AgBioForum – Volume 4, Number 1 – 2001 – Pages 4-13

INNOVATION CHALLENGES FOR THE EUROPEAN AGBIOTECH INDUSTRY

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The European seed and pesticide industries have gone through a period of great turmoil in the last decade of the twentieth century. Restructuring processes have been thoroughly influenced by the developments in plant biotechnology. Also changes in the consumer market for food products and changes in government policies have led producers of plant protection products (PPPs) and producers of seeds to reconsider their innovation activities. The agrochemical companies are the main drivers behind the integration of pesticides, biotechnology, and seeds.

This article analyzes the innovation strategies of the European plant biotechnology industry. Innovation is a multidimensional activity. Firm strategies for developing and introducing new products and processes are determined by at least three factors: path, position, and process (Teece *et al*., 1997). Path refers to the body of knowledge and experience a firm incorporates, and the path dependencies that result from existing knowledge and routines. Position refers to the current products a firm sells and the position it has in particular markets. It also refers to the products it wants to sell, and the effort needed to establish a position in a new market. Process refers to the organization of innovation: to decision-making, information exchange, coordination, and incentive alignment. With insight in path, position, and process the main part of innovation strategies of firms can be explained. While processes have also been studied in the Policy Influences on Technology for Agriculture (PITA) project, this article focuses on positions and paths.

The next section introduces the European companies that have been studied within the PITA project. These firms are among the largest in the world in the pesticide industry and the seed industry. The third section focuses on the innovation strategies of these companies. The fourth section describes the main developments in the environment in which these firms are operating. Both markets for plant protection products and seeds, and government policies regulating these markets, are discussed. The last section gives conclusions, stressing the uncertainties that European firms in the agricultural biotechnology industry continue to face.

Biotechnology, Seeds, And Plant Protection In Europe

Historically, one can distinguish three types of firms that have been developing plant biotechnology products: new biotechnology firms (NBFs), agrochemical companies, and seed companies. In plant biotechnology only a small number NBFs have been established in Europe. Most of these firms have focused on enabling techniques (e.g., genetic markers) for the development of new plant varieties and new PPPs. A notable exception is Plant Genetic Systems (PGS) of Belgium. This small company, established in 1983 by researchers from the University of Ghent, has made a major contribution to the European plant biotechnology industry. Plant Genetic Systems has developed and acquired major

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patents for herbicide-tolerant plants, insect-resistant plants, and transgenic hybrid plants. In 1996, PGS was acquired by the German agrochemical company AgrEvo. The herbicide for which PGS has developed tolerant plants is glufosinate (brand names Basta, Finale, and Liberty), produced by AgrEvo—which is now Aventis. The biotechnology products developed by PGS are now marketed by Aventis under the names of LibertyLink for herbicide-tolerant crops, StarLink for insect-resistant crops (e.g., corn), and SeedLink for transgenic hybrids (e.g., canola).

Producers of plant protection products have been the main private investors in plant biotechnology. Already in the 1980s, companies like Sandoz and Ciba Geigy (later merged into Novartis) of Switzerland, Shell and ICI/Zeneca of the United Kingdom (UK), Hoechst (later AgrEvo) of Germany, and Rhône-Poulenc, and Sanofi of France acknowledged the potentials of biotechnology for their innovation activities. Some of these companies have later divested their agrochemical divisions, thereby discontinuing plant biotechnology research. Interestingly, some producers of plant protection products have only recently invested in biotechnology, like BASF and Bayer in Germany.

