*HI*).

Recent work shows the importance of sustaining C supply to developing maize grains immediately after anthesis. These C allocation processes are extremely sensitive to water availability and if water relations are adverse during this critical period of crop development then grain yield fails (1), in spite of favourable water relations and development of the vegetative crop.

N fixation and drought

Soil drying can reduce nodule mass substantially, having a negative impact on N accumulation through fixation. Interestingly, *Rhizobia* are quite resistant to soil drying and their survival is probably not a limiting step for N fixation under drought, even though symbiosis establishment is extremely sensitive to drought. Despite the apparent robustness of *Rhizobia* in water-limited environments, data indicating superior performance of some, often indigenous, strains in dryland environments are limited.

In many legumes, N fixation per unit mass of nodules is highly sensitive to drought, often more sensitive than other plant physiological and developmental processes (12). Carbon and oxygen limitation in the nodules and/or feedback regulation of N fixation by N accumulation are possible explanations for this sensitivity, linked directly to changes in the water status of the plant. However, nodules obtain most of their water from the phloem rather than the xylem. Variation in phloem flow can be highly sensitive to small changes in plant water status and can impact severely on nodule activity.

Variation in phloem and xylem functioning could also affect chemical regulation of nodule activity. For example, if an increase in the concentration of phloem contents occurs at reduced fluxes, assimilates delivery to nodules may be sustained. However, export of N products from nodules via the xylem may be decreased by stress, resulting in N accumulation and N feedback inhibition of nodule activity. Suppression of N fixation of this kind can result from local signalling (8) or a more systemic signal imported by the phloem (12).

Manipulation of chemical signalling

There is significant genetic variation between cultivars in N-fixation sensitivity to soil drying, but there is still some uncertainty over the basis of this variation. Until there is some agreement over the mechanism by which soil drying reduces N-fixation activity, the opportunities for manipulating this activity will remain restricted, and we will not be able to benefit from the development of novel biotechnological techniques for plant improvement.

Increased understanding of chemical signalling mechanisms in drought-affected plants raises the possibility that artificial manipulation of signal synthesis and accumulation may enhance plant performance when water is restricted. This may be achieved via plant improvement or via a change in management practice, for example, via deficit irrigation. One of these techniques, partial root drying, has been designed so that some plant roots are always in contact with drying soil and will therefore continue to produce chemical signals. Using deficit irrigation, signal production can be enhanced or decreased at critical periods of plant development resulting in restricted shoot growth and water use with very little limitation in reproductive yield (increased *HI* – Equation 1) (4). Other manipulations, such as addition of specific bacteria to the rhizosphere (2) or fertiliser treatments will augment or restrict other chemical signals in plants. These could, for example, ensure rapid canopy development in drying soil (16) or ultimately promote plant senescence thereby enhancing partitioning of C and N to increase *HI* of grain crops (17).

Opportunities for plant biologists

A range of plant stress-sensing mechanisms has evolved so that, during mild soil drying, plants start to shut down growth and functioning to save scarce water for critical phases of their development, even when there is still water available in the soil. This suggests that there is some scope for plant biologists to over-ride these defensive responses with the benefit of sustained plant development and yielding as the soil dries. Further elucidation of the drought-sensing system to increase the efficiency of water use in agriculture ('more crop per drop') is most relevant as rainfall patterns are disrupted by climatic change. ■

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Plant traits and crop managment to limit the effects of water stress in Mediterranean agronomic situations

Caractères des plantes et conduite des cultures pour limiter l'impact de la sécheresse en agriculture méditerranéenne

by François LELIÈVRE*

Water deficit is the main constraint for agricultural production in Mediterranean environments. Genetic improvement and agronomic optimisation of harvested yield, HY (g DM/m^2) depend on three terms according to the relation (Equation 1) proposed by Passioura (3, 4):

Equation 1: HY = T x WUE x HI
(with DMt = T x WUE)

where T (g H_2O/g DM per m^2) is the crop transpiration, WUE is average water use efficiency (g DM/kg H_2O), HI is the harvest index, and DMt (g DM/m^2) is the total dry matter elaborated. If E (g H_2O/m^2) is the soil evaporation, ET = E+T is the actual evapo-transpiration of the crop during its cycle. WUE is often related to aerial dry matter, DM_a, instead of DM_t (aerial + underground). All these variables are sums or means for the whole cycle of the crop, representing several months or even years when pluri-annual yields are considered. The improvement of each term T, WUE and HI has limits which are discussed.

Increasing and stabilising harvest index

In annual grain crops in all environments, yields have progressed in the last half century through continuous genetic HI increase (from 0.1–0.2 to around 0.5 in many species). In rainfed semi-arid environments, subsequent improvement of HI stability has been obtained in winter cereals by plant breeding through: (i) genetic control of vegetative growth and stem length; (ii) drought resistance of pollination-fertilisation phase; (iii) drought escape of the grain filling period through earliness and deep rooting; (iv) increased resistance of late photosynthesis and late translocation during grain filling; (v) improved diseases resistance. Much less significant are the results obtained in HI stability of grain legumes, but progress should be obtained by following the same objectives.

Optimising crop transpiration

Crop transpiration (T) can be increased through plant cycle duration (earliness) within limits in one year. In temperate areas, annual rainfall (P_a) generally exceeds annual potential evapo-transpiration (ET_{pa}); actual transpiration (T_a) is limited by ET_{pa} ($T_a \leq ET_{pa} \leq P_a$). In Mediterranean areas ET_{pa} exceeds P_a which is the upper limit of T_a ($T_a < P_a < ET_{pa}$). To optimise yield, the crop transpiration, T_a must be as close as possible to P_a. This requires the unproductive fractions of P_a (run-off, drainage, evaporation) to be minimised through plant material traits and agronomical conditions: crop cycle matching the rainy period; early autumn sowing; vigorous establishment of the cultivated plants at the onset of the wet season (rapid extension of canopy to cover the soil; high root growth rate); continuous weeding; rainfall well distributed through the growth period; high soil permeability; important final root depth; high soil water reserve; drought resistance at the end of the wet season. Even when all these conditions are fulfilled, T_a tends to have an upper limit between 60% and 85% of P_a because soil evaporation, E_a, cannot be avoided during the non-growing period (hot dry summer) and at early stages of autumn growth when the wet soil surface is not covered by the canopy. In Mediterranean cultivated fields, E_a values often range between 50 and 150 mm (5). The unproductive fraction of annual rainfall is at least 15–35%, increasing with aridity. It is much higher than in temperate climates,

(Photo François Lelièvre INRA Montpellier, France)

Creeping self-reseeding annual legumes tested to intercrop vineyards on stony shallow soils in southern France.

*INRA, UMR SYSTEM, Montpellier, France.
(lelievre@supagro.inra.fr)

(Photo François Lelièvre INRA Montpellier, France)

Trial to intercrop vineyards with perennial legumes and grasses on shallow soils in French Catalogne (southern France).

where the non-growing period is winter.

Recent work on wheat in semi-arid conditions has demonstrated that early autumn sowing combined with genotypes with high leaf and root extension rates at low temperatures (autumn, winter, early spring) are very efficient to increase T_a if the balance between reproductive and vegetative growth is controlled by genetic factors (6). A similar approach is valuable for winter grain legumes in the Mediterranean.

Optimising water use efficiency

Water use efficiency (WUE) is the effectiveness of a crop in H_2O/CO_2 exchange, the value representing a very long and complicated process of development and growth in real conditions (1). Values of 3–5 g DM/kg H_2O represent high utilisation of water by agriculture, from which approximately a half can be allocated to seeds in grain crops. Such levels are not possible everywhere at any time, because WUE follows biophysical laws: it decreases under high temperatures and high climatic demands (2–3 times lower in hot compared with cool seasons/climates). In hot periods or climates, it is higher in C4 than in C_3 plants. High nutrient availability increases WUE, especially nitrogen for cereals and grasses and phosphorus for legumes. In North Africa, WUE of irrigated alfalfa is 3.0–4.0 g DM/kg H_2O in spring but falls to 0.5–1.0 in summer. In annual legumes, adaptation to early autumn sowings with efficient nitrogen fixation and growth at low temperatures is important. Conventional selection for DM yield in rainfed field plots selects efficiently for WUE because high yielding material of similar earliness use approximately the same quantity of water (2). However, conventional breeding for DMt and WUE increase is slow because of low variability in high yielding material in a species. Molecular engineering should provide opportunities to modify H_2O/CO_2 exchange (1).

The case of a perennial forage crop

Harvested yield for one year (HY_a b = T_a x WUE_a) is generally the sum of several cuts (growth cycles at different development periods having different daily T_j and WUE_j. For pluri-annual forage crops like alfalfa, yield is the sum during n years: $HY_n = S_n$ (HY_a).

