EIP-AGRI Focus Group Protein Crops: final report

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Report EIP-AGRI Focus Group Protein Crops

REMCO SCHREUDER
CHRIS DE VISSER
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FINAL REPORT

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Summary

The Focus Group on Protein Crops of the European Innovation Partnership addressed the challenge of improving the profitability of protein crops in Europe in order to make it an attractive crop for farmers while satisfying the requests of the animal feed industry (and to some extent the food industry) and promoting more technically, economically and environmentally sustainable European agricultural production systems. With this as objective, a group of 20 experts from across Europe assessed the challenge and identified possible solutions.

Increasing soybean production together with enhancing the range of protein crops cultivated in European countries, including grain legumes (mainly faba bean, field pea, lupins together with other minor crops) and forage legumes (mainly alfalfa), was a strategy which was widely shared by the group of experts. Moreover, sunflower and rape meals are also recognised as important protein feedstuff. This cluster of crops was considered as the most promising to face the protein challenge and to cover all the agro-climatic zones characterising European agriculture.

The experts pointed out the financial gap of starch and oil-based protein crops (including alfalfa) that needs to be overcome to make these crops competitive for European arable farmers. This topic revealed the importance of making a distinction between intensive and non-intensive (including organic) agricultural systems, the former being more closely related to compound feed supplied by the feed industry and the latter being more closely related to the use of locally grown feedstuff in order to link the final animal products to the territory of production. Local, regional and European scale production chains were all recognized as important for the EU agriculture as a whole.

The experts also collected information on protein quality for animal feeding and linked to the demand side of the value chain into its debates and considerations. The Focus Group agreed on the overall usefulness of reintroducing protein crops, mainly legumes, to improve the sustainability of European agricultural systems. In fact, the use of protein crops in arable rotations has high potential to increase the resource efficiency and environmental performance of European cropping (soil quality and health, nitrogen management, agro-biodiversity, reduction of greenhouse gas emissions) for all value-chain scale levels involved. The group also pointed out that protein production involves local value chains as well as more industrial, European-scale value chains. The expert group holds the view that the different scale levels of the value chains will require different products (from feed compound or raw industrial products to cereals, protein grains or raw fodders used as such). Also, it was stated that the diversity of European climates would require a certain level of diversity of protein crops to be developed with priority to seize the opportunities of each individual agro-climatic zone.

However, central to the group's discussions was the present day situation in which European output of protein crops is restricted to, relatively speaking, niche activities, while supply-chain logistics are poor or nonexistent. Associated with this, the investments of the supportive industry (plant breeding) are low. The expert group recognises the dimension of the transition process ahead and realises that resources will be limited for this process. Therefore an intensive co-operation between all parties involved is needed. The expert group advises that breeding companies should be included in the dialogue and to foresee sufficient support for pre-breeding (and possibly breeding) activities carried out by public research institutions, as new cultivars will be a prerequisite for a successful transition process. However, private breeding investment will be limited until protein-rich crops gain much greater market importance. Farmers should also be involved because they need to produce the raw materials and to take account of the consequences of protein crops in their financial perspectives. Next, NGOs need to be involved to increase the likelihood that the transition will be acceptable for the society. Governments need to support the transition because societal interests are involved while research establishments and Agricultural Knowledge and Innovation Systems (AKIS) should be engaged in order to advise on the steps to be taken to ascertain that the role of science has the required impact.

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Introduction

The Focus Group (FG) on protein crops was launched by the European Commission in 2013 as part of the activities carried out under the European Innovation partnership for Agricultural Productivity and Sustainability (EIP-AGRI). The most important source of protein for people in the EU is animal products. Of the daily protein intake, around 59% comes from animal products (meat, fish, milk) and 41% from plant products of which more than half comes from wheat (FAOSTAT, 2009). Pulses (including soya) account for around 3% of the daily protein consumer intake. The importance of animal products supports the focus of the protein crops group to be on proteins for animal feed. This focus is also justified by a number of drivers:

- The world population increase in the coming decades to reach a total of 9-10 billion people;
- The expected increase in per capita income and the associated increase in animal products worldwide;
- The dependency of the EU on the import of protein-rich animal feed (around 70%), mainly based on soya bean meal;
- The sustainability impact of increasing areas of soya bean at the expense of forest and savannah land in South America; and
- The growth in animal production in the EU in the past decades.

Amongst other considerations, these drivers underlay the EU Parliament motion (Häusling, 2011) that calls on the Commission to support research into breeding and supply of protein crop seeds in the EU, including their contribution to disease control, and to make proposals for research and development on ways to improve extension services and under the heading of rural development on services training farmers in the use of crop rotation, mixed cropping and technical facilities for on-farm feed production.

The European Innovation Partnership 'Agricultural Productivity and Sustainability' (EIP-AGRI) is one of five EIPs which have been launched by the European Commission in a bid to promote rapid modernisation of the sectors concerned by stepping up innovation efforts. The EIP-AGRI aims to catalyse the innovation process in the agricultural and forestry sectors by bringing research and practice closer together – in research and innovation projects as well as via the EIP-AGRI network.
EIPs aim to streamline, simplify and better coordinate existing instruments and initiatives and complement them with actions where necessary. Two specific funding sources are particularly important for the EIP-AGRI: the EU Research and Innovation framework, Horizon 2020, as well as the EU Rural Development Policy.
EIP AGRI Focus Group is one of the building blocks that aims at complementing the construction of the EIP-AGRI network, which is funded under the EU Rural Development policy. Working on a narrowly defined issue, Focus Groups temporarily bring together 20 experts (such as farmers, advisers, researchers, up- and downstream businesses and NGOs) to map and develop solutions within their field.
The concrete objectives of a Focus Group are: to take stock of the state of art of practice and research in its field, listing problems and opportunities; to identify needs from practice and propose directions for further research; to propose priorities for innovative actions by suggesting potential projects for Operational Groups working under Rural Development or other project formats to test solutions and opportunities, including ways to disseminate the practical knowledge gathered. Results are normally published in a report within 12-18 months of the launch of a given Focus Group.
Experts are selected based on an open call for interest. Each expert is appointed based on his or her personal knowledge and experience in the particular field and does therefore not represent an organisation or a Member State.

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The task of the Focus Group on protein crops was defined as follows:

- Analysing the demand for protein crops in Europe:
  - What are the requirements for the feed sector (quality, price)?
  - What are the key findings (e.g. comparative analysis of cost/benefit of protein crops in Europe)?
  - What strategies can be developed to increase competitiveness of protein cultivation in Europe?
- Assessing the potential of relevant, protein-rich crops and forages.
- Taking into account the value of protein crops in the crop rotation (e.g. effects on soil fertility, reduced nutrient use, reduced weed infestation, micronutrients, reduced compaction).
- Making suggestions on how to increase productivity and protein content of soya bean in the EU, pulses (lupins, beans and peas), alfalfa and clover, and oilseeds (rapeseed, sunflower).

The members of Focus Group are listed in Annex 1. They served in a personal capacity rather than representatives of particular organisations.

This report is the result of the findings of this Focus Group and serves to inform those who have an interest in developing relevant value chains. It summarises the views of a Europe-wide group of experts, and to call for Europe-wide co-operation to face the protein challenge by innovating on the indicated pathways.

Process

The Focus Group convened on two occasions. The first meeting was held in Oss, the Netherlands on 12 and 13 September 2013, hosted by the Dutch compound feed manufacturer Agrifirm. The second meeting was hosted by the Spanish research group CARTIF in Valladolid, Spain on 16 and 17 January 2014. The EIP-AGRI Service Point assisted the group's meetings (Remco Schreuder). Supported by the key expert Chris de Visser, the Service Point prepared the meetings by supplying input and content as well as by formatting the meeting in such a way that a maximum outcome could be achieved and that all expert opinions could be addressed.

The Oss meeting was provided with the input that supported the focus on animal feed and the associated problems and challenges: one of the compound feed facilities of Agrifirm set the scene to illustrate the demand side of the value chain. At the meeting, Ruud Tijssens, Director of Corporate Affairs of Agrifirm and president of the European Feed Manufacturers' Federation (FEFAC), indicated these demands by detailing Agrifirm's soya strategy. The strategy had two important lines, the first being the use of responsible and certified soya and the other being the production of European soya in general and north-west European soya in particular. Ruud Tijssens expressed the key factors determining the importance of a European alternative crop to soya import as:

- High (ileal) digestibility of the essential amino acid lysine;
- Competitiveness of the alternative to arable farmers; and
- The availability of large volumes to the industry.

Chris de Visser introduced the main drivers and explored the possible alternatives to imported soya bean meal by indicating the pros and cons of these protein sources. In plenary and break-out sessions, the group of experts brought forward the following results:

1. Identification of the 8 most important constraints and bottlenecks on the route to substantially increasing EU plant protein production;
2. Setting the challenges for each of these 8 topics, identifying technology gaps and the knowledge necessary to make progress; and

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3. Describing the implications of the results for 1) operational groups, 2) R&D, 3) dissemination.

The eight most important constraints and opportunities were:
1. Breeding chain and genomics
2. Yield improvement and stability
3. Transition: developing or adapting a value chain
4. Crop diversity
5. Mixed cropping
6. Extension and farmer's unfamiliarity with protein crops
7. Diversification of the livestock chain
8. Sustainability and transparency demands.

The experts were clustered in 8 groups based on these items and according to their special interest, and were asked to elaborate on the items on the basis of questions supplied to them and to present the findings at the second meeting in Valladolid.

During the first meeting, Frederick Stoddard of Helsinki was appointed chair of the group.

At the Valladolid meeting, the expert group was confronted with an approach to identify the competiveness of different oil and starch-based protein crops, based on the component's values (oil, starch, protein). To elaborate on the innovation challenge ahead, the experts were introduced to the concept of innovation failures. These express the variety of aspects that are taken into account when considering and shaping the innovative process of realising a substantial increase in EU plant protein production. On the basis of the input supplied, the experts designed a view on the future EU plant protein market in break-out sessions. Upon presentation of these views, the experts were asked to group important aspects of these views within five innovation failure aspects:

- Knowledge infrastructure
- Physical infrastructure
- Market structure
- Co-operation and interaction
- Values and beliefs

Subsequently, the experts were supplied with a matrix confronting different groups of protein crops (oilseeds, starchy seeds and forages) with different market scale levels (local, regional and European) and asked to locate their views on the expected developments of future EU plant protein production within this matrix. Finally, the experts combined their thoughts in the innovation-failure matrix mentioned above in break-out sessions and discussed the results.

These discussions, views and findings are the basis of this report.

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EU market on plant proteins

According to FEFAC (Feed & Food Statistical yearbook 2012), around 470 million tons (Mt) of feedstuffs are consumed by EU livestock on a year basis. Of this amount, 230 Mt are roughages being produced on-farm and 240 Mt are compound feed (153 Mt), cereals grown on-farm (53 Mt) and other feed materials purchased (including soya bean meal). The compound feed consists mainly of feed cereals (48%) and oilseed meals and cakes (28%) with the third largest component (11%) being co-products from the food industry. Pulses and dried forages contributed only 1% each.

