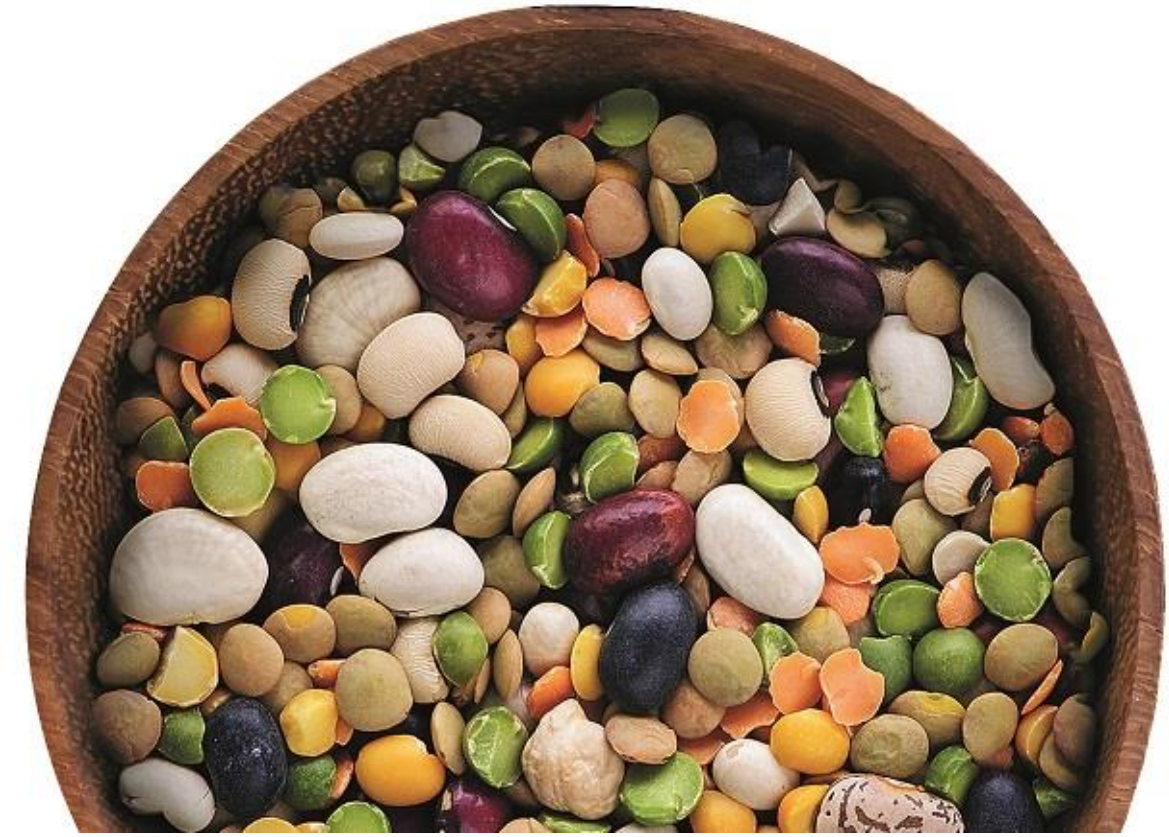
TRansition paths to sUstainable legume-based systems in Europe

Report of the 1st Mediterranean Legume Innovation and Networking (LIN) Workshop

20 April 2018

Agricultural University of Athens, Greece



This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Contents

1. Executive Summary 3
2. Introduction 4
2.1 Background & Objectives 4
2.2 Workshop framework, participants and methodology 4
3. Presentations 5
3.1 Presentations Overview 5
3.2 Poster Session Impressions 5
3.3 Presentations Summary 6
3.4 Poster abstracts 14
4. Outputs of discussions 36
4.1 Summary of Stakeholders' Views 36
4.2 Markets Workshop: production, processing/retailing and consumers 37
4.3 Policy and Society session 39
5. Annex 42
Annex I – M-LIN programme 42
Annex II - List of participants 44
Annex III - Presentation & poster pdfs 46
Annex IV – Results of discussions (pictures) 48
Literature Cited 49
Disclaimer 49
Copyright 49
Citation 49

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

1. Executive Summary

The first Legume Innovation and Networking (LIN) Workshop of the Mediterranean region took place on April 20th 2018 at the Agricultural University of Athens in Greece.

The main objectives of the participatory workshop were to exchange knowledge about innovations around legumes and on the changes needed to increase legume production and consumption in Europe. The workshop convened 50 participants, which included TRUE members and stakeholders across the whole legume-based value chain. In addition, 7 oral presentations and 25 poster presentations, 2 workshop sessions were organised to discuss markets and policies.

The main **points** outlined by the **presentations** focused on legume production in Greece. Statistical data were presented to reflect the current situation of production and markets, imports and exports, yield and yield quality in the country. Agro-ecology, sustainable farming, CAP policies were also discussed.

The **outputs** from the workshop can be clustered into 4 topics related to barriers and opportunities in: 1, production; 2, marketing; 3, Consumers; and, 4, policy. The main **issues** identified regarding **supply/production** were the difficulties encountered in working with local producers and imports/exports. In contrast, the main opportunities were linked to the traceability of pulses and the need of PDO (Protected Designation of Origin) and PGI (Protected Geographical Indication) products. Discussions on **markets**, highlighted the need to raise awareness on the sustainability and environmental benefits of legumes. Ready cooked pulse- based products, including snack foods, are seen as the most effective means to encourage greater consumption of legumes, with benefits for commerce and consumers alike. Innovation in these areas was identified as an opportunity to expand the diversity of legume-based products available as well as improving their flavour. A lack of knowledge on how best to cook legumes, as well as a shortage of legume recipes, are thought to act as another significant main barrier to legume **consumption**. **Policy** discussions suggested that significant improvements are needed, mainly related to taxes, EU policy and CAP greening. The term “Agroecology” also seemed to be understood differently by the various stakeholders (farmers, breeders, ex-situ seed banks, researchers, consumers) depending on the contexts. This could provide TRUE with the opportunity to offer further insights on how stakeholders perceive relationships between ecosystems, wellbeing, innovations and governance.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

2. Introduction

2.1 Background & Objectives

TRUE is funded by the European Commission's Horizon 2020 Programme over four years until March 2021 to explore strategies to reduce the EU's dependency on imported protein food (soy) and synthetic nitrogen fertilizers. In this context, TRUE aims to identify the best routes, or "transition paths" to increase sustainable legume cultivation and consumption across Europe and includes the entire legume feed and food value chains. During the course of the project, **Legume Innovation and Networking (LIN) Workshops** are organised to involve relevant stakeholders in a multi-actor approach. They take place in three geographical regions with different pedo-climatic conditions: Atlantic, Continental and Mediterranean. In 2020, a final common European Workshop will be organised to build a European Legume Innovation Network. The workshops are intended to help:

- share legume focused activities with other **networks and actors**;
- exchange insights from **legume-based innovations**;
- collate **challenges and needs** regarding legumes across the entire value chain;
- gather stakeholder assessments on **legume markets and policies;**
- identify key leverage points for **improving framework conditions for legume-based food- and feed-chains**.

2.2 Workshop framework, participants and methodology

The first Legume Innovation and Networking Workshop of the Mediterranean Region was hosted by the Laboratory of Vegetable Production of the Agricultural University of Athens in Greece, on April 20th 2018.

ΓΕΩΠΟΝΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
AGRICULTURAL UNIVERSITY OF ATHENS

The workshop brought together 110 TRUE members and stakeholders across the whole legume-based value chain to exchange ideas on how to increase legume production and consumption in Europe. The represented stakeholder groups spanned producers, advisors, breeders, processors, machinery-suppliers, retailers, consumers and scientists.

Besides oral and poster presentations, two workshop sessions took place to allow participants to share their opinions on the challenges and needs affecting legume markets and policy.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

3. Presentations

Two presentations have been uploaded to the TRUE website HERE. In addition, video recording of the workshop can be accessed on YouTube HERE.

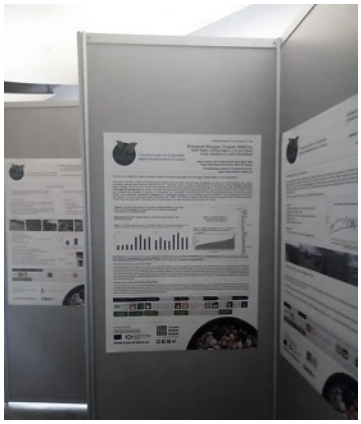
3.1 Presentations Overview

The **main points** highlighted during the presentations were:

- the **importance** of the TRUE project and its **main impacts**;
- the **cultivation needs** of legume crops and the **current situation** in Greece (i.e. statistical data, climate requirements etc);
- the current **product trends** in Greece and **GAIA SENCE** (programme developed to adjust protection and nutrition models combining the experience and knowledge of Pelekanos Cooperative);
- the importance of **local and traditional varieties and effective pest management methods** to allow the introduction of a high nutritional value product to the market;
- the **benefits** of legumes for food and feed;
- the **current policies** in productions of Legumes in Europe;
- the **need** to compare legume genetic resources using **morphological and molecular markers** (**LEGATO** project).

3.2 Poster Session Impressions





This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

3.3 Presentations Summary

Background to the TRUE project and TRUE case studies activities and innovation

Pietro Iannetta

TRUE Project Coordinator, The James Hutton Institute, UK

Legumes **fix nitrogen** from the air into protein without the need for nitrogen fertilizer. Despite their benefits, **legume cultivation** in EU countries is **low** according to Eurostat. Consequently, there is currently an **unhealthy EU28 dependencies** reflected in the high use of N fertilisers (10 m.t.y^{-1}) and 23% of N fertilisers and 70% of protein (42 Mt in 2009) being imported. To solve this puzzle of high demand in **legumes vs. low supply/production,** 3 major shifts are necessary: 1, **integrate more home-grown (on farm produced) legumes into meat production, and encourage less meat consumption in European diets** (*e.g. a Mediterranean one*); 2, **increase use of legume and legume-based co-products in aquaculture production** of protein for human consumption; and 3, one of the most important transitions necessary to underpin this shift is an **"awareness and logics transition"** – concerning legumes and their functional significances. Such shifts need supported in all sectors of the supply chain plus society more generally - including all levels of education sectors – that is, extending to higher (university) education and research.

TRUE Activities and Innovation Background

	The 'TRUE Pillar' of Sustainability: and work package (WP) structure	The main impacts of TRUE
24 Partners equally balanced academic and non-academic	• Assess the roles of "consumer citizen" and "sustainable consumption" • Policy to reinforce the internal supports of the Society pillar • Economy must also reinforce Society pillar, and struts therein	• Enable sustainable legume-based cropping systems and agri-food and feed chains. Local and non-GMO • Increase the commercial competitiveness of legume crops • Reduce the environmental impact of food- & feed-production and processing • Integrated support for EU policies: CAP, Water Framework, IPCC, etc

TRUE Case Studies
see poster abstracts p.12

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Production and marketing of legumes consumed as vegetables in Greece

Christos Olympios

Emeritus Professor, Agricultural University of Athens, Greece

There are four main grain legume crops cultivated in Greece. These are snap beans (*Phaseolus coccineus*), common pea (*Phaseolus vulgaris*), broad bean (*Vicia faba*), and a more recently introduced species of cowpea (*Vigna unguiculata*). These are generally cultivated as vegetables (not grain crops), and potential used in a crop rotation as green manures. The commodities were described specifically in terms of their concentrations of **nutritional elements** (proteins, soluble carbohydrates, carotenoids, polyphenolics, vitamins, *etc.*) and levels of biological nitrogen fixation (BNF). In addition, details were given, for each of the four vegetable legume crops on statistical data relating to their production in Greece (area, yield *etc*.); climate requirements (temperature, photoperiod, time and season of growth and production); soil requirements (type of soil , pH, salinity); propagation (methods, planting distances); cultural practices (fertilizer application (basic, top- dressing)), irrigation: (methods, amount of water); weed, pest and disease control; earthling and pruning; harvest (methods, average production); storage conditions (temperature, humidity, control atmosphere); preparation for the selections, sorting, packing, type of containers and marketing.

The unique properties of some crops were highlighted. For example, that cowpea flowers change colour when pollinated. This feature does seem to have been exploited by life scientists wishing to understand pollination behaviour for this species (and outbreeding grain legume types), which is an important crop in many parts of Africa. Also, cowpea is now being developed for Mediterranean climates of Southern Europe too, owing largely to it potential to maintain yields under conditions of water-deficiency.

Finally, suggestions for future work on vegetable legume crops included the evaluation of local genetic resources, the collection and maintenance selection of new varieties and the isolation of new rhizobia strains with high BNF potential.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Markets Workshop: production, processing/retailing and consumers

*Summaries by **Marta Vasconcelos** (UCP, TRUE WP3 Leader), **Giannis Panagiotakis** and **Vasiliki Vougeleka** (AUA)*
Facilitators: Pete, Iannetta, Dimitrios Savvas and Marta Vasconcelos

Innovations in legume production and consumption

Nikolaos Papakonstantinou

Gaia Epicheirein, Greece

An overview on the legume production in Greece was provided highlighting an increase in production due to high demand and legumes being perceived as providers of good health for humans and the environment. It was noted that producer organisations can form rapidly in Greece, and that contract farming is expanding between buyers and farm producers, which represents an advantage for the uptake of legumes. From 2014 and 2017, there was a strong increase in the production of beans (52%), lentils (145%), chickpeas (113%) and fava bean (532%), with corresponding increases in land acreage dedicated to pulse production. This increase has been accompanied by a rise in the number of products incorporating pulses, with visible trends towards the creation of differentiated products. In fact, global human food product introduced containing plant protein leaped by more than 80% between 2013 and 2015 according to Mintel's Global New Products Database. Indeed, pulses can be used in a variety of forms to make them more appealing for consumers, since they can easily be dehydrated, milled, pre-cooked and reconstituted in minutes.

