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INVITED REVIEW

Transgenic soya beans: economic implications for EU livestock sector

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Abstract

World oilseed trade consists of many closely substitutable commodities, with canola and cottonseed as possible alternatives to soya beans for many purposes. Transgenic events in all three crops have been widely adopted, particularly in North and South America, for compelling economic or agronomic reasons. Despite the close attention from organizations concerned about the potential consequences of transgenic crop adoption, there appears to be no substantiated evidence of transgenic DNA in meat or milk products when such crops are fed to livestock. The global area of these transgenic crops continues to increase. No transgenic canola, cotton or soya bean crops are permitted for commercial cultivation in Europe, and although transgenic feed resources are permitted for import, importers risk shipments being denied entry if the traces of an unauthorized transgenic crop are detected. These tight controls can mean that livestock farmers in the EU are disadvantaged due to restricted access to cheaper feed or higher feed costs, and they are thus loosing a degree of competitive advantage. This paper reviews the extent to which transgenic soya beans have become the 'conventional' method of cultivation elsewhere, and notes implications this has for livestock nutrition, traceability and economics within the EU. The paper concludes with discussion regarding the implications for the EU of delayed acceptance of newly available transgenic traits.

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Introduction

World oilseed trade consists of many closely substitutable commodities, with rape-, sunflower- and cottonseed as alternatives to soya beans. Divergent requirements for protein meal, vegetable oil and oil for biofuel determine the ratio of oilseeds to oilseed products that countries import. Soya bean oil remains the most widely used edible oil in the United States, with consumption of 7.57 Mt in 2009 representing 65% of all vegetable oil consumption (USDA, 2010). It is a major ingredient in cooking oil, margarine and mayonnaise. Lecithin is a natural emulsifier derived from soya bean oil. Soya products are also used to make baby food, diet-food products, beer and ale and noodles. Technical uses include adhesives, cleansing materials, polyesters and other textiles (FAO, 2007).

Indeed the economic viability of soya production is determined by the commercial utilization of both its subproducts, meal and oil, which, respectively, account for about two-thirds and one-third of the crop's economic value. High investment costs involved in soya bean cultivation, storage, crushing and marketing have fostered vertical integration within the sector as well as horizontal operations across commodity sectors and countries.

The crop is an easy-to-grow rotation crop for the millions of hectares in cereal and root crop production. There are, in some cases, other options for rotation crops, but soya bean can be a good choice especially when other legumes are

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*Contributed for research and discussion.

subject to heavy insect and disease pressures and where there is a clear market link from the grower to the industry.

Against this backcloth, transgenic soya has been grown internationally since 1996 (Brookes & Barfoot, 2006) and now accounts for 73% of all plantings worldwide. Herbicide-tolerant (HT) soya bean, largely the RoundupReady® Soya bean from Monsanto, is often viewed as the most important biotech crop, and in 2009 the crop occupied 69 Mha worldwide, compared with 26 Mha of conventional soya bean (James, 2009). Bernard *et al.* (2004) analysed survey data from farms in Delaware, USA, and found consistent improvement in yield from HT soya beans, in addition to consistent reduction in weed control costs. However, no transgenic soya is currently cultivated in the EU, although three transgenic varieties are approved for import.

The economics of growing transgenic crops has been reviewed elsewhere (Park *et al.*, 2011); Demont *et al.* (2007) estimated that, worldwide, two-thirds of benefits are shared between farmers and consumers, one-third being retained by input suppliers, and the ratio is similar in Europe, with about 38% retained by suppliers. The sharing ratio, and specifically the consumer benefit, was confirmed by Moschini (2008), and Qaim (2009) pointed out that transgenic crops contribute to global food security and poverty reduction, with over-regulation being a threat to further progress. Concern has been expressed about the effects of transgenic crops in general on biodiversity (Altieri, 2009), but James (2009) reported the continuing pace of growth in adoption of GM crops, and the US Board on Agriculture and Natural Resources (2010) quantified benefits for farmers in the United States.

Issues surrounding authorization of cultivation of transgenic crops within Member States of the EU await resolution; a proposal made by the European Commission (EC) that Member States issue local authorizations is being challenged (GMO-Compass, 2010a).