Table 1 gives a summary of the EU balance of protein rich feeds and shows that in total the EU is almost 70% dependent on imports, and for soya bean meal this figure is over 97%. Keeping in mind the unique properties of soya bean meal (high protein content with high ileal lysine digestibility), this illustrates the dependency and associated risk in view of increasing demand, questionable sustainability and price volatility.

Table 1. EU balance of protein-rich feeds in 2012 (source: FEFAC/PROLEA)

Material	EU production (Mt)		EU consumption (Mt)	
	products	proteins	products	proteins
Soya beans / meal	1,189	452	34,134	15,904
Rapeseed and sunflower seed / meals	27,481	5,213	19,721	6,329
Pulses	3,045	670	2,800	616
Dried forage	4,056	771	3,900	741
Miscellaneous plant sources	2,877	654	5,859	1,260
Sub-total	38,648	7,760	66,414	24,850
Fish-meal	398	275	599	433
Total	39,046	8,035	67,013	25,283

Data (above) on soya consumption by the different animal categories isestimated by Gelder, van, et al (2008). The data shows that the percentage of soya in compound feed used in the EU for pigs was 29%, for layers 22% and for broilers 37% while this amount was lower in compound feed for dairy cattle (10%) and beef cattle (14%). They also calculated the amount of soya used per unit of meat, being 232 g per kg for beef and veal, 648 for pork and 967 g per kg for poultry. This illustrates that monogastrics are more dependent on soya protein than ruminants, which is also supported by a study of Westhoek et al (2011). They calculated the types of feed used per animal sector and showed that protein rich feeds are relatively more important for pigs and broilers than for dairy and beef cows, measured in tonnage feed. Finally, FEFAC statistics available on the FEFAC website (http://www.fefac.eu/publications.aspx?CategoryID=2061) provide final 2011 compound feed production figures for different animal categories. Cattle use 40 Mt of compound feed per year (according to Gelder, van et al, 2008 with less soya protein content) while 50 Mt is produced for pigs and poultry each.

Supply chain

The supply chain of plant proteins starts with breeders who provide arable farmers with grain cultivars adapted to the local climatic conditions and provide beef, sheep meat and milk producing farmers with forage cultivars of grass, alfalfa and silage maize. Breeders are more likely to develop cultivars when

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the market is large and margins in seed sales are good. For protein crops in the EU a breeding gap is indicated because the market is small and limited commercial breeding activity takes place. Arable farmers sell their products either to the processing industry (oilseed crops) or to the compounding industry, directly or via intermediates (feed grains, pulses). The pricing of these commodities is mostly based on the Chicago Board of Trades (CBOT) and Euronext commodity price level for future markets.

Supply chains are active on local, regional or global levels. Much of the raw material for the compound feed industry is sourced from global supply chains (oilseed cakes, feed grains) but part is also sourced from more locally functioning chains. Forage is usually sourced locally (production and use on the same farm). There is a growing trend for "local food", based on local supply chains and a corresponding "local feed" market could develop for locally grown protein crops. Therefore, the experts identified three markets that will show different developments of European plant protein production:

1. A global market with intensive, large-scale production and trade;
2. A regional market more linked to crop cultivation opportunities offered by regional climatic characteristics;
3. A local market with local production, chains and consumption, possibly supported by labels and certificates of origin.

Figure 1. Link between plant protein source and market level.

According to the Focus Group experts, different scenarios can develop where these markets differ in volume. These scenarios are named 1) business as usual with a predominance of the global market), 2) link to the territory with regional markets being dominant and 3) local (including organic) with still substantial shares of global and regional markets but with a considerable local market share.
At the Valladolid meeting, the experts produced the matrix presented in Figure 1. As a group, they expected that oilseed crops would be the most largely used source of EU high-protein crop commodity in the future on EU market level (notably due to the size of the industrial processing units at present: from 0.4 to 1 million tons oilseeds per year each). At the other extreme, they expected that protein-rich roughage (e.g. alfalfa hay) to be predominant in local value chains. Between these two ends of the spectrum, the experts believed that starchy crops would find their place on a regional level. This is in line with the scenarios identified.

EU plant protein production

As indicated before, the EU depends on imported high-protein plant products. The main reason for this is that protein crops in the EU are not competitive with the crops currently being produced. This competitiveness was assessed by using yield data of different protein crops and benchmarking this to wheat and maize, being crops that can be expected to be replaced by protein crops. This was done by collecting yield data on the level of the EU and on the level of regions and countries within the member states EU-27. Regions and countries for which data was collected were the following: France, Netherlands, Spain irrigated and rainfed agriculture, Hungary, Ireland, United Kingdom, Poland, Germany as a whole and the regions Baden-Würtemberg, Bavaria, the north, middle and the south of Germany, Italian regions like Lombardy, Emilia-Romagna, Tuscany and Puglia, Sweden and Finland. The value of the crops was assessed by using the average component rates of starch, oil and protein and by using market values for these products, including the different oil market prices for soya, rapeseed and sunflower oil (Table 2).

Table 2: Recent price levels for feed components (IndexMundi, January 2014)

Commodity	Price (€/ton)
Starch price	€ 300
Soya oil	€ 619
Rapeseed oil	€ 743
Sunflower oil	€ 868
Lupin oil	€ 868
Maize	€ 156
Wheat	€ 239
Soya meal	€ 361
Protein	€ 801

Based on these price levels and the content of protein, starch and oil, the yield level was calculated for the potential crop to equal the calculated crop value of (soft) wheat or maize. This yield level can be referred to at as the competitive yield level. The difference between the current yield level and this competitive yield level represents the benchmark yield gap, either for wheat or maize. The data from the different member states give a rough overview of the differences calculated. In Table 3 this is presented with wheat as a benchmark crop and in Table 4 for maize grain crop. However, the competitiveness of crops can be expected to differ between regions within Europe because local conditions have a high influence on yield levels. The more homogeneous a region is (climate, soil, water availability), the more reliable the benchmark comparison is to indicate local competitiveness. In the end, decisions on what crops are produced are made on farm level.

The experts agree that the benchmark yield gaps are caused at least in part by the relatively few investments made in the past decades in developing these protein crops relative to that of wheat or maize. Tables 3 and 4 also show that there are differences between crops and it appears that rape is closest to its desirable yield level to be more competitive. In fact, in 2005 rape seed cake in Europe was financially equal to or even more attractive than soya, expressed as intestine digestible grams protein per Euro (Kamp et al, 2008, Figure 5.1). Tables 3 and 4 also mention the amount of oil or starch that is produced alongside the protein for the different crops if 50% of the imported soya protein would be replaced. For oil seeds such as soy, rape, sunflower and lupine, this is important as the protein production in seed cakes is associated with a certain amount of oil that will be available to the market. The starch based seeds such as pea and field bean produce starch which is abundantly available (wheat, maize) and has a lower price than oil. On the other hand, the production of protein crops will mostly compete with the starch crops wheat and maize that are used for animal feeds. Starch based protein crops can to a certain extent counteract the loss of starch available to the animal feed industry. The amounts of co-products associated with the production of protein crops are estimated in Tables 3 and 4. One can notice that the choice of the benchmark crop is not influencing the amount of co-products produced because the baseline is to produce the same amount of protein and hence the same amount of co-products. Tables 3 and 4 also show that the competitiveness towards wheat is lower than towards maize following the higher yield of starch with maize than with wheat while producing the same amount of protein.

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Table 3: Indication of required yield level increase to match wheat yield based on EU-member states averages

Crop	yield			oil	starch
	actual	increased	% increase	produced	produced
				[Mton]	[Mton]
Soy	2.7	3.4	30%	3.9	0.0
Rape	3.1	3.1	0%	13.8	0.0
Sunflower	2.2	2.9	31%	20.3	0.0
Lupin	1.0	4.2	334%	1.9	0.0
Pea	2.7	4.8	76%	0.0	15.5
Field bean	2.7	4.5	69%	0.0	11.1
Alfalfa	22.9	24.8	8%	0.0	0.0

Table 4: Indication of required yield level increase to match maize yield based on EU member states averages

Crop	Yield			Oil	Starch
	Current	Increase required		produced	produced
	(t/ha)	(t/ha)	(%)	[Mt]	[Mt]
Soya	2.7	4.3	63%	3.9	0.0
Rapeseed	3.1	3.9	25%	13.8	0.0
Sunflower	2.2	3.6	64%	20.3	0.0
Lupin	1.0	5.2	443%	1.9	0.0
Pea	2.7	6.0	120%	0.0	15.5
Faba bean	2.7	5.7	112%	0.0	11.1
Alfalfa	22.9	31.0	36%	0.0	0.0

Of course, Tables 3 and 4 are based on EU aggregated data and gives an indication of the competitiveness, but data based on more homogenous regions can be expected to show a large variety in the increase in yield needed to compete with maize or wheat. The data for the selected regions and countries for both maize and wheat as benchmark crops can be found in Annex 7. When considering wheat as a benchmark crop, Annex 7 shows some negative percentages for yield increase required. This means that for these regions the crops in question could already produce more value than wheat or maize. For instance, in Hungary, sunflower already produces more value based on its content compared to wheat, but not to maize. In the Italian region of Lombardy, soya and sunflower seem better than wheat but not maize. For Tuscany and Puglia the same applies for rape and sunflower while in the irrigated areas of Spain rape and alfalfa seem better suited based on the components values. But overall, Annex 7 underlines the numbers in Tables 3 and 4, namely that the competitiveness of protein crops at the moment is low and that if the EU would like to see more protein crops produced, the yield level should increase substantially.

Table 4 also indicates that the starchy protein crops are less competitive than soya, oilseed rape, sunflower and alfalfa, and this appears to be related to the low financial value of starch. Lupine seems to be largely uncompetitive (price level of sunflower oil was used) because of the low level of oil produced while the protein yield is not higher than that of other crops. However, alfalfa could be an interesting alternative but processing costs are not included in the calculations and the drying (or water removing) cost of alfalfa could perhaps only make the crop interesting when sun drying is applicable or when valuable co-products can be produced.

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Nevertheless, there are important remarks to be made to interpret these figures. Of course, as mentioned before, processing and logistics costs are not included. Next, the protein price level used is that of soya bean meal and, thus, the value this product has for the feed industry. As indicated before, protein concentration and quality are very important parameters. Table 5 gives an insight into these parameters. It shows lysine contents and the ratio of methionine plus cysteine to lysine, which is important for pigs and ideally should be around 60 (at digestibility levels). The table also shows the attractiveness of the starch-based crops pea and bean compared to soya. Based on their protein quality, a mixture of maize and pea protein could very well match the needs of pigs. The protein content level of the co-product in Table 5 is the maximum attainable levels if all oil and starch are extracted which is not the reality. However, protein contents could rise closer to these calculated figures with more advanced refinery steps (leaving out other components like hulls in sunflower). For more details see Annex 3 and the reference list.