In temperate areas, forage yield HY_a is maximised when T_a tends to ETP_a (daily $T_j = ETP_j$ throughout the year). It requires: (i) high plant density; (ii) early start of growth in spring and late end in autumn; (iii) drought resistance in summer. Plants must have the ability to maintain optimal or significant T, growth and yield during moderate dry periods that do not exceed two months with cumulated climatic deficits (ET_P-P) not lower than –250 mm. It is obtained through depletion of deep soil water reserves, mainly conditioned by soil and root depth.

In rainfed Mediterranean areas, adapted plants must alternate: (i) a productive strategy with high T and high WUE during the cool rainy season (5–9 months, P: 300–700 mm, ETP: 300–600 mm); (ii) a conservative strategy (survival) without growth, with partial senescence and very low T, during the long hot dry season (3–7 months, P: 0–100 mm, ETP: 400–1000 mm). During this period, surviving organs lose water which is compensated for by extraction from the soil to maintain hydration above the lethal level for as long as possible. This conservative transpiration (Ts), not used for direct production, is the 'water cost' of summer survival and perenniality, in addition to soil evaporation. Adaptation in perennials depends on a combination of plant traits like deep rooting, different levels of summer dormancy, and relative desiccation tolerance of surviving organs (7, 8). Interest and limits of perennial *vs*. annual (reseeded or self-reseeding) forage legumes and grasses must be evaluated at the farming systems level. In this area, the gap from plant physiology and molecular genetics studies to the availability of innovative cultivars as commercial seed must be reduced. ■

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How genomics may help to understand tolerance to abiotic stress in legumes?

Comment la génomique contribue t-elle à comprendre la tolérance aux stress abiotiques chez les légumineuses?

by Véronique Gruber* and Martin Crespi*

Legumes provide more than one-third of mankind's nutritional nitrogen requirement and represent about 25% of the world's major crop production (6). Legumes can interact symbiotically with nitrogen-fixing soil bacteria to fix atmospheric nitrogen, reducing production costs and environmental damage because they do not require soil fertilisers. In addition, the roles of legumes in the whole crop rotation (for N cycle, soil structure and activities, disease and weed break, etc) benefit other subsequent non-nitrogen fixing crops. Therefore legumes play an essential role in sustainable agriculture.

Only 10% of arable land is considered to have non-stressed soils, implying that crop growth on the remaining 90% of arable land is submitted to diverse environmental stresses (3). Indeed, various abiotic stresses including salinity, drought, extreme temperatures (heat, freezing, chilling), waterlogging and mineral toxicities, reduce the yields of most major crops by more than 50% (1). Abiotic stresses affect legume growth, yield and productivity as well as the efficiency and function of the symbiotic nitrogen fixation process. In general, exposure of plants to dehydration or osmotic stress causes a decline in photosynthetic activity due to stomatal closure and reduced activity of photosynthetic enzymes limiting carbohydrate metabolism and plant growth. On a world scale, soil salinity is also a primary cause of crop yield losses on more than 20% of agricultural land and 50% of cropland (4). High salt depositions in the soil generate a low water potential zone making it increasingly difficult for the plant roots to acquire both water and nutrients. Both hyperionic and hyperosmotic stress induce drastic metabolic changes that can lead to plant death. In legumes, salt stress also inhibits nitrogen fixation, affecting total nitrogen uptake in the legume host as well as its contribution to the soil combined nitrogen content.

*Institut des Sciences Végétales – CNRS, Gif-sur-Yvette and Université Paris Diderot, France. (gruber@isv.cnrs-gif.fr, crespi@isv.cnrs-gif.fr)

Abiotic stress activates complex signalling pathways

To cope with these stresses, plants have evolved complex cell signalling pathways activating metabolic functions and developmental switches to permit their adaptation to these conditions. The plant root system, which is the primary site of perception of environmental changes, is able to adapt its growth and architecture. This adaptation is a result of integrated events occurring at all levels of organisation, from anatomical to morphological, and to cellular, biochemical, and molecular. Cellular responses to stress include changes in the cell cycle and cell division, modifications in the endomembrane system and vacuolisation of cells, and changes in cell wall architecture, all leading to enhanced stress tolerance of cells. At the biochemical level, plants alter their metabolism in various ways to accomodate environmental stresses, including the production of osmoregulatory compounds.

The molecular events linking the perception of a stress signal with the genomic responses leading to tolerance have been investigated intensively in recent years, mainly in *Arabidopsis*. However, the universal nature of these mechanisms is still debated because different strategies may be used by different plants to cope with environmental stresses. Insights into gene functions and regulatory control of biological processes that are associated with stress responses in legumes have been facilitated with the development of genomic resources and information for the two model legume species, *Medicago truncatula* and *Lotus japonicus* (7, 8). For each of these two reference legumes, extensive investments are being made to generate a full range of genomics resources, including sequencing the entire genome and thus giving access to a complete description of the response at gene expression level. The increasing availability of genetic and genomic data as well as the high degree of synteny between legume genomes has resulted in these two species becoming valuable models for the molecular genetic study of abiotic constraints hampering yield, since they are very close to legume crops. Indeed, combining genomic and biological knowledge about reference legumes that has a bearing on other food and feed legumes of major economic importance, presents a major scientific opportunity that can impact upon other less-easily handled crops.

Transcriptome analysis gives promising results

A critical step of the cell signalling pathways controlling stress responses involves transcriptional regulation, generally mediated by transcription factors that may govern and coordinate the expression of large groups of genes. In legumes, extensive sequencing highlighted around 2,000 transcription factors per genome, less than 1% of them genetically characterised (9) and only six involved in abiotic stress tolerance (drought, salinity, extreme temperature). The development of novel powerful tools for transcriptome analysis increased considerably the access to gene functions on a global genome-wide scale for the identification of differentially expressed genes in response to stress in legumes. These tools include suppression subtractive hybridisation (SSH) library, super serial analysis of gene expression (SuperSAGE) for genome-wide quantitative gene expression profiling, array-based transcript profiling technologies (measuring expression levels of tens of thousands of genes in parallel), and massive quantitative real time PCR (qRT-PCR) with specific *in silico* designed primers against known genes, such as transcription factors (9). Recently, a Mt16K microarray covering 16,086 tentative consensus sequences derived mainly from approximately 164,000 *M. truncatula* ESTs collected in the TIGR *M. truncatula* Gene Index 5 (http://www.tigr.org/tdb/mtgi), was obtained. This Mt16K microarray was used to monitor, for example, changes in the transcriptome of dessication-sensitive radicles of *M. truncatula* seeds at different points in time, and therefore to investigate regulatory processes and protective mechanisms leading to dessication tolerance in seeds (2). Another example is the application of SuperSAGE technology to profile transcripts of drought- and salt-stressed roots and nodules from chickpea given access to a series of genes exclusively expressed under both stresses, but not in non-stressed controls.

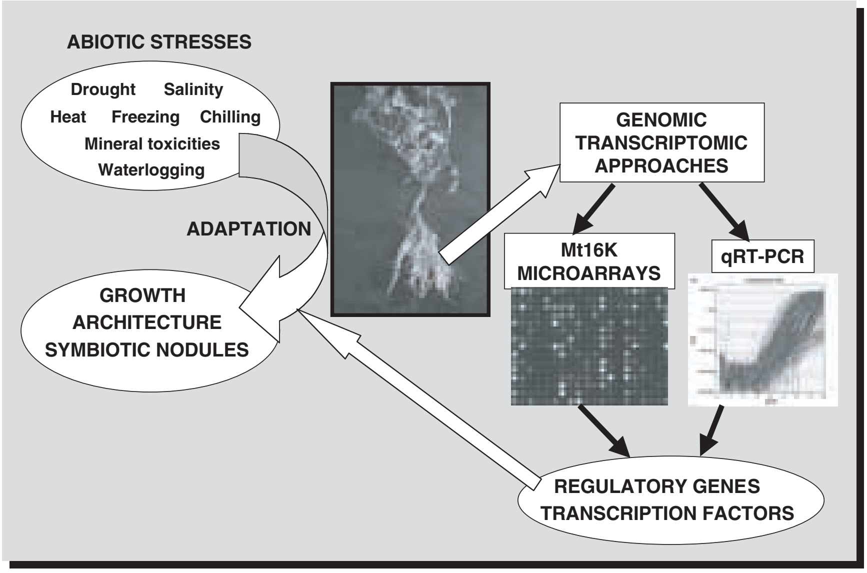

Figure 1. General view of the different steps linking genomics to the identification of key regulatory genes involved in abiotic stress responses in legumes. Exploiting genetic diversity in model legumes combined with transgenic approaches will reveal regulatory mechanisms involved in legume adaptation to abiotic stress.

