

SRI



CHEMICALS

GMOs: the seeds of growth ?

- **GM global penetration growing**

Penetration has increased to 60% in soybean and 19% in corn, as GM technology reduces overall costs for farmers, offering greater ease of use. Key crops are soybean, corn, cotton and canola. Key traits include herbicide tolerance and insecticide resistance.

- **Sources of growth in GM seeds**

Short-term growth should come from stacking and second-generation herbicide tolerance. Further growth should come from Latin America and Asia, where we see less resistance to biotechnology from governments and consumers.

- **Industrial applications**

New GM applications are likely to come from increased non-food sectors, dedicated to biofuels (starch-enriched corn, corn with enzymes, enzyme-rich biomass) and animal feed. This will also create new growth opportunities for seeds.

- **The next generation – yield traits**

Next-generation traits are targeting yield improvement and are much more complicated to produce. We think GM will be complemented by smart breeding. A 1-2% yield improvement per annum is feasible in North American corn, while Brazil should also see soybean yields increase. Overall, the next-generation traits could generate a market of USD5bn-10bn for seed companies.

- **Risk mitigation remains key**

Consumer resistance to GMs, mainly in Europe, poses the most immediate risks for the technology but may prove to be relatively transitory. As the EU leads the way in environmental risk awareness, it is critical for the industry to implement a new governance model on innovation and risk assessment to overcome consumer resistance.

- **Stock selection**

We have 1/Selected List ratings on both Syngenta (target CHF320) and Bayer (target EUR68). BASF (3/Underperform, target EUR100) is more exposed to early-stage discovery, and its route to market remains highly dependent on Monsanto, the clear leader in GM.

Investment recommendation

GM crops: impressive growth

The market for GM seeds is now estimated at USD6.2bn, around 32% of the global seed market. Soybean is still the largest GM crop, though corn has seen the strongest growth in the past three years. The Americas continue to dominate GM acreage and value; Europe lags due to negative consumer perceptions. We see also strong growth in emerging markets, with Brazil's acceptance of GM soybean and corn, and the development of GM cotton in India and China. We forecast a 12% CAGR in acreage over the next five years, with still little development in Europe.

Next generation of traits – the need for higher yields

The next generation of traits is focused on yield improvement – drought-tolerance and nitrogen-efficiency. US corn yields are forecast to reach 160 bushels/acre by 2010 and 200 bushels/acre by 2020. Soybean acreage is set to expand in Brazil, with yield differentials expected to narrow. Rapeseed acreage and yield should increase in Europe, driven by biodiesel developments. The next generation traits will, in our view, be a combination of molecular-breeding optimisation and GM technologies, but also helped by traditional chemistry (like the *Invinsa* strategy).

Risks for development

Europe's view of how the risks relating to GM crops (from health to environmental) have been addressed differs greatly from the rest of the world. Some European countries are reluctant to authorise the commercialisation of GM seeds. It may take years to counter European distrust, which is motivated by a lack of long-term scientific studies and uncertainty over the results of clinical research. Lack of insurance creates liabilities and conflicts between the different types of agriculture.

The players: what can we expect?

The major players' R&D budgets have clearly increased in order to bring these new traits to the market by 2011E. **Monsanto** has a clear advantage (USD700m of R&D, USD4bn in sales of 2006/07) but its leadership is increasingly being challenged. **Syngenta** (1/Selected list, price target CHF320) is set to launch its proprietary platform in corn and recent deals should help it narrow the gap with Monsanto. **DuPont** has also secured several partnerships and is launching its second-generation herbicide tolerance traits. **Bayer** is focusing on cotton, canola and rice. Consolidation is on the cards, as access to technology and germplasm will have an increasing impact on value propositions for farmers: we believe the agchem sector is likely to see significant M&A activity, in order to realise the full potential of the next generation technologies.

Conclusion

GM technologies have had an important impact on the economics of crop production, and are poised to further enhance yields and overall productivity over the next 10 years – this is particularly important as demand for food, animal feed and 'green' chemicals has in our view been underestimated by governments. We believe that environmental effects and health impacts on one hand, and other potential benefits on the other, need continuous reassessment. Providing the major risk of contamination is addressed and the 'zero-tolerance' of GM presence ends, we see Europe progressively adopting GMOs.

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I— Current traits and the biotech market

In 2006, the global seed market was worth around USD20bn. The current market for GM seeds is estimated at USD6.2bn, or 32% of the market.

The first generation of traits is focused on simple, unconditional areas: herbicide tolerance (HT) and insecticide resistance (IR). HT accounted for 68% of total GM acres in 2006, and IR 19%.

Soybean is still the largest GM crop, with more than 59 million hectares being planted in 2006, 57% of the total surface.

GM corn has witnessed the strongest growth in the past three years, driven by CRW stacking.

US and Latin America dominate GM acreage and value. Europe clearly lags as consumer perceptions are still negative.

Output traits offer currently limited upside, focusing on higher quality oils and downstream processing improvement.