The main marketing advantages of pulses are based on their functional ingredients such as fiber for inclusion in baked products, such as chips (French fries), snack bars, meat substitutes and ready or pre-cooked meals. The concept of the "*double pyramid*" (Ruini *et al.*, 2015) was also introduced. Here foods are re-classified on the basis of their effect on the environment, and therefore showing that there is a connection between health and environmental protection and that food groups that are good for our health also have a low environmental impact.

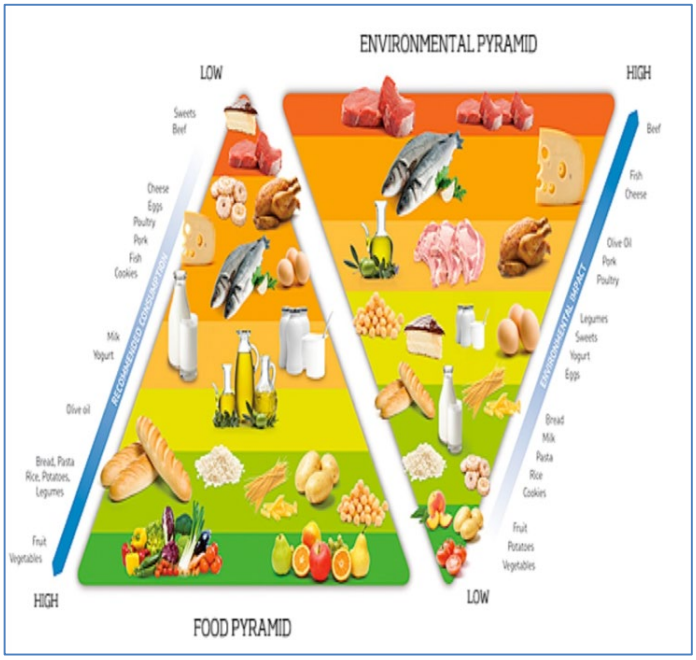


Figure 1. The "double pyramid" concept

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Legumes exploited sensibly in a holistic crop-rotation can enable cropping systems with significantly reduced greenhouse gas emission footprints. This is largely due to BNF, which with proper legume residue management impacts positively on the above and below ground food webs. Such effective management in a no- or minimum -till (Conservation Agriculture) environment is especially beneficial for earthworms, which are of highly functional importance ecologically, acting to enhance many attributes contributing to good soil health and resilience – which in turn are extended to improve production.

Food-miles is another important concept, which refers to the distance that food travels from the time of its production until it reaches the consumers. As examples, 40% of lentils and 26% of kidney beans are imported to Europe from Canada, totaling a 6000 Km distance. Thirty-eight % of chickpeas come from Mexico, at a distance of 5800 Km. The consequences of these food miles include: more fuel and energy consumption; more packaging for transport and therefore more waste; more food losses due to longer time and distances to the final destination. These numbers could be lowered by motivating local pulse production.

Finally, the Gaiasense technology (developed in collaboration with Neuropublic using the experience and knowledge of Pelekanos Cooperative) was described. This solution, that uses databases and telemetric sensors, may bring benefits to farmer such as reducing production costs and environmental impact, improving the competitiveness of the products produced and adapting the production process to EU directives.

The white vanilla beans and fava of Feneos

Yiannis Mitropoulos

DIKOTYLON, Greece

DIKOTYLON is a cooperative enterprise involving stakeholders in **the pulse production chain.** It connects growers directly with consumers *via* the marketing of attractive, flavoursome and high nutritional value products.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

The production, processing packaging and retail strategy for the commercialisation of the white vanilla beans were described. These products are a result of a collaborative effort, and effective systematic work, and most of all a work done with great pleasure and love, resulting in an excellent outcome. The Feneos plateau is located at an altitude of 1000 m, and features a lake surrounded by high mountains, in an area with a good supply of water and with a unique micro-climate very favorable for pulse production. The goal is to produce legumes of special nutritional value, certified by the EU for the white Vanilla Beans and Fava (*Lathyrus sativus*). The white vanilla beans and fava of Feneos are local **traditional varieties** and they have been certified by the EU as **PDO** (Protected Designation of Origin) and PGI (Protected Geographical Indication) products. The Vanilla beans of Feneos differ from other common beans due to being richer in dietary fibers, and proportionally richer in essential minerals such as calcium and with lower amounts of sodium. The favas are rich in proteins (24%), carbohydrates (44-60%) and natural dietary fibers (12-25%). Recipes can be found at http://www.dikotylon.gr/recipes_en.html.

There is a strategy to ensure product authenticity, as it affects product's price, farmers' income and food quality. Greece imports about 60% of its annual needs in legumes, and strategies such as the ones promoted by DIKOTYLON help counteract this tendency.

Policy Workshop

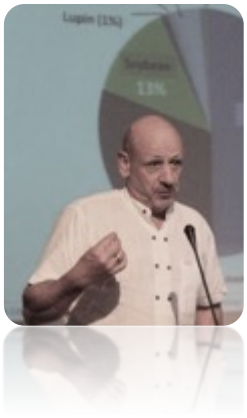
*Summaries by **Balázs Bálint**, **Eszter Kelemen** (ESSRG, TRUE WP7 Leader), **Giannis Panagiotakis** and **Vasiliki Vougeleka** (AUA)*

Facilitators: Dimitrios Savvas, Balázs Bálint, Eszter Kelemen

Legume chains diagnosis for animal and human food and development prospects

Christophe Salon

Research Director, INRA, France



Legume production and consumption trends in France were described, which highlighted a significant decrease in both production and consumption since the 1960s. Although from 2010, a revitalisation started in the production of legumes, it is still at lower levels than 50 years ago. Of the agricultural systems of France, legumes account for less than 2 % of the arable crop area 300.000 ha of land is used for pulses *vs.* 2 million ha for oilseed and 9 million ha for cereals. Both of these synthetic nitrogen demanding commodities are used intensively by animal

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

feed manufactures in the form of wheat directly, and processing co-products from rape.

Legumes offer better nutrition

- Rich protein: digestible, low fat and gluten free, essential amino acids;
- Balanced supply of essential amino acids when combined with cereals;
- Protein content varies among grain legumes 23-40%, while cereals 10-15 %;
- Dietary fibres: soluble and insoluble fibre (cotyledons, integuments and cell walls);
- Rich in vitamins (B1, B2, B3, B9 and E) and essential minerals (Fe, Mg, K, P, Zn, Ca).

INRA's scientific research main objectives lie in: 1, identifying plant ideotypes for lower input agriculture; 2, improving crop adaptation and resistance to environmental constraints; and 3, implementing breeding programmes to achieve these goals. This focus aims to address the following questions:

- Which cropping systems to increase plant protein production?
- Which choices to adapt to climate change?
- How to improve autonomy, sustainability and resilience of farms?
- How best to exploit BNF as part of a cropping system diversification strategy?
- How to facilitate feed self-sufficiency on farm, and or regional water-catchment levels?

It is also important to overcome the challenges associated with genetics and the exploitation of natural and induced genetic diversity was encouraged to improve the nutritional and taste qualities of pea and faba bean seeds. The identification of new legume varieties for vegetable protein production and, for pulses with improved taste and processing characteristics should be a special focus. That is, there has been an over-focus on genetics for yield and disease resistance. These taste and nutrition aspects are of critical importance for the development of new food products that meet consumers requirements and expectations

Current policies in production of legumes in Europe and their dependence on breeding of new cultivars

Dimitrios Vlachostergios

Senior Researcher, ELGO-DIMITRA, Greece

An overview of the current European policies aiming at reducing protein deficit by influencing legume production was provided. The EU faces the longstanding problem of protein deficit with significant amounts of protein products being imported. Environmental problems derived by the heavy use of agrochemicals and their negative impact on humans, animals and environment, have focussed the EU's attention (policy, public opinion, scientific community) on more sustainable farming systems.

Current EU policy (CAP2014-20) has adopted the **sustainable management** of natural resources and **food security** as main targets. The inclusion of certain regulations for legume crops in the reformed CAP was considered of great importance.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Current policies related to cultivation in Europe

- **Voluntary Coupled Support** (Regulation (EU) No.1307/2013, Art. 52 and 53; EU2013b)
- **Greening** (Regulation (EU) No. 1307/2013, Art. 43; EU 2013b
- **Rural Development** (Regulation (EU) No. 1305/2013; EU 2013a

EU policies and Legume Breeding

A key factor expected to play a central role to meet the targets set under EU policy related to legumes, is the development and cultivation of improved varieties such as:

- **Lentil (*Lens culinaris* Medik) var. ELPIDA**, a large-seeded variety developed using the honeycomb methodology after single plant selection within a landrace. Selection was applied under organic and conventional environment, for 3 years in 2 locations. Elpida is a very early maturing variety. Its flowering begins from 15th to 20th of March, while the other varieties cultivated in Greece begin to flower after 15-25 days. These characteristics help ELPIDA to escape: a) the dry period; and, b) the critical period of seed Bruchid infestation. ELPIDA leaves the field available for double cropping (corn, sorghum, soybean, beans) as it is harvested around May 15th – 20th. Mean yield is 1.5-2.0 t/ha under non-irrigated field conditions. It has a short cooking time and excellent sensory traits. Registration in National Variety Catalogue: 19-9-2016. Vlachostergios *et al., Crop & Pasture Science* (2018). 69, 387-394
- **Common vetch (*Vicia sativa* L.) var. LEONIDAS** was developed with the pedigree selection method, after a cross of the cvs Armandes X Girlag. The breeding target of the programme was the development of new varieties with high grain and hay-yield (residue provision), suitable for sustainable farming systems. At the end of the programme, selected lines were evaluated for their weed and weed suppression ability for three consecutive years. In two locations under organic management and with high weed populations of wild mustard (*Sinapis arvensis*), venus comb (*Scandix sp*) and field poppy (*Papaver rhoeas*), LEONIDAS showed the best performance in both weed tolerance and weed suppression ability.

Phenotyping legume genetic resources using morphological and molecular markers

Photini V. Mylona

Greek Gene Bank of the Institute of Plant Breeding and Genetic Resources HAO-Demeter, Greece.

LEGATO Project: Legumes for the Agriculture of Tomorrow.

The project aimed to promote the culture of grain legumes in Europe, identify priority issues limiting grain legume cultivation and production and devise solutions for variety development, culture practices, and food uses. These were achieved by conceiving sustainable legume based cropping systems, studying different pedoclimatic zones, respecting local constraints and testing legume varieties and cropping systems.

The legume genetic resources are very important as a source of high nutrition and income but there is a gap between current yields and the increasing demand of legumes as food and the limited availability of data on grain quality.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Through the case example of Lefkada lentil local landrace (Eglouvis), genetic diversity showed to be dependent on the seed morphological characters and primarily seed size and colour – with preference for large pale and pale hulled types being encouraged.

Another significant factor driving pulse breeding negatively is the high foci on factors determining what is seen as low productivity. It is argued that on the science-society interface, there are serious knowledge gaps concerning the breadth of what legumes deliver and there was a call for a revitalisation of the multi-dimensional provision and specifically by encouraging greater knowledge and awareness of old local landraces, and the capacities to re-vitalise skills among the farming community to re-enable the breeding of new local varieties.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

3.4 Poster abstracts

The pdf files of the Posters can be found at https://www.true-project.eu/lin-workshops/mediterranean/documentation/

No. 1) Carbon Footprint reduction of dairy systems

Iris Nonhebel, James Humphreys

Teagasc, Livestock Systems Research Department, Moorepark, Fermoy, Co. Cork, Ireland. E-mail: *iris.nonhebel@teagasc.ie*

Two dairy systems were established at Solohead Research Farm (52° 51' N; 08° 21' W) in January 2017: Lower Carbon (LC) footprint herds and control herds, and each system has an overall farm stocking density of 2.5 cows/ha. The entire herd of 130 spring-calving cows at Solohead was divided into seven main groups on the basis of lactation number (times a cow has calved); the lactation groups. The cows with the highest economic breeding index (EBI) (*i.e.* provision of most milk with least input) within each lactation group were selected for the LC herd of 24 cows. The remainder of the herd was further divided into seven main groups as described above and then sub-divided into sub-groups of four on the basis of calving date. From within each sub-group, one cow was randomly assigned to the control with the same number of cows per lactation group as the LC herd. Annual fertilizer N input was 150 kg/ha on the LC system, which also relies on biologically fixed N achieved by the white clover in the sward, and 280 kg/ha on the control system (maximum allowed under nitrates directive regulations at this stocking density). Fertilizer N was applied in the form of urea treated with the urease inhibitor N-(n-butyl) thiophosphoric triamide (NBPT) in February, March and August and September to the LC system and as urea between February and April and as calcium ammonium nitrate from May to September to the Control. Slurry produced during housing was applied back in equal volumes to both systems using a trailing shoe for LC and a downward facing splash-plate for control (which represents current common practice on farms). To date milk production on the LC system was 6076 L per cow or 517 kg of milk fat and protein (MS) compared to 5704 L per cow or 471 kg MS in the control group. The LC system has given higher output with lower inputs. Field measurements of nitrous oxide emissions from both systems and soil C storage are ongoing. Life Cycle Assessment of the data of obtained in 2017 indicates that the Carbon Footprint of the LC system is 10% lower than that of the Control.