Novel regulatory genes revealed by genomics

Thus, genomics and transcriptomics provide powerful tools to fully understand the molecular basis of responses to abiotic stresses in legumes as well as to the capacity of the plant to cope with environmental stresses. This may lead consequently to the identification of regulatory genes able to modify crop behaviour under adverse conditions (as schematised in Figure 1). As a recent example, expression analysis in model *Medicago* plants using a 'dedicated' macroarray (containing selected genes from SSH libraries), revealed novel regulatory genes, including transcription factors, associated with reacquisition of root growth after a salt stress (5). These selected genes were classified into different functional categories depending on homologies to other species. Several stress-related genes include specific legume ESTs suggesting, therefore, the presence of novel pathways linked to abiotic stress responses in this family. Over-expression of one of the transcription factor genes (MtZpt2-1) linked to recovery processes in transgenic *Medicago* roots allowed them to grow under salt stress conditions and affected the expression of three putative targets in a predicted manner: a cold-regulated A homolog, a flower-promoting factor homolog and an auxin-induced proline-rich protein gene. This establishes a role for this gene in the activation of a specific genetic programme in the adaptation of legume roots to salt stress.

Combining genomics and genotypic diversity

A large diversity of genotypes adapted to abiotic stresses was found in the glycophyte *M. truncatula*. This resource of diversity is used by breeders to manage abiotic stresses in their cultivation areas. Complex genetic systems subject to interactions between genotype and environment controlled the plant traits for adaptation to environmental stresses. Therefore, by using comparative genomic approaches between these genotypes, the right complements of genes and alleles in a breeding programme could be proposed. The understanding of the genetic mechanisms involved in these adaptive processes is particularly important in cases such as drought or salt tolerance where few genes may drastically affect the behaviour of related genotypes in a specific environment. Advances in genomic tools combined with the exploitation of genetic diversity from model legumes are allowing the dissection of the genetic control of complex traits. Determination of physiological tolerance mechanisms in diverse genotypes to various abiotic stresses in legumes may direct agronomic improvement of legumes increasing production in a sustainable way. ■

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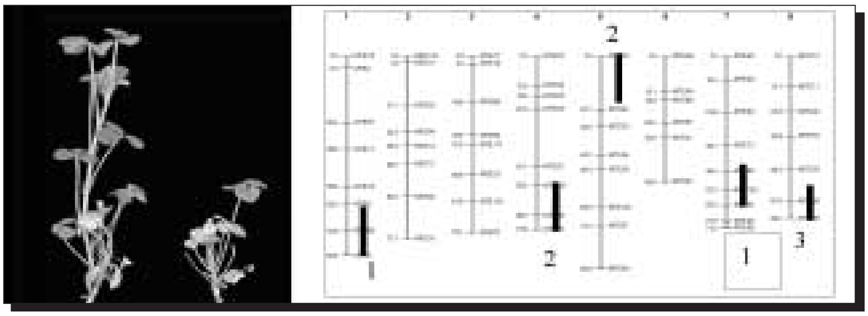
Integrating molecular and genetic data in legumes

Intégration des approaches moléculaires et génétiques chez les légumineuses

by Thierry HUGUET*



(Photo T. Huguet, INP-ENSAT, Castanet Tolosan, France)

Figure 1. Contrasting tolerance to NaCl (45mM) of M. truncatula Jemalong (left) and F83005.5 (right); M.truncatula genetic map based on LR5 population of RILs. Vertical lines indicate QTL locations involved in the reduction of stem growth (1), reduction in the number of leaves (2), reduction of root growth (3).

Abiotic stresses, salinity, cold and drought have the largest impact, causing yield losses of up to 50% in legumes. Evidence from various species suggests that abiotic stress tolerance is a quantitative, developmentally regulated, stage-specific phenomenon, and that tolerance at one stage of development may not be correlated with tolerance at other such stages. This suggests that specific stages should be evaluated separately to develop cultivars with stress-tolerance characteristics (1). Altogether, this implies that abiotic stresses have an impact on a large number of interacting genes. Plant breeding thus faces two questions: a) how to identify all the genes, and their allelic variations, that each confer a better tolerance to stress and b) how to combine all these genes in elite cultivars (3)?

A number of genes involved in abiotic stress tolerance have been identified using molecular approaches (4, 6). However, it is very difficult to reveal their contribution to the plant phenotype in a given environment, especially since these genes are often involved in more than one stress. Only the combination of molecular genetic approaches such as Transmission genetics, Association genetics or Ecotilling allows a bridge between molecular and genetic data.

The need for a model plant

The large number of gene x environment x cultivated species combinations required for legume breeding justifies the use of taxonomically related model plants. Special interest in *M. truncatula* as a model plant for legumes relies on its capacity to support molecular genetics programmes and its taxonomic proximity with crops such as alfalfa, pea, chickpea, lentil and fababean. Many molecular and genetic tools (cDNA and BAC banks, software, genetic maps) have been developed in conjuction with *M. truncatula* (5) and the sequence of its expressed genome is expected to be finished in 2008.

One factor of major interest is that *M. truncatula* grows spontaneously all around the Mediterranean basin in very diverse, and sometimes hostile environments. Therefore, allelic variations responsible for adaptation to most abiotic stress could be expected within *M. truncatula* natural variations. In addition to the existing collections of *M. truncatula* (8, 2), a dedicated collection has been created based on Tunisian natural populations growing in diverse eco-environmental conditions (7).

Molecular genetics of *M. truncatula* salt tolerance

We first selected the genotypes Jemalong and F83005.5 which show contrasting phenotypes when submitted to salt stress (Figure 1). Using the *M. truncatula* genetic map and the population of Recombinant Inbred Lines (RILs) already developed, we identified a number of Quantitative Trait Loci QTLs) involved in salt tolerance (Figure 1). These QTLs underly genes whose allelic variations are responsible for the observed phenotypic differences between these two genotypes. But how are QTLs and the actual genes connected? Transcriptomic approaches provide important information about putative candidate genes but only the cloning of the alleles from one parent and its transfer to the other will give the final proof. This map-based cloning of these QTLs is in progress.

Since the genes/alleles responsible for salt-tolerant behaviour are not always the same as in the plants analysed, this genetic approach should be repeated using other contrasting genotypes in order to identify more QTLs/genes and evaluate their role in the plant response to salt stress.

From models to crops

Due to the conservation of genome organisation between related species, the location of a gene in a crop species could be deduced from model species studies and could thus be used for marker- or genome-assisted selection of crops. However, it still has to be established whether the function of a gene, and its allelic variations, are similar in different, even closely related, species. This research should be developed in the future. ■

*Laboratoire Symbioses et Pathologies des Plantes (SP2), INP-ENSAT, Castanet Tolosan, France. (thierry.huguet@ensat.fr)

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Benefits of inoculation under abiotic stress in the Mediterranean region

L'intérêt de l'inoculation sous stress abiotique en région méditerranéenne

by Carmen VARGAS* and Mohamed Elarbi AOUANI**

(Photo Y. G. Yanni, Sakha Agricultural Research Station, Egypt)

Faba beans with inoculation (left of photo) and without inoculation (right of photo), grown in sandy soils in Beheira in Egypt.

If appropriately managed, and especially under abiotic stress (drought, salinity), microbial biofertilisers can improve food legume yield and soil fertility and reduce pollution by inorganic fertilisers. In general, three types of inoculants can help legumes overcome stressful environments:

• Efficient and stress-tolerant symbiotic rhizobial strains, used when native populations are scarce and/or inefficient. The Aquarhiz project[1] targeted four south Mediterranean countries (Algeria, Egypt, Morocco, Tunisia) to study the inoculation of faba bean, chickpea and common bean under drought and/or saline conditions. Several trials showed a positive effect of inoculation, with variation according to countries and crops but also according to strains. At some experimental sites the inoculation had no effect or the increase in yield was not significant. In the case of faba beans in Morocco, soils are naturally hosting efficient local strains. However, in several other cases, sowing seeds with addition of these stress-tolerant rhizobium strains enhanced nitrogen fixation activity and improved yield of grain legumes. The symbiotic systems which are inhibited by abiotic stress are well known: oxygen permeability, shortage of water supply to nodules from the phloem, overproduction of reactive-oxygen species, feedback inhibition involving shoot N status. However the mechanisms underlying the stress tolerance of symbiosis remain unclear. Candidate systems from the plant (aquoporins, carbonic anhydrase) or the bacterial (osmoprotectants, bacteroidal respiration) side should be investigated in order to select successful combinations of legume and microsymbionts better adapted to stress.

• Arbuscular mycorrhizal fungi (AMF) colonise root systems and form symbioses called mycorrhiza with almost all legumes. By exploring a greater volume of soil through the fungal hyphae, mycorrhiza enhance nutrient (particularly phosphorus) and water uptake from the soil, thereby enhancing plant growth under drought stress.