In terms of the economics and benefits, yield and overall farmer returns are difficult to measure precisely, but the convenience effect and the reduction in crop protection usage have triggered exponential growth. This is particularly true in the high oil price environment. However, no advantages have yet been seen for the consumers.

With more players entering the market, we expect prices for existing technologies to come down, and penetration to continue to grow with the next generation of traits. We expect a 12% CAGR for acreage growth over the next five years, driven by corn in the US, soybean and cotton in emerging markets and rapeseed in Europe.

In 2006, GM crops were planted on some 102m hectares, compared with 87.2m in 2006, or some 31% of total crop acreage (corn, soybean). In 2007, we expect another 12% surface growth to 114m hectares, driven by US corn and recent GM corn approval in Brazil.

We estimate the overall seed market to be worth USD20bn, with GM seeds at USD6.2bn, or 32%. GM crop plantings have been on a CAGR of 51% over the past ten years, and 14% over the past five years. In terms of value, we estimate that the GM seed market has grown by a CAGR of 12% in the past five years, with higher value traits and stacking being introduced only recently.

■ Input traits

The first generation of traits, introduced commercially by Monsanto in 1996, is clearly focused on **agronomic traits to benefit farmers**. These input traits make the plants tolerant to certain non-selective herbicides (glyphosate, glufosinate, etc) or make them produce toxins that deter pests such as worms and lepidoptera (European corn borer, corn rootworm, *Heliothis virescens*, *Pectinophora gossypiella*).

By trait

By far, the most important trait is **herbicide tolerance**. We estimate that out of the 102m hectares of GM crops, HT was planted on 69.9m hectares, or 68%, in 2006. It was incorporated in all crops – soybean, cotton, corn and canola. HT is essentially linked to glyphosate and glufosinate. All companies plan to launch second-generation HT traits in the coming years.

Insect resistance, generally called *Bt*, is introduced in the plant via the insertion of genes from *Bacillus thuringiensis* (a natural bacterium) coding for toxins such as Cry1Ac, Cry2Ab and Cry1F that kills larvae. Insect resistance crops were planted on 19m hectares or 19% of all GM surfaces in 2006.

**Herbicide tolerance
clearly dominates**

**Bt largely present in
cotton, strong
momentum in corn**

Stacked traits: fastest growing segment

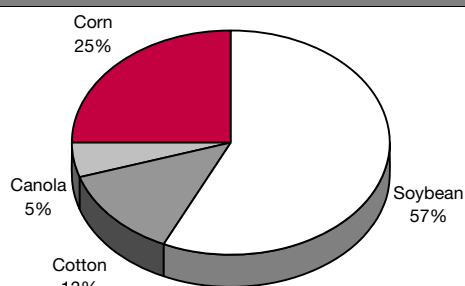
Soybean dominates by acreage and value, but corn should overtake by value in 2007

Stacked traits – a combination of HT and IR, introduced as vectors – are the fastest growing segment of GM crops, and accounted for 13.1m hectares (or 13%) in 2006. The segment grew 30%, vs 17% for IR and 10% for HT. The trend has accelerated in 2007, as triple-stacked corn acreage (HT, ECB and CRW protection) is boosted not only by increased penetration but also by strong corn rotation in the US. Of the 92m corn acres planted this season in the US, 73% were GM and 28% were stacked. Monsanto reports some 25% triple-stacked penetration in its brands, and is targeting 50% penetration for its leading brands.

By crop

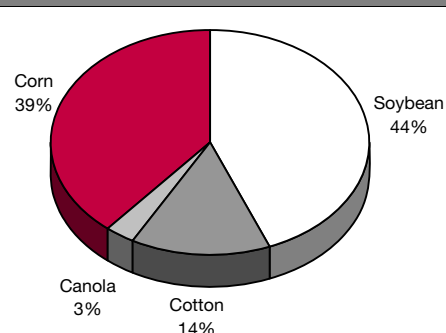
The first GM crop, a genetically modified tomato, was introduced in 1994, but was quickly abandoned due to consumer pressure. In 1996, the first large scale planting of HT soybeans occurred in North America, with some 1.6m hectares being planted (after Monsanto bought DeKalb). In 2006, we estimate that GM soybean is planted on 58.6m hectares (57%), while corn accounts for 25.2m acres (25%). In terms of value, GM corn accounts for 39% of the USD6.2bn market, as stacking has clearly penetrated faster than in other crops. It is also due to the fact that GM corn is mainly grown in the US, where prices and fee collection mechanisms are the most robust. GM cotton has grown steadily since 1996, but is currently showing a strong growth driven by India. Canola is mostly planted in Canada and is benefiting from strong demand for rapeseed for biodiesel.