Table 5: Content of key essential amino acids in protein crops and protein content of co-product after starch or oil extraction

Crop	Amino acid content of protein (%)				Protein content of
	Lysine	Methionine	Cysteine	(M+C)/L	co-product (%, DM basis
Soya	6.3	1.4	1.6	48	53%
Rapeseed	5.5	2.1	2.2	79	40%
Sunflower	3.9	2.0	1.8	97	33%
Lupin	4.5	0.6	1.2	40	42%
Pea	7.2	1.0	1.4	33	49%
Faba bean	6.3	0.8	1.2	32	52%
Maize	3.1	2.1	2.0	132	34%
Wheat	2.9	1.6	2.0	124	41%

These figures show that there is a large competitiveness gap for the protein crops, so investments are needed to increase the yield levels and to make these crops more attractive to farmers. The experts have indicated several aspects requiring attention:

1. **Breeding of crops**: the expert group produced an elaborated list of breeding characteristics for consideration in breeding programmes. A summary of the current situation of breeding programmes was also included (see Annex 2). The breeding gap on European protein crops has been indicated (Table 4), and this could make progress in practice difficult. However, public breeding programmes could support an increase in yield levels of protein crops.

2. **The large yield gaps to overcome**: Yields of protein crops are more variable than those of the cereals wheat, barley and maize. Much of the yield gap could be overcome by breeding, but attention is still needed from the agronomy side. For instance, the expert group pointed out opportunities to use mixed cropping to increase the combined yield per hectare of a cereal with a grain legume. Water use has been pointed out as an important aspect of the agronomy of protein crops, especially in the Mediterranean climate. The contributions of protein crops to rotations were emphasised, along with the requirements to embed them in the rotations, as well as the aspects of the crop protection requirements of the protein crop and their differences from those of the main cereal crops. The nitrogen management of rotations including legumes needs particular attention, and so does the influence of these crops on soil quality and health (nematodes, fungi).

3. **Crop diversity:** the expert group agreed that protein crops could contribute to crop diversity in Europe, and so could introduce associated benefits such as a more attractive landscape, less disease and pest pressure, improved nitrogen management, fewer nitrogen emissions, and increased opportunities for local value chains.

4. **Extension and farmer's unfamiliarity with protein crops:** the group was convinced that European arable farmers would be able to adopt protein crop production when the prospect exists for improved returns (on crop and/or farm level). However, such an adoption process would need support and guidance from within agricultural knowledge and innovation systems. The group stressed the importance of combining knowledge and experiences across such systems, from researchers to farmers, and of instruments such as discussion group programmes or EIP-AGRI operational groups.

The above list of items of a more technical nature does not exclude that attention should be paid to some of the items mentioned on page 4 such as transition-related challenges, sustainability and diversification of the livestock chain.

Consumers and sustainability

Sustainability is an important issue related to imports of soya bean meal. The discussion surrounding this crop is associated with land use effects and the decline of forest areas and of sensitive subtropical savannas. The Round Table of Responsible Soya is a value-chain-wide approach of to sustainable sourcing. The motion for a European Parliament resolution on the EU protein crop deficit also shows the sustainability issues associated with imports of soya bean meal. The Donau Soya Initiative (www.donausoja.org) aims to provide a sustainable, non-GM soya supply within the EU and addresses the concerns about the sustainability of imports of soya bean meal. The expert group has indicated several potential sustainability aspects of increasing protein crop production in the EU (biodiversity, nitrogen management, soil quality and health). Nevertheless, the wider consequence of EU protein-crop production should be taken into account. For instance: to what extent can the EU compensate for a decrease in wheat production following a substantial increase in protein crop production?
The European non-GM market could create the necessary market opportunities and incentives to increase protein crop production. Especially, the market for non-GM plant proteins for human food products could be the necessary stepping stone for a European plant protein production chain, eventually serving the feed industry as well.

Status in research on protein crops

Annex 4 lists some of the recent research projects and programmes relevant to the issue of European protein crop production. Throughout the past 20 years, a number of EU-funded projects have been carried out on European legumes. It is not always clear to what extent these projects were directed at improving the competitiveness of these crops as a raw material input for livestock farming, and it is even more difficult to assess in how far they contributed to increasing yield levels. However, it seems fair to state that competitiveness and yield levels were seldom an issue of study. In any case, it seems reasonable to assume that the projects as a group reveal no coherent research strategy to increase the required competitiveness, notwithstanding the excellence of individual projects.

Innovation process and fail factors

Commercial innovation is a process that takes place in practice at economic actor level. It produces a product or a service or improves a production process that will allow the entrepreneur to add more

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value, decrease cost, enlarge his/her market or produce more sustainably. Therefore, innovation enables business improvement. This puts the entrepreneur at the heart of the process. It is known that many attempts to innovate fail. Klein Woolthuis et al (2005) studied innovation processes and detected a list of factors that can be seen as having the potential to influence the success or failure of innovation. From this, it can be learned that in striving for innovations to happen, it is important to address these fail factors and thus help to build an agenda for the process, eventually leading to innovation in practice. Therefore, the expert group was asked to explore these fail factors in the case of increasing protein crop production in the EU.

Knowledge infrastructure

The experts agreed that much knowledge is still needed to support the innovation process. It has been pointed out that breeding is necessary to close the yield gap. Also, it is clear that commercial breeding activities are scarce as the EU market of these crops is very restricted at the moment. Knowledge is also needed on the agronomic issues of cultivation and crop rotations, particularly when referring to soil quality being an important issue for long term profitable crop production. The Focus Group indicated that most of the crops addressed could have genetic variation that would allow them to be grown in many of the agro-climatic zones, but probably not all. Knowledge is also needed on improved processing, as oil meal cake co-products require additional attention from the feed value aspect. Starch-based seeds also need some processing to reduce anti-nutritional factors, improve digestibility and increase palatability. The discussion on scenarios and scale levels (see Figure 1) asked for value-chain-wide approaches (complementarity between local, territory-based chains and products and industrial bulk commodity value chains). Focus was also given to the differences between ruminant-based value chains and monogastric value chains that diverge according to the physiological characteristics of the animal species and the farming designs associated with the specialised husbandry systems.

Physical infrastructure

The experts brought forward several aspects relating to the functioning of value chains that need attention. For instance, the machinery associated with cultivation and the role of farmers and contractors. Processing was addressed, for starch-based crops, some form of processing could reduce anti nutritional factors and make these products more valuable. Also, processing could increase their protein content to a level similar to that of soya. Soya, rapeseed and sunflower could already be supported by the existing processing capacity in Europe while some degree of decentralisation could be realised based on the operating cost of smaller crushers, toasters or extruders. In fact, the existing large-scale soya bean meal infrastructure is orientated for processing shiploads of GMO-soybeans from overseas. A transition strategy will be necessary for up-scaling processing from existing smaller units to big scale units in coexistence with on-farm installations. Also, stocking capacity was mentioned along with the logistics of the value chain.

In contrast with the industrial perspective of oil-rich crops, starch-rich crops (pea and faba beans) and lupins are readily usable as a protein-rich feed on the farm as grains and with some processing (such as separating starchy, fibre and protein fractions) on the feed industry as feed ingredients. On the contrary, soybean grains are usually too oily for self-utilisation on the farm. Increased on-farm self-utilisation of protein-rich crops could do much to alleviate the farm, regional and EU dependency from the international market of feed proteins.

In the end, it is important for a value chain to supply a reliable and stable (in terms of price and quality) product to the market and where such a value chain does not exist yet, it needs to be developed. This will cost time, efforts and investment. For local value chains this might be less difficult, but it may be more difficult for industrial value chains.

Values and beliefs

The experts discussed the GM issue and agreed that from the point of view of breeding, this technology is not an important issue (genetic variability and technical alternatives exist). However, the issue is important for the market and farmers' opportunities. The current situation could support the development of the European plant protein value chains. The group also agreed that EU plant protein production would not be linked to extensification and that, on the contrary, these crops could support the intensive agricultural production systems of Europe, especially regarding soil fertility, agro-biodiversity and mineral management aspects. The question is merely how to get the best output in the best conditions.

This fail factor (values and beliefs) is important because innovations such as EU plant protein production will require people to adopt new ways of thinking and doing within every step of the value chain. It is not only an arable farming issue but it has large implications within the value chain depending on the raw materials chosen.

Co-operation and interaction

The transition from the present situation to a situation where Europe has substantially increased its self-sufficiency ratio for protein crops requires co-operation, not only throughout the value chains (from local to industrial level), but also between the value chain and the enabling environment (research, advisory, agrochemical and fertiliser industry, etc.). A strong link and communication is especially needed between all stakeholders like farmers and their cooperatives, the industry and research institutes. In general the group agreed that a coherent research programme should ensure protein crop innovations in practice rather than ensuring research.

Market structure

This aspect is very much shaped by the scale level. Local value chains will require a different market structure than large, commodity scale level value chains. Nevertheless, irrespective of the scale level, the value chain should supply economic markets. At the moment there is no European future price level for protein crops, which means that contracting is the available market mechanism. It was also stated that the European volumes are very low and that the dominant value chains at the moment require large and reliable volumes. Also, price levels of European protein crops are high. This will require a step-by-step growth process, building up a market based on high priced human food products and at the same time reducing price levels through better varieties, better yield levels and more efficient logistics. This calls for a comprehensive, well organised and co-ordinated approach, as a fragmented approach will fail to create the necessary market structure.

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Recommendations

As has become clear from the work of the Focus Group that the financial yield gap is substantial. At the moment, the crops are not competitive and much has to be done to make them so, while keeping in mind that progress on the benchmark crops maize and wheat will not cease. So, the innovation task is substantial in all cases, and co-operation is of pre-eminent importance.

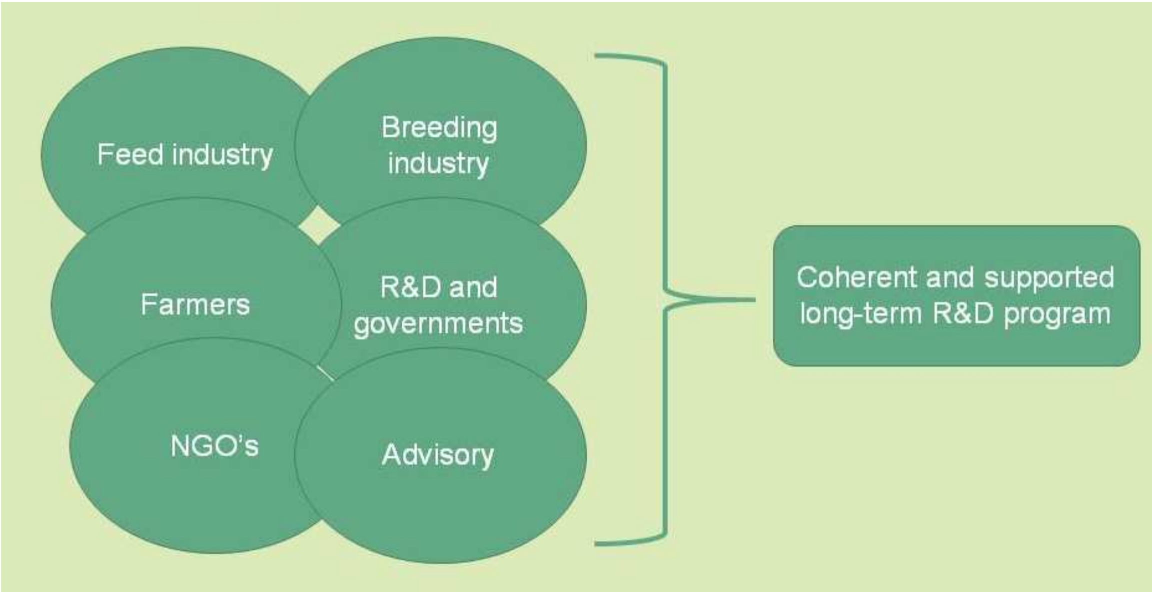

Figure 2. Co-operation and an integrated plan.

