GRAIN LEGUMES

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The challenge of developing food and feed legumes over the next 25 years

Communicating the benefits of grain legumes

Exploiting model species for studies of legume seed biology

Biofortification of grain legumes

Exploiting model species for studies of legume seed biology

Legumes for Global Health

Echoes of IFLRC V and AEP VII in Antalya, Turkey

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FOR AUTHORS

Grain Legumes is aiming to interest and inform a worldwide multidisciplinary readership on very different aspects of legume research and use, including genetics, agronomy, animal production, human nutrition and health and economics.

Please write your article so that it will assist in the exchange of information between people working in different expert fields of legume research: write to the length requested; provide a review of the most important information on your topic; try to avoid (or explain) specialist words, unusual jargon and acronyms; emphasise results and conclusions; choose titles carefully and add subheadings that tell readers something. *Grain Legumes* prefers a clear, simple and comprehensive writing style that would make its articles interesting and useful for both academic and amateur audience. Your manuscripts does not have to follow the usually strict structure of the research papers.

Please provide an abstract of between 90 and 100 words and from 4 to 6 key words.

We strongly encourage you to submit either longer (1,250 words + 2 tables, figures or photos + up to 8 references) or shorter (450 words + 1 table, figure or photo + up to 4 references) manuscripts. Editorial Board may allow any variation from case to case. It is only authors that are responsible for the quality of the use of English language. The manuscripts seriously lacking it will be returned to itheir authors for improving with the help of the help of a native English speaker.

The manuscripts should be prepared in MS Word, using Times New Roman font, 12 points size. The references should be listed alphabetically, formatted in the style used by any journal published by Springer. It is highly recommended the tables, figures, photos and other accompanying manuscript files are submitted separately.

EDITORIAL

Despite the fact that both authors and readers have been waiting for the publication of this issue of Grain Legumes for more than three years, we have finally managed to release it.

It contains several keynote papers on diverse topics of the joint Fifth International Food Legume Conference merged with the Seventh European Conference on Grain Legumes, with the latter organised by the European Association for Grain Legume Research (AEP).

The merged conference brought forth an idea to establish a new international society that would link all legume research communities into a simple and functional network to the benefit of the global legume research and industry communities, as suggested during the last AEP General Assembly.

We all are immensely grateful to Kadambot Siddique, Bert Vandenberg and Tom Warkentin for their successful scientific strategy of the event, Cengiz Toker for an excellent organisation and Barbara Hoggard-Lulay for her strength, patience and enthusiasm in making so many technical issues possible.

Enjoy reading the issue!

Gérard DUC
Aleksandar MIKIĆ
Managing Editors of GLM55

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Carte blanche to…

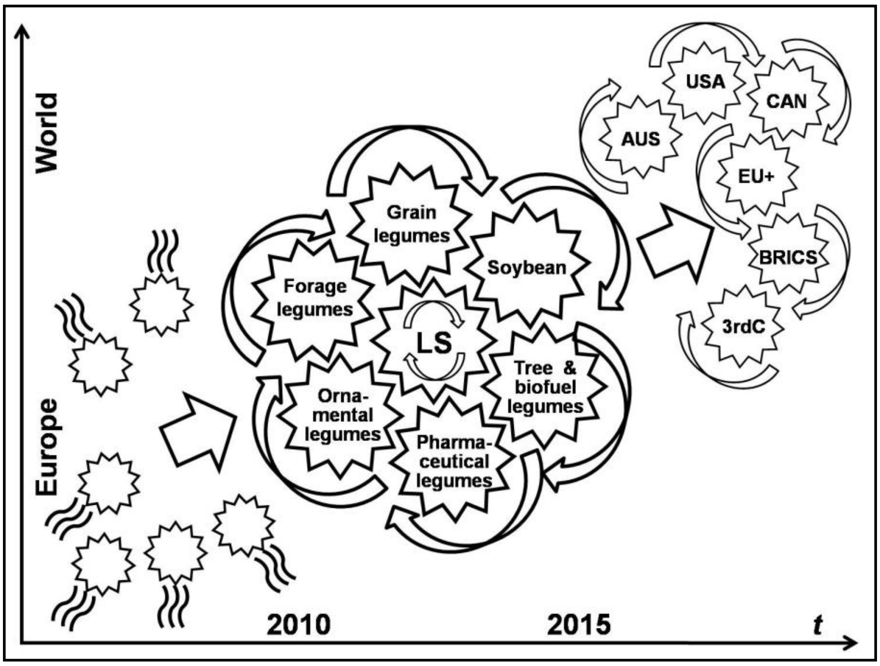
…Aleksandar Mikić

"Legumes for nothing…

…Chickpeas for free". This was a funny modification of the famous hit of Dire Straits, made by Tom Warkentin, Petr Smýkal and myself made during the Second Grain Legumes Technology Transfer Platform (GL-TTP) Workshop, held in November 2008 in Novi Sad. Of course, that was only a joke. Merging the Fifth International Food Legume Research Conference and Sixth European Conference on Grain Legumes, in Antalya, Turkey, from 26th to 30th April 2010, proved to be a rather successful event for the whole global legume research and industry communities, demonstrating that no legume is less important than any other crop.

All the sessions of the conference, whether in the form of oral or poster presentations, were full of novel knowledge on the various topics. I will take liberty to select two topics that could be considered perhaps more far sighting than the others. One of them is the session devoted to communicating the benefits of grain legumes for the whole society, from researchers and farmers to industry and decision makers. The other was the last General Assembly of the European Association for Grain Legumes (AEP), reflecting the last meeting of its leaders in June 2008, when had been decided that AEP should be transformed into a new society comprising all legumes, as shown at the figure below.

So, we may say that an new chapter in the legume research and its transfer to industry is beginning, promising and beneficial for the whole mankind and its needs.



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Opportunities to increase grain legume production and trade to overcome malnutrition

by John D.H. KEATINGE[1]*, Warwick J. EASDOWN[1], Ashutosh SARKER[2] and C.L. Laxmipathi GOWDA

Malnutrition or 'hidden hunger' severely stunts human potential due to imbalanced diets and a lack of vital vitamins and minerals. Good health depends on the availability, affordability, and acceptability of the foods essential to a balanced diet, and these include hardy multipurpose food legumes that can be consumed as vegetables or grains.

Grain legumes provide a third of humanity's protein needs and for those living under subsistence conditions can provide twice this amount. They are the cheapest available source of protein for the poor, an important source of many essential micronutrients and a valuable source of animal nutrition and maintaining soil health. As often low-input crops they are well suited to poor farmers have a vital role to play in overcoming growing malnutrition, particularly in South Asia and sub-Saharan Africa.

Population growth over the next 40 years will require a doubling of food production in developing countries and climate change will make achieving this goal more uncertain. The strongest negative impacts of climate change are expected to be in sub-Saharan Africa and to a lesser extent in South Asia. Legume supplies in these regions may be increased by greater local production or through greater international trade.

In the past, most production increases in developing countries have been through expanding areas rather than improving yields. Between 1990 and 2004 global plantings of grain legumes increased by almost 8% and production increased by 11%, but productivity grew by less than 3%.

These low average yield improvements can hide important local successes. Given a favorable investment climate for farming, good investment in agricultural research and extension, protection of property rights, and the existence of demand that is transmitted to the farm gate smallholders have shown they can very effectively rise to the challenge of increasing production. They can also be more productive than larger farmers, particularly when labor is a major component of production and capital is costly, as is often the case in sub-Saharan Africa. When such conditions are in place, and smallholders have access to adequate seed supplies, they can take full advantage of the opportunities that improved varieties provide.

Breeding improved varieties has been one of main strategies used by national and international agricultural research centers to increase grain legume production over recent decades. Higher yielding and disease resistant varieties make growing legumes less risky, more profitable and more attractive to farmers. There have been some spectacular successes. For instance, collaborative plant breeding efforts involving national and international partners in Asia over 40 years created the modern mungbean industry out of low yielding semi-wild types. These high yielding, disease-resistant mungbean varieties that matured synchronously in 60 to 65 days revolutionized the industry. They created new cropping niches, allowing mungbean to be incorporated in between rice/wheat rotations and increasing global production by 35%. Similar successes have been achieved with lentil, ground nut, chickpea, pigeonpea, faba bean vegetable soybean and grasspea resulting in the release of thousands of new varieties.

However some legume production constraints have been very difficult to overcome by conventional breeding and new genetic approaches promise exciting opportunities for breaking yield barriers. Rapid advances in plant genetics and genomics are being driven by related technical improvements medical research and are expected to continue.

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Burgeoning data sets and functional genomics are greatly increasing our knowledge of plant biology, and the opportunities to improve both crop performance and quality. The identification of genes for disease resistance through the application of marker technologies could have a major impact on yields.