European producers of plant protection products are among the largest in the world. In 1998, out of the top 10 of global pesticide companies, six were headquartered in Europe. These were all studied in the PITA project. After further mergers and acquisitions in 1999 and 2000, the top 10 of the world's largest producers of plant protection products contains seven companies fully dedicated to innovation. Four of these companies are European and three are American (table 1). Aventis was formed by the December 1999 merger of Rhône-Poulenc and Hoechst. Aventis CropScience combines the crop protection activities of Rhône-Poulenc Agro and AgrEvo. Syngenta is the result of the October 2000 merger between Novartis Agribusiness and Zeneca Agrochemicals. BASF has acquired Cyanamid in July 2000. Cyanamid was the agrochemical division of American Home Products (United States (US)). The seven largest companies now account for 72 percent of the US$ 30 billion (or Euro 32.6 billion) world pesticide market.[1]

Restructuring and concentration processes in the agrochemicals industry have been profound. In the early 1990s, worldwide there were still ten to fifteen companies with the resources to develop new active ingredients. Studying the restructuring process in the first half of the 1990s, Hartnell (1996) forecasted that as few as seven major agrochemicals companies would survive past the year 2010. As shown by table 1, this number has already been reached in the year 2000. The other three companies in the top 10 are mainly generic pesticides producers.

There are several reasons for European producers of plant protection products to invest in biotechnology. First, the slow-down in market growth, at least in developed countries, caused firms to reconsider their strategies. This slow-down was due to the end of production growth in agriculture and to low prices for agricultural products forcing farmers to economize on plant protection. Second, societal concern about the negative environmental impact of chemical plant protection products, as expressed by strong environmental non-governmental organizations (NGOs), led to more stringent environmental policies. Third, the potential of biotechnology opened new opportunities for (integrated) crop protection methods. Thus, market, regulatory, and technology developments provided the incentives for the European pesticide industry to look beyond the traditional focus on active ingredient development.

Producers of plant protection products investing in biotechnology research realized that the route for commercialization of research outcome was through the seed (Kloppenburg, 1988). Full exploitation of the commercial opportunities of plant biotechnology research required access to existing and new varieties of agricultural and horticultural crops. Thus, seed companies became a major target for strategic alliances and acquisitions.

Table 1: World Top 10 Pesticide Producers (2000).

Company	Pesticide Sales[1] (in Million US$)
Syngenta (Switzerland)[2]	5,888
Aventis CropScience (France)	3,534
Monsanto (US)	3,531
Bayer (Germany	2,274
BASF (Germany)[3]	2,248
Dow AgroSciences (US)	2,086
DuPont (US)	2,013
Sumitomo Chemical (Japan)	780
Makhtesim-Agan (Israel)	738
FMC (US)	665

Note. [1] Sales figures do not include seed sales. [2] Syngenta: proforma sales, excluding divested products. [3] BASF's sales include half a year of Cyanamid sales. From Wood Mackenzie (personal communication, April 27, 2001).

Independently, the European seed industry has also invested in biotechnology, but on a much smaller scale than the agrochemical industry. Although seed companies looked upon biotechnology as a promising technology for developing new crop varieties, the high cost of biotechnology research and development (R&D) led to limited investments. Also the many uncertainties about public acceptance, patent positions, and regulation forced seed companies to be reserved. Still, seed companies had access to the latest techniques through their relationship with public agricultural research institutes. Many government subsidy programs for the development of (applied) biotechnology were explicitly designed for the collaboration between seed companies and public research institutes. This was particularly the case in France and the Netherlands, and later also in Germany.

The European seed companies in the PITA sample were (in order of size): Novartis (Switzerland), Limagrain (France), Advanta (Netherlands), KWS (Germany), AgrEvo (Germany), Cebeco (Netherlands) and Danisco (Denmark). Table 2 shows what position these companies (or their successors) hold on the top eleven of largest seed companies.[2] European companies are less dominant in the seed industry than in the pesticide industry. American companies like Pioneer and Monsanto have profited from the sheer size of the North American market. The third position of Syngenta is also due to its market share on the North American continent. The total seed industry is less concentrated than the pesticide industry. Figures on the size of the world commercial seed market differ substantially. According to the Rural Advancement Foundation International (RAFI) (2000) the world market is 25 billion US$, while industry representatives indicate a total market size of US$ 15 billion. In the first case, the top 10 companies would have a 30 percent share of the market, while in the second case they would be responsible for 50 percent of the market.