The group recommends that co-operation is needed between the feed industry, breeding industry, farmers, research and advisory, government and NGOs (Figure 3). The experts see a number of protein crops that could have good potential to increase protein production in Europe and at the same time increase sustainability and reduce supply risks for the compound feed industry. Although the variety of potential protein crops is wide, as is the variation of agro-climatic zones in Europe, it is necessary to focus on a limited number of crops as financial resources will be limited. The total innovation process will require many years, keeping in mind the fail factors and the opportunities identified.

To increase Europe's self sufficiency of protein crop production, a step-by-step approach might be needed in the transition period. Having low competitiveness and low volumes at the moment, local value chain solutions could provide the stepping stone to support this transition period. These value chains require fewer investments and could be economically feasible with a link to the territory and using techniques like mixed cropping and supporting co-operation between arable farmers and livestock farmers. For this purpose, more interaction between farmers, advisors and researchers is necessary to improve knowledge on the effectiveness of broadening the choice of protein crops for animal feeding. An accelerator for European soya production could be provided by the human food market where a non-gm premium is paid and the development of this market could give time to increase yields and increase competitiveness. The Danube Soya initiative and the Agrifirm North West Europe Soya initiative can act as a practical example of this.

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Annex 1. Member of the Focus Group

- Nóra Adányi, Hungary
- Paolo Annicchiarico, Italy
- Martijn Buijsse, Netherlands
- Yvan Dejaegher, Belgium
- Myriam Gaspard, France
- Paloma Gatón, Spain
- Felipe Gómez de Valenzuela, Spain
- Ana Hurtado, Spain
- Nathalie Gosselet, France
- Volker Hahn, Germany
- Jacques Morineau, France
- Donal Murphy-Bokern, Germany
- Salvador Nadal, Spain
- Tim O'Donovan, Ireland
- Etienne Pilorgé, France
- Jürgen Recknagel, Germany
- Frederick Stoddard, Finland
- Stefano Tavoletti, Italy
- Johann Vollmann, Austria
- Rebecca Ward, United Kingdom

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Annex 2. Breeding characteristics

Advantages and challenges provided by each crop in breeding programmes.

Soya bean
Advantages:
- high protein content (≈ 40%) and high protein quality
- low protein cost arising from concurrent oil extraction
- largely used for feed rations.
- plenty of genomic and other advanced scientific data that can be used to accelerate crop improvement

Challenges:
- not well or widely adapted to northern latitudes
- modest sustainability in southern Europe where it requires irrigation
- it is mainly bred outside Europe (need for traceability with respect to imported GM soya bean for feed; limited future non-GM elite genetic resources available)
- difficult self-utilisation of grains on the farm (due to high fat content) and need for processing to eliminate anti nutritional factors.

Alfalfa (envisaged mainly as high-protein pellet following dehydration, which is currently marketed with 17% to 22% protein content on a DM basis or in local chain value and on-farm growing.)
Advantages:
- much higher harvested protein yield per unit area than any other legume crop
- established transformation industry (over 300 000 ha of transformed crop in Spain, Italy and France)
- high agricultural sustainability (largely rainfed; anti-erosion function; etc.)
- high levels of omega-3, carotenoids, minerals.
- Varieties adapted to a wide variety of climates available
- On-farm utilisation possible

Challenges:
- moderate protein content (17-22%)
- limits to use for monogastrics (10-15% of diet dry matter)
- energy needed for dehydration (which is high in less suitable cool regions).

Pea
Advantages:
- good climatic and soil adaptability
- high sustainability (due to rain-fed cropping and possible autumn-spring cycle in Oceanic and Mediterranean climates)
- prospect of yield increases via extended autumn-sowing in suitable climatic conditions.

Challenges:
- modest sustainability in Mediterranean climate (need irrigation)
- abiotic and biotic resistant varieties (Anthracnose, drought…).
- moderate protein content (≈ 22%).
- Trypsin inhibitor is the first limiting factor for monogastric feed. Low-inhibitor lines exist but have to be handled separately from normal-inhibitor material in the value chain.

Faba bean
Advantages:
- wide climatic and soil adaptability, stronger stems than pea
- moderate sustainability (due to rain-fed cropping and possible autumn-spring cycle in Oceanic and moderate irrigation in Mediterranean climates).
- prospect of yield increases via extended autumn sowing.

- very efficient in the rotation (more so than pea)

Challenges:

- moderate protein content (26-28%)
- somewhat lower and/or less stable yield than pea in some cropping regions, but world average yield is higher than that of pea
- abiotic and biotic resistant varieties are needed (rust, drought…)
- limits to use for monogastric animals (overcome by some recent cultivars without tannins and vicine/convicine).

White lupin

Advantages:

- higher protein yield per unit area than any other annual legume (where well adapted)
- high protein content (38-42%)
- foreseeable oil extraction if current oil content (10-15%, of high food quality) was somewhat increased
- high sustainability (due to rain-fed cropping and possible autumn-spring cycle)
- prospect yield increases via extended autumn-sowing.

Challenges:

- narrow soil adaptation (adapted to soils with active lime ≤ 1% and pH ≤ 7)
- limits to use for monogastrics (pigs 15%, and poultry 5-10%, of diet dry matter).
- in central Europe subject to severe risk of annihilation by anthracnose (Colletotrichum)
- The main limitations featuring the set of crops considered of lower interest are the following:
    - narrow-leafed lupin: lower protein content (33-34%) and yield potential than white lupin; relative tolerance against anthracnose (Re).
    - yellow lupin: lower yield potential than white lupin; severe risk of antracnose (Re);
    - Andean lupin: poor adaptation to European environments;

Others:

- chickpea: moderate protein content (≈ 22%);
- vetches: moderate protein content (26-28%), lower yield potential than pea, vining stem so not free-standing, and unsuitability to feed monogastric animals due to secondary compounds.

Current situation of relevant breeding programmes

Soya bean

- Breeding programmes: mostly public or semi-public, in various countries (Croatia, Austria, Switzerland, Germany, Italy, Serbia, Hungary, France).
- Biotech-based selection: marker-assisted selection (MAS) implemented in USA and, to some extent, in some European programmes.

Alfalfa

- Breeding programmes: public or semi-public, in Italy, France and some East European countries; private programmes (usually small sized) in a few countries.
- Biotech-based selection: MAS under study in a few public programmes; genomic selection under study in Italy.

Pea

- Breeding programmes: private ones mainly in France (supported by strong public research) and Germany; public or semi-public in Spain, Italy, and Czech Republic.
- Biotech-based selection: MAS under study by public institutions in France, UK, Spain, Italy; genomic selection under study in France.

Faba bean

- Breeding programmes: private ones in France (supported by public research) and, of limited size, elsewhere (Germany, Spain, Italy, Austria, Finland).
- Biotech-based selection: very limited MAS research in Europe and elsewhere but this is developing very rapidly following recent breakthroughs.

White lupin

- Breeding programmes: one public programme closed, and one private programme active in France; small-size public breeding in Italy and Germany (private).
- Biotech-based selection: very limited MAS research in Europe and elsewhere, but again this is developing rapidly following recent advances.

Crucial targets for European breeding of the strategic crops

The following synthetic list of main targets for crop improvement largely reflects the needs for closing (or shortening) the gap between the current crop ideotype and the one which would be required for extensive crop utilisation in the main target climatic regions.

Soya bean

- Water use efficiency (for cropping in southern latitudes)
- Adaptation to cool climates (based on short growth cycle, daylength insensitivity and greater tolerance to temperatures below 15 T°C)Improved tolerance to drought
- Higher yield potential
- Broadening the (non-GM) genetic base for European breeding
- Varieties for farm self-utilisation (featuring low grain content of trypsin inhibitor and oil).

Alfalfa

- Higher protein content and digestibility
- Higher yield potential, and innovative variety types (e.g. free hybrids)
- Higher stress tolerance (mainly to drought, low winter temperatures and long snow cover)
- Exploring the dual-purpose crop (separate harvest of leaves for protein and stems for energy – through equipment developed in USA).

Pea

- Marker toolkit for domestication traits to facilitate recovery of useful material after wide hybridisation
- Higher protein content
- Resistance to biotic stresses, especially Aphanomyces euteiches
- Higher tolerance to terminal drought (for southern European environments) and low winter temperatures (to expand autumn sowing).

Faba bean

- Higher tolerance to terminal drought (for southern European environments), transient drought (for all environments), low winter temperatures and prolonged snow cover (to expand autumn sowing)
- Widespread introduction of zero-tannin and low-vicine/convicine traits in new, regionally adapted cultivars
- Resistance to biotic stresses (Botrytis fabae for spring-sown beans, Ascochyta fabae for autumn-sown beans)
- Higher protein content
- Reduced harvest losses.

White lupin

- Higher tolerance to drought and low winter temperatures (to expand the autumn sowing)
- Higher yield potential and earlier, more uniform maturity
- Broader adaptation to soil type (calcium tolerance)
- Higher oil content (to make oil extraction economically viable)

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- Tolerance to Colletotricum gloeosporioides.

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Annex 3. Starting paper Protein Crops

July 31, 2013, Chris de Visser

Objective

This paper has the sole intention to serve as input to the first meeting of the EIP Focus Group on Protein Crops. The working area of the Focus Group mainly focuses on protein demand by and supply to the feed sector in the EU-27 and the objective of this Focus Group is to identify the most promising European protein sources (crops) and their roadmap to full development. The paper describes the main drivers in this dossier and will address the pros and cons of alternative protein crop sources from European origin.

Main drivers

Soya bean meal is the current main source of protein in the feed sector. According to FAO statistics, the EU-27 yearly imports around 20 Mt of soya bean meal (net import) and 12 Mt of soya bean of which some 10 Mt is processed into meal, taking total EU-27 consumption of soya bean meal to some 30 Mt. The EU-27 soya bean crop production stands at 1 Mt (with around 0.8 Mt soya bean meal). So only 2,5 % of the EU-27 soya bean meal consumption is produced in the EU-27. Total world consumption of soya bean meal is around 150 Mt, so the EU-27 is consuming around 20% (representing some 15 million ha of arable land). According to the FAO agricultural outlook 2015-2030 total world meat production will continue to increase in this period by 1,5% per year while milk production is estimated to increase at 1.3% annually. Thus, demand for vegetative protein sources for animal production will increase accordingly.

The price level of soya bean meal (Chicago Board of Trade) has risen in 2012 to a year average of $473 compared to $359, $331, $379 in 2009, 2010 and 2011. So far, 2013 prices were even higher in the first 6 months compared to the same period in 2012. The price for non-gm soya bean meal is even higher and a premium of around $160 is currently being paid.