• Plant Growth Promoting Rhizobacteria (PGPR), include a diverse group of free-living soil bacteria that can stimulate plant growth by a number of direct or indirect mechanisms. Interestingly, many strains isolated in the Aquarhiz project are free-living non-rhizobial species with promising applications as inoculants.

Inoculation is limited and decreasing

Although inoculation is a well developed agricultural practice in Australia, Canada, USA and Latin America, it is not common in Europe and Africa. The status of legume inoculation in the Mediterranean region and the related research strategies were discussed at a FABAMED[2] workshop organised at Rabat in February 2005, following the first General Meeting of the Aquarhiz project. It was shown that legume inoculation with rhizobia was limited and decreasing in the region, whereas the use of N fertilisers was increasing, especially at Egypt.

The workshop participants concluded that the symbiosis should be taken into account in research activities and in the technical messages disseminated to farmers to improve legume production in the Mediterranean region, but some key points should be considered:

- The inoculation is not the unique solution as shown in past experience, and a systematic diagnosis is required to rationalise where and when inoculant application can have an impact.
- Active rhisophere and an efficient relationship between enhanced cultivars and the best adapted rhizobia, either present in the soil or added as inoculant, is a key component to boost N fixation and root growth leading to better tolerance of abiotic stress.
- Inoculation should be associated with appropriate crop and soil management. Plant genotype and nutrient conditions are key factors influencing inoculation success.
- Progress in inoculation technology is required, i.e. second generation inoculants (rhizobial plus mycorrhiza or PGPR).
- Inoculant production is an easy and cheap technology that could be scaled-up with institutional support.
- Farmers' adoption of the technology will require participatory field research and appropriate technological packages. These activities have been initiated within the framework of the Aquarhiz project. ■

*University of Seville, Spain. (cvargas@us.es)

**Centre de Biotechnologie, Technopole de Borj Cedria, Tunisia and NEPAD/
North Africa Biosciences Network (NABNet), National Research Centre, Cairo, Egypt. (mohamedelarbi.aouani@cbbc.rnrt.tn)

[1]FP6 project www.grainlegumes.com/aquarhiz and *Grain Legumes* **39**, 23.

[2]FABAMED is a network of scientists interested in N fixation in the Mediterranean Region. Set up in 1994, it meets on a regular basis for information exchange, workshops and the preparation of joint projects.

Abiotic stress breeding at ICARDA

Amélioration variétale et stress abiotique à l'ICARDA

by Michael BAUM*

The mission of the International Center for Agricultural Research in the Dry Areas (ICARDA) is to meet the challenges of dry-area environments, which are harsh, stressful and variable. ICARDA has both global and regional mandates. It has a global responsibility for the improvement of three important food crops – barley, lentil, and faba bean. ICARDA's regional responsibility within Countries of West Asia and North Africa (CWANA) focuses on the improvement of wheat, chickpea, forage and pasture crops.

ICARDA holds the largest gene bank in the Mediterranean region, with about 133,000 accessions, which represents approximately 20% of the germplasm in CGIAR centres. Particularly important are the landraces and wild relatives that have evolved under harsh conditions over millennia. About 70% of ICARDA's collections are now geo-referenced. This collection-site information combined with climatic layers in Geographical Information System (GIS) allows targeted collection and a rapid exploitation of accessions with tolerance to drought and heat to meet the anticipated effects of climate change. ICARDA has been sharing these resources freely with partners all over the world. On average, the Center distributes 35,000 samples per year. Overall, the shift from collection and *ex situ* conservation of plant germplasm to its characterisation, evaluation and documentation will help to utilise the biodiversity held at ICARDA.

Using modern technolgies

ICARDA collaborates with advanced research institutes (ARIs) and the National Agricultural Research Systems (NARS) in using modern technologies for its crop improvement programmes. Emphasis is given to the identification and exploitation of genetic resources for improved stress resistance and water-use efficiency. DNA molecular marker techniques allow construction of linkage maps for crops. Together with statistical techniques these linkage maps can be used to locate and estimate phenotypic effects of quantitative trait loci (QTL) and the genes responsible for the expression of agronomic traits. For a homozygous population derived from a cross with parents contrasting in response to, for example, water, QTL analysis reveals the approximate map location of loci associated with performance under dryland conditions. This is then amenable to marker-assisted selection using DNA markers flanking the identified QTLs.

Lentil and chickpea improvement

Radiation–frost injury is an important abiotic constraint to lentil production in West Asia. If cold tolerance of lentil could be improved, its yield in low rainfall areas could be increased by early planting. Recombinant inbred lines of a lentil cross were tested in northern Syria for plant frost injury levels and genotyped with 254 DNA markers. DNA markers were identified linked to the locus for radiation–frost tolerance trait and Fusarium wilt resistance. These are proving useful in lentil improvement. Instead of selecting for radiation–frost tolerance and Fusarium wilt, breeders can select for the resistance marker alleles.

Chickpea is an important dryland crop sown in spring in WANA. Its yield and water-use efficiency can be nearly doubled by advancing its date of sowing to winter. Ascochyta blight, a fungal disease attacking chickpea, has developed into a major threat for winter-grown chickpea. DNA markers have been used to characterise the available pathotypes of the fungus. This allows the development of geographical distribution maps of the pathogen and the deployment of effective host-plant resistance genes. For tagging host-plant resistance genes in chickpea, microsatellite based markers have been developed in collaboration with the University of Frankfurt. Host-plant resistance for Ascochyta blight is being mapped in several populations and genetic backgrounds.

(Photo Houcine Irekti, INAT, Algeria)

Field of chickpeas at Ain Temouchet, Algeria in April 2007.

Biosafety

ICARDA is also exploring the possibility of using genetic transformation to achieve improved tolerance to drought and other abiotic stress resistance. ICARDA also actively promotes the development and establishment of national and regional biosafety regulations. So far, Egypt and Syria are the countries in the region that have established biosafety regulations. In several other countries the preparations for the development of biosafety regulations are underway. ICARDA's policy is guided by international biosafety practices and the regulations of the Syrian Arab Republic for the development and deployment of GMOs. ■

*ICARDA, Aleppo, Syria. (m.baum@cgiar.org)

Where we go from here – concluding remarks of the abiotic stress in legumes workshop

Quelles perspectives pour la suite – conclusion du séminaire sur le stress abiotique chez les légumineuses

by Martin CRESPI*, Anne SCHNEIDER**, Thierry HUGUET*** and Mohamed Elarbi AOUANI****

Maintaining or improving crop productivity under conditions of abiotic constraint in the field is one major concern in many areas in the world where legumes are grown. Abiotic stresses refer to different environmental factors: water deficit, high temperatures, saline stress, mineral deficiency, frost, chilling, and others, which can occur at different levels and development stages. As shown in the Tunis workshop[1], it is very useful to integrate different disciplinary expertise to apprehend the complexity of tolerance and susceptibility traits.

From whole plant to genomic approaches, a strategy to exploit genetic diversity

The whole plant approach allows key variables of the plant/genotype interaction that maintains yield under stress to be assessed. Environmental signals and plant physiological mechanisms activated at different growth stages can be useful to determine their hierarchy and relevance in the physiological processes involved. Adapted agronomic management techniques are needed to cope with abiotic stresses in the field. However, modelling the eco-physiological interactions between plants and the environment, considering the particular aspects of legume physiology, will enhance the basic understanding of mechanisms for further agronomic improvement.

In legumes, the symbiotic bacterial partner, the rhizobium, and other components of the rhizosphere have key roles in the agronomic performance of these crops, and should be taken into account in the analysis of plant response. Improving symbiosis under stress conditions will contribute to the development and use of legumes as pioneering crops since dry or saline soils are also poor in combined nitrogen.

Parallel development of genomic approaches will reveal molecular mechanisms involved in the regulation of the plant physiological responses. Exploiting the data obtained for different plant species (particularly different legumes) will highlight key molecules and genes involved in stress responses. These approaches should evolve from the initial description level under specific conditions to more elaborate screenings defining traits and genes involved in crop adaptation strategies. Targeted crop strategies should focus on the enhancement of tolerance to abiotic stress during grain filling or on rapid soil coverage in specific systems by controlling germination potential and initial root growth.

In addition, exploiting genetic diversity is crucial to obtain both contrasted types and sources of tolerances. Genetic resources are in fact mutants already selected by specific environmental conditions, possibly making them more suitable for field conditions than laboratory mutants.

Interdisciplinary approaches should be developed

Integrating molecular and genetic data into eco-physiological models is required in order to define the regulatory mechanisms involved in the control of plant growth and development under abiotic stress constraints and to create novel elite cultivars. This will bring new perspectives to the development of novel crop management techniques and to the identification of crucial breeding targets.