How European are these companies? The pesticide industry really is a global industry. The costs of developing a new compound are so high that a worldwide presence is needed to earn back R&D investments. Moreover, given the high costs, new compounds are only developed for the major crops in the world, like corn, wheat, soybeans, and cotton. Thus, all companies have a position in the main production regions for these crops. This is equally valid for European and non-European companies. Figure 1 shows that the European market accounts for less than 50 percent of sales for all pesticide producers. Zeneca Agrochemicals and Novartis generate more than 70 percent of turnover outside of the European market. The recent acquisition of Cyanamid can be explained by the desire of BASF to enlarge its position in the North America market (this acquisition is not included in the data of figure 1). An interesting difference between the European and the North American pesticide market is the relative importance of various products. In Europe, fungicides are relatively more important, while in North America herbicides are relatively more important. European companies traditionally have a strong position in fungicides, while US companies (particularly Monsanto and DuPont) have a bias towards herbicides. As herbicides are by far the largest product group (more than half of the total pesticide market), European companies have been expanding in North America to benefit from this large herbicide market and to complete their product portfolio.

Table 2: The Top 11 in the World Seed Industry (1999).

Company	Parent Company/Companies	Seed Sales (in Million US$)
Pioneer Hi-Bred (US)	DuPont	1,850
Monsanto (US)	Pharmacia	1,700
Syngenta (Switzerland)	Novartis and AstraZeneca	947
Limagrain (France)	Limigrain cooperative	700
Seminis (US)	SAVIA/Grupo Pulsar	531
Advanta (Netherlands)	Cosun and AstraZeneca	416
Sakata (Japan)	Sakata	396
KWS (Germany)	KWS	355
Dow AgroSciences (US)	Dow Chemical	350
Delta & Pine Land (US)	Delta & Pine Land	301
Aventis CropScience (France)	Aventis	288

Note. From "The Seed Giant – Who Owns Whom?" (Seed Industry Consolidation Update) by Rural Advancement Foundation International (RAFI), 2000. Winnipeg, Canada: RAFI. Available on the World Wide Web: http://www.rafi.org/web/docus/pdfs/masterseed2000.pdf.

Of the specialized seed companies, only Advanta has a substantial presence outside of Europe. Zeneca Seeds, one of the two companies that merged into Advanta in 1996, already had a major position on the North American market with its subsidiaries Garst and Zeneca Seeds Canada. The companies in the right upper corner of figure 1 can be considered as truly European.