In 2011 a motion was adopted by the European Parliament (Häusling, 2011) taking into account the present situation and the potential risks of this situation to the EU. The motion calls on the commission for several measures to be taken amongst which the following is of special interest to this Focus Group: "Calls on the Commission to support research into breeding and supply of protein crop seeds in the EU, including their contribution to disease control, and to make proposals for research and development on ways to improve extension services and under the heading of rural development on services training farmers in the use of crop rotation, mixed cropping and technical facilities for on-farm feed production."

Another important driver of the protein crop development is explained in the report by Nowicki et al (2010) that was executed on behalf of the Directorate-General for Agriculture and Rural Development European Commission. The authors identify the risk of trade disruptions following asynchronous authorisations of GM-traits between the producing countries and the EU with forecasts for very high price increases when this disruption would refer to the USA, Brazil and Argentina suppliers simultaneously.

Finally, sustainability is an important driver for alternative sources of protein. There is growing concern about the production systems of soya in part of the production area and the impact that these have on deforestation and soil decline amongst others. This has led not only to initiatives on sustainable soya (like the RTRS soy: **www.responsiblesoy.org**) and more recently the Danube Soya initiative (**www.donausoja.org**) but also to a call on alternative protein sources by NGO's (for example **www.commodityplatform.org/wp**).

Alternative sources of protein for feed

Alternatives to soya bean meal should meet some requirements in order to be or become an option for the compound feed or the animal husbandry industry:

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- The protein content should be high. The two main components of compound feed are starch and protein. While starch is largely available from wheat and maize, protein depends heavily on soya bean meal. Therefore, alternatives should have a high protein content.
- The protein quality should be high: good digestibility of amino acids and amino acid profile. The digestible amino acid profile of feed (and therefore its constituents) should in total match the dietary requirements of the animals. Partly, indigestibility of proteins is linked to the presence of anti-nutritional factors (ANF's) in feed constituents like protease inhibitors. Other ANF's can also play a role in digestibility of feed (minerals, vitamins) and all grain legumes (including soy) contain these (Mikic, 2009).
- The price level should be low. Animals feed is optimised to minimise the price level under the restriction that it matches the dietary demand by the animals. Thus, alternatives should have prices comparable to those of soya bean meal.

The widespread use of soya bean meal in the animal compound feed industry and husbandry represents the high value of this product for meat, egg and dairy production. Alternatives should match this quality or have the potential to do so in the future following an appropriate R&D roadmap. Many of the potential alternatives to soya bean meal have been listed by Sauvant et al (2004). More recently, non-crop sources like insects, aquatic biomass (algae, duckweed) or products from biorefineries (green leaves) have made their entry as a potential source. Most of the potential alternatives have been reviewed by Krimpen et al (2013) on production, processing and nutritional aspects and much information can be assessed through **www.feedipedia.org**. More recently, a renewed interest can be witnessed on the concept of single cell protein (methane to protein by bacteria).

European soya bean

Import soya bean meal could well be (partly) replaced by European soya beans. This crop is produced on some 400.000 ha (data: Eurostat), mainly in Italy (33%), Romania (18%), Croatia (14%), Austria, Hungary and France (all 9%). For these production circumstances, varieties have been bred. It is not known to what extent these crops are used for food or feed purposes. But competitiveness of these crops to wheat and corn is not very good and yields need to improve, except for the Italian Po-valley where average yields are more than 3 tons/ha. Breeding programs in Germany, Switzerland and Austria show that potential yields can be as high as 4-5 tons provided sufficient water is available. Protein quality and content of European soya bean is questioned but results from practices show that the quality can match that of the import soy, even though some variations in protein content exist. An important advantage of European soya bean would be that in Europe still a crushing capacity remains (although in decline) that is needed to defat the beans. To this remark it should be added that in some areas European soya beans are processed as full-fat beans and are only toasted and not crushed. Most probably, this is the best way forward if volumes do not allow investments in crushing and negative effects of the oil in animal feed are not important. When scaling up, the toasting would probably need to be replaced by crushing. On European soya bean much information is available through **www.sojainfo.de**, **www.sojafoerderring.de** and **www.sojanetz.ch**.

Other oil seed meals

Other defatted oil meals that are available in Europe are rape seed and sunflower seed meal. For rapeseed meal the protein content is less (30-40%) than that of the benchmark (soya bean meal with 45-50%) while it contains high levels of ANF's and high levels of fibre, making the product less attractive compared to the benchmark. Sunflower seed meal contains 30-35% of protein (however with a low level of the essential amino acid lysine) but has high levels of ANF's reducing the maximum inclusion level in animal feed.

Grain legumes

Grain legumes like field peas, chickpeas, field and broad beans and lupins are all to some extent interesting alternatives to soya bean meal. Production figures available from Eurostat in 2012 are field pea 520.000, field and broad beans 460.000 ha, lupins 84.000 ha. Not classified dry pulses reached just over 1 million ha in 2012. The grain legumes have high protein content but distinctively lower than the benchmark and contents of methionine and lysine (essential amino acids) are lower compared to the benchmark product. They all have high potential as regards the levels of ANF's some of which have been reduced in level due to breeding and this facilitates inclusion in animal feed. Yield levels of field peas and field and broad beans are high while lupins yield considerably less and are therefore less attractive. Peas, beans and lupins are sensitive to diseases and pests and can only be grown in a wide crop rotation and therefore need much attention from farmers. Beans are preferred by arable farmers because this crop is easier to grow, and has more steady yield levels. From a nutritional point of view, peas are the favourite of the grain legumes. It must be mentioned here that crop rotations for soya bean would tend to be the same, even though crop diseases and pest at the moment are restricted compared to the situation with grain legumes.

At the moment the competitiveness of grain legumes in arable crop rotations in Europe is limited and yield increases are needed to replace crops like wheat, barley or corn. As mentioned earlier, this would also be needed for European soya bean.

Compared to the benchmark product, the grain legumes are not processed. However bio-refinery of these pulses could have considerable advantages: the protein content would rise (and with it the content of essential amino acids), heat treatment would reduce ANF's and multiple marketable products (starch to ethanol or lactic acid and fibres) could make the business case more feasible. Protein concentrate of peas is a product that contains up to 80% protein and has been tested as a feed product with good results. However, such a processing industry needs to be founded and developed if feasibility would be proved.

Leaf proteins

Protein levels in leaves are low, due to high moisture content, but bio-refineries of green leaves could potentially produce high protein content products, free of fibres that negatively influence digestibility. At present, alfalfa protein extracts (>50% protein) are commercially available on the market but in restricted areas. With products like grass and sugar beet leaves experimentation is on-going but economic feasibility is still questionable at the current level of technology and market prices. Feasibility would be enhanced if all co-products of these refineries would have market value (protein, fibres, fatty acids). Sugar beet leaves could be available at 40 tons per ha and if processed at an early stage a protein rich juice could be produced with in total 120 kg of protein per ha. Grass would be interesting because of the protein content of about 200 g per kg dry matter at a dry matter percentage of around 16-17%. In all cases a considerable amount of water needs to be removed to produce an alternative to the benchmark product.

Aquatic biomass

Recently, products like duck weed, macro- and micro-algae have surfaced as potential protein sources for animal feed. Micro-algae can (depending on the species contain 50-70% protein in the dry matter with good methionine and lysine values (Becker, 2007). With dry matter productions reaching 15-20 tons per ha per year, this crop would yield unmatched production levels of protein. However, digestibility figures are not available yet and at present production cost are too high to make bulk markets accessible to algae. Duckweed is also considered as a potential alternative because of the relative high protein content in the dry matter (25-35% but some sources claim even over 40% crude protein content in the dry matter) and with good amino acid profiles. With a yearly dry matter yield level of 15-20 tonnes, this would result in protein production levels as high as 4-8 tonnes per ha per year. With a dry matter content of 6-8% this potential protein source would need processing to produce a credible alternative to soya bean meal. However, for cows this product could be a roughage product, much like grass, and thus contribute to protein uptake. Nevertheless, digestibility studies are scarce, so digestibility and ANF's are still to be investigated.

Insects

Insects are a well-known source of protein. In the dry matter crude protein level can be higher than 50% and the animals grow fast on organic waste materials (Huis et al, 2013). Wang et al (2005) reported good animo acid digestibility of field crickets fed to poultry, but still much knowledge is yet to

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be collected to judge the real potential of insects as protein sources for animal feed. If grown on waste material, insect protein could be price competitive, but at high production levels, the question will arise whether or not insect feed needs to be produced in an efficient way beyond organic waste sources. And then, the incorporation of an extra trophic level in the production of animal feed based on insects, could result in drawbacks that could affect their potential as an alternative source of protein. Also, little is known about processing cost of insects, so much R&D is needed.

Sustainability remarks

The replacement of soya bean meal by other protein sources does not automatically imply that a sustainability gain is realised. This requires additional attention. For instance, the enlargement of the production of European soya or grain legumes will be realised at the expense of wheat and corn in most countries. So some extent this could be counteracted by increases of yield level, but to a larger extent it will imply import or reduced exports of wheat and corn from outside the EU. In sustainability studies, this aspect needs to be taken into account.

Often the production of aquatic biomass is considered as not competing with the food value chains. However, aquatic biomass needs sunlight to be produced and that sunlight could also be used for other purposes (human food production). If explained in this way, a sustainability issue could still arise.

Implementation remarks

When considering alternatives to soya import, it is necessary to consider the impacts on the whole value chain. The larger the impact the larger the challenge of the transition. Also, it is important to consider the transition road of the benchmark to the alternative(s). The soya bean meal value chain is illustrated in Figure 1. The blue marked boxes present activities outside the EU (the America's) while the purple marked boxes are EU activities. The orange marked activity is more and more being done in the America's while at the same time the EU processing capacity is steadily decreasing. The production of European protein, based on soya or grain legumes, will not much distort the feed value chain. Note however that the breeding activities directed at EU varieties need to be built up commercially. Also note that these alternatives are not very competitive at present in European arable production compared to wheat, barley or maize. A difference between grain legumes and European soya can be noted at the processing activity: soya bean processing capacity is still available in the EU at present.

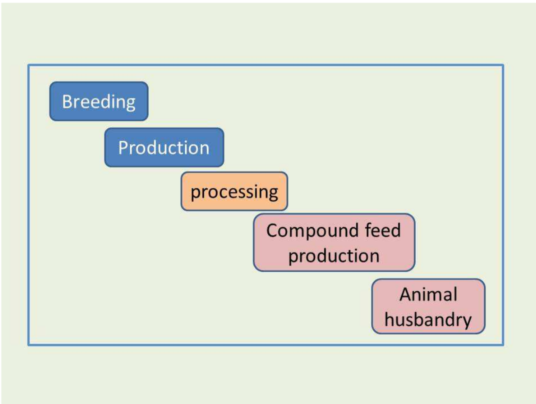

Figure 3. Soya bean meal value chain.

Some other potential protein sources like aquatic biomass or leaf proteins are high in moisture content and/or need to be processed without any delays after harvest. This would make them more local and less adequate for integration with the value chains at present. This would require more energy on the implementation side before these resources would lead to significant alternatives to soya bean meal. The transition of the benchmark value chain to the alternatives should also be considered as mentioned before. The mainstream feed value chain needs substantial amounts of price and quality competitive alternatives and it will take time and efforts to build up a supply chain large enough to meet these demands. Therefore, a transition needs a wide industry commitment to be successful.