The general approaches favoured in order to make progress in this area were discussed among Tunis workshop participants. The need for interdisciplinary approaches to enhance knowledge in abiotic stress responses and tolerance was agreed upon. Plant physiology expertise should be reinforced particularly to establish common references and protocols in case studies: how to apply stress, what sort of stress and its level of intensity, what type of plant response is targeted (e.g. survival or adaptation). Genetic models will provide information on plant responses at different levels that can be applied in crop species although the specificity of these responses according to species or even lines should also be considered. Two different research strategies were debated: one focussing on the search for few key genes whose modulation would provide a breakthrough effect on crops or a more integrative approach aiming to dissect the complex mechanisms involved in stress responses. Both will contribute to the development of improved varieties adapted to cropping systems.

In spite of strong debate, specific points were unanimously agreed: the kind hospitality of the Tunisian hosts, the interest in participating in interdisciplinary workshops and the need to structure collaborations between experts from different fields to increase the relevance of the strategies in crop management.

*CNRS-ISV, Gif sur Yvette, France
**AEP, Paris, France
***INRA-ENSAT, Toulouse, France
****CBBC-LILM, Hammam Lif, Tunisia

[1]'Abiotic stresses ain legumes' (Tunis, 22–24 March 2007), a scientific workshop organised at the initiative of the Grain Legumes Integrated Project (GLIP) which is supported by the European Commission from 2004 to 2008.

Dynamics and prospects for grain legumes in the European feed market

Dynamiques et prospectives pour les protéagineux sur le marché européen de l'alimentation animale

by Anne SCHNEIDER*, Frédéric PRESSENDA** and Katell CRÉPON***

Until now, the animal feed industry has been the predominant outlet for European grain legumes even if there are recent expanding added value markets: food exports and ingredients for food, feed or non-food uses.

About 85% of European pea production and 58% of faba bean production was used by the feed industry in 2003/2004, especially in France, Germany and Spain. In the UK, the percentage was smaller (75% feed and 25% food uses). At least 3.5 million tonnes (Mt) of grain legumes are used by the animal feed industry (1), and there are also niche markets such as pigeon feed or pet food (stable demand) as well as on-farm feed uses.

Legume grains are energy- and protein-rich raw materials used for different animals with different nutritional requirements: monogastrics and ruminants constitute the major segment, fish diets a minor one. Faba bean which is richer in protein than pea is interesting for poultry. Lupins are more suitable for ruminants than pea and faba beans. In France in the last 12 years peas have been used mainly for pig compound feed (90%), and in smaller amounts for poultry (8%) (1).

Current use could be much larger

Less than 3% of the 130 Mt of the EU compound feed is from protein crops. The demand for grain legumes from the compound feed industry greatly exceeds the level of home production, which makes the EU highly dependent on imports. The deficit in Materials Rich in Protein (protein content >15% of dry matter) in the EU27 amounts to 73% and two-thirds of this is offset by imports of soyabean seed and meal which amount to 35 Mt annually (2).

In recent GLIP[1] analyses, it has been shown that with current seed nutritional composition, technical constraints and market prices, more European grain legumes could be utilised for feed than the volumes currently utilised (Pressenda, personal communication, March 2007). When the production levels of pea and faba bean and their apparent utilisation (compound feed production and on-farm feed uses) are analysed, two types of countries can be defined:

(i) producing countries: France, Germany, UK, Denmark, Czech Republic;

(ii) importing countries: Spain, Netherlands and Belgium.

In Germany, when the potential use of peas and faba beans in compound feed destined for different animal species was analysed, only half the apparent consumption was used for compound feed (194,000 t *vs.* 400,000 t) and according to the model, using the observed market price, the potential use could reach 730,000 t (Figure 1). The maximum potential use could reach 1.05 Mt if the market price was halved. Interviews with German compound feed manufacturers highlighted diverse reasons for the current under-use of peas: (i) negative attitude of their clients towards pea, (ii) interest in pea prices but problems of year-round availability for some manufacturers, (iii) higher pea prices in Germany because of pea exports to the Netherlands caused by an attractive market.

Analysis of the shadow prices[2] of pea shows that nearly all formulas (except that of ruminants) were able to incorporate pea during the period July 03 to June 04, the market price of pea being lower than the shadow price. Pea is particularly interesting for piglet, fattening pig and sow diets, but also for broiler and laying hen diets.

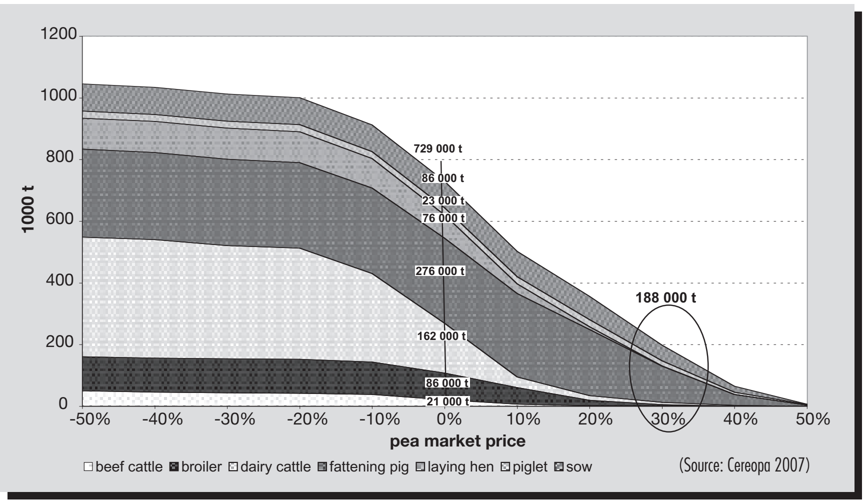

Figure 1. Assessment of pea potential feed uses by different animals according to variation of its market price in Germany (July 03 – June 04).

*AEP, Paris, France. (a.schneider-aep@prolea.com)

**CEREOPA, Paris, France. (fpressenda@hotmail.com)

***UNIP, Paris, France. (k.crepon@prolea.com)

Similar analyses in the Netherlands showed that the potential use of pea reached 1.6 Mt when its price was 25% lower than the observed market price. According to statistical data, the feed uses of pea amount to 195,000 t, showing that all imported peas are used by compound feed manufacturers. Most available peas are used in pig diets, and their use is highly sensitive: if the market price decreases by 3%, the uses of pea would be 200,000 t (or 450,000 t for the market price observed during the period July 03–June 04).

The discrepancy between the actual and potential feed uses of grain legumes in several EU countries is due mainly to the small quantities available on the market in recent years. Sufficient volumes available on the market and regular availability are required for the compound feed industry to establish a purchasing policy.

When volumes are low, grain legumes are used mainly in pig diets; with increased volumes, dairy cows could become a potential important user (Cereopa expertise).

Competition with other raw materials?

The clear correlation between pea market price and its uses shows that pea is a raw material that can be easily substituted in the feed industry. The price of feed pea is linked directly to the prices of the two main raw materials used in animal feed: wheat (or barley) and soyabeans.

Imported soyabeans (seeds and especially meals) are the major competitor for EU grain legumes. The nutritional composition of soya meal fits especially well with the nutritional requirement of intensive poultry and dairy cows. Another key advantage is its relatively low price due to large volumes of soyabean production and its two outlets (oil and meal).

However seeds of other grain legumes grown in the EU are richer in energy (starch) and have potential for less intensive animal production. In addition they ensure regional autonomy and security by producing raw materials close to their areas of use, and providing an environmental benefit to feed chains. When the uses of Brazilian soya meal and German peas in German pig production are compared using Life Cycle Analysis, the results for the criteria ‘energy consumption’ and ‘global warming potential’ show a clear environmental benefit for local pea (Nemecek, personal communication, GLIP, 2006). The benefits are even clearer when the grain legume is produced and used for animal feed on the same farm.

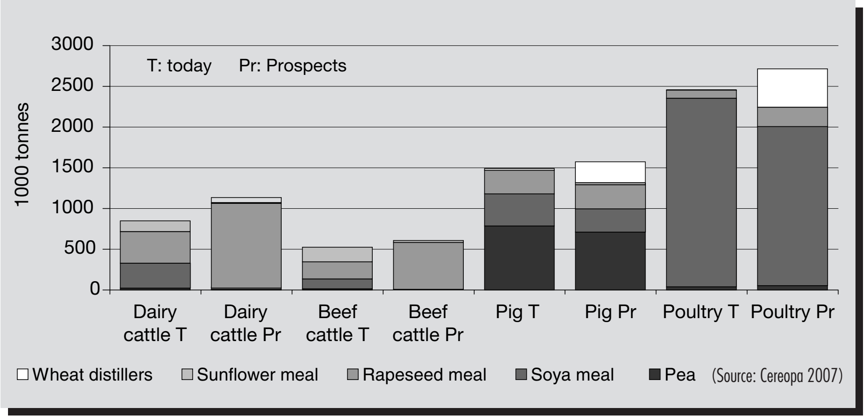

Figure 2. Case study in France: current use of protein-rich raw materials in compound feed compared with projections of their likely uses with the availability of by-products from bio-fuel.