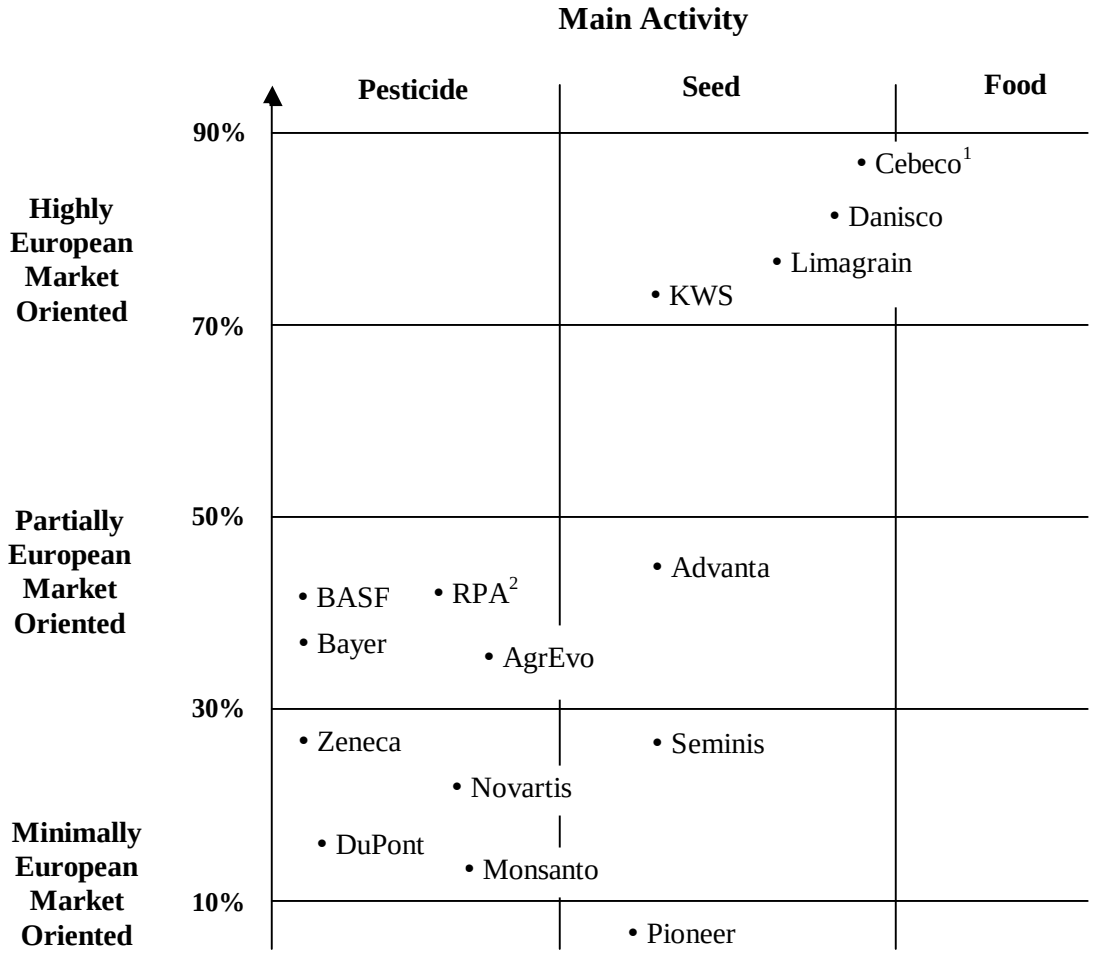
Innovation Strategies

The innovation strategies of the European agrochemical and seed companies, as studied in the PITA project, show significant diversity. Technological trajectories in the pesticide industry, with its focus on scientific research and large-scale industrial production, are quite different from those in the seed

industry, which has its background in farming and experience-based innovation. Even within the two industries under study, substantial differences occur, due to the history of the company, its product portfolio and main markets, and its internal organization. Given that Europe consists of many different countries and cultures, nationality has always been important, not only because the domestic market affects the kind of products, and the culture of business, but also because of special relationships with regulatory agencies. Despite all these difference, similarities within the agrochemical industry and within the seed industry do exist.

Traditionally, innovation in the agrochemical industry had a strong focus on finding new active ingredients of Plant protection products. This focus on new chemical compounds shares similarities with new chemical entity innovation in the pharmaceutical industry. Both industries are science based, highly R&D intensive and crucially dependent on patent protection. Innovation in the agrochemical industry operates within a framework determined by the interaction of the regulatory system (for registering new products), the patenting system (for granting temporary monopolies to appropriate the benefits of new products) and market competition (Hartnell, 1996).

Figure 1: European Share of Company Sales and Main Field of Activity



Note. [1] Cebeco has a small pesticide subsidiary (Luxan), but it is minor compared to seed.
[2] RPA = Rhône Poulenc Agro.