2006 GM SEEDS, BY CROP (ACREAGE)



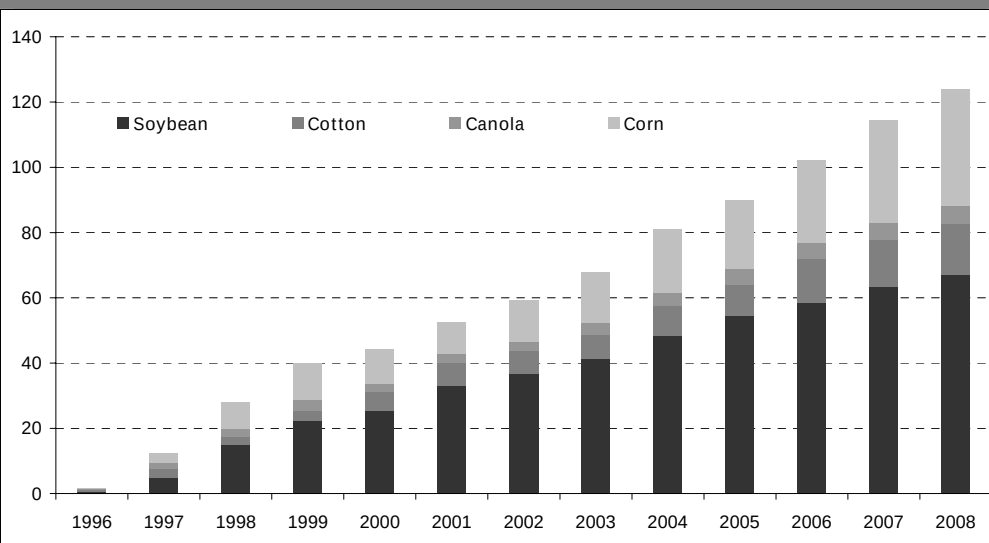
Source: ISAAA, Cheuvreux

2006 GM SEEDS, BY CROP (USD)



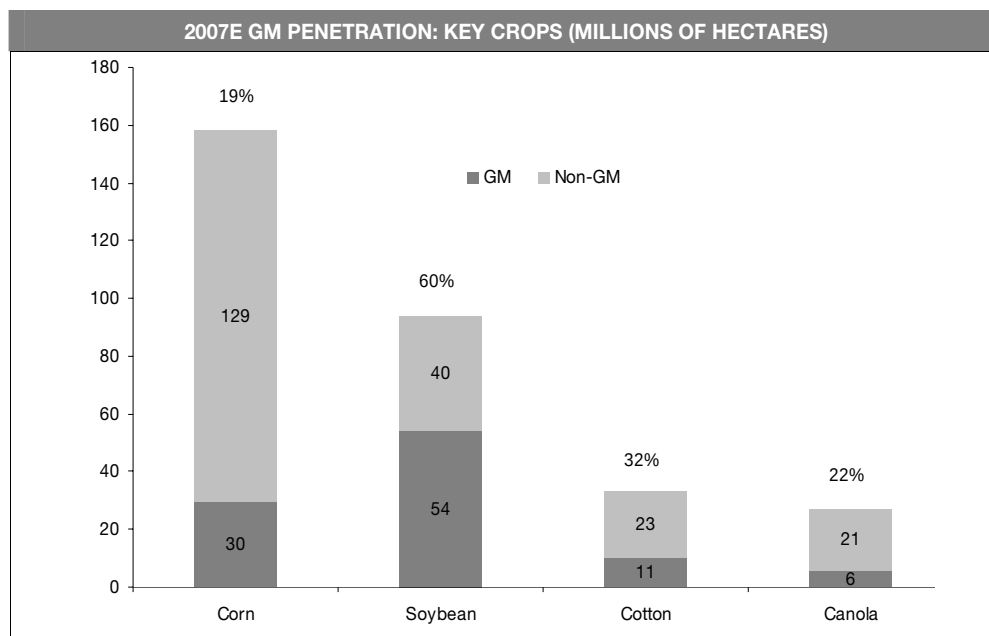
Source: ISAAA, Cheuvreux

GM PENETRATION, BY CROP, 1995-2008E (MILLIONS OF HECTARES)



Source: ISAAA, Cheuvreux

In terms of penetration, we estimate that 2007E GM penetration soybean is the highest with roughly 60%, while cotton and corn are reaching 32% and 19% respectively.