This paper reviews the extent to which transgenic soya beans have become the ‘conventional’ method of cultivation elsewhere, and notes implications this has for livestock nutrition, traceability and economics within the EU. The paper concludes with discussion regarding the implications for the EU of delayed acceptance of newly available transgenic traits.

Transgenic soya bean

Farmers generally welcome the agronomic opportunities provided by transgenic soya beans as a rotation crop (Norsworthy, 2003; Qaim, 2009). Piggott and Marra (2008) reviewed non-pecuniary benefits of transgenic crops using survey data and found that farmers valued the convenience of RoundupReady® soya beans in allowing herbicide applications that consist of using a spray boom that can spray up to 20 rows at a time, and at a much higher ground speed, when compared with a post-directed application, which is the only post-emergence option for conventional soya beans.

Where herbicides are used as integral parts of biotechnology-based weed management strategy, an environmental risk assessment must also consider their potential impact on biodiversity under Directive 2001/18/EC (EFSA, 2009), although glyphosate is in US EPA toxicity class III on a scale of I–IV (where IV is the least dangerous). In relation to toxicity, Kleter *et al.* (2008) have shown that the use of glyphosate on HT transgenic crops has improved Environmental Index Quotients compared with comparable conventional herbicides.

Regarding the growing concern that reliance on glyphosate is leading to emergence of resistant weeds, seed providers are seeking to introduce soya beans tolerant to alternative herbicides. Field studies of soya bean crops in northern and southern regions of the United States reported by Scursoni *et al.* (2006) indicated that in northern temperate agro ecosystems, one-pass glyphosate management systems in HT crops may serve agronomic and environmental needs simultaneously. Also in North America, Bertram and Pedersen (2004) found that the impact on the weed community is mainly due to changes in the management system (i.e. rotations, tillage systems and herbicides strategies).

Soya beans were the largest of EU agricultural imports during the decade from 1999 to 2008, with imports of soya-based feed increasing by 7 Mt, and in soya bean oil the EU went from being a net exporter to a major importer during that period (von Witzke & Noleppa, 2010). EU Member States currently import annually approximately 40 Mt of soya material. Three HT soya bean varieties are approved for food and feed import and processing; these are MON40-3-2 RoundupReady® (approved before Regulation 1829/2003), Bayer A2704-12 Liberty Link and MON89788 RoundupReady2Yield.

Without the protein offered by soya, Europe would not be able to maintain its current level of livestock productivity (ISAAA, 2006; Peisker, 2009). The EU is self-sufficient in vegetable oil production, but its protein deficit still makes it the world’s largest importer of soya bean meal and second-largest importer of soya beans.

Gryson *et al.* (2009) noted, as mentioned above, that EU regulations have allowed the placing on the European market of transgenic products in food and feed chains, and have defined their rules of traceability and labelling. For some supply chains, such as for derived products that are used in the production of feed, manufacturers have to face both non-transgenic and transgenic production, although there are no labelling requirements for animal products derived from animals fed with genetically modified organisms (GMOs) (GMO-Compass, 2007). Quantitative methods for detection of GMOs in food and feed were assessed by Marmiroli *et al.* (2008), who commented on the issues of liability and redress surrounding international trade.

According to the EU Joint Research Centre (JRC) (Stein & Rodriguez-Cerezo, 2009) only one transgenic soya bean event was available worldwide in 2008, with two further events approved and four in the regulatory pipeline, but they predict that the total will increase to 17 by 2015. This suggests that transgenic soya bean will be playing an increasing role within EU livestock nutrition, with associated traceability issues.

Livestock nutrition and feed traceability

Approximately 400 Mt of oilseeds were produced worldwide in 2009; soya beans represented 53% of the total, followed by rapeseed, cottonseed, peanut, sunflower seed and palm kernel that contributed 15%, 10%, 9%, 8% and 3%, respectively, of the total global production, according to the American Soybean Association (ASA, 2010).

There is a complex network of worldwide supply chains for soya beans and related products, illustrated in Figure 1. Products are consumed in four broad categories, in order of importance:

- livestock feed,
- protein for human consumption,
- oil for human consumption,
- feedstock for biofuel.

In each category there is competition for market share from alternative products from various other sources; in every category soya beans command a major share of the market.