In recent years, other factors have been added to the innovation challenges in the pesticides industry. First, plant biotechnology has transformed the knowledge base on which innovation is built. The next phase in biotechnology, functional genomics, will generate even more knowledge of the interaction between chemicals and the working of plant genes. Second, within the agrifood sector the balance of power is shifting from production to consumption, and from quantity to quality. This development has greatly broadened the range of stakeholders a producer of plant protection products has to take into account. Third, in agriculture and society at large integrated pest management (IPM) has become the dominant cognitive frame within which plant protection products have to fit.

Searching for new active ingredients, particularly for so-called "blockbusters," remains a strong focusing device in the agrochemical industry. The imperative to find and develop "champion" products is reinforced by the conjuncture of three factors: increasing regulatory costs, slow global market growth, and industry consolidation. New strategies for the development of agrochemicals are based on spinout technology from the pharmaceutical industry. These technologies are high throughput screening, combinatorial chemistry, and gene mapping of host and pest organisms. The creation of new active ingredients as the dominant design of innovation is very much associated with the laboratory-based knowledge of organic chemistry and with the related analytical approach of the invention. The "one problem - one solution" cognitive frame hardly takes into account systemic interactions related to the dynamics of ecosystems.

Although not contradictory, the development of IPM systems appears as a marginal road in the technological trajectories, and faces major cognitive and organizational constraints. Moreover, the move towards greater use of services (as implied by integrated crop protection) brings forward problems of economic pay-off. Farmers are not used to paying for services, and once knowledge has been transferred, farmers can continue using it without having to return to the original source. Thus, appropriability of research findings is rather difficult once physical products (pesticides) are substituted by services (IPM). Other elements that reinforce path dependency in agricultural pest control are uncertainty at the farm level and coordination problems in moving from one system (or configuration) to another (Cowan & Gunby, 1996).

Although the seed industry shares the need for long-term investments with the agrochemical industry, it has a rather different tradition of innovation processes. Seed firms have traditionally been small-scale family-owned businesses, operating in close interaction with its farmer-customers. Innovation has been mainly incremental, building on existing firm-specific germplasm. Plant breeding is an ongoing evolutionary process of creating variation (by making crosses and inducing mutation) and making selections. To a large extend, knowledge is embodied in the plant breeder himself, who makes the choices in crossing and selection. Once selection choices have been made, it is not easy to change the goals of the breeding program. Long term commitment is a basic element of the corporate culture of any seed company. In Europe, new varieties ready for commercialization receive protection under plant breeders' rights, which entails a regulatory regime far weaker than patent protection. Public research institutes have always played a major role in developing new techniques to be used in plant breeding, and for some crops even develop new varieties. Therefore, close interaction has always existed between the seed industry and the public agricultural research community.

All seed companies now use certain biotechnology techniques, like molecular markers and cell and tissue culture, to speed the development of new varieties, to improve the targeting of specific traits, and to enhance research capabilities. The use of genetic engineering to develop genetically modified crops generally has been done in association with NBFs, public research institutes, or large agrochemical companies. The strategy of introducing genetically modified (GM) crops holds significant risks for a seed company. Once a variety has been genetically modified, it cannot be used any more for breeding conventional varieties. In a market with great uncertainties, as is currently the

situation in Europe, seed companies developing GM varieties also want to maintain conventional varieties, which raises R&D costs.

Thus, the new agro-biotechnology trajectory is bringing together the agrochemical industry and the seed industries with their different traditions, cultures, and knowledge bases, and different modes of interaction with the regulatory environment. This process of integration is creating serious strains in both sectors. As shown in other papers in this issue, each company has its own way of dealing with these challenges.

The newly formed integrated agrochemical/seed companies are focusing more and more on the crop instead of on the pesticide. Biotechnology provides the opportunity to develop integrated solutions of pest control, by combining natural resistance embodied in the variety with chemicals sprayed, either to directly kill the pest organism or to trigger a pest-resistance mechanism incorporated in the plant. Because of the appropriation problem, agrochemicals continue to be important for agrobiotechnology firms, but only in combination with some kind of control over variety development and seed marketing.