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Conclusion

The main conclusion at this point in the EIP Focus Group process would be that for all alternatives intensive R&D roadmaps would be needed. Additionally, implementation issues should be taken into account and sustainability gains should not be taken for granted.

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Annex 4. Status of European research on protein crops

An overview of relevant research and innovation activities is given here. The list is not intended to be exhaustive, but is an indication of recent and current activities.

Crop	Country/countries	Name	Description	Date	contact	Funding	Partners
Legumes	EU	Legume Futures	Investigated Legume-supported cropping systems for Europe	2010 - 2014		FP7	
Legumes	EU	LegumePlus	Focussing on forage legumes to improve protein utilisation in ruminant livestock farming	2012		FP7 Marie Curie	
Soya	The Netherlands		A soya bean programme. Variety comparisons and cultivation practices. In 2013 Agrifirm set up a soya producing farmers' network which it intends to increase in 2014 with farmers producing soya and exchanging experiences with support from experts.	2013			Agrifirm and Wageningen UR
Soya	Belgium		Started a multi-year soya bean research programme.				ILVO
Legumes	EU		Intercropping of cereals and grain legumes for increased production, weed control, improved product quality and prevention of N-losses in European organic farming systems	2003 - 2006			
Legumes	EU	GL-PRO	A European extension network for the development of grain legumes production in the EU in order to reduce the plant protein deficit. A strong demand was seen for home-produced, traceable and good quality protein crops. The GL-PRO concerted action aimed at developing grain legume crop production in different regions through a better valorisation of available scientific tools and genetic materials and through the reinforcement and the networking of existing extension services of 6 European countries. This project was connected with the thematic network project "PROLINK" and several other concerted actions and research programmes on grain legumes.	2003 – 2006		EU	
Lupins	EU		The creation of varieties and technologies for increasing production and utilisation of high quality proteins from the white lupin in Europe.	1997 - 2000		EU	
Legu	EU	Preleg	On pathogen resistant grain legumes using gene transfer	1997		EU	

mes			methods. The rationale of this project was the need to reduce the EU's unacceptable risk of its reliance on imported protein (the protein self-sufficiency rate was about 36%). The project therefore aimed at making grain legume production more efficient and competitive.	- 1999			
Legumes	EU	EuroLegume Enhancing of legumes growing in Europe through sustainable cropping for protein supply for food and feed	The project is aimed at the sustainable use of leguminous plants and soil resources in order to ensure European citizens have access to balanced and safe food, ensuring the high quality protein sources in their daily diet by increasing competitiveness and cultivation of grain legumes (pea, faba bean and cowpea) for food and feed. Short-term S&T objectives: 1. Evaluation of pea, faba bean and cowpea local genetic resources for the development of new varieties for food and feed and further use in breeding; 2. Development of new food and feed products from available European varieties of pea, faba bean and cowpea; 3. Selection of appropriate rhizobium strains and arbuscular mycorrhizal fungi to support nitrogen fixation and development of new, commercial inoculants; 4.Evaluation of influence of leguminous plants on the soil properties in sustainable, regionally specific cropping systems. 19 partners from 10 EU Member States The Legato project (2014-2018) has complementary objectives, focusing on pea and secondarily on faba bean and white lupin.	2014 - 2017			
Legumes	EU	GL-IP	The GRAIN LEGUMES Integrated Project (GL-IP) aimed to integrate European scientific research on grain legumes by addressing the following objectives; i) To identify optimal parameters for legumes in feed quality and safety, including GMOs while using legumes to develop healthy and sustainable agriculture, ii) To investigate variation in grain legume seed composition and the factors affecting it. iii) To develop new genetic, genomic, post-genomic and bioinformatic tools to improve and sustain grain legume seed production and quality. To achieve these objectives the project combined biochemistry, plant & crop physiology, agronomy, plant genomics & breeding, and animal nutritional studies, including then-new methodologies	2004 - 2008		EU	

			such as genomics and bioinformatics, together with transcriptomics and metabolomics.				
Forage legumes	EU	CAGED	The objective of this project was to produce bloat-free forage legumes with improved assimilation of proteins. A preliminary investigation of the nutritive value of populations (varieties, landraces, spontaneous populations) of the most cultivated species (Medicago sativa, Trifolium repens, Lotus corniculatus) was performed and the relevance of condensed tannins in affecting protein degradation and forage digestibility was assessed for each species.	1999 - 2002			
Soya	EU	SoyLife	Focuses on lifespan controls in soya bean leaves (as the source of assimilated carbon metabolites) and nodules (as the source of assimilated nitrogen metabolites). Crucially, this project will determine how the lifespan of these organs is altered in transgenic plants by ectopic expression of cysteine and serine protease inhibitors.	2012 - 2014		FP7 Marie Curie	
Soya	SE Europe	DonauSoja initiative	The objective to promote GMO-free soya cultivation and processing in the Danube region for Austria and the rest of Europe – using the trademark Danube Soya		**www.donausoja.org**		
Faba bean	EU	EU-Faba project	Provided improved faba bean germplasm for use by all breeders on the continent, with focus on climatic adaptation, abiotic stress resistance, and resistance to different populations of the main pathogens and parasites.	2003 - 2007		FP5	
Faba bean, Field Pea, Grass pea	ITALY – Marche Region	The reintroduction of forage and grain legumes in the agricultural systems of the Marche Region.	On farm field and feeding trials based on the use of faba bean and field pea as protein sources replacing, totally or partially, soybean. Feeding trials involved beef and dairy cattle and swine. Development of a DNA approach to possibly certify the raw materials used as feedstuff.	2001 - 2004	s.tavoletti@univpm.it	Marche Region	Farms, Animal farms, Cooperatives, Producers' Associations.
Faba bean,	ITALY – Marche	Development of GM free	Field and feeding trials, development of DNA approaches to identify the raw materials included in the feed, define approaches	2008 -	s.tavoletti@univpm.it	Marche Region	Farms, Animal

Field Pea,	Region	animal production chains in the Marche Region.	to increase local production of protein crops. Creation of a Consumer's group (about 200 families) involved in direct selling of Organic Products (mainly beef cattle and pig meat) produced following the results of the research project (both technical results and consumer's information on project objectives and final results).	2011			farms, Cooperatives, Producers' Associations.
Faba bean, field pea, lupins	ITALY	E.QU.I.ZOO. BIO Efficiency, Quality and Innovation in Organic Animal Farming.	Field and feeding trials in organic agriculture	2006 - 2008	r.zanoli@univpm.it	Italian Ministry of Agriculture	Universities, Regional Experimental Stations and Extension Services.
Faba bean, Field Pea,	ITALY – Marche Region	Development of new processes and products in the dairy production chain.	Development of a production chain aimed at the valorisation of dairy products including the animal feeding system as a parameter for quality evaluation.	2013 - 2015	s.tavoletti@univpm.it	FEASR Marche Region	Universities, Cooperatives, dairy farms.
Soya	France		Coordinated private- public programme (GIE Soja), + varieties registration (CTPS), varieties tests and agronomy trials (CETIOM)	On going		Private-public	RAGT, Euralis, INRA, CETIOM, ONIDOL
pea	France	PEAMUST	Pea MUlti-STress adaptation and biological regulations for yield improvement and stability. Research project: biotechnologies for agriculture and food, genomic, breeding	2012 - 2019	http://www6.rennes.inra.fr/igepp/EQUIPES-DE-RECHERCHE/Resistance-et-Adaptation/Projets/Pea-Must	French Gvnt + private	Public research INRA + private + CETIOM-UNIP
Oilsee	France	RAPSODYN	RAPSODYN – Optimisation of the RAPeSeed Oil content anD Yield	2012	http://www.rapsodyn.fr	French	Public

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d rape			under low Nitrogen input: improving breeding of adapted varieties using genetics and genomics. Research project: biotechnologies for agriculture and food, genomic, breeding	- 2019	/en/project	Gvnt + private	research INRA + private + CETIOM-UNIP
sunflower	France	SUNRISE	To develop the economic competitiveness of the sunflower crop, an environmentally friendly agronomic solution in the context of climate and agricultural practices changes	2012 - 2019	http://www.sunrise-project.fr/en/	French Gvnt + private	Public research INRA + private + CETIOM-UNIP
Legumes	EU	ABSTRESS Improving the resistance of legume crops to combined abiotic and biotic stress	It applies combined, integrated systems, biology and comparative genomics approaches to conduct a comprehensive study of the gene networks implicated in the interaction of drought stress and Fusarium infection in legumes. It uses Medicago truncatula as a model to rapidly identify characteristics for introgression into elite pea varieties and a field test of their performance against existing commercial varieties. The project will demonstrate the advantages of applying advanced phenotyping methods for the generation of improved varieties of a commercial crop. Legumes have been chosen as the preferred study crop because they are susceptible to a combination of abiotic and biotic stresses.	2012 - 2016	http://www.defra.gov.uk/	Collaborative Project targeted to a special group (such as SMEs)	A lot of European ones
Legumes	EU	SWUP-MED Sustainable water use securing food production in dry areas of the Mediterranean region	The project will work mainly in farming communities to improve farming systems, by strengthening a diversified crop rotation and using marginal-quality water for supplemental irrigation, aiming at: Introducing and testing new climate-proof crops and cultivars with improved stress tolerance, selecting promising varieties of cereals, grain legumes and new crops. Climate-proof traits will be identified for breeding programmes using advanced physiological and biochemical screening tools. Supplemental irrigation will be performed as deficit irrigation by different sources of water. Investigating the sustainable field applicability of the farming systems, such as environmental effects related to irrigation water quality assessed by monitoring groundwater and soil quality. Financial implications for the farmer and economic costs and	2008 - 2013	http://swup-med.dk/	Collaborative project for specific cooperation actions dedicated to international cooperati	A lot of European ones, plus Turkey, Morocco, Egypt and Syria.