Five countries, the United States, Brazil, Argentina, Paraguay and Canada dominated global soya bean exports which were 77 Mt in 2009 (ASA, 2010). Of the 44 Mha of soya beans grown in these countries, 84% are transgenic, and are responsible for approximately 90% of world exports of soya beans and soya bean oil. A large but declining proportion of the soya bean exports from Brazil, Argentina and Paraguay are imported by EU, as illustrated in Figure 2.

Organizations in these countries are able to exploit economies of scale. For instance Newell (2009) presented a case study of the role of large Argentinian agribusiness companies that cultivate and export transgenic crops, drawing on interviews with public-sector and private-sector actors in biotechnology in Argentina. Newell noted that large-scale transgenic soya bean cultivation was established in 1996, and made up almost half of Argentina's agricultural output in 2002–2003; 98% of this was exported, in the form of beans, feed meal and edible oil.

Soya bean meal is the product remaining after extracting most of the oil from whole soya beans. The oil may be removed by solvent extraction or by an expeller process in which the beans are heated and squeezed. The protein content of solvent extracted soya bean meal is about 48%, and is the preferred protein supplement for livestock production. Approximately 60–70% of this soya bean meal is used in poultry and pig rations and 15–20% is used in beef and dairy cow rations. Soya bean meal is nutritionally superior to other oil seeds meals as it has an excellent amino acid profile containing all essential amino acids. Soya bean meal is the dominant protein supplement used in US livestock and poultry feeds; 33.4 Mt of soya bean meal were used in 2008 in total consumption of 41.3 Mt of high-protein feed (USDA, 2009).

Particular advantages of soya bean meal have been described in numerous studies, including Wilcox and Shibles (2001) and Dilger *et al.* (2004). These studies make no distinction between transgenic and conventional soya bean. At a physiological level, Phipps *et al.* (2003) addressed the question as to whether transgenic DNA could be transferred to and accumulate in milk, meat or eggs. They confirmed that transgenic DNA could not be detected in milk derived from animals receiving diets containing GM feed ingredients. The DNA is detectable in the duodenum, but they concluded that this presents no risk of contamination of any food products derived from the animal. Similarly, Jennings *et al.* (2003) investigated the digestive fate of protein from transgenic feed fed to pigs, and demonstrated that no immunoreactive fragments of transgenic protein are detectable in pigs fed a diet-containing RoundupReady® soya bean meal. Later studies quoted by Guertler *et al.* (2010) have confirmed these findings; Agodi *et al.* (2006) found GM maize and soya bean DNA sequences in samples of milk from the Italian market, but the results have not been replicated, and Agodi and colleagues commented that the results could have been a consequence of sample contamination.

Despite these studies, which show no trace of transgenic protein in meat and milk products there is still very tight