In addition to soyabeans, several other EU raw materials are of interest for animal feed (meals from rapeseeds and sunflowers, corn gluten and coprah and cotton, dehydrated forage and others) but grain legumes can complement any of these. Pea is characterised by a high starch content, with a good energy value, and by protein, especially rich in lysine, which complement cereal proteins that have a low lysine content. Rape seed meal is richer in protein than pea and its proteins are rich in sulphur amino acids which can complement the pea proteins. Therefore the priority uses of these two raw materials rich in protein are different and are often not for the same formula: pea is suitable for pig diets, oilseed meal is especially suitable for ruminants and poultry.

Future competition?

The development of biofuel and bioethanol production could lead to a significant increase in the amount of rapeseed meal and cereal distillers’ residues in the EU, and these materials could be available for the animal feed industry. Rapeseed meal and cereal distillers’ residues are used mainly in ruminant feed, whereas peas are used mainly in pig feed, but they can also compete with peas in pig formulas. Simulations using a French formula show that an increased use of rapeseed meal in the feed industry only slightly decreases the use of peas, since rapeseed meal is used primarily in ruminant formula (Figure 2). Peas are still useful in feed rations because they are a good complement for rapeseed meal in pig formulas.

Therefore the likely future increase in protein-rich by-products from biofuel production may not be a major threat. In France, for example, an increase in biofuels production could add about 2 Mt rapeseed meal and 700,000 t wheat distillers’ residues on the market, but an analysis by Cereopa in 2007 (Figure 2) shows that two-thirds of oilseed meal will be used in ruminant formulas, 25% in pig formulas and 10% in poultry formulas. Pea is used mainly in pig formulas so will not compete directly with other protein-rich materials. An adjustment of only 5% decrease in pea price would be enough to maintain the current volume of peas used in the pig feed industry (2005-06 basis). In addition, the energy rich raw materials may become more expensive with the development of bio-fuel so protein-rich materials could be interesting.

In conclusion, prospects for the feed market are difficult to forecast because of the changing economic and political context which influence market dynamics, but for grain legumes the offer appears to be the major factor limiting utilisation since this falls far short of the level of the potential utilisation. ■

(1) Pressenda, F. (2006). The place of peas in the feed industry and ways to improve pea uses. GLIP Deliverable D 2.2.1b.

(2) More at: http://www.grainlegumes.com/aep/production/economic_integrated_chain/current_state_of_the_art

[1]Grain Legume Integrated Project (2004-2008) Food-CT-2004-506223 – www.eugrainlegumes.org

[2]the price that a raw material must reach to be included in the compound feed formula

Decision support system for efficient disease control

Système d'aide à la décision pour une lutte efficace contre les maladies

by Thomas VOLK and Julia-Sophie VON RICHTHOFEN*

Farmers decide to grow grain legumes primarily because of their good break crop effects – faba beans, field peas and lupins improve soil fertility and lead to high additional yields of the following crop, in most cases winter wheat.

However, the yield of the grain legume crop itself should also be high and stable. Diseases can – depending on the year and the region – reduce grain yields significantly (Table 1). In these cases the use of fungicides seems to be advantageous economically.

In Germany in many cropping seasons and in many fields the level of infestation is low because

– the acreage cultivated with grain legumes is only small in most regions,

– very few winter types are grown,

– field peas are grown mainly in the eastern parts of Germany, characterised by a continental climate and low precipitation.

Experience shows that if the infestation level is high, fungicide treatments can lead to significant additional grain yield (for example >10 t/ha for faba bean rust) and a higher gross margin. If the weather conditions are favourable for pathogen development farmers and advisers need to decide on the optimal products, application rates and dates to control the disease effectively.

In Germany the number of fungicides registered for grain legumes is very limited.

Table 1. Important grain legume diseases in Germany.

Crop	English name	Latin name
Field pea	Ascochyta blight	*Ascochyta pisi*
	Downy mildew	*Peronospora pisi*
	Botrytis grey mould	*Botrytis cinerea*
	Pea rust	*Uromyces pisi*
Faba bean	Chocolate spot	*Botrytis fabae*
	Faba bean rust	*Uromyces vicia-fabae*
	Downy mildew	*Peronospora viciae*
	Ascochyta blight	*Ascochyta fabae*
Lupin	Anthracnose of lupin	*Colletotrichum lupini*

*proPlant Ltd, Muenster, Germany
(J-S.Richthofen@proPlant.de)

Currently only two foliar fungicides are allowed for faba beans, namely Folicur (tebuconazole) and Amistar (azoxystrobin). For field peas farmers can use Amistar and Verisan (iprodione), for lupins Amistar, Folicur and Switch (fludioxonil, cyprodinil).

So in which cases does a fungicide treatment pay off in grain legumes? This is shown for faba beans:

Weather for infection

On the chosen application date a farmer should have diagnosed disease infestation in his field, and the weather conditions should favour an increase in the existing infestation. Faba bean diseases have different climatic requirements. Whereas Ascochyta blight spreads during long humid periods even if the temperatures are relatively low, faba bean rust requires only a short spell of rain or even dew, but combined with much higher temperatures. Consequently the first rust symptoms are usually found some weeks later than Ascochyta spots. Fungicides should be applied between the beginning and end of flowering. Because of the limited preventive efficacy of the registered fungicides, earlier treatments bear a higher risk of late infections. The mixture of 0.5 l/ha Folicur and 0.5 l/ha Amistar is an alternative solution to the single use of 1.0 l/ha Folicur or 1.0 l/ha Amistar because it combines the curative properties of Folicur with the preventive properties of Amistar.

Furthermore the susceptibility of the variety plays an important role in the treatment decision. In varieties susceptible to infection the infestation appears earlier than in varieties with low susceptibility. For example, a higher yield increase regularly results from fungicide treatment against faba bean rust of the highly susceptible variety Scirocco than from treatment of Gloria, which is not so susceptible to rust.

Table 2 gives the results of a field trial implemented by FH SWF[1] in 2004 within the GL-Pro[2] trial network. Compared with the untreated control the yield increase for Scirocco was 16% when treated with 0.75 l/ha Folicur at full flowering and only 9% for Gloria.

The increase in yield is due primarily to a higher thousand seed weight (TSW) and at high yield levels (> 6 t/ha) the yield increase with a fungicide treatment is higher than at low yield levels. Therefore the use of fungicides is more efficient if high yields are expected.

proPlant expert.classic

For many years the computer-based decision support system 'proPlant expert.classic' has proved of value for cereals, rapeseed, potatoes and sugar beet. Since 2005 the system has been used to assist growers of field peas and faba beans to make field specific fungicide treatment decisions.

Each consultation is based on both field specific data and climatic data from official meteorological services. Together with information on the infestation level, the system processes the data to develop a recommendation for the application of a specific fungicide, if necessary.

Table 2. Fungicide treatment of faba beans: difference between varieties.

Variety	Susceptibility to rust[a]	Yield (untreated) t/ha (86% dry matter)	Yield (treated)[b] t/ha (86% DM)	Relative yield (treated)
Gloria	4	4.33	4.71	109
Scirocco	6	6.88	8.00	116

[a]German National List of plant varieties 2004: 1 (not or very low) – 9 (very high)
[b]Fungicide treatment: 0.75 l/ha Folicur on 21 June 2004 (full flowering)

Source: GL-Pro trial network. Trial results 2004 at the experimental station Merklingsen of FH SWF near Dortmund in Northwest Germany (750 mm average annual rainfall, 9°C average annual temperature, fertile soils with 80–85% silt).

Figure 1. proPlant expert.classic warning service: conditions for faba bean diseases in June 2004 and efficacy of a treatment with 0.7 l/ha Folicur at full flowering on 21 June 2004.

Infection probability

At the beginning of a consultation the user gets a quick overview of the situation in his region. The so called 'warning service' shows the weather conditions during the past 3–4 weeks and a weather forecast for the following three days. The climatic overview gives at least daily maximum and minimum temperatures, hours of sunshine and rainfall levels. As rainfall may vary between the farm and the location of the meteo station, the user can change precipitation levels according to his own recordings. This is important because rainfall has a significant impact on the spreading of fungal diseases.