No. 2) Teagasc Clover Group

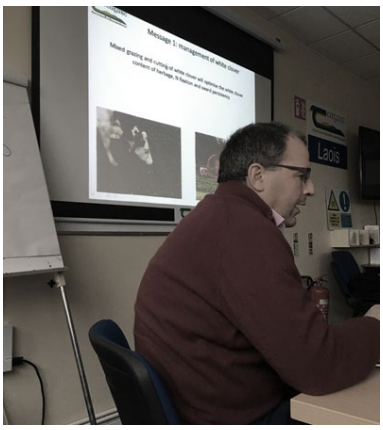
Dan Clavin[1], James Humphreys[2]

[1]Teagasc, Farm Management and Rural Development Department, Athenry, Co. Galway, Ireland; [2]Teagasc, Livestock Systems Research Department, Moorepark, Fermoy, Co, Cork, Ireland

Despite clearly demonstrated benefits for pasture-based farms in terms of lower fertiliser N use, lower costs of production and lower greenhouse gas emissions associated with legumes such as white and red clover, neither are widely used on Irish grassland farms. This can be attributed to a lack of knowledge of best management practices and ambiguity in the past about the usefulness of

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

white and red clover along the knowledge transfer chain. Rising costs of fertiliser N relative to the farm-gate prices received for milk and beef cattle coupled with the increased uptake of organic farming has brought the use of such legumes into sharper focus. To promote the wider use of legumes on grassland farms, eight high caliber organic dairy and/or beef farmers have been selected as demonstration farmers to disseminate the potential of and new approaches to legume use on their farms. These demonstration farmers are supported by Teagasc specialists. The demonstration farms also act as hub for eight grassland discussion groups to promote the wider use of white and red clover on farms. These discussion groups benefit from the peer-to-peer farmer learning experience through visiting each other's farms. These visits are facilitated by a Teagasc advisor. As a demonstration farm, farmers keep accurate records of activities on the farm and host farm walks including visiting discussion groups. Data on economic performance of farms are collected by advisors and farm surveyors on an annual basis.



James Humphreys talking to the clover demonstration farmers about the management of white clover in grassland.

Dan Clavin talking at a demonstration farm walk about the use of white clover in grassland.

No. 3) Intercrops for food (alcoholic beverage) and feed

Kirsty Black[1,2,3], Geoff Squire[1], Philip White[1], Graeme Walker[2], Pietro Iannetta[1]

[1]Agroecology, James Hutton Institute, Dundee DD2 5DA, Scotland UK; [2]Yeast Research Group, University of Abertay Dundee, Dundee DD1 1HG, Scotland UK; [3]Arbikie Distillery, Arbikie Highland Estate, Inverkeilor DD11 4UZ, Scotland UK

Sufficient Nitrogen (N) fertiliser is essential for high crop yields, and spring cereals such as barley (*Hordeum vulgare* L.) receive around 110 kg N ha^{-1}. However, 'intercropping', cultivating two or more crops in the same field at the same time, can allow cereal production without added man-made N fertiliser. For example, barley can be sown with a legume crop such as peas (*Pisum sativum* L.). The legume can meet its entire N demand using a natural process called "biological nitrogen fixation". Here atmospheric nitrogen, a renewable resource, is fixed into biologically useful forms. The legume can also deliver nitrogen to its companion non-legume crop (barley), which cannot fix nitrogen biologically. The average carbon footprint (carbon dioxide equivalents, CO_2e), for applied nitrogen (as ammonium nitrate, AN), is 5.6 kg CO_2e kg AN^{-1}. So, for every hectare of AN (110 kg) application

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

avoided, 616 kg CO_2e ha^{-1} is also offset. In the UK, the spring barley area was 682 kha (2016), and so approximately 75 kt of N would have been applied. If the same area was sown with a pea-barley intercrop without N fertiliser application, 420 kt CO_2e would be saved. To put this into a tangible context, this is equivalent to removing 176k cars from the road annually. Financially, and without factoring application costs and pesticide savings accrued by intercropping, use of AN fertiliser would cut cost and save £13.5 million, at the current low prices of around £180/t.

Important questions remain:

- Is intercropped grain of suitable quality for malting, brewing and distilling? Three years of barley pea-intercropping trials have been completed and have been assessed against typical barley quality parameters. Malting and distilling trials are also ongoing. If successful, the approach would represent a major contribution to ensure malt spirit production in the most sustainable of manners.
- Is the alcoholic beverage industry a feasible, premium market for legumes from both a technical and commercial point of view? Beers have been successfully brewed with an inclusion rate of up to 50% faba beans. Higher rates pose separation challenges therefore filtration trials are ongoing. Theoretical yields for distilled spirits appear promising.
- Is the protein coproduct of the brewing & distilling processes of suitable quality and nutritional value to meet the aquaculture feed market needs? Both liquid and solid coproducts are to be assessed nutritionally. If of an appropriate quality this sales route would greatly contribute to the commercial viability of using legumes by the alcohol industry.

No. 4) The use of legumes and leguminous by-products within dairy systems

March, M.D., Toma, L., Shrestha, S., Rees, R.M

SRUC, Kings Buildings, West Mains Road, Edinburgh, EH9 3JG

Two contrasting dairy production systems are being examined for the TRUE Case Study: a By-product (BP) system containing leguminous co-products with 100% housing of animals, and a Home-grown (HG) system containing legumes grown on the farm. Holstein cows consuming each diet are of either high (Select) or average (Control) genetic merit, giving effectively four herds. Within the BP system, leguminous co-products represent 10% of the ration and include (imported) soya bean meal. Legumes grown on the farm include spring beans, red clover and lucerne (alfalfa) and account for up to 15% of the ration. In addition to legumes, crops grown on the farm were maize, grass and wheat. Cows within the HG system were grazed for two periods when grass was available, housed overnight and fed a HG total mixed ration (TMR). Performance results showed that the BP system cows produced an average of 9,375 kg milk with daily yield averages of 29.7 kg and 34.6 kg for Control and Select animals respectively (milked three times per day). Cows consuming a HG diet produced an average of 8,440 kg milk, with daily yield averages of 23.2 and 25.1 kg for Control and Select cows respectively. Contrasting technical performance as well as GHG emissions and nutrient use efficiencies are expected to arise from the diets, genotypes and housing systems.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

No. 5) Nitrogen fixation by faba bean (*Vicia faba* L.) in a 4 year crop rotation in East Scotland

Euan K. James, Laura Lopez del Egido, Marta Maluk, Mark Young, Cathy Hawes, Geoff Squire, Pietro P.M. Iannetta

The James Hutton Institute, Invergowrie, Dundee DD2 5DA, UK

Faba bean (*Vicia faba L.*) is an important grain legume in the UK, being used for human consumption (abroad mainly), as well as for livestock and fish feed. It forms a nitrogen (N) -fixing symbiosis with *Rhizobium leguminosarum* sv. viciae, and is capable of obtaining all its N requirements through biological N-fixation (BNF). However, almost nothing is known about its ability to fix N in the UK, particularly for modern genotypes. To address this, grain yield, the proportion of nitrogen (N) derived from air (%Ndfa), total BNF, and the molecular- and functional-diversity of nodule-associated R. leguminosarum (Mutch & Young, 2004) of five faba bean varieties were quantified in response to 'Conventional' (C) and 'Sustainable' (S) growing regimes in an experimental rotation at the Centre for Sustainable Cropping (CSC; www.hutton.ac.uk/csc) over four growing seasons (2012-2015).

The beans obtained >90% of their N through BNF regardless of genotype, treatment and year, but the total amount of N fixed was dependent on grain and dry matter yield. Yield varied from year to year, with grain yield being 4 – 8 t ha^{-1}, $year^{-1}$, depending on growing conditions. In a good year (e.g. 2012, 2014), faba bean fixed >200 kg ha^{-1} y^{-1}, but in a poor year (2013) this was halved. The residual N left in the field after grain harvest was over 50 ha^{-1} y^{-1}, and if properly managed over winter this N could be made available to the next season's non-legume crop.

Nodulating isolates obtained from root nodules were distinguished by ribosomal 16S subunit (16S rRNA) PCR, and their genetic diversity assessed using sequencing of the symbiotic loci *nodA* and *nodD*. Rhizobia from nodules of cropped faba bean were similar from year to year, regardless of plant genotype and treatment, and could be grouped into two broad *nodD* clades, one containing only *V. faba* strains and the other containing a mixture of isolates from *V. faba* and from wild species of *Vicia* and *Lathyrus* that were growing adjacent to the experimental rotation. Glasshouse screening for the effects of individual rhizobia strains to increase the biomass of pea (cv Corus, a petite poise), over 60 d of glasshouse culture identified a large difference in functional capacity. Pea dry biomass varied over a 12-fold range, from around 0.2 to 2.4 g.

It is concluded that modern faba bean varieties can obtain all their N-requirements through BNF in association with local indigenous rhizobial strains if managed properly, thus making substantial savings in terms of costly and environmentally damaging fertiliser applications. The rhizobia strains identified as 'potentially elite' from glasshouse screening trials will be assessed to test whether the biomass benefits see in glasshouse culture can be translated to biomass and grain-yield improvement in field. If so, the high-performing strains may be developed as new commercial inoculants.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

References
Mutch & Young (2004) *Molecular Ecology* 13,2435–2444; Unkovich *et al*., (2008) Measuring plant-associated nitrogen fixation in agricultural systems. *Australian Centre for International Agricultural Research* (ACIAR).

No. 6) Development of Precision Agriculture Technology-led agronomy for strip-sown combined systems, using leguminous living mulch

Jennifer A. Banfield-Zanin, David R. George

Stockbridge Technology Centre, Cawood, Selby, YO8 3TZ, UK

Prior research supports that living mulches can address multiple key challenges being faced by the arable sector, including soil erosion control, surface water pollution reduction, as well as improvement of soil structure, fertility, water retention, soil organic matter content and nitrogen availability. They can also support soil biotic health, promoting micro- and macro-fauna, and pollinator provisioning, while also helping reduce pest, disease and weed burden when managed well. Living mulches also have the potential to play an important role in carbon storage, particularly where leguminous mulches are used (as these can simultaneously reduce N_2O emissions by replacing or reducing the need for nitrogen fertiliser application). They therefore represent a 'multifunctional' opportunity for agriculture and the environment. Despite the demonstrated benefits, commercial uptake of living mulches in the EU has been prevented by production conflicts and practical difficulties in the management of these polycultural systems. Such issues (including elements of slug and weed control, and establishment) and concerns regarding crop competition must be addressed and resolved in order to encourage uptake, with evidence supporting use across multiple broad-acre crops.

As part of the TRUE project, the STC Case Study will seek to develop in-crop leguminous living mulch management within growing seasons for multi-scale field production. A Precision Agriculture Technology (PAT) approach will be utilised, employing strip-tillage approaches combined with precision-assisted band-sowing to sow a clover living mulch understory alongside multiple broad-acre crops with poor sustainability credentials (e.g. maize, cereal, oilseed rape and sugar beet). Compatibility with current management approaches will be evaluated, with development of solutions to manage, for example, pernicious weeds that may develop in understories assessed. Novel machinery solutions with potential to optimise management of clover living mulches in-crop will be developed and tested in collaboration with a PAT-specialist. Throughout, the impact on main crop yield will be evaluated, to ensure that developed solutions maximise potential yield in the multi-crop system. If successful, the package of management options could deliver benefits to clover in-crop management, providing necessary evidence and support for the use of living mulches with multiple broad-acre crops to maximise benefit.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

No. 7) Heritage varieties for enhanced human and beneficial insect nutrition

Barbara Smith, Francis Rayns

Centre for Agroecology, Water and Resilience (CAWR), Coventry University, Ryton Gardens, Coventry, CV8 3LG, UK

Modern crop varieties have been selected for yield and other agronomic characteristics rather than food quality. A decline in the content of vitamins and minerals in a range of vegetables since the second World War is widely acknowledged; this could be due to a range of factors but changes in the varieties grown is likely to be important. A great number of older varieties have been preserved, although they may no longer be commercially available at present due to seed legislation. We are working with the Heritage Seed Library, part of the UK charity Garden Organic (https://www.gardenorganic.org.uk/hsl), that hosts a collection of vegetable varieties including beans and peas; some of these are ex-commercial varieties that are no longer registered on the National List and some of them have never been commercial, having been selected by individuals in the past and passed down as heirlooms. There is potential for these to be brought back into wider cultivation or used in breeding programmes. Hodmedods, which whom we collaborated on this project (https://hodmedods.co.uk/), are a British company that aims to stimulate demand for indigenous.

Legumes also play a vital role in ecosystem service provision; we need to know more about the utilisation of cultivated pulses by beneficial insects, especially pollinators, and how this relates to differences in the quantity and quality of nectar and pollen. There is potential to grow varieties that will support important pollinating insects by selecting those that provide high quality floral resources, but first we need to understand more about how those floral resources differ and how the bees respond to them.