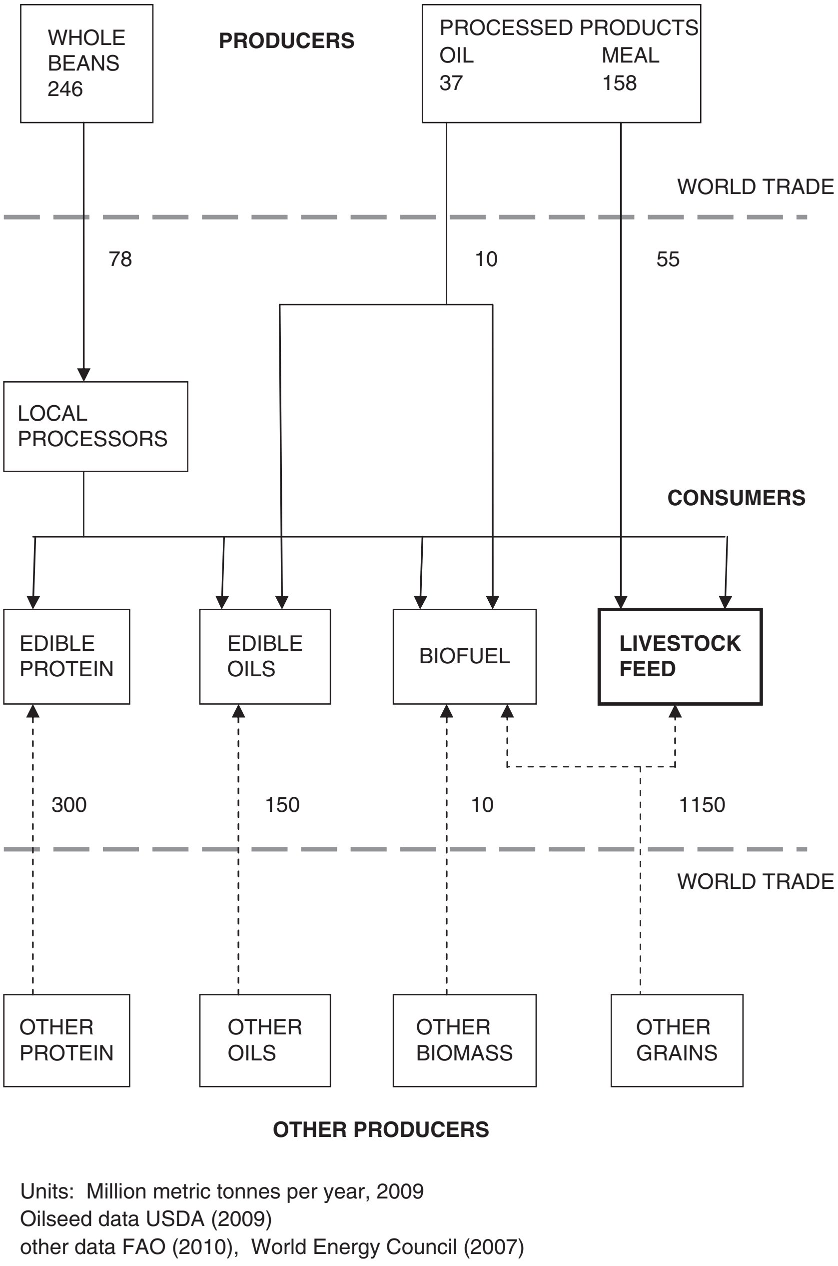

Figure 1 Supply chains schematic, world soya production and consumption compared with alternative inputs.

regulation regarding the import of transgenic soya. The traceability and labelling of transgenic crop products is summarized in an overview of EU legislation issued by the EC JRC (Plan & Van den Eede, 2010). For traceability, it is mandatory that all persons who sell or buy transgenic crop products (operators) make and retain a record of each transaction, with the unique GMO identifier, and that the record is available to public authorities on demand.

Devos *et al*. (2006) discussed the refinement of regulations regarding cultivation and use of transgenic crops in Europe in the context of public distrust towards developments in biotechnology. EU Regulation 258/97 (the so-called 'Novel Food Regulation') covered the safety assessment and labelling of transgenic foods, on the principle of substantial equivalence between a transgenic foodstuff and its non-transgenic counterpart. The subsequent Regulation 1830/2003 extended the labelling provisions, indirectly introducing the need for traceability 'from farm to fork': specific information is transmitted throughout the production and supply chains. The preamble to 1830/2003 said that

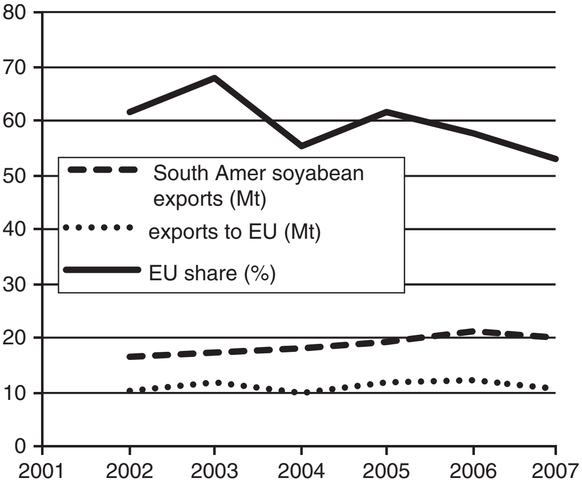

Figure 2 European proportion of South American soya bean exports. *Source*: FAOSTAT.

'traceability should facilitate the implementation of risk-management measures in accordance with the precautionary principle.'