Source: Cheuvreux

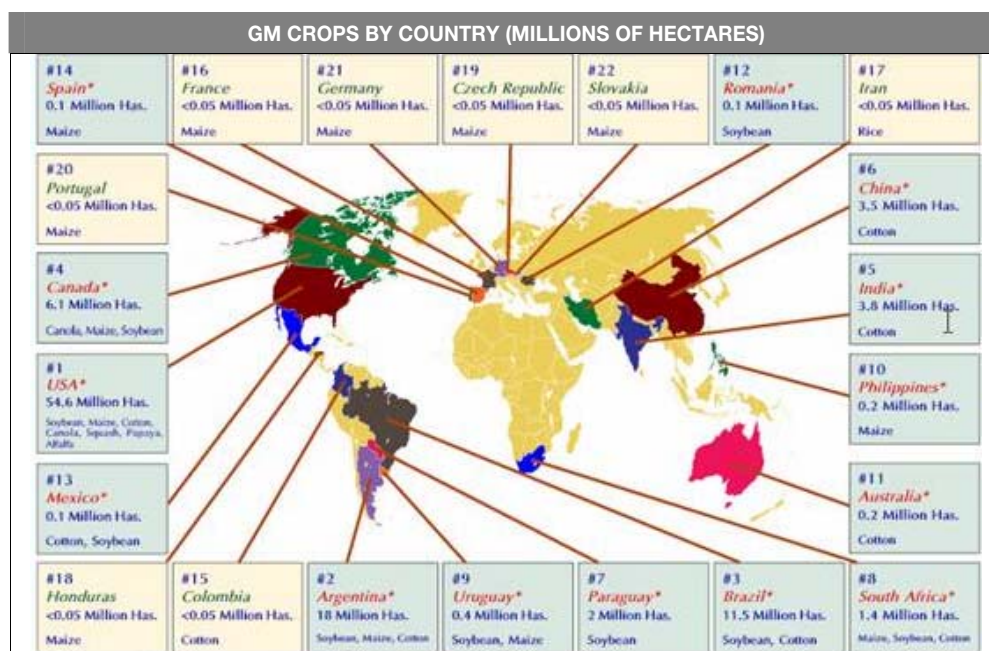
By region

Unsurprisingly, the US is the largest market for GM crops. Out of the total value of USD6.2bn, we estimate that the US accounts for more than 85% or USD5bn. Latin America (Argentina and Brazil) accounts for 29.5m hectares, or some 30% of acreage, but technical fee collection is quite difficult there and pricing remains well below US levels. We estimate that the average premium per trait in Brazil is around USD2.5 per acre (vs. USD10 in the US). China has also been an early adopter of the technology, essentially in cotton, but Syngenta and BASF have recently signed to R&D collaboration for next generation traits.

GM CROPS BY COUNTRY, 1996-2006

(Millions of hectares)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
US	1449	7460	19259	26252	28245	33024	37528	40723	44788	47395	54600
Canada	139	648	2161	3529	3331	3212	3254	4427	5074	5858	6100
Argentina	37	1756	4818	6844	9605	11775	13587	14895	15883	16930	18000
Brazil	0	100	500	1180	1300	1311	1742	3000	5000	9000	11500
China	0	34	261	654	1216	2174	2100	2800	3700	3300	3500
Paraguay	0	0	0	58	94	338	477	737	1200	1800	2000
Australia	40	58	100	133	185	204	162	165	248	275	200
South Africa	0	0	0.08	0.75	93	150	214	301	528	595	1400
India	0	0	0	0	0	0	44	100	500	1300	3800
Others	1	15	62		94	112	136	209	527	710	900
Total	1666	10071	27161	38651	44163	52300	59244	67357	77448	87163	102000

Source: ISAAA



Source: Clive James, 2006

It is worth looking in detail at the US market, the most advanced in terms of penetration. In the US, GM soybean acreage accounts for 91% of total surface planted in 2007 and the growth in value will come from higher-quality oil traits, and from second-generation HT traits. Corn is the fastest growing GM crop, now accounting for 73% of total corn acreage.

US GM CROP AREA AS % OF TOTAL, 2004-07

		2004	2005	2006	2007
Corn	Bt	27	26	25	21
	Herbicide tolerant	14	17	21	24
	Stacked	5	9	15	28
	Total	46	52	61	73
Soya	Herbicide tolerant	86	87	89	91
Cotton	Bt	18	18	18	17
	Herbicide tolerant	28	27	26	28
	Stacked	30	34	39	42
	Total	76	79	83	87

Source: NASS, June 2007

GM acreage still minimal in a rather hostile Europe

Finally, in Europe, GM acreage is still minimal, apart from in Portugal and Spain. This is due to the moratorium that was in place until 2004, and more importantly, consumers' negative perceptions of GM technologies. Europe has also developed its own regulations on labelling and limits (see chapter 3). Although recent trends have been more favourable for GM trials and imports, we expect no acceleration of GM penetration for cultivation in the next five years.

EUROPEAN GM CROP AREA, 2007E

(Millions of hectares)	2006		2007E
Spain	53,667	40%	75,148
France	5000	323%	21174
Czech Republic	1290	288%	5000
Portugal	1250	260%	4500
Germany	950	183%	2685
Slovakia	30	2900%	900
Romania	90,000		350
Poland	100	220%	320
Total	62,287	77%	110,077

Source: EuropaBio

■ Output traits

Although the bulk of the biotechnology market is in input traits, several companies have developed what are referred to as "output traits", where desired qualities of the crop are optimised or modified. This is particularly true for oilseeds, where the quality of oil for food applications is an issue. Syngenta has also chosen another route, focusing on improving downstream processing applications of crops (animal feed, biofuels).

