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RESEARCH ARTICLE – DOSSIER

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PROTEIN SOURCES IN ANIMAL FEED
LES SOURCES DE PROTÉINES DANS L'ALIMENTATION DU BÉTAIL

The EU's dependency on soya bean import for the animal feed industry and potential for EU produced alternatives

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Abstract – The European Innovation Partnership Agri has set up a consultation process involving 20 experts from 11 EU countries to discuss the potential of a substantial increase in protein crop production in the EU. The dependency of Europe on soya bean meal imports and the associated drivers are described and underline the need for change. The EIP Agri process resulted in the assessment of the present-day yield gap of protein crops using an approach based on the market values of the protein, starch and plant oil components. Oil-based protein crops seemed to be overall better positioned than starch based protein crops because the price of oil levels is higher than that of starch. Alfalfa was identified as being interesting for regions where drying cost are low. The process also resulted in the identification of opportunities and constraints to be encountered by the innovation process, combining the knowledge and physical infrastructure, market structure, co-operation and interaction and the influence of culturally determined values and beliefs. Therefore, the recommendation is to develop a comprehensive approach to meet the challenge of substantially increasing the EU's protein crop production.

Keywords: Soya / feed industry / EU protein production / protein-rich feed / competitiveness

Résumé – La dépendance de l'Union Européenne aux importations de soja pour l'industrie de l'alimentation animale et les potentialités en termes de productions de substitution en Europe. L'initiative *European Innovation Partnership* (EIP) Agri a engagé un processus de consultation impliquant 20 experts de 11 pays d'Europe afin de discuter du potentiel d'une augmentation considérable de la production de protéines végétales en Europe. La dépendance de l'Europe envers les importations de tourteaux de soja et les facteurs associés sont décrits et souligne la nécessité d'un changement. Le travail d'EIP Agri a consisté en l'évaluation de l'actuel écart de rendement des cultures protéiques en utilisant une approche basée sur la valeur marchande des protéines, de l'amidon et des composantes huileuses. Les protéines issues des variétés oléagineuses semblent mieux positionnées que celles des plantes amylacées, en raison d'un prix plus élevé de l'huile comparé à l'amidon. La luzerne a été identifiée comme intéressante pour des régions où les coûts de séchage sont faibles. L'étude a également permis d'identifier les opportunités et contraintes qui peuvent être rencontrées dans le processus d'innovation, prenant en compte à la fois les connaissances et les infrastructures physiques, la structure du marché, la coopération et l'interaction, et l'influence de valeurs et des croyances guidées par la culture. Par conséquent, la recommandation est de développer une approche commune afin de répondre au défi d'une importante augmentation de la production de protéines végétales en Europe.

1 Introduction

According to FAO statistic data of 2009, the EU population consumed 105 g of protein per capita per day of which 59% was from animal derived products, 27% from cereals, 3.6% from vegetables and 1.6% from pulses. Therefore, animal products are of major importance in protein supply to Europe's citizens. The majority of these products are produced in the EU according to figures published by the European Commission (Anonymous, 2013). In 2012, 96% of the total available meat in the EU was produced in the EU itself while 92% of the available amount of meat was consumed. The comparable figures for fresh dairy products were both 99%. So, the self sufficiency of the EU's consumer protein consumption based on animal-derived products is very high. However, the plant protein input for the EU's animal production industry

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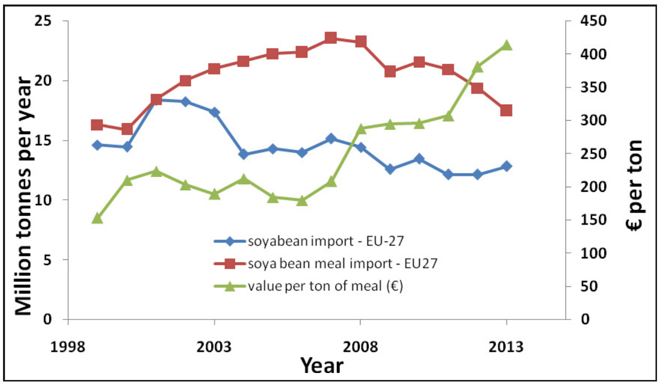

Fig. 1. Import data for soya bean and soya bean meal and value per ton of meal imported (data: Eurostat). The value per ton of meal was calculated from Eurostat data.