Legumes that have multiple uses and markets can have a large impact on overcoming malnutrition and increasing smallholder incomes. Soybean dominates world legume production and trade. It is the world's greatest legume success story and can be used for food or industrial uses; as a source of both protein and oil. Diverse specialist high value types have been developed for human food; for consumption as grain, as vegetables or manufactured foods such as tofu. Vegetable soybeans are larger and more nutritious than grain soybean but constitute less than 2% of global soybean production. Well known as fresh vegetables in East Asia, they are highly suited to smallholder agriculture or home gardens, producing among the highest yields of crop protein per unit area, and can earn smallholder farmers three to four times the price of commodity soybeans. They are well established in intensive cropping systems in Asia, but are little known elsewhere.

In many cases great progress in legume production and trade can be made by simply expanding the application of existing improved varieties to new locations. More promotion and minor adaptive research can make these regionally successful crops much more widely available to help overcome malnutrition. The adaption of soybean production technology from the temperate regions of North America to the tropical regions of Brazil has led to a massive expansion of global soybean production. Most growth in legume production over the last thirty years has been in developing countries, and this can create export income opportunities even when the crop may not be culturally suited for local consumption.

Trading patterns for grain legumes are shifting and this can create opportunities for smallholder farmers in developing countries – even in those countries that may not be known as large legume producers. India has traditionally been the world's largest producer of many legume crops but in recent years it has become a major importer. A number of developed countries have developed new legume industries that are now capitalizing on such opportunities. Mungbean and desi chickpeas are relatively new crops to Australia but now India has become the major market for its production. Similarly Canada has become a major exporter of kabuli type chickpeas along with Turkey and Mexico. However, Myanmar has also emerged as a major producer of pigeonpea and mungbean for export, while Ethiopia has become a major producer and exporter of dry beans. Changing trade demands can create opportunities for new producers, that given the right policy environment and quality controls can also include smallholder producers in developing countries.

Grain legumes are already one of humanity's most important food crops. Global production is now around 61 million tonnes but this has been increasing at a much slower pace than that of cereals, and not enough to keep up with population growth. Although advanced genetic techniques hold promise for some major improvements in yields and quality, much more could be done with existing improved varieties and the expansion of regionally successful crops to other countries or regions either for local consumption or for export as cash crops. This will require the active involvement of farmers, researchers, extensionists, policy makers, civil society and funding bodies. The very diversity of food legume species provides many opportunities for progress, and the greatest opportunities may not necessarily come from the crops or countries that have dominated legume production in the past. ■

Exploiting model species for studies of legume seed biology

by Karine GALLARDO[1]*, Björn H. JUNKER[2] and Béatrice TEULAT-MERAH[3]

The capacity of seeds to accumulate large amounts of protein during maturation is an important feature of grain legumes, which makes them an excellent protein source for animal and human nutrition as well as contributing to the establishment of the new plant by furnishing amino acids and derived compounds to the young seedling. Even though legume seeds are rich sources of proteins, they are frequently deficient in sulphur amino acids and attempts have been made to increase methionine and cysteine levels. Sulphate is one of the dominant forms of sulphur found in the phloem supplying pods during legume seed development (9). In plants, sulphate can be reduced to sulfide, leading to the synthesis of cysteine, the precursor for methionine synthesis, or it can be stored in the vacuoles. The delivery of sulfate to seeds and its translocation between seed tissues is likely to require specific transporters. With the availability of genomic sequences for the legume model species *Medicago truncatula* and the non-legume Arabidopsis, extensive post-genomic resources have been generated to describe the transcriptome and proteome of developing seeds at different levels, including whole seed, individual tissues and nuclei (1, 7).

From these data, a number of sulfate transporter genes expressed in the seed envelopes were identified. Some of these transporters are predicted to be vacuole-localised and may play a role in sulfate efflux into the cytosol (group 4 sulfate transporters, SULTR4), while others are predicted to be associated with the plasmalemma (group 3 sulphate transporters, SULTR3) and may play a role in seed sulfate uptake or translocation between seed tissues. In *M. truncatula*, group 3 sulfate transporters were mapped in QTL intervals for seed protein composition (unpublished data), and are now the subject of functional studies using mutants both in the legume species *M. truncatula* and pea, and in Arabidopsis. Interestingly, SULTR3 sulfate transporters were recently shown to influence storage protein maturation and free cysteine levels in mature seeds of Arabidopsis (12), which is consistent with a role for these transporters in sulfate translocation to the embryo and in determining seed composition. In contrast, SULTR4;1 plays a minor role in determining seed protein composition, but may be important in maintaining redox homeostasis in seeds presumably through the delivery of sulfate into the cytosol for the synthesis of thiol-containing molecules, such as glutathione (13).

An understanding of the effect of modifications in nutrient/ion synthesis or transport in seeds requires a detailed analysis of the metabolic and physiological consequences of these modifications, and the way in which the responses overlap and interact. Comprehensive transcriptomics, proteomics and metabolomics studies from separated seed tissues can be used to augment our understanding of the molecular and physiological processes taking place in legume seeds with modified nutrient/ion synthesis or transport activities, in different genetic backgrounds and environmental conditions (10, 11). However, taken individually, these global approaches do not account quantitatively for flux in metabolic networks. Therefore, as mentioned by Schallau and Junker (8), the main task for the future is the reliable and automated acquisition and assembly of high-throughput data into plant metabolic models. Computational modelling, based on a mathematical description of a metabolic network, could be employed to exploit large-scale datasets in the emerging field of systems biology. Recent advances in systems biology have been applied to *M. truncatula* seed metabolism (Junker et al. unpublished), with the aim of getting detailed insights into metabolic fluxes during storage compound synthesis (Fig. 1).

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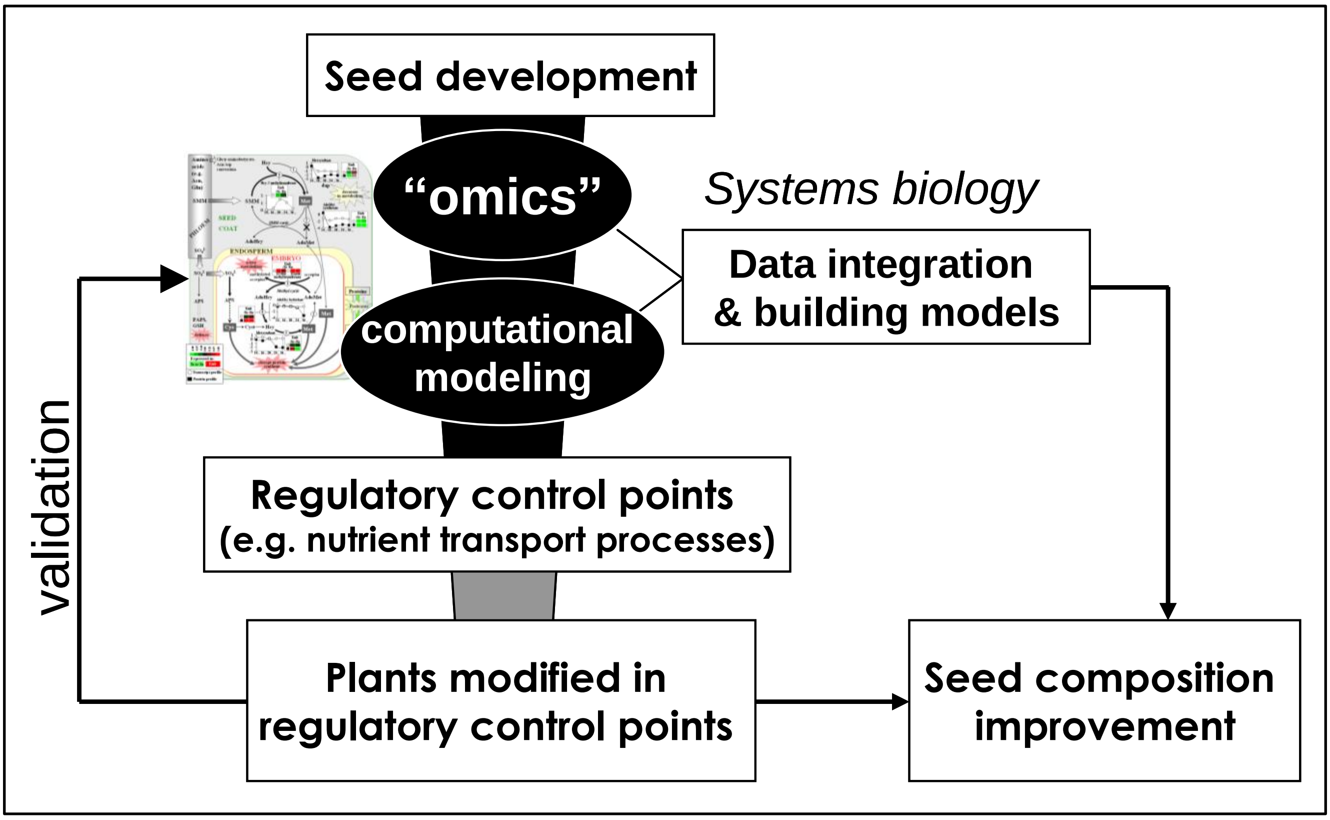

Figure 1. Towards a systems biology approach to improve legume seed composition

Two main approaches are being used. The first, Flux Balance Analysis, is a predictive computational approach that permits the construction of a metabolic model of primary metabolism in developing seeds through the integration of public biochemical, physiological, proteomic and genomic data (5). Such models can be used to investigate the metabolic ability of developing legume embryos to synthesise seed storage reserves in response to genetic or environmental perturbations. The second approach, ^{13}C Steady-State Metabolic Flux analysis, involves stable isotope labelling experiments of developing embryos cultured *in vitro*, followed by analysis of label partitioning into different compounds. This strategy has been applied to soybean seeds and showed that temperature during early stages of development has a major effect on establishing capacity for flux through components of central carbon metabolism (6). These two approaches could therefore be used to select metabolic pathways for genetic manipulation, in an effort towards modifying storage compound accumulation in legume seeds.