Soybean: higher-quality oil for food processing

These traits are not developed through GM processes, but result from marker-assisted breeding (we look at this technology in the next chapter). Linolenic acid naturally occurs in soybeans at a level of 7% to 8%. Linolenic acid causes soybean oil to go rancid quickly, so soybean oil is usually hydrogenated to extend its shelf life and stability. Low-linolenic soybeans suppress the need for hydrogenation and also reduce trans-fats.

Monsanto has developed the *Vistive* brand of low-linolenic soybeans, and hopes to plant the seeds on 1.5m acres in 2007. Monsanto sees the potential for value creation at less than USD10/acre. Additionally, the *Vistive* brand low-lin soybeans will be stacked in combination with Monsanto's Roundup Ready trait, building on the benefit platform that soybean farmers have come to expect.

DuPont has also marketed its soybean variety as NUTRIUM™ Low Lin Soybean Oil. It will be the first product sold under the NUTRIUM™ brand, which was created as part of an alliance between Bunge and DuPont. NUTRIUM™ Low Lin comes from Pioneer® variety 93M20, developed by DuPont subsidiary Pioneer Hi-Bred International, Inc. The new soybean variety features oil with a low linolenic acid profile of less than 3% and offers better natural stability and increased shelf life.

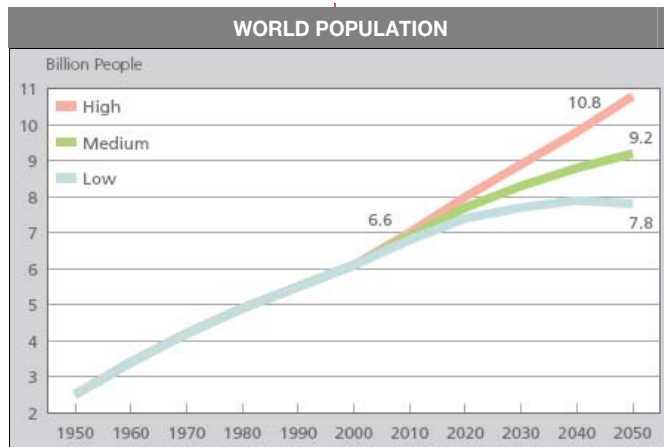
Corn phytase

Feed applications have become a major outlet for key crops (we estimate that 70% of soybean and 50% of all corn is used for animal feed), as meat consumption has been accelerating in the developing world and requires significant grain production: 7kg of grain for 1kg of beef, 4kg for 1kg of pork and 2kg for 1kg of poultry.

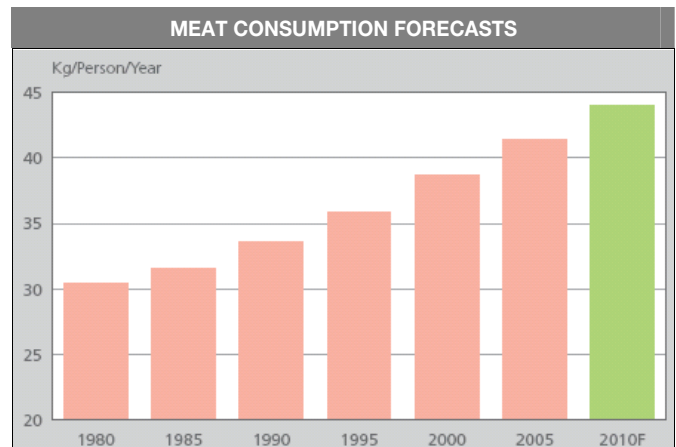
Monsanto plans to plant Vistive brand on 1.5m acres in 2007