shows an entirely different picture. The FEFAC 2012 statistical yearbook (Bouxin, 2013) provides an EU balance sheet for protein-rich feed materials, showing that 69% is imported into the EU (excluding fish meal). Of the 5 materials mentioned, the self-sufficiency of soya bean meal is only 3% while this product supplies 64% of the protein-rich feed materials. To this statistical importance of soya bean meal, can be added the value of this material to the livestock industry. Soya bean meal is a major source of the essential amino acid lysine, which is the first limiting amino acid for pigs and the second for poultry, and the apparent ileal digestibility of this amino acid was 85%, which is higher than that of other oilseed cakes (51−78%) (Cromwell, 2008). The high protein content, up to 50% of dry matter, is also important for the compound feed industry when developing mixtures that are optimal for animal needs.

2 Soya bean meal dependency

The EU imports both soya beans and soya bean meal (Fig. 1). Figure a shows that soya bean import is declining, which is due to the decrease of crushing capacity in Europe. The import of meal to the EU 27 increased almost continuously for four decades and peaked in 2007−2008, since when it has declined due to the increase of the price of the meal. In 2013, a total of 28 million tons of imported soya bean meal was available, based on the assumption that 80% of the soya bean ends up in the meal. Assuming a yield of 2.7 tons of soya bean per ha, this represents 12.8 million hectares of land. The EU's low self-sufficiency in protein-rich feed materials led to an EU Parliament motion (Häusling, 2011) that called for putting more effort in breeding, research and development, and extension to increase the EU's own production of these materials. The dependency of the EU's livestock farming sector can also be illustrated by the amount of soya bean meal used per unit of meat produced: 232, 648 and 967 g/kg for beef, pork and poultry, respectively (Gelder *et al.*, 2008). This underlines the larger dependency on soya bean meal for monogastrics compared to ruminants, also shown by the close correlation of soya consumption with monogastric production in Europe (Bues *et al.*, 2013). The low self-sufficiency exposes the EU to possible trade distortions, sustainability problems, scarcity and price volatility of soya bean on the global market. First, population growth and increase of GDP level per capita are expected to increase annual meat consumption from 41 kg per capita in 2005 to a projected 69 kg per capita in 2050, which implies a 1.15% increase of meat consumption per year world-wide. This market growth will influence the demand for protein-rich feed materials and more specifically soya bean meal. Second, in recent years the price of soya bean meal price has shown increasing volatility. Data from the Chicago Boards of Trade show that in August 2012, the price rose from $364 to $586. The price for non-GM soya bean meal is even higher and a premium of around $150 is no exception. Third, Nowicki *et al.*, (2010) identified the risk of trade disruptions following asynchronous authorizations 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 of soya bean production is the subject of discourse on deforestation and environmental impacts (Elgert, 2013; Minderhoud, 2010).

3 EIP focus group on protein crops

To meet the significant challenges that are facing the food sector, the process of innovation is crucial and deserves special attention. Networks play an important role in this process because innovation is a multiple actor process (Mierlo *et al.*, 2008; Klein Woolthuis *et al.*, 2005). A reflection paper issued by the Standing Committee on Agricultural Research of the EU also stresses the importance of the social aspect of innovation (EU SCAR, 2012). The concept of the European Innovation Partnership on Agriculture and Sustainability launched by the EU is to strengthen this process by bringing together the different actors of innovation in agriculture in so-called Focus Groups to be set up in the period 2014–2020. This task is facilitated by the EIP Agri Service Point together with EU DG Agri who identified important fields of innovation in agriculture, amongst which was protein crops in the EU. A focus group was established with 20 experts from 11 EU countries working in different sectors of the innovation system: science, applied research, extension, government, farming and the compound feed industry. In two meetings, this group was asked to analyze the protein demand in Europe, assessing the potential of relevant crops and forage that are rich in protein and making suggestions for EIP Operational Groups and Horizon2020 research on how to increase productivity and protein content of soya bean, pulses (faba bean, lupins and pea), forages (alfalfa and clover), and oilseeds (rapeseed and sunflower) in the EU. This article focuses on two aspects of the focus group's activities: an assessment of the current competitiveness of protein crops in Europe, and the opportunities and bottlenecks identified.