Improvement of nutritional quality through manipulation of seed composition should not be achieved at the expense of germination performance, which makes a major contribution to crop quality and yield. Studies have been performed in *M. truncatula* to analyse seed germination and heterotrophic growth in a panel of genotypes (2). To further enhance knowledge of the genetic determinism of important physiological characteristics, a quantitative trait loci (QTL) approach was employed by Dias et al. (3) to identify the loci responsible for variation in seed imbibition rate, germination homogeneity and rate, as well as hypocotyl growth at 20°C and at sub-optimal temperatures (5-10°C). This led to the detection of distinct QTLs for imbibition, germination and seedling growth, whatever the temperature tested or genetic background, supporting the existence of different genetic controls. In attempts to improve both seed composition and germination performance in fluctuating environmental conditions, studies are in progress that compare the overall composition of legume seeds with their ability to germinate and to give a vigorous plantlet under various environmental conditions. ■

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Biofortification of grain legumes

by C.L. Laxmipathi GOWDA[1]*, Aravindkumar JUKANTI[1] and Carlota VAZ PATTO[2]

Introduction

Micronutrient malnutrition, often referred to as 'hidden hunger' affects billions of people in the developing countries. Preschool children and women are especially vulnerable to this form of hunger (12). In addition to maternal mortality, micronutrient malnutrition affects cognitive development, disease resistance and vital growth in children. Significant reduction/elimination of deficiencies in iron, vitamin A and iodine (by the year 2000) were the three important goals directly addressed by the landmark 1990 World Summit for Children. Though substantial progress has been achieved, the targets set at the summit are yet to be realized (11). Fighting malnutrition is an integral part of 'Millennium Development Goals (MDGs)' resolution adopted by the General Assembly of the UN (2001). Food fortification has played an important role in meeting the nutrient requirements in the developed countries, but biofortification is considered cost effective for meeting the needs of the poor in developing countries. The importance of breeding legumes to provide adequate quantities of bio-available micronutrients to people in the developing world has been highlighted by R. Welch in the keynote speech in the session on biofortification of grain legumes in this Conference.

Biofortification

Biofortification refers to development of crop varieties that accumulate high amounts of nutrients (minerals and vitamins) in their edible parts (seed/leaf/root etc.). It has multiple advantages compared to the commercially available fortified foods (2) due to: (i) advantage of targeting the low income households; (ii) reach the malnourished populations in the remote areas which have limited accessibility to the commercially available fortified foods, and (iii) it is a one-time investment approach with low recurring costs.

Why biofortification?

It is possible to improve the nutrient (B-carotene, iron, zinc and other minerals) concentration for food crops by exploiting the variability present in the germplasm through conventional breeding approaches and the most recent examples in this area have been reported during this Conference. Among the different minerals iron, zinc, iodine and vitamin A deficiencies were identified as the most serious health threats by WHO (20). Folate deficiency is also a health concern owing to its importance in child development and folate is amenable for biofortification (11).

About 2 billion of the world's population suffers from iron deficiency (18). Iron deficiency accounts for about half of the entire anemia cases reported world wide (20). It is estimated that about 800,000 deaths occur due to iron deficiency anemia annually. Iron deficiency affects cognitive development, causes pregnancy and childbirth complications, decreases disease resistance ability and physical capacity. Vitamin A plays an important role in immune response, vision, reproduction and embryonic development. About 250,000-500,000 become blind every year due to vitamin A deficiency (11). Goiter, cretinism and mental retardation are the common disorders of iodine deficiency (5). The clinical manifestations of zinc deficiency include dermatitis, mental retardation, infections due to immune disorders, growth retardation and delayed wound healing. Folate deficiency in newborns leads to neural tube defects (19). It is also associated with high risk of colon, esophageal and cervical cancer (3, 9); spina bifida and increased risk of cardio vascular diseases (11). From the reported examples on legume nutrients during this Conference, the identification of variability for several important minerals in Canadian grown chickpea varieties, and tocopherol content in several Italian and Albanese grain legume landraces can be readily exploited in breeding programs.

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Protein calorie malnutrition (PCM) is another important factor impacting human health. Protein calorie malnutrition observed especially in infants and young children in developing countries include a range of pathological conditions arising due to lack of protein and calories in the diet. It affects about 170 million especially preschool children and nursing mothers of developing countries in Asia and Africa (8). Legumes provide a major share of protein and calories in the Afro-Asian diet. A significant decrease in the consumption of legumes could be a contributing factor for increased protein malnutrition. Variability in protein and oil content was reported during this conference for ICRISAT-bred elite groundnut lines, and for Turkish chickpea landraces, and fatty acid and oil content in chickpea mutants from Pakistan. Variability was also identified for low molecular weight carbohydrates in wrinkled pea starch mutants.

Anti-nutritional factors

Despite their nutritional and medicinal value, presence of certain anti-nutritional factors (ANFs) limits the use of some legumes. ANFs are divided into protein and non protein factors (6). Non-protein ANFs include alkaloids, tannins, phytic acid, saponins, and phenolics (10) protein ANFs includes trypsin inhibitors, chymotrypsin inhibitors, lectins and antifungal peptides (21). Protease inhibitors interfere with digestion and are resistant to digestive enzymes and existing conditions in the digestive tract (16). Similarly phytic acid can form insoluble complexes of important metal ions in the small intestine thereby making them unavailable for absorption (17). Saponins and tanins, commonly found in legumes give a bitter taste limiting their consumption (13). Cyanogenic glucosides, known to cause respiratory distress are present in cassava and lima beans. Toxic amino acids present in certain legumes (*Lathyrus* and *Vicia*) are classified as (i) neurotoxins – (β-N-oxalyl-a,b-diamino propionic acid) (ii) osteotoxins – (b-aminopropionitrile) (iii) antimetabolites – (mimosine) (4, 15). Interestingly, many of these ANFs have beneficial roles in plants and humans, therefore breeding strategies aimed at lowering their content are not recommended. But, the anti-nutritional/toxic factors can be eliminated (to certain extent) by techniques like soaking, cooking, boiling and autoclaving (1).

As reported during this Conference, variability in legumes for antinutritional factors is subject of different studies. The importance of accurate estimation of antinutritional factors such as phytic acid content for bioavailability studies was also highlighted during this Conference.

Progress in biofortification of food crops

Food production and healthcare issues are two important factors for people living in the underdeveloped regions. Therefore, biofortified foods like 'Golden Rice', with higher β-carotene content (37 μg/g dry weight, 14), orange-flesh sweet potato lines also with higher β-carotene content (> 200 μg/g, 12) and transgenic rice accumulating three fold more iron compared (38.1 ± 4.5 μg/g DW) to normal seeds (11.2 ± 0.9 μg/g DW, 7) together with commercially available fortified foods could be the new public health approach in fighting malnutrition.

Besides the germplasm characterization studies, to identify interesting breeding materials, progress was also reported on protein QTL identification in soybean, release of Serbian soybean varieties with decreased kunitz trypsin inhibitor (KTI), and on the molecular characterization of aminodeoxychorismate synthase (ADCS) and dihydroneopterin aldolase (DHNA), key genes in the folate biosynthesis pathway on common bean. ■

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Control of seed quality traits in legumes: exploiting genetics and novel technologies for improved products

by Claire DOMONEY[1]*, Maria M. PEDROSA[2], Carmen BURBANO[2] and Bert VANDENBERG[3]

The keynote lecture described progress in the genetic and biochemical definition of seed quality traits in *Pisum sativum* L. (pea) which are directly relevant to feed and food industries and thereby impact on the promotion of sustainable agriculture. Genetic and biochemical data are underpinning the development of improved tools and resources for a broad range of end-uses, according to desired alterations to major and minor seed constituents. Some end-uses place conflicting demands on seed product composition such that a higher or lower quantity of a constituent may offer different advantages. The requirements for starch and protein differ according to feed/food end-use, though many legume seeds can supply both as industrial raw materials, thereby providing added-value to the crop (As illustrated for pea by two EU-funded projects, GLIP and TRIGGER). Many so-called anti-nutrients, classified as such for animal feed use, are now recognised as having potential health-promoting properties in food, for example the trypsin/chymotrypsin inhibitor proteins (TI).