In this case study, we will set up field trials of *Vicia faba* (broad bean and field bean types) and *Phaseolus vulgaris* (climbing French bean type) to assess the agronomic performance of heritage varieties in comparison to modern ones. The nutritional quality (protein and carbohydrate content, vitamins and minerals) of the crops will be analysed. During the flowering period, we will quantify visitation of the different varieties by pollinating insects and relate this to the production of floral volatile chemicals that may be responsible for attracting them and the quality of the resources that are provided in return (*e.g.* amino acid profiles of pollen and the sugar content of nectar). The practical work will be conducted in Years 2 and 3 of the project.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

No. 8) Using legumes as a source of fertility in organic protected cropping systems

Francis Rayns

Centre for Agroecology, Water and Resilience (CAWR), Coventry University, Ryton Gardens, Coventry, CV8 3LG, UK

The use of legumes to build soil fertility is at the heart of all organic agricultural systems. However, in protected cropping situations the financial value of the infrastructure (glasshouses and polytunnels) makes it harder to justify dedicating adequate time in the rotation for them. Consequently, many intensive organic growers rely on the import of fertility in the form of animal manures or by-products such as blood and horn meal. This has ethical implications, especially for vegan consumers, and makes the system reliant on external inputs.

In this case study we will investigate a range of innovative ways of using legumes to build soil fertility. The simplest approach is to use fast growing species of green manures that can be sown directly in the soil in a polytunnel; we will evaluate the potential of a number of species, considering aspects such as their establishment, speed of growth, biomass accumulation, water utilisation, nitrogen fixation and nutrient dynamics in the soil after incorporation. These could be more unusual legume crops not normally grown as green manures, at least in a temperate climate. This approach still utilises valuable protected cropping space and so, in parallel, work will be done to determine the effectiveness of bringing in legume green manures grown in an adjacent outdoor area. This could be in the form of freshly cut foliage that could be used as mulch around growing plants, as composted material or as anaerobic digestate. This last option has a number of advantages; methane gas would be produced that could be used for heating and the liquid digestate could be supplied using fertigation methodology, precisely dosing the applications to the crop demand. However, there are a number of practical obstacles to producing it on a small scale that will need to be considered. We will also look at the use of legume meal as a source of nutrients. This relatively high value material would be most suitable for incorporation into growing media, for example those used in the production of vegetable transplants prior to these being planted out in the field.

Throughout this case study, we will work closely with commercial producers (for example members of the Organic Growers Alliance) to overcome existing technological and practical barriers and to facilitate uptake of the findings. The practical work will be conducted in Years 2 and 3 of the project.

No. 9) Retailer-producer quality chains and innovations

Karen Hamann

IFAU Institute for Food Studies & Agri Industrial Development 15, Agiltevej DK 2970 Hoersholm Denmark; Tel +45 45 57 05 82

The assortment of food and drink products made with legumes is very wide and with traditional products such as canned, fresh and frozen legumes as the main traded goods. New products play a key role in driving market dynamics. Bringing new products (food and drink) made with legumes

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

into the retail market can provide a big challenge for large as well as small producers. A thorough understanding of the supply chain, market-power and -drivers are crucial for decision making about entering the market with a new legume-based product. By analysing the food retail markets in Denmark, Germany, the UK, the Netherlands and Greece, this case study provides detailed findings about retailer-producer quality chains for legume-based products.

The case study builds on interviews with key market actors; observations of assortment, prices, brands and products in retail stores; and analysis of retail market structures and market dynamics. To identify and understand the differences between countries under study, additional interviews are gathered from the market sessions at the regional Legume Innovation Network meetings. Challenges related to product development and marketing in practice are investigated in collaboration with North Jutland Food Cluster, thus using Denmark as a model country.

Across the EU, the key market driver for having more legumes in the food chains is health. This is instigated primarily as a growing demand for plant-based protein to reduce consumption of animal protein, and secondly as a choice of food to match the consumer's lifestyle such as a flexitarian diet with a convenient access to relevant products. Food manufacturers aim to launch new or reformulated products into the retail market that cater to consumers' motivations for food choice making "health" a key quality criterion for marketing new products. Health is not a "one-size-fits-all" quality criteria, as health may be defined by attributes such as vegetarian, vegan, organic, low-fat, fresh or otherwise. An important conclusion is that the market for innovative legume-based products is driven by a strong interest in plant-based diets and a continuously widening of the assortment of products to meet the consumers' lifestyles especially targeting the segments of health and convenience.

No. 10) Market model for legume-based feed for organic pig production

Karen Hamann

IFAU Institute for Food Studies & Agri Industrial Development 15, Agiltevej DK 2970 Hoersholm
Denmark; Tel +45 45 57 05 82

This case study will address the challenges of meeting the increasing demand for organic pork and the constraints experienced herewith. The work focuses on North Europe with Denmark as a model country. Imported organic soy beans from China and Ukraine are the most frequently used protein source for organic pig production in the EU. Due to the upcoming removal of the EU option of including 5% non-organic protein in the feed ration for the pigs, the need to identify alternative and competitive organic protein sources becomes urgent and, which paves the way for legume-based feeds such as peas, lupines, and fava beans.

The case study builds on desk research, interviews with organic pig producers and, a workshop in Denmark. To ensure that the practical challenges and routines in organic pig farming are brought forward and taken into account, the case study collaborates with the association Organic Denmark.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Today, Denmark lacks 30,000 tons of organic protein feed and the market gap is expected to increase further in the coming years. By 2020, it is anticipated that 200,000 organic pigs will be slaughtered in Denmark compared to 160,000 in 2016. But, increasing the cultivation and application of legume-based feed such as faba (*Vicia faba* L., or field-) beans will not provide a sufficient solution, as the amino acid profile of the faba beans does not fulfill the pig's nutritional requirements. Danish farmers already grow organic faba beans for the feed industry but the economics and efficiency of the supply chain needs further improvement if the cultivation of organic legumes is to be increased. Furthermore, legumes are experiencing competition from alternative organic protein sources such as processed starfish, seaweed or clover grass but, the production and use of these alternative protein sources have not yet taken off in industrial volumes. The conclusion is that the market for organic legumes for feed is growing but to exploit the opportunities for legumes in this context, new ways of collaboration within crop production and logistics are required.

No. 11) Legumes in public and private food service

Karen Hamann

IFAU Institute for Food Studies & Agri Industrial Development 15, Agiltevej DK 2970 Hoersholm Denmark; Tel +45 45 57 05 82

Food service accounts for approximately 25 % of the food consumed in the EU. Food service includes the public sector (hospitals, school meals, army etc.) and the private sector (company canteens, restaurant chains). Procurement of food items for the public food service market is subject to governmental regulations and plans including the Green Public Procurement Criteria of the EU. Procurement strategies for food in private and public food service outlets can be influenced by schemes such as the Danish Organic Eating Label. This case study investigates how government regulations and, public and private schemes can impact the procurement strategies in the food service sector towards a greener purchasing of food. The Organic Eating Label was introduced by the Danish government in 2009 to promote organic food in the private and public food service outlets. By 2018, nearly 2,500 public and private outlets were certified with a Gold, Silver or Bronze status within this label. The status refers to the share of organic food in the total food purchase *i.e.* a Gold label equal to an organic share of 70-100 % organic food. Certified outlets have developed more green menus, reduced food waste, and purchase more seasonal produce.

The case study builds on desk research, interviews with key market players and regulators and, observations of menus, purchasing lists, and procurement criteria. Denmark and the UK are used as model countries, and the Green Public Procurement strategies are investigated at EU level and for the model countries.

Green Public Procurement (GPP) is an EU initiative instigated as a management tool to increase sustainability through the outlining of framework conditions for government procurement. Food is included as one of the categories in the Green Public Procurement initiative in line with building materials, medical devices etc. The GPP lays down the detailed requirements for public procurement contracts and for food, the GPP includes specifications for numerous food categories. Yet, legumes are not mentioned at all. This paves the way for investigating how legumes are used in

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

the public food service sector, how legumes are mentioned in procurement contracts, the drivers for sustainability as a purchase criteria and the role of schemes in driving the food service market. The findings will point to policy issues to be addressed to achieve greener food procurement strategies with legumes playing central role.

No. 12) Overview of breadth and diversity for peas

Karen Hamann

IFAU Institute for Food Studies & Agri Industrial Development 15, Agiltevej DK 2970 Hoersholm Denmark; Tel +45 45 57 05 82

The case study will provide an overview of the breadth and diversity given for peas and, as such, will serve as a model for the (unexploited) opportunities in legumes processing. It will list the many options available for processing peas - and by this point to the difficulties of policy making towards larger pea acreage in EU. The case study will map assortment and innovations within peas for human consumption (green peas and dried peas) by fresh, frozen and processed products; for food ingredients (including the range of pea-based ingredients, their applications and potential); and, for use in feed. Market shares for organic pea products are estimated. In addition, the study will investigate the assortment of pea seeds available and the characteristics of each varieties - thus providing an understanding of how different varieties links to different purposes. This includes heritage crops.

The case study will provide an overview of how peas and processed pea-products are traded in the local and international markets emphasizing the role of Canada (major supplier in the global market) investigate the role of technology in driving the demand for peas, particularly in relation to food ingredients. An overview of the by-products from pea processing will provide insights to yet unexploited sources that could be used for building new value chains. The findings will be compared with the diversity of high protein non-legume-based feeds, such as wheat and oil seed mixtures. This will allow conclusions to be drawn on the need for and challenges related to policy making, and for market and value chain integration to accommodate a larger agricultural area with pea crops in Europe.

No. 13) Why is lentil *(Lens culinaris)* cultivation a success story in south-west Germany?

Sabine Gruber, Ann-Marleen Rieps, Sabine Zikeli

University of Hohenheim, Institute of Crop Science, section Agronomy (340a), 70599 Stuttgart, Germany; Tel. +49 711 45922371; Email: *Sabine.Gruber@uni-hohenheim.de*

Lentils disappeared from fields in Germany in the 1950s though there was a long tradition of lentil growing, particularly in the south-west, and though lentil dish is a traditional food with multiple recipes all over Germany. For approximately 10 years, there has been a revival in lentil cultivation, and the growing area is increasing in both, organic and conventional farming. If the driving factors

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

could be identified, the success story of lentils could be transferred to other legumes, and other European countries.

The aim of the case study is to investigate the *status quo* of lentil cropping systems in south-west Germany to identify factors which are important for successful lentil production under the given environmental and socioeconomic conditions of the region. Data were collected from farmers in the form of questionnaires and semi-structured interviews. Whilst the former focused on the cropping management of the lentils, the latter focused on the farmers' personal motivation and obstacles regarding lentil cultivation.

A total of 26 lentil farmers were visited, 22 of them were organic farmers, and four conventional. Most of the organic farmers are partners of a producer group for processing and marketing. A specialty of German lentil cultivation is the need for mixed cropping with a companion crop to avoid lodging. These companion crops were by approximately 50 % oats (*Avena sativa*). Other companion crops were spring barley (*Hordeum vulgare*) and false flax (*Camelina sativa*). The lentil yield (cleaned and dried) ranged among the organically managed fields from 0.45 – 1.1 t ha^{-1} (mean: 0.67 t ha^{-1}), and on the four conventional farms from 0.6 – 0.8 ha^{-1} (mean: 0.74 ha^{-1}). Much more data are available but data evaluation is not yet completed.

No. 14) Why is soybean *(Glycine max)* cultivation a success story in south-west Germany?

Sabine Gruber, Ann-Marleen Rieps, Sabine Zikeli

University of Hohenheim, Institute of Crop Science, section Agronomy (340a), 70599 Stuttgart, Germany. Tel. +49 711 45922371, Email: *Sabine.Gruber@uni-hohenheim.de*

Soybean is not a traditional crop in Germany, mostly due to its temperature requirements during the growing season. However, there has been a considerable increase of the soybean growing area mainly in south Germany for more than 10 years. We therefore assume that various factors make soybeans more attractive to farmers in recent times. First, climatic changes and rising temperatures in Germany provide much more suitable growing conditions than the previous decades and centuries. Second, plant breeding efforts have resulted in varieties, which are better adapted to the cooler local conditions. Third, there is a demand for GMO-free food and feed as added value for many products. Forth, the vegetarian and vegan movement require food rich in protein with specific essential amino acid compositions which soy can easily deliver. All these factors are linked to each other and have probably promoted each other.

The aim of the case study is to collect information about soybean cropping systems in south-west Germany and to identify and describe the driving factors for this success story. We expect to gain more insights in the reasons behind the fast rise in soybean cultivation in the region during the last years. In addition, we want to use this information should enable the creation of a blueprint to help promote other legumes in Germany and Europe.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Data were collected from farmers in the form of questionnaires about crop management, and semi-structured interviews about the farmers' motivation and obstacles. We received information from 8 organic and 9 conventional farmers, who produce soybean for food or for feed. The organic farmers harvested an average of 2.6 t ha^{-1} with an average protein content of 44.5 %, and conventional farmers of 3.1 t ha^{-1} with 39.5 % protein. A subsequent and detailed analysis will explain the differences, which probably depend on variety, soil tillage and crop rotation. In general, the organic rotations included, other pulses, perennial fodder legumes, vegetables, potatoes, winter wheat, winter spelt, winter rye, spring wheat, oats and maize, whereas the conventional rotations included oilseed rape, sugar beet, potatoes, maize, winter wheat, winter rye, winter barley and oats. The analysis of these and further data is in progress.