4 Competitiveness of protein crops

The competitiveness of EU protein crops was assessed by using data on crop composition (Tab. 1) and yield (Tab. 2)

Table 1. Content of dry matter (DM), starch, oil and protein of different protein crops based on expert data and data from www.feedipedia.org.

Crop	Component				
	DM	Starch	Oil	Protein	Others
		DM	DM	DM	DM
Soya	86 %	0 %	23 %	42 %	34 %
Rape	92 %	0 %	43 %	23 %	34 %
Sunflower	91 %	0 %	48 %	17 %	35 %
Lupin	89 %	0 %	10 %	38 %	53 %
Pea	86 %	51 %	0 %	24 %	25 %
Faba bean	86 %	45 %	0 %	29 %	26 %
Maize	86 %	73 %	0 %	9 %	18 %
Wheat	86 %	69 %	0 %	13 %	18 %
Alfalfa	35 %	0 %	0 %	21 %	79 %

and benchmarking this to soft wheat and maize, these being high-yielding cereal crops that would generally be expected to be replaced in farm fields by protein crops. This was done by collecting yield data for the EU as a whole and for selected regions and countries within the EU-27, namely France, Netherlands, Spain (irrigated and rainfed), Hungary, Ireland, United Kingdom, Poland, Germany (as a whole, its states Baden-Württemberg and Bavaria, and northern, central and southern regions), Italian regions (Lombardy, Emilia-Romagna, Tuscany and Puglia), Sweden and Finland.

The potential value of each crop was calculated based on the market value of starch, protein and plant oil. Price data were taken from IndexMundi website (January 2014) and were €300 for starch, €800 for protein (based on soya bean meal), €619 for soya bean oil, €743 for rapeseed oil and €868 for sunflower oil. The price of lupin oil, a currently unexploited resource, was assumed to be equal to sunflower. Based on these price levels and the content of protein, starch and oil per crop, a value in euros was calculated. Subsequently, the required yield increase to match the crop's value to the benchmark crops soft wheat and maize was calculated (Tabs. 3 and 4). The results show that starch crops are less competitive than oil crops or alfalfa. Regarding alfalfa, it must be stressed that drying it requires much more energy than is needed for other crops, since it is harvested as vegetative matter rather than as mature seeds or grains. In northern Europe where sun drying is less reliable, this decreases the competitiveness of the crop even further. The reason for the advantage of the oilseed crops relates to the higher value of oil compared to that of starch. The high amylose content, slow digestibility, and exceptional pasting properties of legume starches may add to their industrial value when supplies can be assured, but this is unlikely to greatly alter the overall competitiveness of the protein crops. The data also show that the protein crop's competitiveness against soft wheat is better than that against maize with its higher yields. Table 3 indicates that amongst the oilseed crops, the potential values of rapeseed and sunflower come closest to that of soft wheat. In fact, in 2005 rapeseed cake in Europe was financially equal to or even more attractive than imported soya, expressed as intestinally digestible grams of protein per euro (Kamp *et al.*, 2008, Figure 5.1). The data in Tables 3 and 4 also show a high variability amongst EU countries and regions, due to the large variability among EU climates, soils and water availability conditions. Also, benchmark crops can be expected to vary between regions and can be other crops than soft wheat or maize in certain areas. In the end, competitiveness is decided at farm level. Nevertheless, the central conclusion to these data is that protein crops have a long way to go before being competitive.

Next to the competitiveness of individual crops, there is another aspect to account for, namely the amount of co-product available if Europe increases its production of protein crops. Data on this aspect are presented in Table 5, based on the assumption that 50% of the imported soya bean protein would be replaced by EU production of each of the mentioned crops when they have reached a yield level competitive to that of soft wheat. The table shows that when sunflower or rapeseed is used as a protein crop, the global production of its oil would significantly increase, by 133 and 62%, respectively. This is different for soya (10%), as the global market for its oil is already much larger than the others. It is hard to predict the consequences of this to price level changes, but they can be expected to be larger for sunflower and rapeseed oils than for soya oil. Table 5 also shows the surface of arable land needed to produce the required amount of protein crops. This surface varies between 4 and 16% of total European arable area, depending on the crop, but the required yield increases must also be taken into consideration. For instance, the area needed for lupin equals that for soya bean, but this is at the (unrealistic) yield increase of 334% for the lupin.