Aramyan *et al.* (2009) presented results derived using a model of a three-tier soya bean supply chain representing producers outside EU, EU importers and feed producers. Different scenarios based on varying tolerance thresholds and varying world-traded quantities of EU-unapproved soya beans were assessed; Aramyan and colleagues concluded that the duration of the EU approval process has more impact on availability and price of EU-approved imports than adjustment of tolerance thresholds. Supply problems are alleviated if EU transgenic-event approval is given simultaneously with approval in supplying countries, in particular Brazil. However, delay on the part of the EU (so-called asynchronous approval) may be costly to EU livestock farmers and consumers by denying access to potentially cheaper soya imports.

Economic impacts, use in biodiesel and EU cultivation

There is ample evidence of the economic benefits of transgenic soya. Konduru *et al.* (2008) reviewed the global economic impacts of RoundupReady® soya beans, and noted that adoption has been associated with non-pecuniary benefits such as ease of use, decrease in health risk for operators and environmental advantages. In modelling yield trends they assumed that HT and conventional soya beans have comparable yields. Trigo and Cap (2003) reported cost reductions of about US\$20 ha^{-1}, mainly because of the reduction in energy costs resulting from more effective weed management techniques. At the same time, there was synergy with no-till practices, which facilitated the incorporation of double-cropping soya beans. Konduru and colleagues concluded that the combination of savings in weed control with tillage benefits was worth US\$28 ha^{-1} to Argentine farmers in 2006. Bonny (2009) noted a global reduction in herbicide treatment costs for all soya bean producers after glyphosate patents expired in 2000, whether they used transgenic varieties or not. Herbicide prices have increased since these assessments, notably in 2008, enhancing the benefit to farmers of reductions in herbicide use.

Although some transgenic soya bean products have been authorized for import, the presence of non-approved GMOs, even in tiny amounts, leads to entire shipments being rejected. Feed industry and grain trade associations suggest that the EU farming sector need to import 6–7.5 Mt soya beans in 2010. These associations continue to seek approval of a workable low-level presence of GMOs to allow urgently needed imports of soya-based feed ingredients.

In a declaration following a meeting of EU GM-Free Regions' Network (GM-Free Ireland, 2007) it was recognized that tensions exist in relations with soya bean meal producing countries, demonstrating that the agricultural use of GMOs is an issue of utmost commercial and strategic importance, both in terms of production and as regards the environmental, economic, social and territorial sustainability of regional and European economies. The meeting was told that the 2007 make-up of animal feed in the then EU-25 countries was 49% fodder, 19% home-produced cereals and 30% compound feed (of which 85% is GM). The premium for non-GM soya was around €22 t^{-1}. It is likely that the premium has imposed cost pressure on users of non-GM soya in countries such as India who would otherwise be unaffected. Europe's seed crushing industry has an annual turnover of about €20 billion, and last year imported some 13 Mt of soya beans, producing 10 Mt of animal feed meal and 2.5 Mt of oil, almost half of which was used in food (FEDIOL, 2010).

Biofuels present another complicating factor. A review of agricultural commodity markets in 2009 (FAO, 2009) noted the distortion of otherwise normal market forces that has resulted from government subsidies for biofuel feedstock. The United States spent US\$5.8 billion on biofuel subsidies in 2006 while the EU spent US\$4.7 billion. The complex supply chains in Figure 1 have been altered by a surge in demand for biofuel feedstock, though van der Hilst *et al.* (2010) have shown that biofuel production from biomass cultivation in northern Europe is far from becoming economically viable, and the impact of biofuel demand is

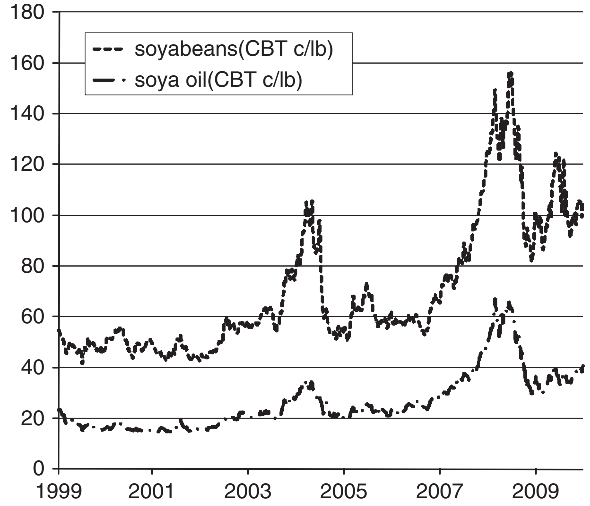

Figure 3 Soya bean and soya oil price trends.

unlikely to be sufficient to alter the pattern of trade illustrated in Figure 1. With the exception of ethanol production from sugar cane in Brazil, no biofuel is currently economically sustainable without subsidies.