A Changing Market And Policy Environment

Innovation in the European plant biotechnology industry is strongly influenced by government regulation. Stringent registration policies affect innovation in the pesticide industry directly, while environmental policies targeted at farming affect producers of plant protection products indirectly. Seed companies have reacted to environmental policies by putting more emphasis on resistance in the mix of breeding goals they pursue. Other forms of regulation affecting innovation in the agrochemical and seed industry are intellectual property rights. The shift from plant breeders' rights to patents seems to be more beneficial for agrochemical companies than for seed companies. Currently by far the most influential element of government policy for the European agrobiotechnology industry is the regulation of genetically modified organisms (GMOs).

The PITA project has focused on the following government policies most relevant for the agbiotech industry: policies to stimulate science, technology, and innovation; policies to support farm income, including regulation of international trade; and policies to regulate industry and farming in order to protect human health and the environment.

European policies in support of science, (bio)technology, and innovation are directly relevant to companies' R&D programs, which rely on the availability of a good supply of well-trained scientists. This seems to be a major factor in decision-making on where to locate R&D facilities. While some companies emphasized the high quality of biotechnology research at European public research institutes, others have set up their main agbiotech research laboratories in the US (notably Novartis).

For high-cost genomics research requiring substantial collaborative efforts, European companies may be in a disadvantaged position compared to their US competitors. The balkanization of the European research space does not favor EU-wide coordination of public spending. Moreover, the negative public attitude has an adverse influence on public support for R&D in plant genomics at the European level.

Farm policies are indirectly important for producers of plant protection products and seeds. Short-term market and policy fluctuations have little effect on industry innovation strategies as the lead-time for new product development is 10 to 15 years. However, the long term strategy for EU agricultural policy, moving towards improving competitiveness by lower support prices and protecting the rural environment, may have major implications for crop production in the EU and,

hence, for pesticide and seed markets. Policy instruments, such as cross-compliance and agri-environmental programs, have an impact on pesticide use as they provide governments with direct means to control the environmental impact of farming methods. Seed companies significantly oriented towards European markets are most sensitive to these types of policy shifts, which alter the relative competitiveness of the location of production and lead to crop substitutions within a specific region. Common Agricultural Policy (CAP) reforms will thus affect farmers' crop choices as well as the intensity of the production systems. Despite the dynamics, producers of plant protection products and seeds look at shifts in farm policies as predictable changes.

Regulation for the registration of pesticides, meant to protect human and environmental health, has become more stringent, making R&D for new pesticides more expensive. These higher costs reinforce the trend towards consolidation in the agrochemical industry as companies need a larger scale of operation to recoup the cost of registration and testing. According to Tait and Williams (1999), tightening risk regulation may even be beneficial to the large companies, as the prohibition of old chemicals provides an opportunity for new, more expensive products, and as the high cost of R&D and registration creates a barrier to entry. The companies in the PITA sample did not have any problem with the incremental changes in pesticide policies, which they consider of a predictable kind.

Almost unanimously the greatest regulatory concern among company managers was the uncertainty surrounding the system for risk regulation of GM crops in Europe. Uncertainty about the regulatory system is severely inhibiting product development in the long run. Although the length of the product development cycle does give companies some protection against short-term uncertainty, the long-term effect of current innovation choices makes the cost of wrong choices very high (potentially endangering the continuity of the company).

This European problem has been seen as political rather than regulatory, and the solution has been seen to lie mainly in recovering a favorable public opinion for the industry and its products. To achieve this, companies have advocated more effective dialogue with a wider range of stakeholders than had been the case in the past. A second strategy suggested is a stronger focus on second generation GM crops, such as functional foods that are expected to have a greater publicly perceived benefits than the first generation GM crops (which are mainly associated with agronomic benefits).