The above results and considerations do not include any consideration of the quality of the protein, as explained by Cromwell (2008). Ewing (2000) published maximum inclusion rates for different livestock categories and feed components which show the broad use of soya bean meal relative to other raw materials. This means that replacing soya bean meal with other products will require a wider range of products to be used to meet the different animal requirements.

5 Innovation aspects to be addressed

If Europe is going to increase its self-sufficiency of protein-rich crop production, it is confronted with the challenge of increasing productivity of these crops in order to make them more competitive. This challenge will demand huge effort from Europe's agriculture knowledge and innovation system (AKIS). To increase focus and stimulate innovation in practice, this requires an innovation-driven approach rather than a science-driven approach (EU SCAR, 2012). Klein Woolthuis *et al.* (2005) have identified different aspects of innovation, including knowledge infrastructure, physical infrastructure, market structure, co-operation and interaction, and values and beliefs. The focus group on protein crops has worked along these aspects and thus developed an integrated palette of items to be addressed by Europe's AKIS to meet the aforementioned challenge.

Table 2. Yield data (t/ha) for protein crops in EU, EU countries and regions (data normalized to dry matter data from Tab. 1).

Country/region	Crop									Source
	soya	rape	sunflower	lupin	pea	field bean	maize	wheat	alfalfa	
France	2.7	3.4	2.4	2.4	3.6	4.2	9.0	6.9	27.1	Eurostat 2004–2011
Netherlands	2.7	3.9	0.0	0.0	4.7	4.7	12.2	8.5	32.0	CBS statline 2004–2011
Spain irrigated	2.6	2.9	2.0	1.2	2.1	2.3	11.7	4.9	35.1	Data from MAGRAMA 2011
Spain rainfed	1.7	1.8	1.2	0.7	0.9	1.4	6.7	3.2	11.4	Data from MAGRAMA 2011
Hungary	2.3	2.4	2.3	1.3	2.2	1.8	6.5	4.3	14.7	Eurostat 2004–2011
Ireland		4.1			4.5	5.0		10.0		O'Donnovan (pers. com.)
United Kingdom		3.4			3.7	3.5		7.8		Eurostat 2004–2011
Poland	1.7	2.6	1.8	1.6	2.3	2.4	6.7	4.1	28.5	Statistical Yearbook of the Republic of Poland, 2012
Germany	2.7	3.7	2.1	1.5	3.0	3.5	9.6	7.4	20.6	Destatis 321 (2006–2011)
Germany – Baden Württemberg	2.7	3.8	3.1		3.5	3.3	9.8	7.1	19.1	Destatis 321 (2006–2011)
Germany - Bavaria	2.8	3.3	3.0	2.5	3.2	3.5	10.0	7.0	24.0	Lfl-DB-Rechner 2008–2012
Germany – warmest regions	3.0	3.3	3.3	2.2	2.8	3.0	10.0	6.9	22.9	Recknagel (pers. com.)
Germany – moderate regions	3.1	3.6		2.5	3.9	3.8	9.0	8.0	24.3	Recknagel (pers. com.)
Germany – coolest regions	2.3	3.9		2.0	4.2	4.5	8.0	8.5	20.0	Recknagel (pers. com.)
Italy, Lombardy (northern Italy)	3.6	2.6	3.2	3.0	3.7	2.3	10.4	5.4	47.8	ISTAT mean 2011–2013
Italy, Emilia-Romagna (northern Italy)	2.8	3.1	2.5		3.1	2.4	8.7	6.5	28.0	ISTAT mean 2011–2013
Italy, Tuscany (centre Italy)	1.5	2.2	2.0		2.3	1.9	5.8	3.4	13.8	ISTAT mean 2011–2013
Italy, Puglia (south Italy)		2.1	1.9		1.6	1.6		2.6		ISTAT mean 2011–2013
Sweden		2.8			2.7	2.5	6.5	5.9		Eurostat 2004–2011
Finland		1.6			2.2	2.3		3.7		Eurostat 2004–2013
Greece	3.1	2.5	1.5		1.8	1.8	10.1	2.6	31.1	Eurostat 2004–2013
EU-27	2.7	3.1	2.2	1.0	2.7	2.7	7.1	5.4	22.9	Eurostat 2004–2013; Alfalfa: 2004–2010

Table 3. Yield increases required for the potential value of the protein crops to match that of wheat.