			benefits in the food sector will be analysed.			on partner countries (SICA)	
Legumes	EU	LEGATO LEGumes for the Agriculture of TOmorrow	The project has been conceived to promote the culture of grain legumes in Europe by identifying priority issues currently limiting grain legume cultivation and devising solutions in term of novel varietal development, culture practices, and food uses. LEGATO will develop tools and resources to enable state of the art breeding methodology and to exploit fully the breadth of genetic resources available. LEGATO will conceive sustainable legume-based cropping systems adapted to different pedoclimatic zones, respecting local constraints. The project has been constructed around the participation of commercial partners including SMEs in the areas of marker development, plant breeding, and legume food processing, who will benefit from the advances made in these areas in LEGATO. Promising legume varieties and cropping systems will be tested at a series of pan-European sites to favour the widest possible take-up in agriculture, and the partners potentially concerned will participate in a stakeholder forum convened regularly during the project.	2014 - 2017	http://www.legato-fp7.eu/	Collaborative Project targeted to a special group (such as SMEs)	A lot of European ones
Barrel Clover	EU	IDOMMSEED	Identification of molecular mechanisms of seed longevity in the model legume Medicago truncatula. The aim was to enhance the global understanding of seed longevity. It will give evidence if the candidate genes have an influence on the seed longevity in different Medicago varieties. In the future, the information could be used to develop molecular markers for seed longevity, which will be useful for breeding purposes, especially in closely related legume crops like soya.	2011 - 2012	**http://www.ist-**world.org/ProjectDetails.aspx?ProjectId=39b0943d7fe3437a9afc88dca92f57d9	Intra-European Fellowships (IEF)	France
Alfalfa	EU	I-GOAT	Isotopic fractionation in goats: Effects of diet, diet quality, and intake. Improving use of stable carbon and nitrogen isotope analysis for diet reconstruction, and applying this to herbivores. A mixed-feeding herbivore (goats Capra hirca) will be designed, to explore interactions of isotope recovery with diet, feeding behaviour and digestive physiology. These effects will be	2009 - 2011	http://www.uzh.ch/index_en.html	International Incoming Fellowships (IIF)	Switzerland

			explored in experimental trials using different diets (grass or alfalfa) and diet mixtures (varying proportions of grass and alfalfa).				
Lupin	EU	LUPIN-CHALLENGE	Characterisation of Lupin B-Conglutin Seed Proteins with a Focus on Health Benefits and their Role in Allergenicity This project will gain in knowledge about the health beneficial attributes of NLL (Narrow Leaf Lupin) seed storage proteins, helping to develop strategies for disease prevention by designing an alternative and more healthy and medical beneficial lupin-enriched foods for Diabesity treatment. In addition, the project will use different approaches to characterise the lupin conglutin protein allergenic properties, and their role in food allergies and cross-reactivity with different food allergen proteins.	2012 - 2015	http://www.csic.es/web/guest/home	International Outgoing Fellowships (IOF)	Spain plus Australia
By-streams	EU	APROPOS	Added value from high protein & high oil industrial co-streams.The focus is to develop new eco-efficient bio-mechanical processing solutions to enrich intermediate fractions from industrial high protein and oil-containing process residues originating from agriculture and fisheries. Enzyme-aided modification steps are developed for the intermediate fractions to obtain value-added nutritive and bio-active components, chemical as well as functional bio-materials suitable for exploitation in food, skin care, wound healing, bio-pesticide and soil improvement product applications.	2012 - 2014	http://www.euapropos.eu/about	Collaborative Project targeted to a special group (such as SMEs)	Some EU countries, plus Kenia, Canada, India and Uganda
Feed & Crops	EU	CANTOGETHER	Crops and ANimals TOGETHER It will design innovative and sustainable mixed farming systems (MFS). A design-assessment-adjustment iterative cycle will be adopted to ensure continuous validation and improvement of the innovative investigated MFS through a participative approach involving stakeholders and researchers across Europe. It will bring together a European network of 24 existing experimental and commercial farms covering a wide diversity of natural and socio-economic conditions in which the most promising MFS will be implemented in order to verify their practicability and to perform an in-depth integrated assessment (economic and	2012 - 2015	http://presse.inra.fr/en/Resources/Press-releases/Cantogether-FP7 http://www.lindhof.uni-kiel.de/de/forschung/cantogether	Collaborative Project targeted to a special group (such as SMEs)	A lot of European ones

			environmental).				
Legumes	Western Mediterranean basin	REFORMA	Breeding and utilisation of lucerne and pea for drought-prone Mediterranean regions, by developing: 1) lucerne varieties with tolerance to severe drought, salinity, heat and grazing; 2) drought-tolerant pea varieties for grain or forage production; 3) cost-efficient marker-assisted and ecologically-based breeding strategies, for lucerne and pea; 4) innovative lucerne-based and pea-based forage crops	2012 - 2016	http://reforma.entecra.it/ paolo.annicchiarico@entecra.it	FP7-ArimNet	CRA-FLC Lodi; INRA Lusignan; CNR-ISPAAM Sassari; INRA Rabat; INRAA and ENSA, Alger; IRA Tunisia
Soya	Germany	Soya breeding – Development of populations for genomic selection	The aim of the project is to develop soybean populations which will be the basis for breeding of early maturing varieties and which are suitable for broad scientific investigations due to their population structure.	2012 - 2015	Volker.hahn@uni-hohenheim.de	Federal Ministry of Food and Agriculture, Germany	Pflanzenzucht Oberlimpurg (PZO)
Soya	Germany	Soja-Projekt	National soybean project for promoting soybean cultivation in Germany by testing cultivars, inoculums and different cultivation methods, breeding new cultivars for food use (tofu) and analysing different processing technologies,	2011 - 2013	www.sojainfo.de	Federal Ministry of Food and Agriculture, Germany	Universities, private and state institutes, SME, councellors
Peas, beans	Germany	BoFru	Increasing soil fertility in organic agriculture by legumes, fertilisation and soil-management	2008 - 2013	http://www.bodenfruchtbarkeit.org/	Federal Ministry of Food and Agricultur	7 Partners

						e, Germany	
All grain legumes besides soybean	Germany	LEGUAN	Development of innovative grain legume products; ingredients, semi-finished products, food	2011 - 2014	http://www.fisaonline.de/index.php?act=projects&view=tab_proj&rp_id=140&lang=en	Federal Ministry of Food and Agriculture, Germany	
Soya	Austria	Soybean breeding	Saatzucht Donau, Saatzucht Gleisdorf and BOKU University have set up breeding research programmes for developing early maturity soybean germplasm.	Since mid 2000s			
Pulses (Peas and beans)	UK	Pulse Crop Genetic Improvement Network	The Pulse Crop Genetic Improvement Network (PCGIN) is a platform that serves the process of legume crop improvement in the UK.	2005 - 2014	http://www.pcgin.org/	DEFRA	John Innes Centre, PGRO, DEFRA, NIAB-TAG, Aberystwyth
Faba beans and peas	UK	Recommended lists of peas and faba beans	Agronomic evaluation of varieties of peas and beans available for UK growers.	On-going	www.pgro.org	PGRO	PGRO, NIAB-TAG, SAC and breeders
Faba beans	UK	OPTIBEAN	Improving the availability of UK sourced protein feed through new faba bean varieties, production and utilisation systems	2011 - 2015		Sustainable Agri-Food Innovation Platform (DEFRA	Wherry and Sons, PGRO, SAF-IP, NIAB-TAG, Garfords

						and Research Councils) and industry partners	and animal feed producers (supermarket producer group)
Lupins	UK	LUKAA	An Integrated Programme for the Development of Lupins as a Sustainable Protein Source for UK Agriculture and Aquaculture	2012 - 2015		Sustainable Agri-Food Innovation Platform and industry partners	IBERS (Aberystwyth), PGRO, NIAB-TAG, Soya UK, Germinal Holdings, SAF-IP
Peas and faba beans	UK	PROTYIELD	Protein content vs yield in legumes: releasing the constraint	2012 - 2015		Sustainable Agri-Food Innovation Platform and industry partners	Wherry and Sons, John Innes Centre, IBERS (Aberystwyth), Food and Environment Research Agency (FERA), SAF-IP, PGRO, Supermar

							ket producer group
Faba beans and peas	Germany		State of knowledge and analysis of research needs for sustainable production and utilisation of field bean and pea (Evaluation of numerous research projects)	2013	http://orgprints.org/23003/	BÖLN	Fachhochschule Südwestfalen Soest

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Annex 5. Innovative action: existing relevant interactive innovation projects and ideas

Product	Country	Description	Contact		Existing or idea
Soya	Netherlands	Group active on soya production and exchange of knowledge and information. Involved are farmers, Agrifirm (compound feed industry) and research (Wageningen UR).	**Martijn.buijsse@agrifirm.com** Ruud.timmer@wur.nl	www.	existing
Soya	Central and South-East Europe	Donau Soja initiative: This is a certification programme for promoting sustainable and GMO-free soja cultivation and processing in the wider Danube region of Europe for both feed and food production. Donau Soja has its members along the value chain all the way from soybean production to food marketing using a trade mark.	bittner@donausoja.org	www.donausoja.org	Existing
Soya	Austria	Verein Soja aus Österreich: This is an association of Austrian stakeholders along the soybean value chain promoting domestic soybean production and uses in food and feed.		http://www.soja-aus-oesterreich.at/	Existing
Soya	Germany	Deutscher Sojaförderring: This is an association of German stakeholders along the soybean value chain promoting domestic soybean production and uses in food an feed;	sojafoerderring@ltz.bwl.de	http://www.sojafoerderring.de/	Existing
Soya	France	Région Midi-Pyrénées initiative for Soybean chains development (research/breeding (RAGT), production, human food, animal feed)	Pierre Labarthe (Vice-chairman of region Midi-Pyrénées / Pierre Jouffret (CETIOM. jouffret@cetiom.fr)		existing
Soya	France	Région Poitou-Charentes initiative for non GMO Soybean development for animal feed / Coopérative Sèvre et Belle	Matthieu Godet (CETIOM. godet@cetiom.fr)		Existing (starting)
Soya	South-East Europe	DonauSoja initiative, the objective to promote GMO-free soya cultivation and processing in the Danube region for Austria and the rest of Europe – using the trademark Danube Soya.		**www.donausoja.org**	Existing

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Soya	D, F, AT, PL	Group active on organic soya production, exchange of knowledge and breeding for food use.	M.Miersch@taifun-tofu.de	www.taifun-tofu.de	Existing
Soya	Germany	Unser Land: Group of farmers, processors, shops and restaurants for products based on regional soy from Bavaria (value adding chain)	http://www.unserland.info/presse/archiv/76-pressearchiv2012/280-unser-land-eier-ohne-gentechnik-mit-gesicht-regionalitaet-bewahrt-wertvolle-vielfalt	www.unser-land.de	existing
Lupin	Germany	Producers, processors and SME for products based on lupin (blue) from north eastern Germany	http://www.prolupin.de/		existing
Soya	Germany	M&D Soybean for strengthening the value adding chain by councelling farmers and processors of soybeans in Germany (2013-16; BÖLN)	www.lfl.bayern.de/schwerpunkte/eiweissstrategie/055066/index.php	www.sojafoerderring.de	Existing
Lupin	Germany	M&D lupin for strengthening the value adding chain by councelling farmers and processors of peas and beans in Germany (2013-16; BÖLN)			Planned
Peas + beans	Germany	M&D peas and beans for strengthening the value adding chain by councelling farmers and processors of peas and beans in Germany (2014-17; BÖLN)			planned
Legumes	UK	Pulse Research Group – a wide group of UK researchers and breeders co-ordinating research and responding to UK research requirements	Roger Vickers (PGRO)		Existing
Peas and beans	UK	Pulse Crop Genetic Improvement Network, focussed on improving legume crop improvement	http://www.pcgin.org/		Existing
All protein crops	Ireland	Protein and oilseed sub-group of Irish Tillage sector development plan. Aim: promote the development of oilseed and starch based protein crops by identifying actions that can be taken by policy makers, research funders, industry and growers in Ireland	Dermot.forristal@teagasc.ie		Existing relativel small scale series of meetings and short reports
CROPQUEST	Ireland	Short desk study to identify opportunities for non cereal crops including protein crops.	Dermot.forristal@teagasc.ie		Existing
Protein Crops	EU but by region	Multi-actor knowledge platform for pulse crop (Beans, Peas Legumes, soya), organised by climatic region within EU. This would provide a knowledge exchange platform for growers, researchers, breeders,	Dermot.forristal@teagasc.ie Tim.odonovan@teagasc.ie		IDEA