Taking into account the previous days and the weather forecast, the system determines whether recent weather conditions were conducive, or will become conducive, to pathogen infection in the next three days. Black or light grey dots[3] mark good weather conditions for an infection, with light grey dots indicating a situation that is conducive to pathogen development and black dots indicating a situation that is optimal for pathogen development. The dark grey background marks days on which curative pathogen management is still possible.

For peas, the system specifies conditions for grey mould, Ascochyta blight and pea rust infections. For faba beans the system determines conditions for faba bean rust, chocolate spot, Ascochyta blight and downy mildew infections. In addition, days with heat stress are indicated for both crops.

For example Figure 1 reflects the situation in the GL-Pro trial mentioned above in June 2004[4]. As the infection dots indicate, the weather conditions were good for disease infection, especially for rust and chocolate spot.

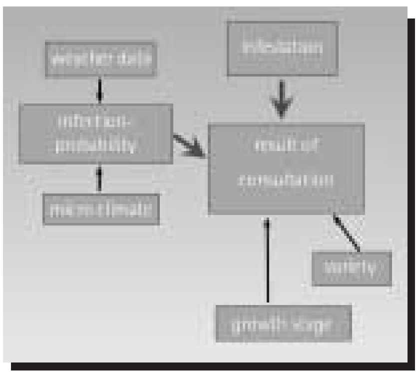

Figure 2. Parameters that influence the results of a consultation.

Specific recommendation

To get a field-specific recommendation the user also needs to enter appropriate data into the system, for example, variety, growth stage and soil drying. Furthermore a field check-up is required to determine the current infestation level. Figure 2 shows the parameters which influence the consultation results. For example, the system suggests a certain treatment for faba bean rust during the flowering stage if recent weather conditions have been optimum for infection and if the variety's susceptibility to infection is average or high.

proPlant expert.classic creates a list of fungicides that are able to manage the specific infestation in the field. Among other factors, the date of infection plays a major role in determining the application rate. If the infection is recent, a low application rate will have a good (curative) effect on fungal diseases. If the infection has existed a long time, higher rates will be necessary to provide effective control. The list of recommended fungicides also provides the optimal application date or period as well as the approximate costs of an application.

The efficiency of a treatment can vary depending on the growth stage, application rate and properties of the chemical used. To ensure an unbiased recommendation for a specific fungicide, the products provided in the database of the system are assessed regarding their curative, eradicative and preventive properties by results that were obtained in official field trials. The preventive effect of a product is indicated by the number of days during which the product provides protection at average temperatures.

The effect of applying 0.7 l/ha Folicur at full flowering on 21 June 2004 in the GL-Pro trial mentioned above is shown in Figure 1. In addition to the infection probabilities the curative, eradicative and preventive properties of the treatment to control the diseases in the specific climatic conditions are given. Because of its curative efficacy on rust, infections since 15 June 2004 could be controlled by the treatment, but not infections which took place earlier.

The dark grey background above shows that it would have even been possible to control rust infections which established on 13 June. But since the conditions on 13

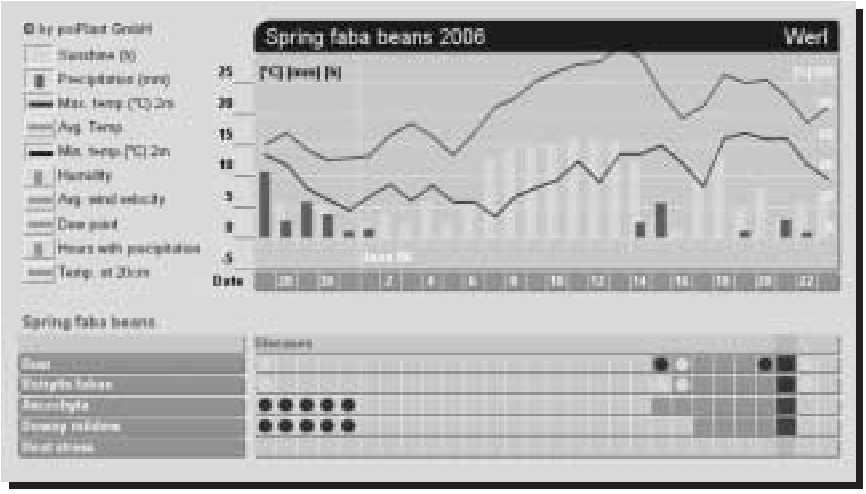

Figure 3. proPlant expert.classic warning service: conditions for faba bean diseases in June 2006.

and 14 June 2004 were not conducive to rust infections, a higher application rate (for example, 1.0 l/ha Folicur) would have had no effect on rust, but would have resulted in higher production costs.

Besides the curative effect, Folicur has a partly eradicative effect on faba bean rust. The preventive effect of the treatment lasted until 7 July 2004 (17 days).

The great variation in fungal disease infestation levels between years becomes obvious when the situation in 2004 is compared with conditions in 2006 (Figure 3). In 2006 a fungicide treatment was not profitable for faba beans in this north-western region. As proPlant expert.classic shows, fewer days with good and optimal weather conditions for disease infestation occurred during the flowering period in mid June and rust and chocolate spot appeared very late in the fields.

In 2007, because of the warm spring temperatures faba beans were already flowering by the end of May in north-west Germany, about three weeks earlier than usual. Because of the long period with high-pressure and dry weather from the end of March until the beginning of May the disease infestation potential was at a very low level.

Control may not be profitable

Usually it is not profitable to control foliar diseases in peas and faba beans in Germany. But in certain years and in certain regions high infestation pressure can cause severe yield losses. The computer-based consultation system proPlant expert.classic provides support for farmers and consultants who need to make field-specific treatment decisions while taking into account agronomic data, weather reports and infestation levels. Against the backroud of small margins in standard feed grain legume production, the decision support system enables input costs to be saved and disease to be controlled efficiently. ■

[1]South Westfalia University of Applied Sciences, Soest, Germany.

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

[3]Normally the graphs are coloured and the black and grey dots are red and yellow respectively.

[4]Weather station Werl close to the experimental station Merklingen of South Westfalia University of Applied Sciences.

A jump in price for French faba beans exported to Egypt

Flambée du prix de la féverole française exportée vers l'Egypte

by Jean-Paul LACAMPAGNE*

With annual exports amounting to between 130,000 t and 180,000 t since 2002–03. France is rapidly becoming the foremost exporter to Egypt, the main country importing faba beans for human consumption.

Previously, Egypt imported faba beans primarily from Australia, but the volume of supplies was irregular, with low yields every two years since 2002–03. In 2006, Australian production was only 108,000 t compared with 329,000 t the previous year.

In 2006 and 2007, in spite of attractive prices, the European supply has also decreased, because of a sharp decline in the production area in France (102,000 ha in 2005 to 55,000 ha in 2007) and problems of quality in 2006 (bruchid attack), and also disappointing yields in 2007 in the UK (the third most important exporting country).

In the context of reduced availability on the world market and notably in the principal exporting countries, together with a steady ongoing demand from Egypt, the price of French faba beans destined for Egypt has been rising for more than a year (Figure 1), reaching a record level of €320/t in French ports in September 2007, in the context of a very nervous world market for wheat and other cereals.

Very attractive prices and high 2007 yields in the northern regions of France (the principal areas of production) could provide a boost for the faba bean crop in France. ■

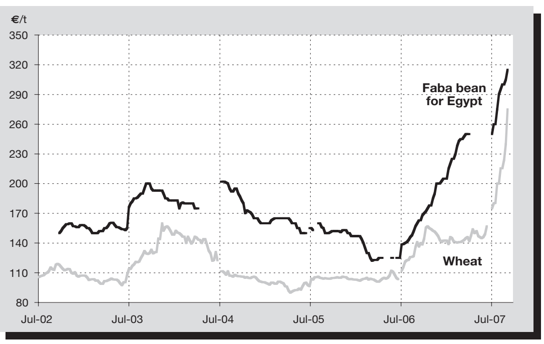

Figure 1. Prices of French faba bean (human consumption quality – trade prices at Rouen, Normandy).

*UNIP, Paris, France. (j.lacampagne@prolea.com)

Ascochyta blights of grain legumes

Bernard Tivoli, Alain Baranger, Fred J. Muehlbauer and B. M. Cooke (Eds)

November 2007, vi + 142 pages

Springer, Heidelberg, Germany

ISBN: 978-1-4020-6064-9 Hardcover

This special issue of the *European Journal of Plant Pathology*, 2007 **119**, No. 1, reflects some major contributions made at the 1st International Ascochyta Workshop on Grain Legumes held on 2–6 July 2006 at Le Tronchet, France (see *Grain Legumes* **47**, 6–7.