No. 15) Blue Lupin for White Shrimp? A step towards sustainable aquafeed

Monika Weiss, Matthew J. Slater

Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Am Handelshafen 12, 27570 Bremerhaven, Germany; E-mail: *monika.weiss@awi.de*

Formulated feeds used for the growing production of carnivorous fish and crustaceans generally have a high protein content which is still met predominantly by unsustainable fishmeal supply. Maintaining the steady and enormous growth of aquaculture production requires practical alternative protein sources. Terrestrial protein sources have been the focus of feed research for more than twenty years. Many studies have involved trials of legume grains such as those from field peas, lupin and faba bean. Several different cultivars of lupin have been tested with different fish species mainly in Australia. The results of these studies are promising for example for salmon and seabass, but lupin diets for high value crustaceans remain untested.

In the present study we formulate aquafeeds with lupin kernel meal (*L. angustifolius*) for the White Leg Shrimp *Litopenaeus vannamei*. Germany and adjacent countries produce *L. vannamei* in environmental friendly Recirculating Aquaculture System (RAS) in a small but growing industry aimed at the regional gourmet food market. A sustainable Europe-sourced feed would underline the sustainability of this high value product.

An experimental diet (Basis) with 30% fish meal as main protein source was formulated. *Lupinus angustifolius* kernel meal was added as 10, 20 and 30 % of the diet, incrementally replacing fishmeal. All diets were balanced to meet the requirements of *L. vannamei* in the grow out phase, concerning energy content, protein and amino acid profile, lipid and fatty acid composition, vitamins and minerals. These diets were compared with a commercial control. Feeding experiments were conducted over 8 weeks in a RAS device, with 18 separate 50 L tanks each stocked with 25 shrimps. Experimental diets were fed in 4 replicates, the commercial diet in duplicate. At the end of the experiment, haemolymph samples for further analyses were taken to determine metabolic parameters (glucose, triglycerides and heamolymph protein), total haemocyte counts, haemocyte types and phenoloxidase.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Mean survival rate of the shrimps was 65% across all treatments. Mean biomass of animals fed with high lupine levels (L30) was significantly lower than in control diets (Basis and Commercial control) and L10 after 8 weeks. Metabolic analyses showed malnutrition of animals fed the L30 diet with regards to glucose and triglyceride levels, although appropriate protein provision was attained with all experimental feeds. The total haemocyte count showed significantly higher counts in animals fed the L10 diet, which hints at an elevated immune capacity of these animals. This apparent immune-stimulation in cultured animals is intriguing and needs further investigation. It was observed that animal colour was very different depending on the feed, with a favorable red/brown colouration in lupine fed animals and blue colour in the fishmeal fed animals.

Untreated lupine meal can be used as an alternative protein source at rates of up to 10% (-20%) of the total feed (= 30-40% of animal protein).

No. 16) Legumes: their potential role in Croatian agricultural production

Valentina Hažić, Jurka Topol

Regional Development Agency Međimurje REDEA Ltd.

The Case Study will focus on the current state of legume production in agri-food sector and on defining, the most important factors affecting the development of legume production process in Croatia. The general aim is to encourage and stimulate farmers to increase cultivation and production of these important crops and to raise consumers' awareness of their importance in a healthy diet. This aim will be achieved through development of regional and national policy recommendation frameworks for sustainable development.

Cultivation, production, processing and consumption of legume crops in Croatia are developed insufficiently with almost no farmers entirely based on the cultivation, processing and placement of legumes on the market. Growing legumes production is delivered by very small family farms that grow them exclusively for their own use. Farms engaged in crop production, use legumes as one component of crop rotation and for green fertilisation. The farmers engaged in livestock production, grow legumes for the production of feed for livestock. But nevertheless, intensity of legumes cultivation is at an unenviable level calling for a need to encourage farmers to develop a network with agricultural producers from other EU countries. This would create preconditions for the transfer of knowledge related to the introduction of growing legumes in production systems, which would contribute to the sustainability of production systems in the agri-food sector.

In Croatia, there is an insufficient awareness of the importance of regular consumption of legume food products, both in terms of their own health but also for the establishment of sustainable systems of food production. Legumes are very important in the human diet, primarily because of their nutritional composition as they represent the most important source of plant protein and amino acids, hence the importance in raising public's awareness about the nutritional content of all kinds of legumes and to encourage it to increase their daily legume consumption.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

No. 17) Pulses in short food supply chains from small-scale farms to urban gastronomy

Gábor Bertényi, Attila Králl

Agri Kulti Ltd., Hungary

This case study aims to examine the possibility to introduce and enhance traditional and new legume varieties into urban gastronomy. The long-term goal is to sustainably revitalize rural areas through enhancing the market stability of innovative, environmentally and socially conscious small-scale farmers and agro-enterprises. This should contribute to the reconnection of rural areas and cities by providing urban consumers with quality, healthy, fresh food in a fully transparent way. Traditional local varieties with special properties will be identified in field- and table studies and tested by mainstream chefs, gastro bloggers and consumers at various scenes of urban gastronomy from street food through catering to leading restaurants.

No. 18) Ancient & heritage variety screening for higher nutritive value

Alfredo Sendim, Nuno Coutinho, Ricardo Silva

Herdade do Freixo do Meio 7050-705 Foros de Vale Figueira, Portugal

The general goal of Herdade do Freixo do Meio's case study is to analyse the new strategies that recreate the multifunctional montado traditional system, and adapt it to new economic, social and environmental challenges. The study also aims at understanding the new forces and dynamics that intercross and which may result in facilitating or preventing the development of farm multifunctionality.

Specifically, there are two main objectives for three different crops: to learn the best processes to grow common bean, Lupin and chickpea; and, to develop new processes to transform these commodities into desirable foods for human consumption.

In addition, we have three field trials underway testing the utility of various legume plus non-legume intercrops strips in an agroforestry-based system. Each legume-based intercrop strip will comprise either: **1)** green beans with pumpkin and sunflower; **2)** chickpea, sunflower, corn and pumpkin; or, **3)** chickpea (only - control). Each strip is in turn sown interspaced with a facilitating agroforestry strip of woody species. This raises the water table and acts as a source of soil carbon assimilation *via* green-manuring. The woody species are selected as perennial, fast growing with good taproots to increasing organic matter throughout the soil profile as well as excellent capacity to regrown following cutting. To maximise the soil carbon (and nitrogen) provision the facilitative forage legume strips will be cut periodically, the resulting residues will be shredded and used as soil cover and additional residue provision or can be removed for used as 'wood' in other processes (*e.g.* biomass of bioenergy production *etc*).

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

We believe this more complex agroforestry will present better results - as an optimised means by which we may increase in soil qualities and crop production.

No. 19) Consumers - legume dishes

Beatriz Oliveira, Elisete Varandas, Eugénia Vilela

Eurest Portugal Eurest Portugal, Lda Edifício Prime, Av. Quinta Grande, 53 - 6º Alfragide 2610-156 Amadora, Portugal

Legumes are considered essential in human nutrition because they are important sources of nutrients such as carbohydrates, vegetable protein, fiber, B-complex vitamins and minerals. According to current recommendations, the consumption of legumes should represent 4 % of the total daily energy *via* 1 to 2 portions. However, according to the Portuguese Food Scale (Balança Alimentar Portuguesa 2003-2008), the intake of legumes is much lower than recommended (about 5 times lower). The need to promote this food group is therefore justified, given the strong evidence linking its consumption to the promotion of good health and prevention of disease. In addition, they are associated benefits in environmental and economically.

Nowadays, consumers are increasingly willing to make sustainable choices, particularly with regards to food products. Legumes are one of these choices, since they have water (19L/g of protein) and considerably reduce carbon footprints by up to 65% compared to wheat production, and have higher nutritional values. The energy cost for the production of legumes of food is also reduced, at about half the cost of cereal production. In light of these nutritional, economic and environmental benefits, Eurest-Portugal has conceived and implemented the *Choose Beans* project in several pilot units. The results obtained after the initial application of the *Choose Beans* project highlighted specific scenarios that favoured the promotion of good-health *via* community intervention. The results show an increase in the frequency of consumption of pulses by 25% following implementation of the project, proving that informing and raising consumers' awareness of the health benefits of legumes, motivate them to be more responsible in their food choices.

The development and testing of new recipes are in the implementation phase and taste/ flavour tests with a consumer panel. The next step being critical – ensuring the uptake of the best pulse-recipes within the menus offered.

No. 20) Legumes' consumption and barriers among Portuguese adults: a quantitative and qualitative study

Mariana Duarte[1], Marta Vasconcelos[1], Elisabete Pinto[1,2]

[1]Centre for Biotechnology and Fine Chemistry - Associated Laboratory, Faculty of Biotechnology, Universidade Católica Portuguesa; [2]ISPUP-EPIUnit, University of Porto; E-mail: *epinto@porto.ucp.pt*

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Population growth and lower amounts of arable land drives the need to increase food production to ensure a good nutritional status for the upcoming generations of consumers. In Portugal, according to the Portuguese Food Balance Sheet, meat consumption presented one of the most significant deviations from the recommended guidelines. In reality, several Portuguese traditional recipes include meat as the main protein source. From a nutritional standpoint, the transition from diets rich in animal products (like meat and fish) to diets with high content of vegetable protein (like legumes or seaweeds) is crucial, for both environmental sustainability and human health. It is, therefore, important to boost plant protein sources, which have been forgotten in the past years.

The aim of this study was to characterise legumes' consumption in a sample of adult Portuguese population. We also aimed to describe the motivation behind the inclusion of different sources of protein in the diet and to identify potential barriers to do so. In this research, we combined two distinct studies: a quantitative and a qualitative study. In the former, a semi-structured questionnaire was disclosed online, a *snowball* sampling method was used and 1741 valid answers were obtained. Inclusion criteria were: 1, to live in Portugal; and 2, to be at least 18 years old. In the qualitative study, ten individual interviews were conducted to study individual behaviors and experiences linked to legumes' consumption. SPSS version 24.0 was used for the statistical analyses of the quantitative data. Qualitative information was studied by a content analysis method.

The most popular grain pulse was common bean, whereas lentils were the least commonly consumed. When asked about the possibility of replacing meat and fish with pulses in some meals, only 20% of participants responded they were already doing so. Females, the elderly and more educated people were more motivated to change their food choices. The interviews highlighted potential barriers for legumes' consumption, such as the lack of knowledge in nutritional benefits, and the presence of anti-nutritional factors.

In order to achieve a complete and balanced diet, pulses should be included more frequently in consumers' daily routine. Although they are nutritionally important, many consumers do not reach the recommended levels of legumes' intake. The identification and understanding of perceived barriers for that low consumption will make it easier to develop new strategies to promote pulses' intake.

No. 21) Comparing the inoculation success of two bacteria strains, under different N supply levels, in the Greek bean landrace Zargana Chryssoupolis

Vasiliki Vougeleka[1], Georgia Ntatsi[1,2], Fotini Mylona[2,3], Costas Saitanis[1], Anastasia Tampakaki[1], Dimitrios Savvas[1]

[1]Agricultural University of Athens, Iera odos 75, p.c. 11855, Athens, Greece; [2]Institute of Plant Breeding and Genetic Resources-ELGO-DEMETER, 57001, Thessaloniki, Greece, [3]ELGO Dimitra, National Greek Gene Bank, Kourtidou 56-58 & Nirvana p.c. 11145, Athens, Greece

Common bean is capable of fixing nitrogen (N) from the atmosphere by establishing symbiosis with soil bacteria (rhizobia) *via* specialized organs known as nodules. While plants benefit from fixed nitrogen, the rhizobia have access to carbon and other nutrients. To balance these costs, the plant

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

limits the formed number of nodules *via* a systemic feedback inhibition signaling network called the *autoregulation of nodulation*. It also limits nodulation when the requisite N is available. Other factors affecting nodulation are the host plant genotype, the rhizobium strain and environmental conditions.

Landraces serve as genetic resources as they are farmer developed populations of cultivated species that show inter- and intra-population diversity. These populations are often cultivated in parallel by more than one farmer resulting in landraces containing the bulk of the genetic diversity of species. They can be useful in the development of locally adapted high yielding varieties with resistance to biotic and abiotic stresses.

To study the possible bacteria inoculations of a Greek landrace and to determine the optimum N-concentration, the following experiment was conducted: seedlings of the Greek common bean (*Phaseolus vulgaris* L.) landrace Zargana Chryssoupolis, (provided by the Genetic Conservation Bank of the Institute of Plant Genetics Resources in Greece) were either inoculated with a bacteria liquid culture (containing either *Rhizobium tropici* or *Rhizobium vuka*) or not- inoculated (control group). The seedlings were then planted in pots containing perlite substrate and grown hydroponically. The nutrient solution provided the plants with 100% of the required nitrogen (N) until the 27th day after sowing. For the remaining 82 d until harvest the plants were treated with different nutrient solution which provided them with either 100%, 50%, or 25% of the required N. At the end of the experiment, fresh and dry biomass (above and underground), nodules and yield were measured. Subsamples from the dried biomass are stored for further measurements of mineral nutrients (*e.g.* K, Ca, Mg, Zn, Mn, Fe, P, B, NO_3, NH_4) and Biological Nitrogen Fixation. Gas chromatography-mass spectrometry (GC/MS) metabolomics will be performed for the analysis of the samplings. Preliminary analysis of the data suggests that *R. vuka* performed a better inoculation in comparison to the *R. tropici* bacteria. The plants provided with 100% of N supply returned higher yield. Further and more detailed results will be presented.

No. 22) Impact of legume and non-legume crops on soil-N availability and greenhouse gas emissions during winter cultivation period

Ioannis Karavidas[1], Georgia Ntatsi[1,2], Dionisios Yfantopoulos[1], Theodora Ntanasi[1], Anastasia Tampakaki[1], Dimitrios Savvas[1]

[1]Laboratory of Vegetable Production, Agricultural University of Athens, Iera Odos 75, 11855, Athens, Greece; [2]Institute of Plant Breeding and Genetic Resources-ELGO-DEMETER, 57001, Thessaloniki, Greece.