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		technology transfer / dissemination actors, and processors / other industry participants. Aims would include: Rapid, efficient information exchange; Co-ordinated research, breeding and tech transfer actions resulting in synergy and greater output delivery. Possible ERAnet developed simultaneously to formalise co-ordination of national research efforts, but with strong technology transfer and industry linkage.			
Protein crops used as feed for livestock.	France, Italy, Spain, Portugal, Scotland, Belgium, Finland, Netherlands, Ireland.	Active Network of different interactive innovation groups from different countries. The aim is looking for protein self-sufficiency for animal feeding in Europe. Multi-actor group: Farmers, Cooperatives, Feed industry, Research actors, Regional agencies, Official organisms, Consultants, Extension services, Products commercialisation stakeholders, etc.	Mr. Jean-Luc.Millecamps Jean-Luc.Millecamps@agrocampus-ouest.fr		Existing SOS Protein

Annex 6. Ideas on research needs

This annex is based on ideas of the Focus Group raised in the discussion by the group or by individual member

Description of research needs (summary in English)	Keywords	Geographical area	Name(s):	Surname:	E-mail(s):	EIP-AGRI website users (yes/no)?	Comments
Research projects should involve farmers both for field grain legume cultivation and animal feeding trial. Therefore "on-farm" research will be necessary to implement feeding systems based on the use of European protein sources. Within each agro-climatic zone the best adapted protein crops will be chosen. A European research network will be extremely useful to coordinate, exchange and discuss research and experimental results in order to drive a common strategy to replace as much as possible imported soybean. Agricultural systems should also be designed in order to produce a reasonable income for all the actors of the production and commercializsation chains.	On farm research, protein crops, agro-climatic zones, Agricultural systems.	EU countries interested in the development of programmes to improve self-sefficiency of protein sources for animal feeding.	Stefano	Tavoletti	s.tavoletti@univpm.it	YES	-----

Processing and Production of proteins in large quantities (concentrates, isolates and by-products appraisal) with industrial feasibility.	Food and Feed Self-sufficiency	Europe	Paloma	Gaton	palgat@cartif.es	Yes	
Mixed crop: they could be a great solution for on-farm grown in farms with ruminants. - What kind of mixed crop and mixed forage can we sow in each climate area? We need both to compile the information and practices and to provide news trials more "practical" (the farmers used to sow from 4 to 6 different species and not only two) - How can we know the value of this mixture? we need a tool for the farmers/advisors which give them the answer quickly and cheaper (like it is with Nitrachek® or N-sensor®)	Mixed crop, mixed forage, on-farm, Ruminant, self-sufficiency	Mediterranean, Oceanic, Continental, Nordic	gaspard	myriam	Myriam.gaspard@ languedocroussillon.chambagri.fr	Yes	
Faba and peas : - Resistance against Aphanomyces (peas including chickpea) and diseases (faba) and drought (spring) - New cultivars more adapted for monogastrics	Genomic, fabas, peas, Climate, diseases	Mediterranean All the areas of UE	gaspard	myriam	Myriam.gaspard@ languedocroussillon.chambagri.fr	Yes	

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Chickpea : - Pool of genomics to improve the yield in Mediterranean area including the South of the Mediterranean: network of researchers (including development structures such as chambers of agriculture) and platform for exchange practice between farmers.	Genomic, Chick pea, Mediterranea, human consumption	Mediterranea	gaspard	myriam	Myriam.gaspard@languedocroussillon.chambagri.fr	Yes	
Soya bean : Varieties adapted to rain fed production in southern EU	Genomic, soya, Mediterranea	Mediterranea	gaspard	myriam	Myriam.gaspard@languedocroussillon.chambagri.fr	Yes	
Oilseed rape, sunflower	Processing : implementing new oil extraction processes respecting proteins quality/ biorefinery, protein extraction ….	all	Pilorgé	Etienne	pilorge@cetiom.fr		

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Finding practical economic and research ways to make farmers more profitable changing cereals for protein crops.	Farmers, cooperatives, feed industry, networking, shortening chain.	Europe	Paloma	Gaton	palgat@cartif.es	Yes	
Knowledge development and exchange CEE – NW Europe concerning protein crops. Coordinated yield optimisation and varieties research.		Europe	Martijn	Buijsse	m.buijsse@gmail.com		
How can modern breeding tools (genomic selection, marker assisted selection and so on) be used for soybean breeding for higher yield?	Soya breeding, genomic selection	Europe	Hahn	Volker			
Faba bean agronomy for Oceanic climate to improve yield, yield stability and reduce production costs including: Understanding yield formation to determine most productive areas for future research and breeding including: Crop establishment (methods, winter vs spring types, dates, seed rates, etc) Crop Nutrition , Crop development Disease and weed control. Rotation benefits. Optimising agronomy for any new variety type introductions	Beans, Yield formation, Agronomy , Costs	Ireland, UK, Oceanic	Dermot	Forristal	dermot.forristal@teagasc.ie	Yes	

Bean breeding for Oceanic climates with improved yield capability, more determinate growth, improved disease control.	Bean breeding	Ireland, UK, Oceanic	Dermot	Forristal	dermot.forristal@teagasc.ie	Yes	
Oilseed rape agronomy to improve yield and yield stability while reducing costs including: Crop establishment; crop nutrition and disease control. Rotation benefits	Oilseed Agronomy	Ireland, UK, Oceanic	Dermot	Forristal	dermot.forristal@teagasc.ie	Yes	
Investigate scope for adaption and development of protein crops other than beans or oilseed rape for oceanic climates.	Alternative crops	Ireland, UK, Oceanic	Dermot	Forristal	dermot.forristal@teagasc.ie	Yes	

Annex 7. Wheat and maize benchmark yield gaps for protein crops based on regional and country data within the EU member states.

Wheat benchmark: yields to match the wheat crop value based on price levels of starch, protein and oil.

crop	value																
	France	Spain		Hungary	Neth.	Germany			Italy				Finland	Sweden	Poland	Ireland	UK
		irrigated	rain fed			warm	moderate	cool	Lombardy	Emilio-Romagna	Tuscany	Puglia					
Soy	4.4	3.1	2.0	2.7	5.4	4.4	5.1	5.4	3.4	4.1	2.2	1.7	2.3	3.8	2.6	6.4	5.0
Rape	3.9	2.8	1.8	2.4	4.8	3.9	4.6	4.8	3.1	3.7	1.9	1.5	2.1	3.4	2.3	5.7	4.5
Sunflower	3.6	2.6	1.7	2.2	4.5	3.6	4.2	4.5	2.9	3.4	1.8	1.4	1.9	3.1	2.2	5.0	3.9
Lupin	5.3	3.8	2.5	3.3	6.6	5.3	6.2	6.6	4.2	5.0	2.6	2.0	2.8	4.5	3.2	7.6	5.9
Pea	6.2	4.4	2.9	3.8	7.6	6.2	7.1	7.6	4.8	5.8	3.0	2.3	3.3	5.2	3.7	8.9	7.0
Field bean	5.8	4.1	2.7	3.6	7.2	5.8	6.7	7.2	4.5	5.5	2.9	2.2	3.1	4.9	3.5	8.4	6.6
Alfalfa	31.7	22.5	14.7	19.6	39.0	31.7	36.7	39.0	24.8	29.8	15.6	11.9	16.9	27.0	18.9	45.9	63.2

Wheat benchmark: yield increase needed to match the wheat crop value based on price levels of starch, protein and oil.

crop	value																			
	France	Spain		Hungary	Neth.	Germany			Italy				Finland	Sweden	Poland	Ireland	UK	Range		
		irrigated	rain fed			warm	moderate	cool	Lombardy	Emilio-Romagna	Tuscany	Puglia						min	max	average
Soy	64%	20%	20%	20%	101%	47%	65%	136%	-4%	48%	45%				53%			-4%	136%	51%
Rape	17%	-4%	1%	3%	25%	19%	27%	24%	18%	20%	-12%	-29%	31%	21%	-9%	39%	33%	-29%	39%	13%

Sunflower	51%	29%	41%	-1%		10%			-11%	37%	-10%	-28%			23%			-28%	51%	14%
Lupin	118%	215%	252%	153%		142%	147%	228%	39%						101%			39%	252%	155%
Pea	70%	108%	217%	70%	61%	120%	83%	81%	30%	87%	32%	45%	48%	94%	59%	98%	89%	30%	217%	82%
Field bean	38%	79%	92%	99%	52%	93%	77%	59%	98%	128%	51%	37%	36%	99%	44%	68%	89%	36%	128%	73%
Alfalfa	17%	-63%	-26%	33%	22%	39%	51%	95%	-48%	7%	13%				-62%			-63%	95%	6%

Maize benchmark: yields to match the wheat crop value based on price levels of starch, protein and oil.

crop	value												
	France	Spain		Hungary	Neth.	Germany			Italy			Sweden	Poland
		irrigated	rain fed			warm	moderate	Cool	Lombardy	Emilio-Romagna	Tuscany		
Soy	5.5	7.1	4.1	3.9	7.4	6.1	5.5	4.9	6.3	5.3	3.5	3.9	4.1
Rape	4.9	6.4	3.6	3.5	6.6	5.4	4.9	4.3	5.6	4.7	3.1	3.5	3.7
Sunflower	4.5	5.9	3.4	3.3	6.1	5.0	4.5	4.0	5.2	4.4	2.9	3.3	3.4
Lupin	6.6	8.6	4.9	4.8	9.0	7.3	6.6	5.9	7.6	6.4	4.3	4.8	4.9
Pea	7.6	9.9	5.7	5.5	10.4	8.5	7.6	6.8	8.8	7.4	4.9	5.5	5.7
Field bean	7.2	9.4	5.4	5.2	9.8	8.0	7.2	6.4	8.3	7.0	4.6	5.2	5.4
Alfalfa	39.2	51.1	29.3	28.4	53.3	43.7	39.3	34.9	45.4	38.0	25.3	28.4	29.4

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Maize benchmark: yield increase needed to match the wheat crop value based on price levels of starch, protein and oil.

crop	value															
	France	Spain		Hungary	Neth.	Germany			Italy			Sweden	Poland	Range		
		irrigated	rain fed			warm	moderate	cool	Lombardy	Emilio-Romagna	Tuscany			min	max	average
Soy	103%	173%	139%	74%	174%	102%	76%	111%	75%	89%	135%		139%	74%	174%	116%
Rape	45%	119%	102%	49%	70%	64%	36%	11%	117%	52%	43%	27%	41%	11%	119%	60%
Sunflower	87%	194%	180%	43%		52%			63%	75%	46%		92%	43%	194%	93%
Lupin	170%	615%	602%	267%		233%	164%	193%	154%				213%	154%	615%	290%
Pea	111%	373%	532%	148%	120%	203%	96%	62%	139%	138%	114%	104%	149%	62%	532%	176%
Field bean	70%	307%	283%	189%	108%	167%	90%	42%	262%	190%	144%	109%	125%	42%	307%	161%
Alfalfa	44%	46%	157%	93%	67%	91%	62%	75%	-5%	36%	84%		3%	-5%	157%	63%

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