Using near-isogenic lines (NILs) developed in pea, gene haplotypes associated with a low content of seed TI were shown to give rise to a higher ileal digestibility of protein in broilers (8), whereas it is now clear that the same TI can inhibit the growth of human cancer cell lines *in vitro* (3). Therefore, genetic markers developed to distinguish TI gene haplotypes may be exploited to select for either lower or higher content of these proteins depending on the use of seeds (3). While the biological function of TI in seeds is unclear, TILLING mutants (http://urgv.evry.inra.fr/UTILLdb) where the structure of these proteins is affected are being studied for their impact on seed biology. An apparent association between TI and overall seed protein content has been attributed to variation at the closely linked *Vc-2* locus, where a vicilin gene with a disrupted coding sequence has been shown to be present in some pea lines (2). The disruption leads to the loss of a highly conserved cupin domain within the encoded protein and a loss of normal 3' transcribed sequence, while the gene does not appear to be expressed. The repetitive element within the disrupted sequence provides a convenient marker for this locus, which may be a candidate for one QTL for protein content (Fig. 1, 2). Genetic variants for the anti-nutritional and poorly digested protein, pea albumin 2 (PA2), have been characterised, where a loss of PA2 is associated with an apparent deletion of most of the PA2- encoding genes. The null mutation has been introgressed into a cultivar, using a robust gene-based marker throughout for selection of the mutant allele. Quantitative variation in PA2 has been linked to changes both in seed metabolites (7) and the techno-functional properties of the protein (unpublished data). The crystal structure of PA2 from *Lathyrus sativus* provides clues to the possible role of this protein in metabolite sensing (4).

Visual traits are also relevant to seed quality and variation in seed colour, shape and size is related to market value (6). QTL and candidate genes for many of these traits are being sought and a genetic description of variants is being exploited to study fundamental biological processes, while also facilitating the development of markers for breeding programmes. An example is lipoxygenase (Lox), an enzyme involved in the oxidation of polyunsaturated fatty acids, where further co-oxidation reactions and enzymatic steps can result in the bleaching of pigments and/or the production of off-flavours in seeds, including hexanal. Quantitative variants for seed Lox have been identified in pea, where sequence variation in the promoter and 5' non-translated sequence may explain quantitative differences in expression (unpublished data). These and variants for additional enzymes involved in natural senescence and loss of chlorophyll from seeds are being studied for their relevance to seed colour phenotypes.

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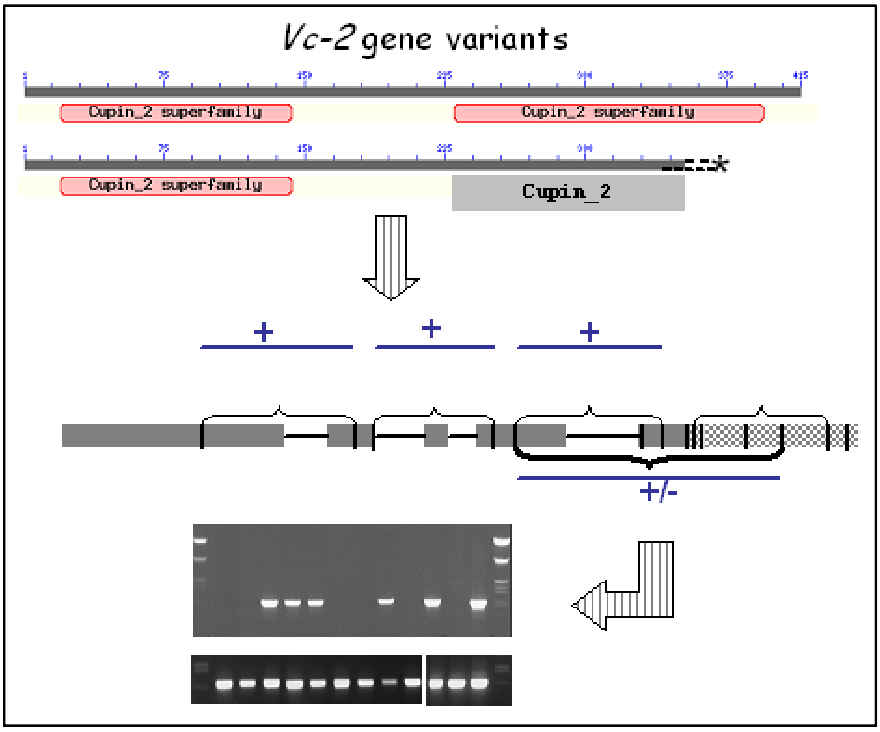

Figure 1. Example of complexity within vicilin proteins and development (block arrows) of corresponding gene markers. Schematic of proteins deduced from a *Vc-2* cDNA showing the positions of the two conserved vicilin cupin_2 domains (upper protein) and from a gene with a disruption in the second domain (lower protein) followed by a loss of sequence similarity (dotted lines) and an early termination codon (asterisk). The region spanning the fourth intron and extending into the disrupted (hatched) sequence identifies pea lines that carry this variant *Vc-2* gene (+/-). The gel shows the amplification of this gene fragment from some but not all pea lines (upper panel), compared with control amplifications where all lines show fragments corresponding to the conserved regions of *Vc-2* genes (marked + on schematic of gene; lower gel panel).

Metabolite analyses are being used to identify changes to compounds in seeds that reflect genetic background as well as the environment (1). The discrimination of metabolites linked to food quality will identify pathways involved in the generation of taste and flavour compounds and thereby provide links to genes and markers for improved selection through breeding.

In parallel with the opportunities presented by genetics for improving seed quality, technological developments to a number of processing methods may improve the functionality of seeds and seed components. Instantaneous controlled pressure drop (DIC®, patent F2708419) treatment is a highly controlled process that combines steam pressure with heat (5) and leads to seeds with a porous texture, following a short processing time. Treatment of a range of legume seeds (soybean, lupin, lentil, chickpea and peanut) by DIC has shown that this process considerably reduces the apparent content of most of the so-called nutritionally active factors, α-galactosides, phytates, trypsin inhibitors and lectins, without affecting total protein or lipid content. However, it should be considered that while denaturation of some proteins may be desirable to improve food/feed quality, this is no longer true for many proteins with potential health-promoting properties that rely on protein functionality, for example TI (3). The potential of DIC to reduce the allergenicity of legume proteins is being investigated. Modifications in the seed protein profiles of some legumes after DIC were related to a decrease in IgE-binding, which was completely abolished with longer treatments, thus offering potential for providing healthy foods to individuals with specific allergic responses to legumes.

Further issues relating to the acceptability of legume foods are being explored in relation to their ease of use. Novel packaging of products that are ready to eat and have a good shelf-life, allowing sensory and nutrient traits to be preserved, offer potential for promoting the use of legume food products among communities unaccustomed to growing, strong and cooking particular legume species. ■

Acknowledgements

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Communicating the benefits of grain legumes

Brondwen MACLEAN[1], Gérard DUC[2], Kofi AGBLOR[3] and Wayne HAWTHORN[4]

General social, environmental and economic benefits of grain legumes are already well known within the international grain legume community. However, their respective quantification in major zones of production, or in the context of new cropping systems have still to be worked out (example of the positive economic value of a new rotation monsoon rice-pea- spring rice for resource poor farmers of Bangladesh was provided by O. Ali and A. Sarker). Integrated and multitrait evaluation collected at territory levels will be helpful to communicate between government, policy makers, producers & users,and the wider community (value of Life cycle analysis of pulse crop production in western Canada was shown by S. MacWilliam et al.).

The keynote of this session given by K.Agblor and W. Hawthorn raised the issue of developing an agreed communication strategy on the benefits of grain legumes. Such a strategy will define the messages, the audiences, what delivery channels are used and later the skills and resourcing required. There will be different messages for different audiences but ultimately the aim is the same, to increase the production and consumption of grain legumes for the benefit of all.

Grain legumes are cultivated and consumed on all continents with arable land. The unique ability of legumes to form symbiotic relationship with Rhizobia to convert atmospheric nitrogen gas (N_2) into a form of nitrogen (N) that is biologically available and readily used by plants, is perhaps, the most widely reported benefit of grain legumes. In addition, the seeds of legumes are rich in protein, mineral micronutrients and vitamins, making them ideally suited to nutritional enrichment of cereal-based diets.

The benefits of grain legumes often cited include: rotational benefits in cropping systems and the related nitrogen credit to the crop following a legume, and reduced use of non-renewable energy; the environmental benefits associated with lower greenhouse gas (GHG) emission in grain legume production, as well when they are used locally in livestock feed; and, the human health and nutritional benefits associated with grain legume consumption. In spite of the tangible benefits associated with grain legumes, their global per capita consumption has been declining and the production has either declined or remained stagnant in the traditional sources in the developing world. The Food and Agricultural Organization (FAO) has projected that the global consumption of grain legumes will remain flat at 6 kg/person/yr, and this trend is similar for both the developing and industrial countries.

We are proposing that communicating the benefits of grain legumes must take an integrated model that combines their benefits to targeted audiences using the relevant and appropriate communication media. The communication model should include defining the message, defining the audience, and refining and targeting the message to align with the audience's perceived values.