In organic agriculture, the availability of fertiliser nitrogen (N) to plants depends on the mineralisation rates of soil organic matter, which are difficult to predict under field conditions. In order to assess and improve N supply *via* alternative renewable organic sources in non-legume field crops grown organically, a field experiment was carried out at the experimental facilities in the laboratory of Vegetable Production at AUA. The experimental field consists of the following crops, organic and conventional farming of broccoli, organic farming of faba bean inoculated with or without *Rhizobium leguminosarum* bv. viciae, while a non-cultivated field was used as control. During the cultivation period, plant biomass characteristics, as well as N levels (total-N, NO_3-N, NH_4-

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

N), and other nutrients in plant tissues and soil were estimated. In addition, this work focused on measures to facilitate the rapid transfer of biologically-fixed N from the legume crop to the following non-legume vegetable crop. This was assessed by testing the efficiency of the system in terms of biological N2-fixation (BNF) and its contribution to the total N needs of the tested non-legume vegetable crop. BNF quantification was performed by 15N natural abundance method. Finally, to determine the effect of the above crops on the global climate change, greenhouse gases (NH_4, CO_2, N_2O) emissions were calculated. More specifically, the results of the present study showed that the fresh weight of shoot of inoculated faba beans range from 253g to 288g and dry weight of shoot range from 26g to 28g while in plants without inoculation the fresh weight of shoot range from 139g to 203g and dry weight of shoot range from 14g to 20g.

No. 23) Development of sustainable legume-based cropping and grassland systems and agri-food and feed chains

Eleonora Barilli

Solintagro SL, c/Escritora Rosa Chacel 4 (local 2), 14004, Córdoba, Spain

Grain legumes have an extraordinary historical importance for the agriculture and environment of the Mediterranean basin. Despite their importance, their cultivation is decreasing due to low and irregular yields and socio-economic and political context that discourage farmers to grow these specific crops, increasing imports of grain legumes as a consequence. It is true that legume consumption has decreased, but this does not justify the decrease in cultivation. In fact, Spain imports 85% of the beans, 60% of the lentils and 75% of the chickpeas that are consumed. A similar trend is also observed in all Mediterranean countries. There is an urgent need to rehabilitate legumes in the cropping systems in order to improve productivity and sustainable exploitation of agricultural lands in these regions, as well as people's quality of life. Development of cultivars with stable yields, adapted to peculiarities of Mediterranean climates will offer significant market opportunities for seed companies and farmers.

A collaborative farm-network is therefore proposed to promote grain legume cultivation in Mediterranean rain fed farming systems. The aim is to evaluate currently and previously grown grain legume cultivars and landraces for characteristics of importance to sustainable agriculture and to apply novel tools to integrate genetics that enable resistance to abiotic stresses with other pest control practices and in a concerted manner. Priority is given to the best combination of increased yield and resistance to stresses and integrated management. This strategy is pursued for the production of stable yields of leguminous grain crops of high value and *via* crop rotations of low input. Towards this aim, we tested 69 legume accessions belonging to 6 genera of agronomic importance to Mediterranean conditions. Specifically, the genotypes were: 5 chickpea accessions, 8 grass peas (Lathyrus spp.) accessions, 16 lentil accessions, 6 white lupin accessions, 21 pea accessions and 13 faba bean accessions. These were sown for Solintagro SL at the end of November 2017 in collaboration with local farmers under real commercial in-field conditions and at 3 different locations. Accessions came from elite, traditional and/or local legume varieties from Mediterranean origin that the enterprise previously selected principally for pathogen resistance. Each accession was established on 6 m^2 plots (rows 5 m long, 1.2 m apart) in a completely randomised design, with

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

three blocks. In the context of zero or minimum external inputs - crops were agronomically evaluated (% of seeds germination, density, productivity, resistance to naturally occurring stresses, time to flowering, pods formation and pod ripening, lodging and plant height) in order to select the most well-adapted to each location.

Using legume-based cropping systems will make Mediterranean agriculture less dependent on N fertilisers and self-sufficient for protein supply, which will decrease dependency on imports. It is of tremendous importance to provide income to Mediterranean farmers through new cultivars and optimised crop production and protection practices. Creation of an effective Mediterranean network that can fully exploit this valuable group of crops will contribute to improve food and feed security for the Mediterranean pedoclimatic region.

No. 24) Productivity of cereal-legume intercrop under smallholder farms in western Kenya.

Makatiani ET., Otieno JO, Magare CO, Gitu J., Gathara M., Odee DW.

Kenya Forestry Research Institute, PO. Box 20412-00200, Nairobi, Kenya.

This Case Study is located in the smallholder farming systems of western Kenya, which is typical of the agricultural production systems in sub-Saharan Africa. Farm sizes average 0.3 - 3.0 hectares. Maize, common beans and cowpeas are important staple food crops for the region. The key legume-based technologies involve various crop combinations, namely maize-bean, maize-cowpea, maize-bean-cowpea, and fallow or relay intercropping with N_2-fixing trees and shrubs for soil fertility management and provisioning of other ecosystem services. The main problems being addressed are: (i) low agricultural productivity due to poor soil fertility; and, (ii) irregular supply chain to end markets, and under-developed value addition from farm gate to consumers. There is also dearth of knowledge on environmental impacts, especially in the legume-based agroforestry systems.

The experiment aims to evaluate the impact of intercropping of legumes (grain and woody legumes) and non-legumes (cereals) in enhancing soil fertility/health and subsequent crop yields in agroforestry/silvo-arable systems. Legume-non-legume mixtures will be evaluated with varying spatial and temporal designs conditions in at least 2-year crop seasons, with legume tree and/or crop used as organic input/biomass transfer compared with inorganic fertilizer inputs. The species mixtures include maize (Zea mays), common bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), Rattlebox (*Crotalaria ochroleuca*), white Tephrosia (*Tephrosia candida*) and Sesbania (*Sesbania sesban*). Growth, biomass, grain yield, phenology, nutrient content, nodulation, biological nitrogen fixation, and rhizobial diversity and their effectiveness in N_2-fixation will be assessed. Life cycle-based assessment (LCA) studies will be undertaken to compare with European legume cropping systems in order to identify socio-economically and environmentally optimised legume- based silvo-arable (agroforestry) cropping systems in sub-Saharan Africa settings.

In the preliminary surveys and activities, we have reaffirmed the importance of legume-based cropping systems in the region, predominantly maize-bean intercrops, and include the innovative ‘push–pull’ technology. The “push-pull” technology concerns pest control and soil fertility, and

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

involves a combination of Maize-Beans-Napier grass (*Pennisetum purpureum*)-Mulato grass (*Brachiaria* sp.)-*Desmodium* (*Desmodium uncinatum*). We have also collected samples for baseline (pre-experimental) physico-chemical analysis and microbial (symbionts) composition.

No. 25) Agricultural Development and the role of legumes in Kenya

David W. Odee, Emmanuel T. Makatiani, and John O. Otieno

Kenya Forestry Research Institute, PO Box 20412-00200, Nairobi, Kenya; E-mail: *dwodee@gmail.com*

Agriculture sector is the mainstay of Kenya's economy. It contributes ~30% to the Gross Domestic Product (GDP) of Kenya (*cf.* services and industry, ~50 and 20%, respectively), and is pivotal in enhancing food security and reducing of poverty, therefore meeting some of the Sustainable Development Goals (SDGs), specifically #1 [No Poverty] and #2 [Zero Hunger]. Since independence, Kenya has developed several policy documents and regulatory frameworks to improve the agricultural sector. The far-reaching Kenya's Vision 2030 (2008-2030) is aimed at transforming the country to a newly industrialised middle-income country by the year 2030. Food security is at the top of the priority list of the current administration's development agenda. However, agricultural sector continues to face challenges in terms of land productivity, land use, supply chains and value addition of agricultural products. Central to agricultural productivity is poor soil fertility and low inputs; for example, average fertiliser use is 20-32 kg ha^{-1}. These challenges are most prevalent in the smallholder farming systems (averaging 0.2 – 3 ha in size), which account for 75 % of the total agricultural output and 70 % of the marketed agricultural produce in the country. Legumes such as pulses (common bean, cowpea and pigeon pea) and N2-fixing trees and shrubs (NFTs, *Crotalaria* spp., *Tephrosia* spp., *Sesbania* spp., *Calliandra* spp. and *Acacia* spp.) are integral to the smallholder (and silvo-pastoral) systems, providing nutrition to humans and livestock, and are also an important source of organic inputs for improving crop yields. Maize-bean intercropping is the most common legume-based system, accounting for 31% of total caloric intake, while NFTs may fix up to 300 kg N ha^{-1} yr^{-1} depending on species and soil fertility status. We highlight the importance of these legumes in Kenya, and opportunities for improvement in the framework of the TRUE project.

Figure 2: Acacia senegal, the gum arabic tree, a vital NFT for people and economy in the drylands of Africa.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

No. 26) Smart farms for the future

Bob Rees

Scotland's Rural College, Edinburgh EH9 3JG, Scotland, UK; E-mail: *bob.rees@sruc.ac.uk*

The case for increasing legume production in European farming systems is compelling, and yet European legume production has shown long term decline despite increasing consumption. In 2013, grain legumes were produced on 1.8 M ha of land (less than 2% of the arable area). There is increasing interest from policy makers in supporting increased production of legumes, but to do this effectively we must first understand the barriers, and then come up with smart solutions to changing agricultural practice.

The Legume Futures project (Legume Futures 2014) was valuable in demonstrating wider impacts of legume-supported cropping systems within farming systems. The use of legumes can help alleviate major environmental risks associated with nitrogen loss to the environment and therefore address wider concerns about greenhouse gas emissions, eutrophication and environmental impacts of farming systems. However, the way in which they are utilised influences their effectiveness in delivering these benefits. Some examples of smart approaches to utilising legumes will be provided. Through its network of case studies, the TRUE project offers the opportunity to use these innovative approaches, understand barriers and deliver a step change in the adoption of legume-supported cropping systems. This will support policy initiatives and contribute benefits to European farming systems and wider society.

References

Legume Futures 2014. Legume-supported cropping systems for Europe **http://www.elrc.eu/**

No. 27) Beneficial legume-microbe interactions: A case study on the diversity of rhizobial strains nodulating common bean landraces growing in Greece

Evdoxia Efstathiadou, Anastasia Tampakaki

Laboratory of General and Agricultural Microbiology, Department of Crop Science, Agricultural University of Athens, Iera Odos 75, Votanikos, 11855, Athens, Greece

P. vulgaris forms nitrogen-fixing symbiosis with bacteria belonging to different genera and species. Initially, all bean-nodulating rhizobia were classified as *Rhizobium leguminosarum bv. phaseoli*. However, *Phaseolus vulgaris L*. (common bean) is considered a promiscuous legume in its association with rhizobia since it can be nodulated by several species of the Rhizobiaceae family, such as *Rhizobium etli*, *Rhizobium gallicum*, *Rhizobium giardinii etc*. The diversity of rhizobia nodulating *P. vulgaris* has been widely studied, but, due the promiscuous nature of this plant in terms of its association with rhizobia, novel endosymbionts should be expected as more ecological niches are examined. Moreover, little is known about the genetic and symbiotic diversity of indigenous rhizobia nodulating common bean in Greek soils. The objective of the present study is to investigate the genetic and symbiotic diversity of indigenous rhizobia isolated from field-grown

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

bean nodules in different Greek regions. Authenticated strains will be subjected to a detailed polyphasic taxonomic study in order to identify and determine their taxonomic position at species and symbiovar levels. The genetic heterogeneity of the isolates will be assessed by DNA fingerprinting analysis and representative strains will be further analyzed by multilocus sequence analysis (MLSA) using well-known housekeeping and symbiosis-related genes. The isolated rhizobial strains will be assessed for their ability to promote plant growth in different common bean landraces in order to select the most appropriate combinations of rhizobia and bean landraces with enhanced nitrogen fixation and number of nodules. Such research will allow to select strains for common bean with high nitrogen fixing capacity to be used as inoculants and to finally contribute to the sustainability of traditional cropping systems.