Despite this, EU biodiesel policies have encouraged EU farmers to increase oilseeds area, especially rapeseed. Trade in whole oilseeds, particularly soya beans, is relatively unrestricted, but oilseed meals are subject to tariffs. Soya bean prices (in Chicago) were relatively stable from 1999 until 2007, apart from a period of shortage in 2003–2004, when poor harvests led to simultaneous price rises in wheat and corn as well as soya beans. The price of soya-based oil is closely correlated with soya bean prices, as illustrated in Figure 3. Soya prices also correlate with the price of maize (corn) and to some extent with the price of crude oil (Figure 4).

Further, while soya bean is not currently regarded as a major crop within the EU, eight EU countries grew conventional soya bean in the years 2003–2009, as shown in Table 1. The quantity produced is small in comparison with worldwide production. Table 2 shows annual production of soya beans in EU, and also the consumption of soya bean meal in EU, South America and the United States, together with the EU imports and American exports. It is clear from Table 2 that even when GM soya bean varieties are approved for cultivation in EU, it is unlikely that EU will ever be self-sufficient in soya beans for processing to provide high-protein feed, and considerable imports of soya bean or soya bean meal will still be required.

Of the eight countries listed in Table 1, Brookes (2009) reported selling price in just four countries in 2008/2009: 290€ t^{-1} in Hungary, 282€ t^{-1} in France, 240€ t^{-1} in Austria and 223€ t^{-1} in Romania. Using these prices coupled with

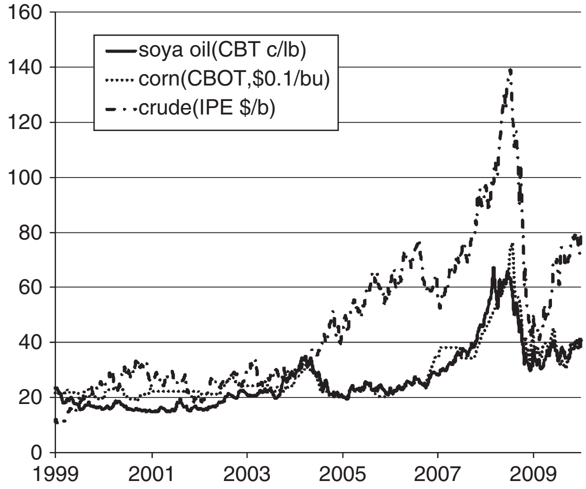

Figure 4 Soya, maize and crude oil price trends.

Table 1 European soya beans, by area

	× 1000 ha						
	2003	2004	2005	2006	2007	2008	2009
Italy	152	150	152	178	130	108	135
Romania	129	121	143	191	133	50	49
France	81	59	57	45	32	22	44
Croatia	50	37	48	63	47	36	43
Hungary	30	27	34	36	33	29	31
Austria	16	18	21	25	20	18	25
Slovakia	11	9	11	12	8	5	10
Czech Republic	8	9	9	10	8	4	6

Source. Eurostat (2010).

Table 2 Soya bean meal consumption and trade

	Mt							
	2000	2001	2002	2003	2004	2005	2006	2007
EU 27								
Soya bean production	1.9	2.1	2.0	1.9	2.5	3.1	3.6	2.6
EU 27								
Meal								
Imports	21.2	24.8	26.8	28.0	28.7	29.8	30.9	32.2
Consumption	28.6	32.9	34.1	34.8	33.2	33.6	34.3	36.5
South America								
Meal								
Consumption	8.4	7.2	9.1	9.9	10.0	11.0	11.7	14.6
Exports	23.4	27.2	30.3	34.0	34.5	37.0	38.2	40.4
USA								
Meal								
Consumption	29.8	29.7	29.5	27.8	33.1	32.4	32.0	33.0
Exports	5.9	6.9	5.3	5.3	4.1	5.1	6.0	6.4

Source. FAOSTAT.