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Defining the message

We propose that the thrust of the message should be based on the inherent benefits of legume production and utilization, i.e., its contribution to sustainability. Legume production and utilization contribute to Sustainable Environment, Sustainable Food Production, and to Sustainable Socio-Economic Development. We believe that these are key areas that will resonate with most audiences and stakeholders that are concerned about the impact of climate change, food production to a growing global population and socio-economic development.

Sustainable environment

Grain legume production and utilization contributes to:

- •Improved soil organic matter and carbon sequestration;
- •Reduced carbon dioxide emissions (CO_2) emissions from energy inputs;
- •Reduced non-renewable energy use;
- •Reduced nitrous oxide emissions and
- •Conserving vital nitrogen (N) sources.

For example, using conservative nitrogen-fixation values, it is estimated that the amount of fixed N from grain legumes in Canada in 2009 was 195,000 t. This is equivalent to the amount of natural gas required to heat 132,000 homes equipped with high efficiency furnaces in the cold Canadian prairies.

Sustainable food production

The contribution of grain legumes to food production systems is well documented and include:

- •Fixed N is the main source of nitrogen for grain legumes. In the Canadian example above, the value of fixed N was $105 million;
- •The N-credit for crops following in the rotation;
- •Improved disease, weed and pest management;
- •Increased crop diversification and enhanced risk management and
- •Improved soil health and water management.

Simply put, grain legumes provide eco-friendly food for people and feed for livestock and aquaculture.

Sustainable socio-economic development

Grain legumes can play a significant role in socio-economic agenda of all nations, especially with respect to human health and well-being and the associated financial resources that are committed. Contribution include:

- •A balanced source of carbohydrates, protein and fibre, making it a whole food;
- •High in micronutrients of iron (Fe), zinc (Zn), selenium (Se) and folate;
- •Evidence that consumption is beneficial to the management of diabetes and cardiovascular diseases and
- •Applications in weight management, gut function, blood sugar regulation and energy for endurance sports.

The audience

The target audience for messaging the benefits of grain legumes include: consumers (the general public), growers, media, funders and governments.

Consumers

- •Adopt and increase the consumption of grain legumes as environmentally friendly foods;
- •Maintain a healthy and active lifestyle by consuming grain legumes daily and
- •Actively seek out foods that contribute to sustainability of our planet's resources.

Governments and policymakers

- •Maintain adequate funding for research, development, and innovation in grain legumes;
- •Actively promote the consumption of grain legumes in food guides;
- •Address tariffs and trade impediments through advisory panels and
- •Negotiate with major importing countries for access to grain legumes.

Farmers

- •Maintain sustainable food production by including grain legumes in crop rotations;
- •Maintain the quality of grain legumes and
- •Continue to support research and innovation in grain legumes.

Media

- •Highlight the environmental and health benefits and
- •Advocacy for public and private support for innovation in grain legumes.

The media

We propose that the benefits of grain legumes be communicated beyond scientific conferences and publications to include these media:

Trade journals

- •Highlight trade barrier issues;
- •Discuss standards and quality issues;
- •Highlight emerging new uses and innovations arising from research and
- •Provide up-to-date statistics on production, demand and supply.

Internet and social media

- •Create a global website to promote the use of grain legumes;
- •Use Twitter to highlight specific legumes, e.g., "twit for lentil day", etc;
- •Use Facebook to disseminate information on recipes and tasty foods with grain legumes and
- •Include blogs in telling stories about the benefits of grain legumes.

Advertisements:

- •Use innovative advertisement campaign to generate public awareness and benefits of grain legumes (e.g., "Get cracking" for Eggs, and "Got milk?" campaigns); and
- •Create public awareness of ongoing efforts in Canada and Australia (Go Grains) to increase the use of grain legumes as healthy foods.

News releases and press conferences

- •To disseminate information on research findings and breakthroughs and
- •To ensure information about grain legumes remain current in the public domain. ■

For more information please visit http://www.saskpulse.com/consumer/

Strengthening our diverse options: the challenge of developing food and feed legumes over the next 25 years

John D.H. KEATINGE[1*], Warwick J. EASDOWN[1], Ashutosh SARKER[2] and C.L. Laxmipathi GOWDA

Food and feed legumes are essential for feeding humanity and our livestock and for sustaining and diversifying agriculture, particularly that of smallholders farmers in low-input and rainfed production systems. They provide a major source of protein and many micronutrients to help fight hunger and malnutrition and they improve soil health and cereal yields. We can't live without them, but current varieties and practices may not be enough to meet future challenges. Over the next 30 years world agriculture will face a brewing perfect storm of increasing food demands from a population of nearly 9 billion, increasing climate variability and land degradation combined with a loss of biodiversity, a looming energy crisis and limited fertilizer supplies.

Today legumes are not what they used to be, thanks to plant breeding. Exploiting the genetic diversity in maturity and adaptation within and between species has created new global niches for crops that were formerly only regionally known. The international agricultural research centers in collaboration with national partners have bred thousands of new varieties with higher yields and greater adaptability. For instance, short-duration, chickpeas tolerant of heat and drought are now extensively grown in central and southern India, which was unknown two decades ago. Extra short duration mungbeans are diversifying cereal monocropping across South Asia to arrest its decline in productivity, and the potential to expand such Asian crops into other areas of nutritional need such as in sub-Saharan Africa is virtually untapped.

Food and feed legumes are highly diverse, and that is both a benefit and disadvantage. Exploiting that diversity has created new cropping possibilities, but a lack of resources means that breeding efforts have also been spread thinly over many crops. The international agricultural research centers hold in trust the world's largest public legume germplasm collections, but only a small proportion of these have been fully characterized and used to develop improved lines of major legume crops. Many minor legume crops have received little breeding attention. Much breeding work could be done, but crop management is equally important.

Despite extensive breeding improvements to a few crops, significant increases in productivity have yet to be realized at the farm level. Policies and marketing infrastructure also affect the prices received, and when other crops are more profitable farmers lose interest in legumes, particularly if they can't get access to seed of improved varieties - a common problem for smallholder farmers. Production problems also require agronomic as well as breeding solutions, and greater farmer skill levels to overcome the constraints. Improving post-harvest management such as appropriate storage and value addition can increase farmer's income and create employment opportunities. The involvement of farmers, researchers, extensionists, policy makers, government and non-government agencies, marketing chain participants and national and international funding bodies are all needed to work with researchers to improve yields and returns from food and feed legumes so that they can continue to be an essential part of meeting the challenges of coming decades. ■

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Pea breeding for disease resistance

by Diego RUBIALES[1]*, Eleonora BARILLI[1] and Sara FONDEVILLA[2]

Pea (*Pisum sativum* L.) yields are limited by major diseases. Breeding for disease resistance involves diagnosis, development of efficient screening methods, availability of resistance sources, and the development of effective breeding methodology. Mayor genes conferring resistance to several pea diseases have been identified but unfortunately no efficient sources of resistance have been described to date to the most important pea diseases (broomrape, ascochyta blight, Aphanomyces…) or it is scarce and of complex nature, making necessary the implementation of other control measures. Still, significant genetic variation for these traits exists for pea.

The most important root diseases are fusarium root rot (*Fusarium solani* f.sp. *pisi*), fusarium wilt (*F. oxysporum* f.sp. *pisi*), aphanomyces root (Aphanomyces *euteiches*) and the parasitic weed broomrape (*Orobanche crenata*). Resistance to *F. solani* is quantitatively inherited. Three QTL associated with resistance and STMS markers for use in marker assisted breeding have been reported (2). Single dominant genes have been reported for the various known races of *F. oxysporum*, gene *Fw* to race 1, *Fwn* to race 2 and *Fwf* to race 5. Gene *Fw* is bred into most cultivars grown currently (7). Genetic resistance to *A. euteiches* in pea is known to be quantitative and largely influenced by interactions with environmental conditions. QTLs have been identified associated with partial field resistance (9). Only incomplete resistance to *O. crenata* is available in pea germplams (13). Four genomic regions associated with field resistance and several QTL governing specific mechanisms of resistance "in vitro", such as low induction of *O. crenata* seed germination, lower number of established tubercles per host root length unit, and slower development of tubercles have been identified (6).

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Major aerial diseases are ascochyta blight complex (*Ascochyta pisi*, *Mycosphaerella pinodes* and *Phoma medicaginis*), powdery mildew (*Erisyphe pisi*), downy mildew (*Peronospora viciae* f.sp. *pisi*), rusts (*Uromyces pisi* and *U. viciae-fabae*), bacterial blight (*Pseudomonas syringae* pv. *pisi*), Pea Seed-borne Mosaic Virus (PSbMV), and Pea Enation Mosaic Virus (PEMV). Some levels of incomplete resistance against *M. pinodes* and *P. medicaginis* have been reported and QTLs identified (5, 11, 15, 16). Three genes for resistance to powdery mildew, named *er1*, *er2* and *Er3* have been described so far. Only *er1* gene is in wide use in pea breeding programs. Expresssion of *er2* gene is strongly influenced by temperature and leaf age. *Er3* gene was recently identified in *P. fulvum* and has been successfully introduced into adapted pea material by sexual crossing (4). Only incomplete levels of resistance not associated with hypersensitivity have been reported to both rust species and preliminary mapping studies initiated (1, 17). Race-specific resistance is known to downy mildew but there are evidences of breaking down of this resistance. Partial resistance is also known (14).