No. 28) Effect of the farming system (organic or conventional) and rotation scheme with legumes (pea and faba bean), on biological nitrogen fixation efficiency, on soil NO_3--N concentration and head cabbage yield

Dionisios Yfantopoulos[1], Georgia Ntatsi[1,2], Anestis Karkanis[3], Dimitrios Bilalis[1], Dimitrios Savvas[1]

[1]Department of Crop Science, Agricultural University of Athens, Iera Odos 75, 11855, Athens, Greece; [2]Institute of Plant Breeding and Genetic Resources-ELGO-DEMETER, 57001, Thessaloniki, Greece; [3]Department of Agricultural Crop Production and Rural Environment, University of Thessaly. Fytokou str., 38446, N. Ionia, Magnisia, Greece

To quantitatively assess the benefits of cabbage from rotation with legumes, a field experiment was carried out at the facilities of AUA, located in Copaida during 2014-2017. From the two field rotation experiments (2015 – 2016, 2016 – 2017), in organic and conventional farming system, with different rotation treatments between pea, faba bean and cabbage, it appeared that pea and faba bean have the ability to leave considerable amounts of soil N (NO_3-N) to the following crop, resulting in increased yield of head cabbage under organic farming practices. At the 1st rotation experiment, the highest nitrate concentration in the organic farming system were observed for the rotation treatments Cabbage after Peas (P-C) and Cabbage after Faba bean (F-C), 14.71 mg kg^{-1} and 15.08 mg kg^{-1}, respectively, compared to rotation treatment Cabbage after Cabbage (C-C), 13.85 mg kg^{-1}. The same impact in the organic farming system was observed at the 2nd rotation experiment. Pea as preceding crop increased significantly the yield of cabbage (68.8 t ha^{-1}) compared with faba bean (63,4 t ha^{-1}), while cabbage after cabbage resulted in the lowest yield (up to 54,4 tha^{-1}), when grown according to organic farming practices. However, in the conventional cropping system, the highest yield of cabbage was obtained when the preceding crop was also cabbage. The quantification of biological N_2 fixation, by measuring the natural abundance of ^{15}N in the tested legume species and reference plants at anthesis, revealed that peas were capable of fixing from 45 to 125 kg N ha^{-1}, while faba beans fixed from 118 to 193 kg N ha^{-1}, respectively, during the first and the second cropping year.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

4. Outputs of discussions

4.1 Summary of Stakeholders' Views

Stimulating factors for the Production of Legumes

- Reducing imports, sufficient production
- Reduction of fertilizer inputs
- Low input crop rotation schemes
- Traceability: "where is it from?"
- Invest in farmers' education/awareness – work closer –

Barriers in Legume Production

- Lack of knowledge for farmers
- Difficulties in working with local producers, import/export always miles
- A lot of farmers are mixing both traditional methods and tested (scientific) methods to achieve their goals. At times, this is elusive.

Opportunities in Markets

- Environmental and sustainability as a target to "catch" the consumers
- Packaging with the instructions and time to spend on preparing/cooking
- Think easy ways to eat legumes – "fast" legume alternative e.g. hamburgers, meatballs and appetizers
- Promote access and consider displaying recipes on packages

Stimulating factors for the demand for legumes

- New products catered for kids and small toddlers.
- More dishes with legumes in markets and restaurants

Hampering factors in the demand for legumes

- Many people don't know how to cook legumes
- The cost for poor family to switch from cheap available food
- Time to prepare meal needs minimised
- Children often times don't like pulse texture or flavour

Changes Opportunities in Policy Change

- Public procurement
- European Plant Protein Strategy should be extended to develop similar plans nationally and regionally
- Consumers information needs developing to increase awareness of alternatives to 'every-day food' (made from less nutritious and synthetic fertiliser dependant commodities only)
- Include legumes as an alternative of protein source in meat products
- Include pulses in all EU "food pyramids" (i.e. public information on healthy eating)
- Consider recommending a % legumes for pulse-based products in public menus
- Demand that legumes are included in menus for public-schools, -hospitals *etc…*
- Encourage lower taxes for sustainable products/legumes

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Barriers to Policy Change

- Too much focus on production
- No clear policy on minimum legume availability in schools, hospitals etc…
- Taxes in miles done in legume transport in import/export

4.2 Markets Workshop: production, processing/retailing and consumers

*Summary by **Pete Iannetta** (JHI, TRUE Coordinator) and **Giannis Panagiotakis** (AUA)*

Group facilitation: Pete Iannetta, Marta Vasconcelos, Dimitrios Savvas

The session contained three presentations and a panel discussion.

At the end of the session, the following topics were discussed:

Farmers / business acumen

Farmers are "on the wrong side of the deal", and get far too low a price considering what is made further up the supply chain. Supply chains are too long, farmers should operate to regain control of these.

Agronomy and on-farm capacities

- Not enough work is carried out on establishing the best plant densities for the different (grain) legume types. The various aspects of the pedo-climate (weather and soil) should be modelled against plant density, architecture and row spacing. Tools like PGROs OptiBEAN tool for faba bean have been established and are being developed further; however, the approach could be more widespread.
- The need for seed certification. Although, several protocols are used in the EU, knowledge should be transferred on disease control. Molecular tests for the main legume diseases exist in UK, so some technologies may be transferable to other countries. Certainly, the capacity exists in other countries too, such as German and France.
- There are two contrary facts about seed diseases in Greece. On the one hand, the imported seeds are followed by phytosanitary certifications, which protects the growers and but on the other hand local growers do not follow the legislation. Growers must be educated on the benefit of such certifications. It should be compulsory for all imported seed, whatever its use to have a phytosanitary certificate.
- There is a need to diversify cropped systems but regions like Greece lack the organisational capacities to enable such a transition.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

- Landscape-scape potentials within countries or larger allied areas should be considered: *e.g.* in France different legume supported systems (mainly pea or faba bean) are used in different regions. Such complementarity should be encouraged.
- Farmers often used home saved legume seed for the next year's crop. Often these are stored poorly, and there is also a risk of other poor quality attributes. Therefore, to minimise the risks, more needs to be done to ensure that farmers use good quality certified seed.
- Farmers must learn and be encouraged to work-together more effectively. Educating farmers and establishing effective and trusting farmer-networks must be a priority.
- The development and easier access to more affordable on-farm legume processing technologies should be encouraged. Such as seed sorting, dehulling, milling and fractionation technologies.
- Are precision-ag approaches simply the replacement of one set of financial dependencies (by farmers) with others?

The environment

It was argued that chickpea and faba bean have lower GHG emissions that other grain legume types. Is this correct? What and where is the evidence base for this?

Marketing and labelling of legumes and legume-derived or –based products

- Unique land races should be typed (genetically and physiologically) to ensure that imitations can be identified, and appropriate action taken. Example of counterfeit products are grains (often ground or shattered) sold as being heritage types, or simply main-stream products and more expensive meats, which are meant to have come from legume-grass fed cattle. Two issues are evident here, one is proving legume or legume-based commodities are what they claim to be. The other, is being able to establish the provenance a supply chain and/or product. Generation of a unique and non-copyable product barcode and online checking systems may safeguard producers, retailers and consumers from fraudulent products. Provenancing the supply chain might be achieved with an evidenced Bitcoin-like mechanism. That is, proving where "more-green value chains" exist, and when they do, being clear about their relative potential benefits for the environment and nutritional provision.
- The need of traceability of products. A good example comes from Portugal, where a company selling fish has developed an application, which scans barcodes on fish packages related to the history of the fisherman and the product. This practice creates a sense of trust between producers and consumers.
- There in a need for authenticity of the product -digitizing agriculture can make a difference
- Scientists and all that participate in chain of production must collaborate and exchange thoughts and technologies
- More support is needed for legume-based products, which support and develop regional or national cultural identities.
- Quality certification of legume-based products should be declared on the food or feed.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

- Meat has become a highly traceable commodity though not yet marketed effectively on the basis to which the animal was fed on (home-grown or on-farm derived (legume) feed, or legume-grass or imported grain legumes). Any legume or legume-based food (or feed) should be fully traceable and exploited using appropriate labelling.
- Inter-farm trust is low (in Greece), this is a barrier to sharing knowledge and optimising approaches whether agronomic or developing/diversifying the farm businesses in general.
- The role of legumes as a disruptive- or rebel-technology should be developed and exploited by marketing specialists.

4.3 Policy and Society session

*Summary by **Eszter Kelemen, Bálint Balázs** (ESSRG, TRUE WP7 Leaders)* and ***Pete Iannetta*** *(JHI, TRUE Coordinator)*

Facilitators: Dimitrios Savvas, Bálint Balázs, Eszter Kelemen

The session contained three presentations and a panel discussion.

The key lessons for the TRUE policy work package from the presentations are:

- the early success can be achieved - as in the commitment for the French agro-ecology programme, as well as to the possible future use of carbon taxation in agriculture, which both would incentivise legume production;

- CAP already presented policy approaches to support legume production, but which relies on each individual member state to decide how to implement them. In Greece voluntary coupled support, greening and rural development programs helped significantly increase legume production. Further support could be provided by reforming legume breeding legislation, including encouragement of properly state-funded legume breeding programme, and introducing new improved varieties tailored for different regional needs. Introducing the *Cultivar Identity* capacities for legume production has proved to be helpful in giving incentives to farmers to grow certified seed (*e.g.* in Greece the Amorgos chickpea).

The panel discussion centred on the question of, "*Which intervention would you recommend to policy makers if you could choose only one?*" Panellists raised several different topics. One fundamental idea was awareness raising and filling knowledge gaps, both concerning production (*i.e.* how to produce legumes more efficiently) and consumption (*i.e.* why to eat more legumes). Financial incentives could also possibly increase the volume of legume production (as in the case of Greece). However, there were diverse opinions on how existing financial incentives shape the market. According to some, de-incentivising agriculture drives farmers to choose the more cost-aware and often more natural solutions (*i.e.* using legumes in crop rotation instead of nitrogen fertilisers), as the case of Canada showed. A third option focused on the support of developing better cultivars and then incentivising farmers to choose the more efficient seeds (which provide better yields and can

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

better adapt to climate variance). In addition, the importance of using an ecosystem approach when designing incentives was highlighted. At the end of the discussion, panellists agreed that any policy recommendations should be subjected to in-depth discussion between policy makers from different sectors (*e.g.* agricultural, environmental, climate policy).

During the session, the following topics were also discussed:

Food and Food-System Policies

- There is only one Professor of Food Policy in Europe. This knowledge and philosophy gap needs addressed at the EU level. The generation of such positions should be encouraged.
- There is a need for every country and different pedo-climatic region of Europe to develop food systems strategies to help ensure food security if and when necessary.
- "There is no organisation to enable cropping and food system diversification", especially in Greece which imports 60% of its legume (protein) needs.

Research foci

- Too much work on genetics masquerading as a means by which food security can be addressed. The challenges are often local and regional. In general terms more research is required on the following:
    - The factors underpinning organic nitrogen (legume residue) mineralisation. Understanding this process can lead to a better management and exploitation of legume (and non-legume) residues, which includes the role of crop functional diversity.
    - Related to this, breeding and management of legumes to help ensure best soil qualities.
    - Intercropping, and identifying approaches whereby the main cash crop, in a mixture, can still be produced at yield/ha level matching that of an intercrop. The reduced absolute yield of the main crop is often a barrier to uptake
    - The development of legume processing methods to help identify their various properties and to establish legumes as more competitive compared to other food, and especially fast food, ingredients raised on synthetic nitrogen fertiliser.
    - Better exploitation of the potential role of legumes in enhancing consumption of essential minerals (not just protein) - and especially pulses. This approach, 'legume biofortification' should be applied to many mainstream foods whose constituents would normally only include commodities grown using synthetic nitrogen fertiliser *e.g.* baked products and be extended to popular drinks (*e.g.* beer, soft-drinks and milks).
    - Breeding legumes for taste, flavour and processing-traits. There is evidence that nutrition is being breeded out of our legumes, as breeders select for: 1) yield; 2)

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

resistance to the most prevalent diseases; and, 3) so-called "anti-nutrition factors". Ironically, many pro-nutritional factors are not selected for.
    - Identifying best-fit-for-purpose marketing approaches for legumes, including within measures aimed at educating the public in the importance of legumes in cropped (and semi-natural) systems.
    - Develop IPM strategies for legume-based cropped systems, and especially the legumes supporting the production as the current IPM armoury for legumes is insufficient.
    - Better molecular diagnostics for legume diseases.
- Research funding for legume science such as agronomic approaches (and bio-fortification) are selected against, in favour of reductionist molecular one seen as being "smarter".
- The role of life-sciences to address the food-system issues must be questioned, since, there is an emerging view that science, like art, adds value but does deliver solutions to manage the complexity in a manner which is sustainable over the long term.
- Often many research approaches claim to be holistic or system focused but in fact a full-system perspective is rarely taken despite the rhetoric and claims. Too often approaches are largely biological – *i.e.* genetic, genomic, physiological *etc* with a view to improved yields, not yield qualities. Often environmental level impacts of such innovations are over-looked, or included as an afterthought and addressed only superficially.

Education

Basic education regarding legumes (especially biological nitrogen fixation and nutrition potential), and the impact of synthetic nitrogen fertiliser use need highlighting from a very early age as well as the difference between, and difference impact of, natural and unnatural C-, N- and water-cycling.

Interestingly agroecology is understood differently by various stakeholders (farmers, breeders, ex-situ seed banks, researchers, consumers) in multiple contexts. For some, it is socio-economic and even socio-political. For others, it is an academic or philosophical approach, and often only focuses on the functional biology within the production system. TRUE could offer further insights on how stakeholders perceive relationships between ecosystems, wellbeing, innovations, governance.