DuPont has developed similar technology

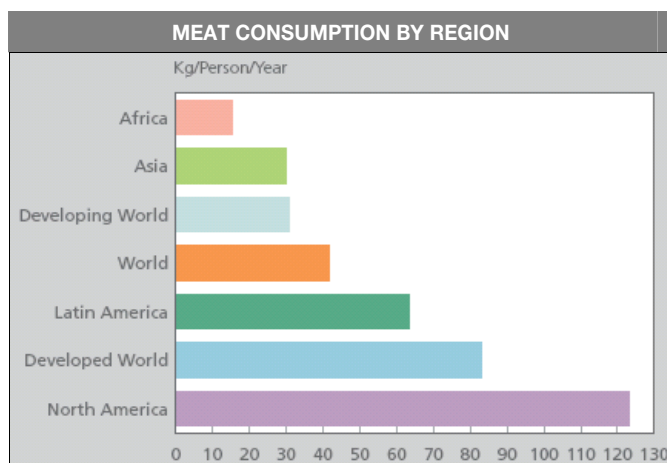
Meat production: heavy user of grain



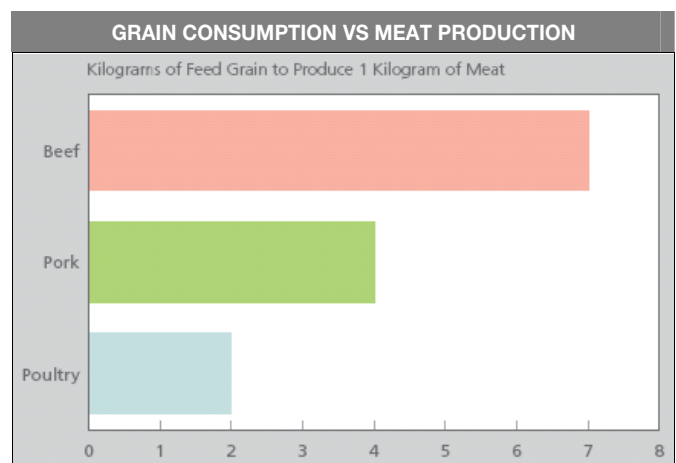
Source: UN, 2006



Source: FAO



Source: FAO



Source: Doane, POT

**A USD200m market,
growing at 7%**

Phytase is an enzyme that can break down the indigestible phytic acid (phytate) part found in grains and oil seeds and thus release digestible phosphorus, calcium and other nutrients. Phytase is normally produced (endogenous phytase) in ruminants. Non-ruminants (like human beings) do not possess this enzyme. As a result, phytase is used as an animal feed supplement – often in poultry and swine – to enhance the nutritive value of plant material by liberating inorganic phosphate from phytic acid (myo-inositol hexakisphosphate) and thereby reducing environmental phosphorus pollution.

Currently, phytase is largely produced by fungi and microbial fermentation. Phytase has recently been produced in transgenic canola, alfalfa and rice. Phytase can also be mass-produced through cellulosic biomass fermentation.

Syngenta's new corn phytase *Quantum* has been designed with enhanced thermostability (using algae as a model) and can resist higher temperatures, giving livestock producers more options in developing feed rations. It is also directly expressed in corn, which reduces overall feed costs. We estimate the market for phytase at USD200m in 2006, growing at a CAGR of 8% over the next five years. DSM, BASF, Novozymes and Danisco are the main players in that market. Danisco recently announced the launch of Phyzyme XP TPT, claimed to be the most heat-stable phytase on the market).

Corn amylase and starch-enriched corn: biofuels

Syngenta is the only company that will have on the market a corn dedicated to bioethanol production. With Diversa, it has developed an amylase that works in boiling water. This is a real step forward for renewable fuel technology, which will improve the economics of greenhouse gas emission control via biofuels, and add value at the farm gate to corn grains used for fuels. Syngenta has developed its heat-resistant amylase starch liquefaction catalyst (AMY797E) to be expressed in corn Line 3272 grain crops that are destined for dry-grind fuel ethanol production in the US.

The fact that the catalyst for starch processing comes from bacteria that grow in water at a temperature above boiling point, being under natural high pressure in the deep ocean, shows that these are truly amazing catalysts. In this case a new version of the microbial enzyme amylase has been developed that is active when exposed to heat needed to ready corn starch for ethanol production. It comes as a hybrid enzyme generated from closely related Archaea bacteria (Thermococcales, Thermococcus), long familiar to microbiologists because their relatives make methane. The bacteria (more correctly Archaea) in this case come from the sea. Not only that, Syngenta's approach cuts out manufacturing steps in amylase production by getting the corn plants to make their own catalyst amylase out in the corn fields. This is a truly green and clean approach. Microbially produced alpha-amylases are already commonly used commercially in the starch-processing step during corn dry-grind and wet milling processing. The purpose of the development of Line 3272 corn, as it is called, is to use the corn grain as the source of amylase enzyme in dry-grind ethanol production, replacing presently added of microbially produced enzyme, and reducing costs.

This new corn has recently been approved by the FDA, while the USDA is still reviewing the dossier. The by-products of the biofuel process – such as distiller solubles – are very suitable for the animal feed markets. For this reason, food use regulatory approval for the feed is needed in countries to which the US might export the corn, and this is now being pursued worldwide by Syngenta. The company is currently conducting large tests to quantify benefits, but pilot tests show excellent yield improvements.

Agrivida, a small plant biotech company created in 2002, is developing corn varieties that are optimised for producing ethanol from corn stover, otherwise known as 'cellulosic' ethanol. Corn stover is, collectively, the leaves, stalks, and husks of corn and it is an inexpensive route to increase yields of ethanol per bushel of corn. It will also clearly reduce the environmental impact (CO2 equivalent). The most probable model will be an integrated biorefinery combining kernel and stover ethanol production.

■ Economics and benefits: mixed

The adoption of GM crops by farmers in the US, Canada and Argentina has proceeded at an unprecedented rate compared with the uptake of conventional hybrids, as we saw at the beginning of this chapter. The economic reasons for this rapid and massive adoption are analysed below: farmers had strong expectations of the profitability of GM crops, particularly as regards yield and/or cost savings, as marketed by Monsanto. However, GM crops have not proved to be significantly more profitable than their conventional counterparts, as shown in several studies. Factors other than profitability can explain the rapid uptake of biotechnology.