Single dominant genes are known for resistance to *Pseudomonas syringae*, gene *Ppi1* to race 2, 3, *Ppi3* to race 3 and *Ppi4* to race 4. Resistance to all races including race 6, for which there are no known commercial resistant cultivars is available in *Pisum abyssinicum* (3). Several recessive resistance genes to PSbMV have been identified (*sbm1*, *sbm2*, *sbm3* and *sbm4*) (11). Hence many commercial varieties of pea remain susceptible to the more common strains of PSbMV. Resistance to PEMV is conferred by a single dominant gene (*En*) and has been incorporated into recently released varieties (8).

Resistance conferred by major genes have been incorporated into pea varieties. However, for most important diseases, only quantitative resistance is available. Although QTLs controlling quantitative polygenic resistance have been identified, the distances between the flanking markers and QTLs are

Figure 1. Broomrape: susceptible (left) *vs* resistant (right) accession

Figure 2. Powdery mildew: leaves of susceptible (left) *vs* of resistant (right) accessions

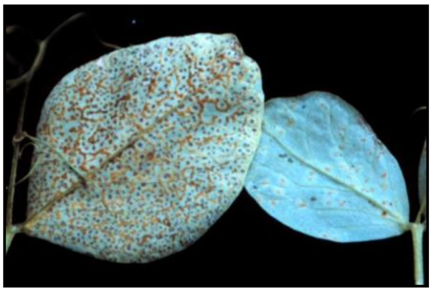

Figure 3. Rust: susceptible (left) *vs* partially resistant (right) accession

still too high to allow and efficient marker assisted selection. Also, accuracy of phenotypic evaluation should be improved as it is of the utmost importance for accuracy of QTL mapping. Dissecting of the resistance into specific mechanisms would improve the accuracy of disease screening and could contribute to refine the position of the QTLs and identify molecular marker more closely linked to the resistance genes. However, available information on responsible mechanisms is still scarce for most pea diseases. In addittion, comprenhensive studies on host status and virulence of the causal agents are often missing. Only after significant input to improve existing knowledge on biology of the causal agents and on plant/pathogen interaction, resistance breeding will be efficiently accelerated.

Effectiveness of MAS might soon increase with the adoption of the new improvements in marker technology together with the integration of comparative mapping andfunctional genomics. Major progress is likely to be made from the use of *Medicago truncatula* as models for pea disease studies, since the genomics effort is greater in these species compared to pea, mainly due to a much smaller genome. *M. truncatula* is affected by many of the pathogens and pest limiting pea yield. In most cases, screening of germplasm collections of *M. truncatula* allows identification of a wide range of differential responses to the pathogen from highly susceptible to resistant. This serves as base for the characterisation of underlying resistance mechanism at cellular and molecular level as well as identifying defence genes and QTLs responsible for resistance. In parallel, the transcriptomic and proteomic approaches developed for this model legume are being used to understand the molecular components and identify candidate genes involved in *M. truncatula* defence against these pathogens (12, 13). ■

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Rhizobium inoculation, cultivar and management effects on the growth, development and yield of common bean (*Phaseolus vulgaris* L.)

by Anthony W. KELLMAN

Genotypic differences in growth and yield of two common bean (*Phaseolus vulgaris* L) cultivars to *Rhizobium* inoculation and management were investigated. In 2003-04, the two bean cultivars (Scylla and T-49) were combined with three inoculant treatments (strains CC 511 and RCR 3644, and a control of no inoculation), two fertiliser levels (0 and 150 kg N ha^{-11}) and two irrigation treatments (irrigated and rainfed). There was no nodulation on either cultivar. To further investigate the symbiotic relationship, 16 rhizobial isolates, including the two used in the first field experiment, were combined with the cultivar Scylla and evaluated in a greenhouse. Subsequently, five *Rhizobium* isolates were chosen for further field evaluation, based on signs of early nodulation in the greenhouse trial. The second field experiment in 2004-05 combined the five inoculant strains (RCR 3644, UK 2, H 20, PRF 81, PhP 17 and a control) with two bean cultivars (Scylla and T-49).

In the greenhouse, nodule number varied from 7 (UK 2) to 347 (H 441) nodules plant^{-1} at 51 DAS and from 13 (UK 1) to 335 (CIAT 899) nodules plant^{-1} at 85 DAS. In 2004-05, in the field, nodulation was also variable, ranging between 1 and approximately 70 nodules plant^{-1}, with higher nodules numbers plant^{-1} being found on cultivar T-49. Of the isolates used in the field, strains H 20, PRF 81 and PhP 17 produced 70, 25 and 12 nodules plant^{-1} at 70, 40 and 54 DAS respectively. Nodules formed were of various sizes and more than 80 % were pink to dark red in colour denoting the presence of leghaemoglobin and active N fixation. The remaining nodules were either green or white.

The importance of selecting an appropriate bean cultivar for the growing conditions was highlighted in these experiments. Leaf area index, leaf area duration intercepted radiation and final utilisation efficiency were significantly affected by cultivar. In both seasons cv. T-49 reached maturity (dry seed) before Scylla, while unirrigated plants reached green pod maturity seven days before irrigated plants. Plants of cv. Scylla gave a final TDM of 730 g m-2; compared to the 530 g m-2 produced by T-49. The average growth rate was 7.0 and 5.2 g m^{-2} day^{-1} for Scylla and T-49 respectively (2003-04). Plants given 150 kg N ha^{-1} produced 665 g m^{-2} TDM which was 12 % more than was produced by unfertilised plants. Application of 150 kg N ha^{-1} gave an average growth rate of 6.4 g m^{-2} day^{-1} compared to 5.7 g m^{-2} day^{-1} from plants with no N. In both seasons inoculation in the field had no significant effect on TDM.

Temperature affected growth and DM accumulation. Accumulated DM was highly dependent on cumulative intercepted PAR. Air temperatures below the base temperature (10 ^{o}C) affected growth in 2004-05, resulting in plants accumulating just 0.24 g DM MJ^{-1} PAR during early growth. This increased to 2.26 g DM MJ^{-1} PAR when the temperature increased above the base temperature. There was a strong relationship between LAI and intercepted PAR. A LAI of 4.0-4.5 was required to intercept 90-95 % of incident solar radiation. Cultivar significantly ($p < 0.001$) affected radiation use efficiency (RUE). Scylla had a RUE of 1.02 g DM MJ^{-1} PAR compared to T-49 at 1.18 g DM MJ^{-1} PAR. Seed yield was significantly ($p < 0.001$) affected by cultivar and fertiliser application. Scylla produced 467 g m^{-2} which was 76 % more than T-49, while there was a 12 % increase in seed yield in N fertilised plants over unfertilised plants. Only cultivar significantly affected HI, while the yield components that had the greatest effect on seed yield were the hundred seed weight and pods plant^{-1}. Inoculation significantly ($p < 0.05$) affected 100 seed weight (2004-05). Plants inoculated with strain H 20 had the highest 100 seed weight at 25.2 g with cv. Scylla producing larger seeds than T-49.

The belief that local environmental conditions play a major role on the field survival of bacteria, led to the use of PCR methods to identify field nodulating organisms. Amplification of genomic DNA from parent isolates using primers fC and rD generated a single band for each isolate. Isolates were identified to the species level as either *Rhizobium* or *Agrobacterium*, using the highly conserved internally transcribed spacer (ITS) region and are known to nodulate common bean. The DNA extracted from the isolates recovered from nodules of field grown beans gave multiple bands with primers fC and rD. Five distinct banding patterns were observed. All of these were different from those of parent isolates. Sequencing of the 16S rRNA demonstrated that nodules of field grown beans in Canterbury were inhabited by *Pseudomonads* either alone or in association with other root nodulating organisms. The inability to identify the inoculant strains in nodules of field grown beans does not rule out their infection and nodulating function in the cultivars used. The results suggest the possibility of both *Rhizobium* and *Pseudomonads* cohabiting in the nodules of field grown beans. The aggressive nature of *Pseudomonads* on artificial media, possibly out competing the inoculant rhizobia is proposed, leading to the inability to identify the inoculant strain from the nodules of the field grown beans by PCR methods.

The need to identify nodule forming or nodule inhabiting bacteria in the nodules is necessary to classify the importance of these organisms and their economic benefit to agricultural production. This study also underlines the importance of using PCR methods to gain insights into the ecological behaviour of *Rhizobium* inoculants and nodule inhabiting organisms. ■

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PhD thesis

Breeding of grain legumes at the All-Russia Research Institute of Legumes and Groat Crops

by Vladimir I. ZOTIKOV, Vladimir SIDORENKO, Tatiana S. NAUMKINA*, Igor V. KONDYKOV and Galina N. SUVOROVA

Basic legume crop cultivated in Russian Federation is peas. According to FAO data, there was produced 1,35 mln. t of peas grain in 2009, that made 13 % of the world production. Soya production in Russian Federation is increased every year and reached 1 mln. t in 2009; vetch is produced in large amounts (0,4 mln. t in 2008); lentil, phaseolus, bean, lupine are less produced.