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

5. Annex

Annex I – M-LIN programme

Friday 20 April 2018 - Agricultural University of Athens

08:30 **Registration**

09:00 **Welcome**
Rector Georgios Papadoulis & Professor Dimitrios Savvas, Agricultural University of Athens (Greece)

09:20 **Background to the TRUE project, TRUE case study activities and legume-based innovations**
Pietro Iannetta, TRUE Project Coordinator, James Hutton Institute (UK)

10:00 **Production and marketing of legumes consumed as vegetables in Greece**
Christos Olympios, Emeritus Professor, Agricultural University of Athens (Greece)

10:30 **Refreshment break**

Markets Workshop: production, processing/retailing and consumers

Facilitators: *Dimitrios Savvas, Marta Vasconcelos*

11:00 **Innovations in legume production and consumption**
Nikos Papakosnstantinou, GAIA Epicheirin (Greece)

11:30 **The white vanilia beans and fava of Feneos**
Yiannis Mitropoulos, DICOTYLON (Greece)

12:00 **Round-up discussion on the 'Markets' session**
led by Prof. Dimitrios Savvas, Agricultural University of Athens (Greece)

13:00 **Networking Lunch & Poster-Workshop**

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Policy Workshop

Facilitators: *Dimitrios Savvas, Balázs Bálint, Eszter Kelemen*

14:00	**Legume chains diagnosis for animal and human food and development prospects** Christophe Salon, Research Director, INRA (France)
14:30	**Current policies in production of legumes in Europe and their dependence on breeding of new cultivars** Dimitrios Vlachostergios, Senior Researcher, ELGO-DIMITRA (Greece)
15:00	**Phenotyping legume genetic resources using morphological and molecular markers** Fotini Mylona, ELGO-DIMITRA, National Greek Gene Bank (Greece)
15:30	**Refreshment break**
16:00	**Round-up discussion on the 'Policy' session** Chaired by Prof. Dimitrios Savvas, Agricultural University of Athens (Greece)
16:55	**Closing Remarks** Pete Iannetta, TRUE Project Coordinator, James Hutton Institute (UK)

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

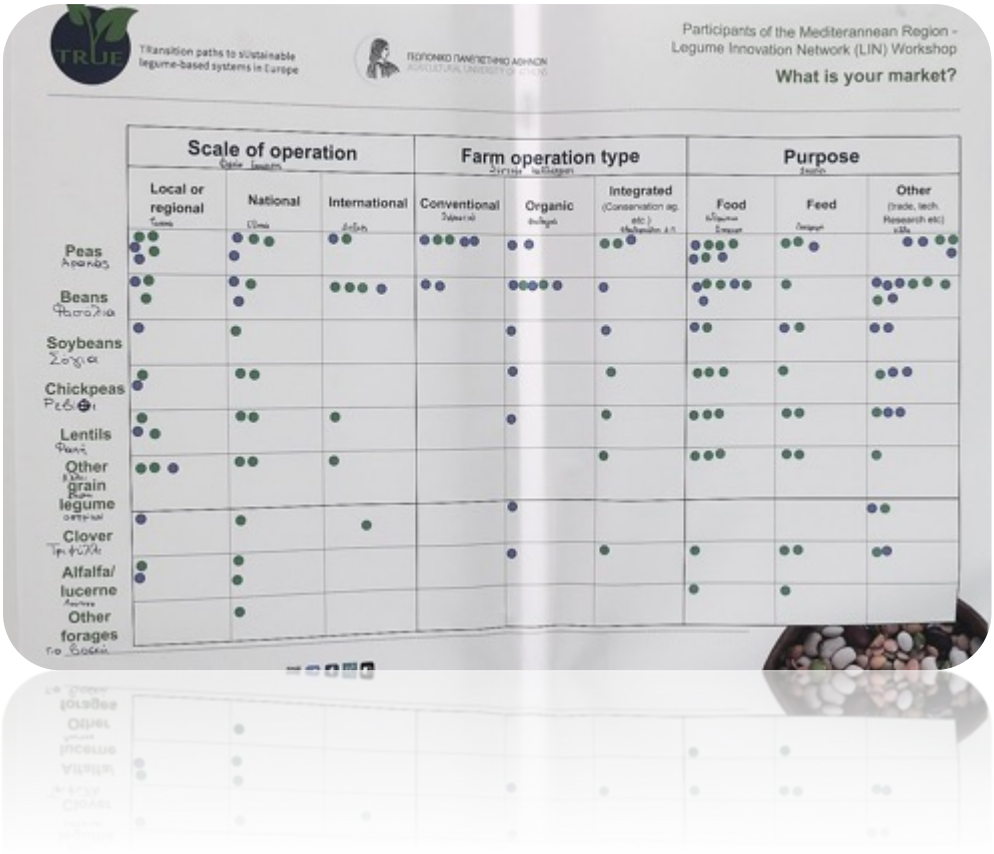
Annex II - List of participants

Table 1: Participants' background

	Organisation Type					
Stakeholders	**University**	**SME**	**Registered Training Organisations**	**Higher Education Institute**	**Commercial Enterprise**	**Other**
Advisor						2
Agroecologist			1			
Agronomist	1		1			1
Breeder		1				
Buisness Manager				1		
Chemical Enginner		1				
Director	1	2	1		1	
Grassroot Campaigner						1
Journalist						4
Nutritionist					1	
Professor	12	1		1		
Researcher	4	4	1	1		
Student	60					
Other	2	2				

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Table 2: "What is your market?" Participants' main focusses



	local	national	intern.	conv.	organic	intergr.	food	feed	other
peas	5	4	2	5	2	3	7	3	5
beans	3	3	4	5	5	1	6	1	8
soybeans	1	1	-	2	1	1	2	2	2
chickpeas	2	2	-	-	1	1	3	1	3
lupins	3	2	1	-	1	1	3	2	3
lentils	3	2	1	-	-	1	3	2	1
clover	1	1	1	-	1	-	-	-	2
alfalfa	2	2	-	-	1	1	1	2	2
Other	-	1	-	-	-	1	1	1	-

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Annex III - Presentation & poster pdfs

The pdf files of the Presentations and Posters can be found at https://www.true-project.eu/lin-workshops/mediterranean/documentation/

Presentations:

- Background to the TRUE project and TRUE case studies activities and innovation - Pete Iannetta, TRUE-Coordinator, James Hutton Institute, United Kingdom
- Production and marketing of legumes consumed as vegetables in Greece - Christos Olympios, Emeritus Professor, Agricultural University of Athens, Greece
- Innovations in legume production and consumption - Nikolaos Papakonstantinou, Gaia Epicheirein, Greece
- The white vanilla beans and fava of Feneos - Yiannis Mitropoulos, DICOTYLON, Greece
- Legume chains diagnosis for animal and human food and development prospects Christophe Salon, Research Director, INRA, France
- Current policies in production of legumes in Europe and their dependence on breeding of new cultivars - Dimitrios Vlachostergios, Senior Researcher, ELGO-DIMITRA, Greece
- Phenotyping legume genetic resources using morphological and molecular markers - Photini V. Mylona, Greek Gene Bank of the Institute of Plant Breeding and Genetic Resources HAO-Demeter, Greece.

Posters:

No. 1) Carbon Footprint reduction of dairy systems
No. 2) Teagasc Clover Group
No. 3) Intercrops for food (alcoholic beverage) and feed
No. 4) The use of legumes and leguminous by-products within dairy systems
No. 5) Nitrogen fixation by faba bean (*Vicia faba L.*) in a 4 year crop rotation in East Scotland
No. 6) Development of Precision Agriculture Technology-led agronomy for strip-sown combined systems, using a leguminous living mulch
No. 7) Heritage varieties for enhanced human and beneficial insect nutrition
No. 8) Using legumes as a source of fertility in organic protected cropping systems
No. 9) Retailer-producer quality chains and innovations
No. 10) Market model for legume-based feed for organic pig production
No. 11) Legumes in public and private food service
No. 12) Overview of breadth and diversity for peas
No. 13) Why is lentil (*Lens culinaris*) cultivation a success story in south-west Germany?
No. 14) Why is soybean (*Glycine max*) cultivation a success story in south-west Germany?

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

No. 15) Blue Lupin for White Shrimp? A step towards sustainable aquafeed
No. 16) Legumes: their potential role in Croatian agricultural production
No. 17) Pulses in short food supply chains from small-scale farms to urban gastronomy
No. 18) Ancient & heritage variety screening for higher nutritive value
No. 19) Consumers - legume dishes
No. 20) Legumes' consumption and barriers among Portuguese adults: a quantitative and qualitative study *(not available online yet)*
No. 21) Comparing the inoculation success of two bacteria strains, under different N supply levels, in the Greek bean landrace *Zargana Chryssoupolis*
No. 22) Impact of legume and non-legume crops on soil-N availability and greenhouse gas emissions during winter cultivation period.
No. 23) Development of sustainable legume-based cropping and grassland systems and agri-food and feed chains
No. 24) Productivity of cereal-legume intercrop under smallholder farms in western Kenya.
No. 27) Beneficial legume-microbe interactions: A case study on the diversity of rhizobial strains nodulating common bean landraces growing in Greece
No. 28) Effect of the farming system (organic or conventional) and rotation scheme with legumes (pea and faba bean), on biological nitrogen fixation efficiency, on soil NO3--N concentration and head cabbage yield

This Project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 727973

Annex IV – Results of discussions (pictures)

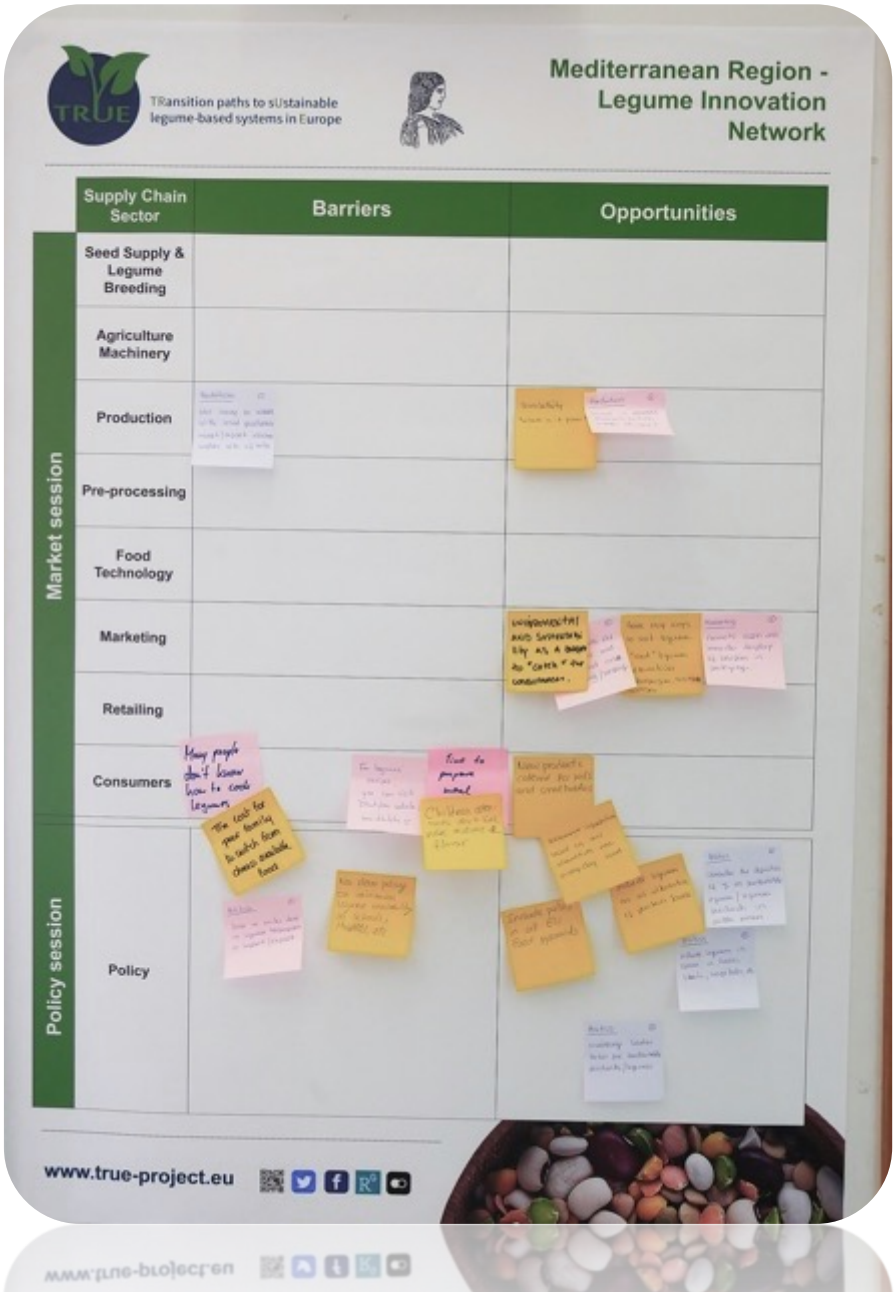


Figure 3: **Market & Policy** group results

Literature Cited

Ruini LF, Ciati R, Pratesi CA, Marino M, Principato L and Vannuzzi E (2015) Working toward healthy and sustainable diets: the "Double Pyramid Model" developed by the Barilla Center for Food and Nutrition to raise awareness about the environmental and nutritional impact of foods. Front. Nutr. 2:9. doi: 10.3389/fnut.2015.00009.

Acknowledgements

We especially thank all participants for their valuable contributions and insights in their experiences. We thank the Agricultural University of Athens for being our host.

Disclaimer

The information presented here has been thoroughly researched and is believed to be accurate and correct. However, the authors cannot be held legally responsible for any errors. There are no warranties, expressed or implied, made with respect to the information provided. The authors will not be liable for any direct, indirect, special, incidental or consequential damages arising out of the use or inability to use the content of this publication.

Copyright

Citation

Please cite this report as follows:
Panagiotakis, G., Ntatsi, G., Vougeleka, V., Tran, F., Maaß, H., Vasconcelos, M., Kelemen, E., Balázs, B., Savvas, D., Iannetta, P.P.M. (2018). Report of the Mediterranean Legume Innovation and Networking (LIN) Workshop. Developed by the H2020 project '*Transition paths to sustainable legume-based systems in Europe*' (TRUE), funded by the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement Number 727973. Online available under www.true-project.eu. DOI: 10.13140/RG.2.2.12944.46088