Crop	France	Spain		Hungary	Neth.	Germany			Italy				Finland	Sweden	Poland	Ireland	UK	EU-27
		irrigated	rain fed			warm	moderate	cool	Lombardy	Emilio-Romagna	Tuscany	Puglia						
Soya	64%	20%	20%	20%	101%	47%	65%	136%	-4%	48%	45%				53%			30%
Rape	17%	−4%	1%	3%	25%	19%	27%	24%	18%	20%	−12%	−29%	31%	21%	−9%	39%	33%	0%
Sunflower	51%	29%	41%	−1%		10%			−11%	37%	−10%	−28%			23%			31%
Lupin	118%	215%	252%	153%		142%	147%	228%	39%						101%			334%
Pea	70%	108%	217%	70%	61%	120%	83%	81%	30%	87%	32%	45%	48%	94%	59%	98%	89%	76%
Faba bean	38%	79%	92%	99%	52%	93%	77%	59%	98%	128%	51%	37%	36%	99%	44%	68%	89%	69%
Alfalfa	17%	−63%	−26%	33%	22%	39%	51%	95%	−48%	7%	13%				−62%			8%

Table 4. Yield increases required for the potential value of the protein crops to match that of maize.

Crop	France	Spain		Hungary	Neth.	Germany			Italy			Sweden	Poland	EU-27
		irrigated	rain fed			warm	moderate	cool	Lombardy	Emilio-Romagna	Tuscany			
Soya	103%	173%	139%	74%	174%	102%	76%	111%	75%	89%	135%		139%	63%
Rape	45%	119%	102%	49%	70%	64%	36%	11%	117%	52%	43%	27%	41%	25%
Sunflower	87%	194%	180%	43%		52%			63%	75%	46%		92%	64%
Lupin	170%	615%	602%	267%		233%	164%	193%	154%				213%	443%
Pea	111%	373%	532%	148%	120%	203%	96%	62%	139%	138%	114%	104%	149%	120%
Faba bean	70%	307%	283%	189%	108%	167%	90%	42%	262%	190%	144%	109%	125%	112%
Alfalfa	44%	46%	157%	93%	67%	91%	62%	75%	−5%	36%	84%		3%	36%

Dossier

Table 5. Yield increases required, associated co-products produced, and area needed, based on EU-27 statistical data and wheat as a benchmark crop (nd = not determined).

Crop	Yield			Oil		Starch		EU
	current (t/ha)	required (t/ha)	increase (%)	produced (M ton)	World oil (%)	produced (M ton)	Area needed (km^2)	arable land (%)
Soya	2.7	3.4	30	3.9	9.5	0	57.264	5.4
Rape	3.1	3.1	0	13.8	61.9	0	111.846	10.5
Sunflower	2.2	2.9	31	20.3	133.3	0	163.277	15.4
Lupin	1.0	4.2	334	1.9	nd	0	51.934	4.9
Pea	2.7	4.8	76	0	0	15.5	72.683	6.8
Faba bean	2.7	4.5	69	0	0	11.1	63.553	6.0
Alfalfa	40.2	43.6	8	0	0	0	40.294	3.8

6 Knowledge infrastructure

Technical innovations on breeding and agronomy are needed to increase the competitiveness of the protein crops. Breeding aspects to be addressed differ from one crop to another but also from one region to another. To this end, the focus group has distinguished four agro-climatic zones, namely the Boreal or Nordic zone, the oceanic or sub-oceanic zone, the continental or sub-continental zone and the Mediterranean zone. Characteristics to be developed range from yield to drought resistance, climate adaptability, disease resistance, protein content, and reduction in anti-nutritional factors. For some crops the private sector invests in breeding, but mostly breeding of protein crops is restricted to the public or semi-public sectors. This relates to the relatively small market for these crops in Europe at the moment, so it indicates one of the challenges to be met: how to involve the private breeding industry while the market for protein crops is still restricted? Besides breeding, there is a need for agronomic research on cultivation aspects (including variety choice, fertilization, disease control, water use, crop mixtures, and environmental effects such as greenhouse gas emissions) and on rotational aspects (such as soil, nitrogen and disease management) which need to be studied in order to stimulate implementation of crop production (see: Jensen (2010) on the role of faba beans in crop rotations, Sinclair and Valdez (2012) on the role of legumes in general, and Sprent (2011) on legumes in European cropping systems). Strongly connected to agronomy is the advisory and direct support to farmers, providing them with relevant information. Networks and EIP Operational Groups could play an important role in this, and also in guiding priorities in applied research. Finally, research is needed in theprocessing of protein crops to increase the feeding value, by reducing the concentration of anti-nutritional factors and by increasing that of protein (Boye *et al.*, 2010).