Breeding work with legumes is mostly performed by state scientific institutions of the Russian Academy of Agricultural Sciences: the All-Russia Research Institute of Legumes and Groat Crops (Orel), V.V. Dokuchaev Research Institute of Agriculture (Voronezh), N.M. Tulajkov Research Institute of Agriculture (Samara), the Don Zone Research Institute of Agriculture (Rostov) and others.

Breeding of grain legumes at the All-Russia Research Institute of Legumes and Groat Crops was begun at the 60^{th} of the previous century; during this period 57 cultivars of peas, 10 cultivars of phaseolus, 14 cultivars of vetch, 10 cultivars of lupine, 4 cultivars of forage beans, 4 cultivars of soya, 4 cultivars of lentil were been created.

In 2010 year 100 cultivars of field peas and 14 cultivars of maple peas were included into the State Register of Breeding Achievements, admitted for use at the territory of Russian Federation, of them 107 cultivars belong to domestic breeding. Of them 13 cultivars of peas were developed at the All-Russia Research Institute of Legumes and Groat Crops.

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Peas cultivars bred by the Institute are cultivated in 9 of 12 regions of Russian Federation excluding Northern, East-Siberian and Far-East zones. Among maple cultivars Zaryanka and Alla are widely cultivated: cv. Zaryanka (leafy cultivar) is created for grain and green forage; cv. Alla with short stem, tendril leaves and non-shattering seeds is grown for grain forage. Maple peas provide stable yield in zones with extreme weather conditions, in particular in North-West region of Russian Federation. Most of contemporary field peas cultivars bred in Orel are semileafless: Mul'tik, Shustrik, Batrak, Faraon. Cv. Mul'tik has small non-shattering seeds, that provides high coefficient of multiplication at the high level productivity and decreases the cost of pea seeds. Early ripening cv. Shustrik has non-shattering seeds and is practically resistant to lodging. Cv. Batrak is one of the most highly technological cultivars owing to its optimal combination of characteristics of determinant growth of stem, non-shattering seeds, tendril type of leaf. New cv. Faraon which is characterized by middle height of stem, tendril leaves, yellow seed color with black hilum, adapted for direct harvesting, resistant to draught and diseases (Figure). Average yield of the Faraon cv. makes 3,2 t/ha, maximal yield 5,6 t/ha was obtained in Republic of Tatarstan. Cultivars of traditional morphotype with usual type of leaf Vizir and Temp remain in commercial production as insurance fund under extreme draughty conditions. Original cultivar Spartak is characterized by a canopy heterophily, caused by transformation of some tendrils into leaflets, that is conditioned by a combination of recessive alleles supervising form of leaf. Perspective semileafless peas cv. Triumph combines high productivity with the increased symbiotic activity.

The basic direction of peas breeding is creation of highly technological productive cultivars, that is provided with use of semileafless, short stem, determinant forms; much attention is given to breeding for resistance to pests and diseases, resistance to drought, high protein content in seeds and in green forage, high symbiotic activity.

Summer vetch, occupying 13...27% of total area of legumes crops in Russian Federation is a widely cultivated legumes crop mainly used for green forage and products of its processing (hay, vitaminic meal). From 34 cultivars admitted to cultivation at the territory of country 8 cultivars are developed by the breeders of the Institute. Widely cultivated vetch cvs. Orlovskaya 84, Orlovskaya 92, Nikol'skaya, and also new cvs. Assorti, Viora, Yubilejnaya 110 provide a stable yield of dry matter and seed yield more than 2,5 t/ha. Attention of breeders is concentrated on development of cultivars with low content of anti-nutrients.

The All-Russia Research Institute of Legumes and Groat Crops performs breeding work with valuable food crops - phaseolus and lentil. Nowadays are permitted for cultivation 6 phaseolus cultivars of Institute out of 17 cultivars cultivated on the territory of Russian Federation. White seed cvs. Nerussa, Oka, Oran differ by high food qualities. Cultivars of new generation Rubin, Shokoladnica, Geliada have colored seeds and are suitable for direct harvesting. The primary goal of breeding work with phaseolus is creation of high-yield and high quality cultivars suitable for machinery cultivation.

Three cultivars of lentil developed at the Institute are permitted for cultivation at the territory of Russian Federation. Cvs. Rauza, Svetlaya, Aida have light large seeds with yellow cotyledons, forming an average yield at a level of 1,7-2,1 t/ha. Breeding work with lentil is directed at creation of high-yield cultivars adapted to machinary cultivation; germplasm of wild species is involved into breeding process; interesting red seed forms were created.

Cultivars of soya Belor, Lancetnaya, Svapa are cultivated at central regions of Russian Federation, are suitable for direct harvesting, forming average yield up to 2,7 t/ha.

Thus, created at the All-Russia Research Institute of Legumes and Groat Crops cultivars of peas, vetch, phaseolus, lentil, soya have high consumer characteristics and are widely cultivated on the territory of Russian Federation. The contemporary breeding of legumes is directed at overcoming of such negative biological features as strong exuberant foliage and indeterminant growth, non-uniformity of ripening, plant lodging, pod dehiscence, seed shattering and susceptibility to diseases.

Much attention is paid to breeding for resistance to abiotic stresses - draught, high temperatures. Drought is one of the most important limiting factors of yield formation. Water stress essentially influences productivity of peas, especially in a flowering time and pod filling. One of methods of drought resistance increasing would be in vitro selection of somaclonal variants resistant to osmotic stress.

New breeding technologies alongside with classical selection use methods of interspecific hybridization, cell selection, embryo rescue technique, dihaploid forms, selection for high symbiotic activity. Creation of principally new cultivars of legumes, resistant to pests and diseases, to unfavorable weather conditions, characterized by high quality and high and stable productivity is expected. ■

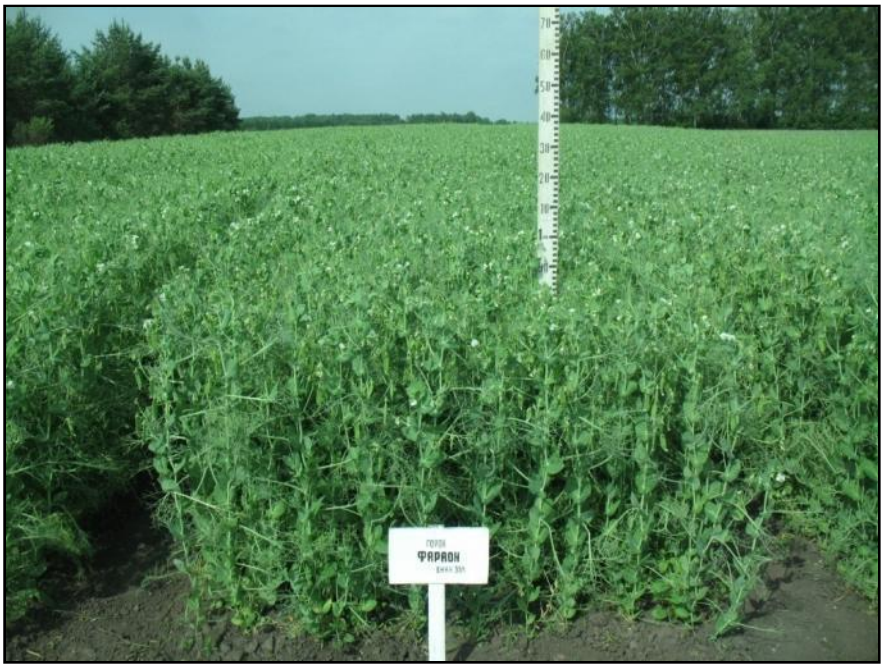

Figure 1. Pea cv. Faraon in the field tests of the All-Russia Research Institute of Legumes and Groat Crops

Towards the half a century of the papers on legumes in *Ratarstvo i povrtarstvo / Field and Vegetable Crops* and legume treasure in the Serbian libraries

by Aleksandar MIKIĆ[1]*, Sanja MIKIĆ[1] and Milena MIKIĆ-VRAGOLIĆ[2]

A peer-reviewed journal *Ratarstvo i povrtarstvo / Field and Vegetable Crops* is published by the Institute of Field and Vegetable Crops in Novi Sad, Serbia, trice a year. It started as *Zbornik radova* [Review of Research Work] in 1963 (Figure 1) and up today brought forth 1651 scientific papers.

In total, 402 papers were related to legume crops. The frequency of the these papers on legumes has constantly increased from 11.7% in the first then years to 27.3% today. The most numerous papers were dealing with lucerne (10.4%), followed by soybean (9%), vetches (7.5%), clovers (6.1%) and pea (5.8%).