other survey data, Brookes calculated a gross margin after all costs and excluding subsidies of about €60 t^{-1} in Romania, France and Austria, and about €150 t^{-1} in Hungary in 2008/2009. If the advantage of transgenic soya beans to farmers in Argentina, estimated by Konduru and colleagues, of US$28 ha^{-1} could be achieved in Europe, where yields of conventional soya beans are in the range 2–4 t ha^{-1}, then net benefit for farmers in EU may result. In 2005 the 27 countries of the EU grew soya beans on 431 kha (Eurostat, 2010), so the advantage to Europe of achieving improvement worth €20 ha^{-1} could be €8.6 M in a normal year from crops worth €250 t^{-1} with average yield of 3 t ha^{-1}, thus having sales value of €(250 × 3 × 431 000) or about €320 M. This represents an increase in revenue of about (8.6/320) or 2.7%, but improving farmers' gross margin by up to one-third.

Discussion and concluding remarks

We have reviewed the importance of the cultivation of transgenic soya bean internationally. Transgenic soya now accounts for 73% of world soya production, and this is likely to increase as new traits become available. Varieties approved for import into the EU are currently limited and it is likely that there will be a lag in approval of new varieties grown in areas from which the EU is a major importer. In combination with other factors such as biofuel policy and the potential for cultivation within the EU, the cost of feed in world markets will have continuing impacts on the economics of livestock production in the EU.

If offered the opportunity to cultivate HT soya beans, arable farmers in EU may not consider it a viable option given the need to take account of the cost of complying with coexistence regulations in their country or region. The European Coexistence Bureau has been established jointly by EU Directorate General for Agriculture and Rural Development and the JRC of the EC. Non-binding recommendations such as a Best Practice Document for cultivation of GM maize have been put forward by European Coexistence Bureau (2010), to help Member States develop their own coexistence guidelines, which are likely to depend on the reproductive biology of the crop (GMO-Compass, 2010b) and may also vary with shape and size of fields. For soya beans, as pointed out in a report from the Plant Research Institute, Wageningen (Bindraban *et al.*, 2009), coexistence in the field is easily achieved, because soya is a self-pollinator, with outcrossing levels on average in the order of 1%.

European livestock farmers will be increasingly at a disadvantage if EU approval of transgenic soya bean events already authorized for cultivation in North and South America continues to be subject to long delays. There is declining incentive for growers elsewhere to operate controls that enable EU-approved varieties to be supplied, when demand is expanding elsewhere that is free of such restriction. It is a direct consequence of delay in EU approval that European livestock farmers will be denied access to lower-cost feed supplies available to their competitors in world markets.

Internationally there is a marked increase in use of transgenic crops containing stacked traits, such as HT and *Bt* traits in combination; these now contribute a higher proportion of the total area than crops modified for just *Bt*. Between 2007 and 2008 the area of transgenic maize grown in the United States with three inserted traits increased from 28% to 48% (James, 2009) and this trend is likely to increase. Multiple traits provide an additional safeguard against the development of resistance, by reducing the probability of appearance of HT weeds, but they are likely to lead to even greater delays in approving transgenic varieties in EU, where stacked traits in a new variety have to be risk assessed for any interactions between the stacked events which could impact on human or animal health and/or the environment (EFSA, 2007).

Recent work has focused on the use of biotechnology to produce abiotic stress tolerant and nutritionally enhanced food and feed with a range of new events being predicted by 2015; Stein and Rodriguez-Cerezo (2009) commented that:

> While currently there are around 30 commercial GM "events" worldwide, it is expected that by 2015 there will be over 120. Given that already with 30 events problems of low level presence have occurred, these issues are likely to intensify when more events become available in more countries – especially if individual events are combined ("stacked"). Solutions suggested by stakeholders surveyed in our study are to replace zero tolerance policies by feasible marketing thresholds, to carry out official testing of imports already at the port of departure, to streamline the regulatory systems and to mutually recognise the risk assessment of GM crops.

If EU authorities continue to delay approval of transgenic traits newly introduced for producers of soya beans elsewhere, EU livestock farmers will continue to be denied access to the most competitively priced feeds on world markets. The expected arrival, forecast by Stein and Rodriguez-Cerezo, of many new transgenic traits and the stacking of new with existing traits will make it almost impossible for

EU to import soya beans or soya bean meal which can be guaranteed 100% free of unapproved traits from countries where the traits have been introduced.

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