Ascochyta blights consistently affect large areas of grain legume production (pea, lentil, chickpea and faba bean) in all countries where they are cultivated. These diseases are capable of causing large yield losses under conducive environmental conditions. This book considers the state of the art by taking a comparative approach of Ascochyta blight diseases of cool season food and feed legumes. Topics considered are pathogen diversity, legume genetics and breeding, and integrated disease management.

This special issue, written for scientists, university teachers, students and extension specialists, has a foreword by the editors, followed by thirteen chapters all written by experts in different areas of Ascochyta research.

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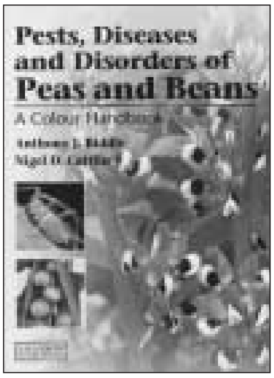

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A. J. Biddle and N. D. Cattlin

2007, English, 268 x 190 mm, 128 pages

267 colour photographs, ISBN 978 1 84076 018 7

In his Foreword Dr John Kraft, formerly of the USDA Agricultural Research Service, Washington, USA describes this book as "a thorough compilation of information on the diagnosis and control of pests, diseases and disorders of peas, faba beans and common beans in one fully illustrated, easy to read publication."

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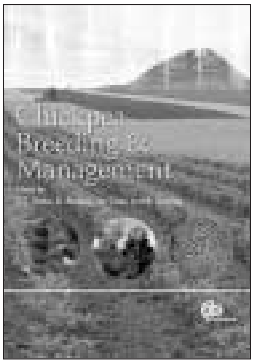

Chickpea breeding and management

S. S. Yadav, R. Redden, W. Chen and B. Sharma (Eds)

April 2007, English, 448 pages

ISBN Hardback 978 184593 213 8

Indian Agricultural Research Institute New Delhi, India, Victoria Institute for Dryland Agriculture Horsham, Australia and USDA-ARS, Washington State University, USA

This authoritative account by international experts covers all aspects of chickpea breeding and management, and the integrated pest management and biotechnology applications that are important to its improvement. With topics covered including origin and taxonomy, ecology, distribution and genetics, this book combines the many and varied research issues impacting on production and utilisation of the chickpea crop on its journey from paddock to plate.

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Pigeonpea development in China

Développement du pois caján en Chine

by Shiying YANG* and colleagues**

Pigeonpea (*Cajanus cajan* (L.) Millsp., $2n = 22$), also called red gram, is one of the major grain legumes in the world. Pigeonpea is important due to its ability to grow under diverse cropping systems and environments and its ability to recover from the losses caused by various biotic and abiotic stresses. Pigeonpea is about 5% of the total world production of grain legumes.

Pigeonpea is grown in more than 90 countries with a total cultivated area of approximately 4.6 million ha, and a yield of approximately 3.3 million tonnes worldwide in 2005. The major pigeonpea growing area is in Asia (88.8%), Africa (10.6%) and Latin America (0.6%). In 2005, more than 76% of the pigeonpea area was in India. The other major pigeonpea growing countries are Myanmar, Kenya, Malawi, Uganda, Tanzania, Nepal, Dominican, Congo and Haiti (2).

China started to plant pigeonpea in the 1950s. It has been used in the forestry industry and as a host for the lac insect that secretes the resinous substance, 'lac'. There were only 4,000 ha of pigeonpea being grown as a crop in China before 1997. In 2000, the sowing area was over 15,000 ha (9, 11), with a stable increase to 60,000 ha in 2006 (12, 3).

A very versatile crop

Traditionally, in the major areas of production, pigeonpea has been used for human food, vegetable matter, animal feed and fuel, but it is a very versatile crop. Dhal (decorticated split seeds of pigeonpea) is the major food for human consumption primarily in south Asian countries, but this is not the case in China where eating habits are very different. Some pigeonpea seed is used for animal feed.

*Diversity Arrays Technology, Canberra, H. Graham Centre for Agricultural Innovation, Wagga Wagga, Australia and Guangxi Academy of Agricultural Sciences, P. R. China (shi6yang@yahoo.com)

**As* also ICRISAT, Patancheru, India and Chinese Academy of Agricultural Sciences, Beijing, P. R. China.

(Photo S. Yang, Guangxi Academy of Agricultural Sciences, P. R. China)

Pigeonpea for soil conservation in Duan county, Guangxi province, China.

At the same time pigeonpea is used as a herbal medicine in India, Indonesia, China, West Africa, Madagascar and the West Indies for healing wounds, destroying internal worms and curing lung diseases (5). It can cause reversion of sickled cells in patients suffering from sickle-cell anaemia (1), and it is a resource for honeybees since its flowering period can last a few months (9).

In recent years, however, pigeonpea has been developed for use in south China in soil conservation, for forest recovery and poverty alleviation. It is also used as a fodder crop for feeding goats , buffalo and rabbits in the Guangxi province of China, and for water conservation and ecological re-construction in Yunnan province of China. The reason for the unbelievably fast increase in the use of this crop is that pigeonpea helps in forest regeneration and poverty reduction being grown both as a shrub and a food legume crop. It suits the steep (>25 degrees) slopes of the karst mountainous landscapes that are dominant in the south-west part of China, a region where different ethnic populations are concentrated and living conditions are poor. This area was considered a key area for a poverty reduction strategy by the central Chinese Government. After pigeonpea was proved to be superior to other crops as a 'gap-coverage' shrub for both forest recovery and poverty reduction in reforestation practices, local farmers gradually developed their own methods of pigeonpea-based agro-forestry using the new pigeonpea varieties/cultivars.

ICM packages

In 1997, a Chinese pigeonpea team began to introduce these new varieties from ICRISAT for farm testing (11). Various pigeonpea variety/farming and eco-system combinations have been evaluated and screened in different targeted counties in China from 2001 to 2006. Farmer initiative Integrated Crop Management (ICM) packages have been optimised with scientists' participation; and scientist designed ICM packages have been optimised with farmers'

(Photo S. Yang)

Fresh branches and leaves of pigeonpea provide good fodder for goats in Longan county, Guangxi province, China.

participation. A farmers' association based on pigeonpea commercial grain production and vegetable production systems has been established in the major pigeonpea production area in Yunnan province (12, 3). ICM packages aimed for ruminant livestock were developed with farmer participation in Guangxi province at the same time. Pigeonpea intercropping systems for soil conservation, pigeonpea intercropped with neem trees (*Azadirachta indica*) and other perennial plants like walnuts (*Juglans* spp.), are the most common practices for degraded soils on steep slopes along the Nujiang and Lancang river banks in Yunnan province (12, 3). Furthermore, pigeonpea intercropping systems for more economic benefits, pigeonpea intercrop with groundnuts and other crops like chilli, are the common practices in dry and hot areas like Yunmu county in Yunnan provinces (12, 3).

Pigeonpea is also being used as a legume vegetable source in China (6), and this use became well developed in most of the pigeonpea sowing areas in China between 2001 and 2006. The three best pigeonpea varieties, ICPL 87091, ICP 7035 and ICP 12746, used for both vegetable and dry grain production are recommended according to their performance in terms of high yield and superior quality of green peas.

Genetic diversity mainly in wild relatives

A genetic diversity study using Diversity Arrays Technology (DArT) for pigeonpea and its wild relatives revealed that most of the genetic diversity was among the wild relatives of pigeonpea or between the wild species and the cultivated pigeonpea (10). There is limited polymorphism among the cultivated accessions. Therefore, the Chinese team are introducing wider ranging genetic materials from ICRISAT which were progenies crossed between different species as a resource to establish new breeding systems (7, 8). Currently, the aim of pigeonpea genetic improvement activities in China is to select for better yield and quality, as well as better disease resistance. This work is undertaken by the Guangxi Academy of Agricultural Sciences, the Yunnan Academy of Agricultural Sciences, the Chinese Academy of Agricultural Sciences and the Chinese Academy of Forestry (12, 3, 4). ■

Acknowledgments: We would like to acknowledge the Department of Guangxi Science and Technology of China, the State Administration of Foreign Experts Affairs of China and the International Fund for Agricultural Development for supporting the pigeonpea development research in the Guangxi Academy of Agricultural Science.

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COVER PHOTO:
Top left: Field of chickpeas at Ain Temouchet, Algeria in April 2007. (Photo Houcine Irekti, INAT, Algeria)
Top right: Salt accumulation in a faba bean field in Al-Sharkia, Egypt. (Photo Y. G. Yanni, Sakha Agricultural Research Station, Egypt)
Bottom: Microarray approach to identify salt stress-responsive genes from legumes (Photo ISV CNRS, France)

PHOTO DE COUVERTURE :
En haut à gauche: *Champ de pois chiches à Ain Temouchet, Algérie, en avril 2007. (Photo Houcine Irekti, INAT, Algeria)*
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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.

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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.

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