Profitability is defined as the margin left for farmers when costs have been deducted from receipts. The profitability of a GM crop is judged against corresponding conventional crops. Comparing the performance of both types of crops raises several methodological issues.

Agrivida – same strategy, but focused on cellulosic-ethanol

Why have GM crops developed so quickly?

Comparing profitability of GM and non-GM crops proves difficult

Premium on GM seeds

On the cost side: the input effect of GM crops

A cost comparison of GM crops and their conventional counterpart is generally limited to crop-specific costs, assuming that fixed costs are more or less the same. GM seeds are sold at a higher price than conventional ones, currently some 100% above for triple-stacked corn. The price wedge is mainly attributable to the value of GM technology or the 'technological fee'. According to a Monsanto communication (1998), the technology fee reflects 'the insect, weed, disease control value of the inserted gene, and a significant part of the fee is used for further research'.

This difference also reflects the fact that markets for GM and conventional seeds are separate. Furman Selz (1998) reported on the premiums observed in the US market in 1998: USD30 per bag of seeds for GM corn and USD5 for GM soybeans seeds, representing a 30% premium to non-GM seeds. They also gave an indication of the average technological fee paid by seed companies to gene providers: USD27 (30% of GM seed price) per bag of corn seeds and USD4.25 (21% of GM seed price) per bag of soybean. Despite the technological fee, GM seeds appear to be more profitable for seed companies than conventional ones.

Convenience of GM seeds

The convenience effect of GM crops allows for reduced or more flexible working requirements. However, the related savings in labour costs have not always been properly assessed. The valuation of family work is rarely broken down on a crop-specific basis. On the other hand, growing GM crops requires new management skills, growing practices and possible constraints. GM seeds are generally sold and sown under contracts. These changes entail transaction and management costs, which are not easy to assess.

GM crops are expected to allow for cost-savings through reduced insect and weed control and/or to achieve higher yields. Assuming the price of non-GM and GM crops is the same, the latter will become more profitable for farmers if increased seed costs are offset by savings in weed and/or pest control costs and/or by higher yields.

The importance of yield

On the income side: yields and prices

Yield is a key factor for profitability expectations and results. In fact, available figures on crop-specific costs are often broken down by area, while prices are paid on a quantity basis. Based on yields, costs and prices are placed on a common footing, often per acre/ha. In other words, the effect of a possible increase in yields is taken into account on the income side.

Comparing the yields of GM and non-GM crops is not straightforward. Yields depend on a large number of factors, and the inserted trait of GM crops is only one among many. It is worth recalling (OECD, 1999) that first-generation genetic modifications address production conditions (pests, weeds): they do not increase the intrinsic yield capacity of the plant. In other words, referring to Bullock's classification, they do not induce a type 1 (maximum yield) technical change. Not surprisingly, the yield performance of GM crops against their non-GM counterparts depends on growing conditions, in particular on the degree of infestation with insects or weeds. Data on the yields of GM crops are widely available, though details of factors that influence yields (temperature, weed control applied, etc) are often missing.

**10-year social and
environmental impact
of GM viewed as
generally positive**

The USDA (1999) has examined different factors affecting the adoption of GM crops. These include farm size, education and experience, location of the farm, use of production or marketing contracts. In the case of herbicide resistant soybeans, the USDA has concluded that 'larger operations and more educated operators are more likely to use herbicide tolerant soybean seeds'. Such differences between adopters and non-adopters of biotechnology have to be taken into account when comparing yields and returns obtained on both types of farms. This study on factors of adoption served as a first step for assessing the impact of GM crops on farmers' returns and on the environment. It allowed these exogenous factors to be controlled statistically and multivariate regressions to be carried out to assess the impact of GM crops on yields, profitability and the environment. The results of this USDA study for each type of GM crop are shown below.

Another key factor on the receipt side is the market price of GM crops. In many profitability studies, the prices of GM and non-GM crops are assumed to be equivalent. Most of the available studies are based on 1997 or 1998 data. In these first years of commercialisation of GM crops, their impact on commodity prices was not manifest or was difficult to assess. Different pricing developments between GM and non-GM crops have been observed in only 1999. However, very few market reviews report on a regular basis about such developments.

A further issue would be the full assessment of costs and benefits of GM crops, including effects on welfare as well as non-market effects, particularly risk assessment and management. However, the studies reviewed below cover only farm profitability in the short term.