Changes in secondary markets (beyond the market for plant protection products and seeds) have forced the plant biotechnology industry to reconsider its interaction with various stakeholders. Traditionally, the farmer was the client of the agrochemical and seed company. Nowadays suppliers of inputs also have to take into account the demands of the food industry, the retail industry, and ultimately the consumer. With the shift of dominance to the end of the agrifood chain and with growing consumer concerns, innovation decision making in the agbiotech industry has become much more difficult. While posing serious constraints on conventional strategies, these changes also present opportunities for those companies that are able to mobilize stakeholders to collaborate in the development of crops with specific quality traits. This may generate more added value in the food chain.

The difficulty in public acceptance of GM food products in Europe has already lead to further restructuring of the agbiotech industry. Most producers of plant protection products have been part of so-called life sciences companies. These firms use their knowledge of living organisms to produce seed and agrochemicals for plant production, veterinary products for animals, and diagnostic and therapeutic products for human health care. The basis of the life sciences strategy lies in the synergy effects of using biotechnological knowledge for various products and application. Several European agrochemical and pharmaceutical companies (Novartis, Zeneca, Hoechst/AgrEvo, Bayer and BASF) enthusiastically embraced this strategy.

However, in recent years doubts have been raised about the wisdom of bundling the various life science activities into one company (Bijman, 2001). From the marketing point of view the life science strategy is questioned because the markets for agricultural products and for health products are very different in size, in growth perspective, and in profitability. The markets for agrochemicals, as well as seeds are growing very slowly, if at all, while pharmaceutical markets are growing rapidly. The concerns of the European public about GM crops do not make the prospects of recouping the huge investments of agrochemical companies in biotechnology very promising. Pharmaceutical companies may even consider it a liability to be involved in a business that encounters the degree of opposition aroused by GM crops. Novartis and AstraZeneca were the first to reconsider their life science strategy. In October 2000, they set their agribusiness activities (crop protection, seeds, and plant biotechnology) at arms' length in the newly formed joint venture Syngenta. Aventis will soon follow by divesting its Aventis CropScience. At the same time, BASF has sold its pharmaceuticals division in order to focus on (agro)chemicals and to increase investment in plant biotechnology.

Conclusions

European agbiotech companies have several loyalties: they have a national cultural background, they are dealing with European regulation, and they operate in a global market. National identities may still be important for those companies that generate most of their European turnover in their home country. This is particularly true for some of the German and French companies. National influences may also still be felt in the internal organization of the company, although most companies are now turning to a more international, project-based structure. Successful operation in Europe requires a large degree of sensitivity to European political and regulatory cultures, as well as an active stakeholder approach. While this need is unanimously acknowledged, companies find it very difficult to deal with the uncertainties. The long-term effects of current investment choices in both the agrochemical and seed industries, together with the uncertainties in regulation and public acceptance, make it very difficult for these companies to decide on innovation strategies. For companies operating on a world scale, challenges lie in how to deal with different regulatory regimes and different public perceptions in combination with the large cross-border product flows.

Uncertainties in the regulation of GM crops are seen as the major challenge for the European agrobiotechnology companies. While low public acceptance of GM foods and long delays in regulatory decision making are interrelated, most companies see the solution in getting the regulatory process back on track. Companies now support a revision of the EU regulatory regime, including compulsory labeling, temporary registrations, and the need for closely monitoring GM crops. Moreover, companies acknowledge that developing those products that consumers will want to buy (i.e., developing second generation GM crops) will be the most effective route for regaining public confidence.

The articles assembled in this issue show how the various European agrobiotechnology companies are dealing with the challenges posed by the market, by regulation, and by technology. While they face the same regulatory requirements, compete in the same markets, and are faced with the same technological opportunities, each company has its own unique set of innovation strategy decisions.

Endnotes

[1] 1US$ = 1.08 Euro (in 2000).

[2] We have chosen to present the top 11 companies instead of the more common top 10 in order to show the position of Aventis (formerly AgrEvo).

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