7 Physical infrastructure

In Europe a physical infrastructure for rape and sunflower seed exists that could support an increase in production of these protein crops and give them a head start in advanced development of the value chain. The same could be true for soya bean, as Europe has an existing (but decreasing) crushing capacity. Nevertheless, this capacity is tuned to the supply of large overseas shiploads. A test to establish a soya bean value chain in the Netherlands showed that only after increasing production to substantial volumes, would this raw material be interesting for the Dutch crushing industry. In the meantime, other market outlets need to be developed, based on the non-GM premium that they pay (Buijsse, pers. comm., 2014). The advantage of the starch-based protein crops, pea and faba bean, is that they can be fed directly to animals and supply the animal with starch at the same time. Nevertheless, most current cultivars of pea and faba bean can be used only at lower inclusion levels for pigs and poultry than soya bean meal (Ewing, 2000), owing to their content of anti-nutritional factors.

8 Market structure

The present day soya bean meal value chain is based on the supply of a reliable product with stable price and quality to the market. The market functions on a global scale, and large volumes are available from the major producing countries in North and South America. It can be debated whether the value chains for European alternative protein crops will be at the local, regional or European level. The EIP-Agri focus group concluded that oilseed crops would probably be developed at a more European scale (following the economics of scale of the processing required), while starch-based crops could be marketed in more regionally based value chains (linked to crop cultivation opportunities offered by regional climatic characteristics), and protein-rich roughage would be more suitable for locally based value chains (possibly supported by labels and certificates of origin). However, the question is what protein crops and what value chain scale levels would be best in terms of economic feasibility and resource use efficiency (Kirwan and Maye, 2013) and will be taken up by the market in the end.

9 Co-operation and interaction

The multi-stakeholder nature of innovation requires co-operation and interaction. The stakeholders involved are not only those directly involved in the value chain but also those that enable value chains, including governments, NGOs, and public research and development organizations. The present-day value chain based on soya bean meal is associated with sustainability issues, the EU parliament desires to increase self-sufficiency in protein crops, the breeding of protein crops is primarily in the public domain, and agronomy issues remain to be resolved, so the involvement of the enabling environment is self-evident. When the challenge faced by industry is examined, the development of a comprehensive program with all stakeholders involved, seems the logical way ahead.

10 Values and beliefs

The adoption of innovations that are incompatible with cultural values and beliefs has a high risk of failure. In the issue of increasing EU production of protein crops to increase self-sufficiency, this aspect of innovation could be supportive. Most of the soya bean meal imported is from GM cultivars and a GM-free supply chain for Europe's animal feed industry would come closer to the cultural values of its citizens. The Danube Soya Initiative (www.donausoja.org) as well as the Brussels Soy Declaration (www.proterrafoundation.org) that are supported by many EU food companies and retailers underline the importance of having a GM-free value chain, including that of animal feed. The premium that is paid for non-GM soya in the market, could be supportive of the development of an EU-based soya bean meal supply chain. Another supportive cultural aspect is the increasing interest in local food systems, as described by Martinez *et al.* (2010) and as exemplified by the EU's Committee of the Regions opinion on local food systems (2011).

11 Conclusions

The GATT and the 1992 Blair House Agreement are associated with Europe's decrease of protein crop production, the accompanying increase in cereal production, and the neglect of innovations in protein crop production in Europe (Häusling, 2011). This has resulted in the yield gap that the EIP Agri focus group on protein crops has pointed out. The lack of competitiveness of protein crops relative to cereals in Europe was also pointed out by Bues *et al.* (2013), advising on nine policy options to support Europe's protein crop production. These authors underlined the added value of protein crops to the sustainability of European food systems. Looking at the challenge ahead, closing the yield gap does not seem to be a matter of separate, single repairing activities relating to policy instruments, extension or research. It requires a comprehensive approach involving the value chain partners as well as the enabling environment, and paying attention to the knowledge required while accounting for the implications for the physical and market infrastructures. The increased interest in local food systems and their advantages as well as the market demand for GM-free supply chains could well be supportive to this development.

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