Figure 1. Various editions of *Ratarstvo i povrtarstvo / Field and Vegetable Crops* from 1963 to 2010

Figure 2. The oldest books on legumes in the libraries of Serbia: *Common bean, lentil and pea: Our major pulses* from 1902 (left), *Establishing a lucerne stand* from1925 (middle) and *Soybean: Chinese Bean: The Future Food of the Mankind* from1929 (right)

Overall, journal has published papers on 144 legume. At least one author from Serbia and other ex-Yugoslavian countries co-authored 55 papers, out of which 45 were published during last ten years.

The electronic issues of the journal are available at: http://nsseme.com/en/ about/ ?opt=casopisi/ratpov&cat=about. Legume researchers all around the world are most welcome to submit their manuscripts via online system available at the same address.

The greatest number of books in Serbia is deposited at the National Library of Serbia and Matica srpska in Novi Sad, with more than 6.4 million accessions.

The majority of the books devoted to grain legumes is on soybean with 71 titles. The oldest one is in Serbian by Nikola Angelov *Soja: kineski pasulj: buduća hrana čovečanstva* [*Soybean: Chinese Bean: The Future Food of the Mankind*] (.Figure 2) The next one is common bean, with 41 titles. The oldest one is also in Serbian by Miloš N. Lukićević called *Pasulj (grah), sočivo i grašak: naša najglavnija variva* [*Common bean, lentil and pea: Our major pulses*]. These are followed by pea (25 titles), faba bean (10 titles), vetchlings, vetches and cowpea with 2 titles each and black gram with 1 book. Lucerne is the most represented among the perennial forage legumes, with 40 titles. The oldest book, in Serbian, *Podizanje lucerišta* [*Establishing a lucerne stand*], was written by D.Đ. Ćatić. Other books on perennial forage legumes are 30 titles on red and other clovers and 1 on birdsfoot trefoil and sainfoin each. One of the most important medicine legumes, melilot is present with 7 books. There is 4 books on black locust, as one of the most significant tree legume species. ■

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Peas do have great individuality

by Aleksandar MIKIĆ

The whole month was exciting: we'd managed to extract ancient DNA from charred pea seeds three thousand years old from the southeast of the country. Moreover, we'd proved it was truly ancient DNA, not contaminated with the modern form. No wonder we were eager to sequence it, and see what it could tell us about the pea variety those ancient people had grown! Had it purple flowers, or white? Were its pods dehiscent, or not? Was it cultivated, or collected from the wild...?

All those questions buzzed within my head as I sat, in the middle of the night, over those hundreds of letters A, T, C and G. Gradually, as I compared the ancient with the modern sequences, it began to fall into place. Other letters started to appear, until the sentences related a tale of genes, peoples and languages, with lively images and clear sounds. Too tired to resist, I surrendered myself to reading it or, should I say, dreaming it...

...Following the many-coloured sea to their right, a small group of weary people forsook the vast continent which had been their ancestral home. They arrived at hills and plains rich in plants that could serve as food. Some were grass-like, with grains densely packed on their tips, while another had grains hidden within small husks, reminding them of the shells they used to eat during their travels. They named the latter after those shells, a name sounding something like *kanka*, or *kaca*, and they showed each other the way those seeds had to be shelled out of their little husks. There were several kinds of them: some were short plants, with very flat seeds; another had long, slender stems and round seeds; and still others had small, inflated pods with one or two heart-shaped grains. They called them all by the same name, in any case, since they all ended up together in their cooking pots...

...The great ice from the north was at its greatest. Many years had passed, and the group dispersed all over the new lands. One band moved northwards, venturing into endless forests rich in rivers and lakes. Their men hunted wild animals, and their women and children gathered what grains and fruits they could find: among them, those they first saw on their arrival, all those centuries ago. Their old name had become corrupted, and changed into *hgerkwa* or *chahkwa*, yet still applied to all the seeds they could find in the clearings and cook together. Other bands, who remained down south, began to be aware that the seeds they stored in pits often germinated, and produced new plants, exactly the same as those from which they'd collected the seed. Gradually, they ceased to rely on gathering them in the wild, and instead, put them in small holes or shallow rows in the soil, close to their abodes. Each time they did so, new plants emerged, each bearing many more seeds: enough to go a long way towards assuaging their almost continual hunger. So one year, they decided not to migrate, but rather to remain where they were, and tend the plants. They nurtured and protected them from the appearance of the first shoots to the final harvest, when the seeds were fully ripe. They also began to distinguish between different species in more and more detail, retaining the old name *kanka* for the long and slender one with round seeds, and coining names for the others simply by describing their individual peculiarities...

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...The cold started to retreat to the north, leaving behind a whole new continent in the west, with fertile plains and great rivers. Generations of the first farmers travelled up one such river, bringing with them their skills of cultivating plants and taming wild animals. They met their forgotten relatives, who were still hunting and gathering: but the hunters feared them, and retreated before them to high mountains and isolated valleys, from the utmost west of the Old World right across to its eastern borders. As time passed, however, the two groups began, tentatively, to exchange their knowledge: though the distinctiveness of each, developed through aeons, remained...

...Despite all change, however, one old name survived throughout the millennia. In the mouths of those peoples descended from the reclusive hunter-gatherers, the old name *hgerkwa* developed into *hkor'a*, in some cases denoting those grasses with great ears of seed, and in other cases, a few pulse species. The field-tilling peoples, meanwhile, continued to spread in all directions, like the waves of a giant ocean. One group occupying the vast plain above two great seas changed *kanka* into *kiker*, shifting the meaning from "round-seeded pulse" to "heart-shaped" pulse, while their relatives, climbing the western slopes of a long mountain range linking north and south, changed *kanka* into *kacha*. And then the story began to move faster, and the peoples and their migrations and interactions began to look like some ever-accelerating cosmic dance. Wonderful it was, save for the shadows obscuring the awareness of a common origin, and resulting in distrust and hatred...

...When I awoke, I found myself stretched over the sequences, with my face bathed in the golden light of dawn. In my left hand, there was one charred pea seed: not dead at all, and within it, a whole library. In my right hand, there was one fresh pea grain, yet to be sown and carrying within itself a new life. A kind of leguminous alchemical chain was complete: back to the future and forward to the past. A sentence from *The Road to Wigan Pier* by George Orwell came to my mind: 'Peas have great individuality.' And I knew it was true. ■

To Noel.

Postage stamps with legumes

by Margarita VISHNYAKOVA

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First International Legume Footbal Cup

by Bert VANDENBERG[1], Bunyamin TAR'AN[2], Tom WARKENTIN[3] and Aleksandar MIKIĆ[4*]

On the margins of the merged 5thInternational Food Legume Research and 7thEuropean Conference on Grain Legumes Conferences, the First International Legume Football Cup was held, with semi-finals on Monday, April 26th, and 3rd place and final match on Wednesday, April 28th (Fig. 1). Although the pairs for semi-finals were selected randomly, it was shown that a choice was good: FC *Cicer* was significantly better than FC *Pisum*, while FC *Vicia* lost in the match against FC *Lens* with an unusual segretation of 9:1.

There was no 1st and 3rd places winners, since both matches ended with draw. The final match between FC *Lens* and FC *Cicer* was full of passion and devotion to the game itself, with frequent and very inflammable moments. On the other hand, the match between FC *Pisum* and FC *Vicia* was loaded of tonnes of good jokes and laugh, with the great Erik Jensen as a more professional referee than Pierluigi Collina.

All in all: an excellent amalgam of science and fun: it will surely be continued! ■

Figure 1. First International Legume Football Cup, Antalya, Turkey, April 2010: FC *Lens* (red), FC *Cicer* (yellow), FC *Pisum* (green), FC *Vicia* (maroon)

[1]FC *Lens*
[2]FC *Cicer*
[3]FC *Pisum*
[4]FC *Vicia* (aleksandar.mikic@nsseme.com)

First Legume Society Conference *2013: A Legume Odyssey*
Novi Sad, Serbia, 9-11 May 2013

We are cordially inviting you to participate in the First Legume Society Conference (LSC1), scheduled from May 9 to 11, 2013 in Novi Sad, Serbia, and organised by the Legume Society and the Institute of Field and Vegetable Crops in Novi Sad.

In the rich world of global agriculture, diverse legumes can play key roles to develop environment-friendly production, supplying humans and animals with the products of high nutritional value.

The Legume Society was founded in 2011 with two primary missions. One of them was to treasure the rich legume research tradition of the European Association for Grain Legume Research (AEP), with emphasis on carrying out its the triennial legume-devoted conferences. Another one is to fulfill a long-term strategy of linking together the research on all legumes worldwide, from grain and forage legumes pharmaceutical and ornamental ones and from the Old World to the Americas.

We do anticipate that your participation will be a unique and genuine contribution to our common goals: to promote the legume research and all its benefits into all spheres of the society, linking science with stakeholders and decision-makers, and to demonstrate how an efficient, useful and firm network of the legume researchers of the world is possible and sustainable.

Please include this event in your busy agenda and share this information with all your colleagues dealing with legumes. If you have not already joined the Legume Society, please do it for a free membership in 2013 by visiting the LSC1 web site at http://lsc1.nsseme.com.

Welcome to Novi Sad and join us in the Legume Odyssey 2013!

GRAIN LEGUMES

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