More recently, a full study by the ISAAA has focused on the global socio-economic and environmental impact of GM crops.¹ Here are the main conclusions:

- **2005 farm income.** In 2005, the overall direct farm income benefit was USD5bn, the equivalent of adding between 3.6% and 4% to the global production of the four main crops.
- **Cumulative farm income.** Farm income has benefited by USD24.2bn (USD27bn including Argentina) since 1996.
- **Environmental impact.** The environmental impact on the cropping area devoted to GM crops has seen a 15.3% reduction since 1996. HT soybean (volume of herbicide lower by 4.1%, environmental impact -20%) and Bt Cotton (-19% and -24%). Overall, pesticide use has been reduced by 224,000 tonnes.
- **Impact on greenhouse gas (GHG) emissions.** Over the period 1996-2005, the reduction of fuel use is estimated at 4.6bn kilograms of CO₂ equivalent. If we include better CO₂ sequestration in soils due to reduced or no-till practices, this number increases to 7.6bn kilograms of CO₂. If we add 2006, emissions reductions are estimated at 11bn kilograms of CO₂.

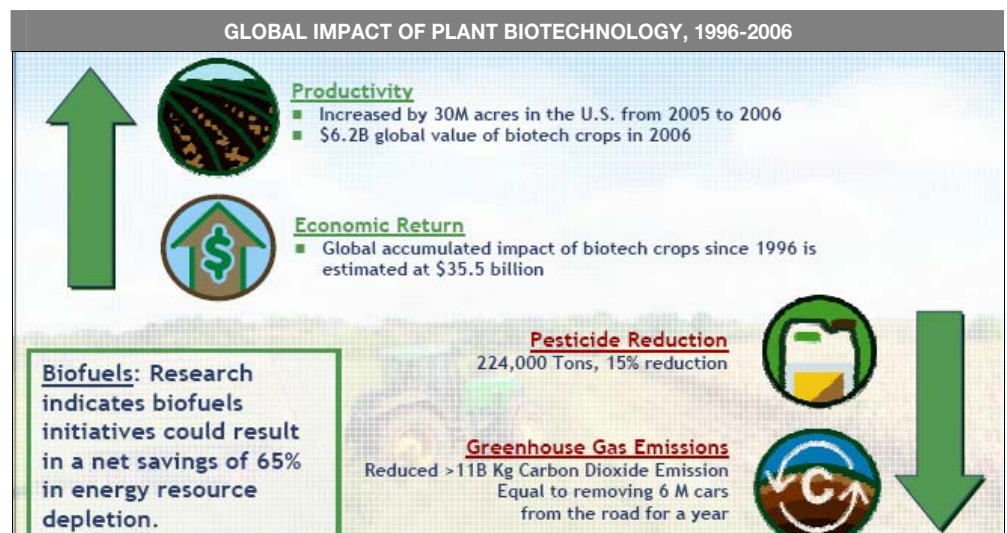
¹ "GM Crops: the first ten years – global socio-economic and environmental impacts", by G. Brookes and Peter Barfoot, as part of the ISAAA briefs (brief 36)

GLOBAL FARM INCOME BENEFITS FROM GM CROPS, 1996-2005 (USD m)

Trait	Increase in farm income 2005	Increase in farm income 1996-2005	Farm income benefit in 2005 as % of total value of production of these crops in GM-adopting countries	Farm income benefit in 2005 as % of total value of global production of these crops
GM herbicide-tolerant soybeans	2,281 (2,842)	11,686 (14,417)	5.72 (7.1)	4.86 (6.05)
GM herbicide-tolerant corn	212	795	0.82	0.39
GM herbicide-tolerant cotton	166	927	1.16	0.64
GM herbicide-tolerant canola	195	893	9.45	1.86
GM insect-resistant corn	416	2,367	1.57	0.77
GM insect-resistant cotton	1,732	7,510	12.1	6.68
Others	25	66	na	na
Totals	5,027 (5,588)	24,244 (26,975)	6.0 (6.7)	3.6 (4.0)

Notes: Others = virus-resistant papaya and squash, rootworm resistant corn. Bracketed figures include second crop benefits in Argentina. Totals for the value shares exclude 'other crops' (ie, relate to the four main crops – soybeans, corn, canola and cotton).

Source: Clive James



Source: Graham Brooks 2006, www.agbioforum.org; NCFAP report 2006; Ford Runge & Barry Ryan 2005; Monsanto; USDA

This study, like most others, does not take into account the cost of GM/non-GM segregation. But in our view, the overall gains are particularly relevant in an environment where the oil price is at USD80 a barrel.

II— Next generation of traits: not just GM!

2006/07 demonstrated the need for higher yields in all major crops, with demand in bioethanol outpacing supply, strong demand in soybean (China, biodiesel) and a poor wheat harvest.

The next generation of traits (both GM and not GM) is clearly focused on yield improvement, beyond the gains of classical breeding. Drought- and stress-tolerance, nitrogen efficiency, photosynthesis optimisation and nutrient transport optimisation are the key areas of research.

There is a clear movement from classical breeding towards GM and 'smart'-breeding, and from field experiments towards labs.

Drought-tolerance already shows consistent results in yield, and could help increase arable land. Recently, Syngenta and ROH announced the development of a chemical solution (Invinsa) to heat stress, which should be launched in 2009.

US corn yields are forecast to reach 160 bushels per acre on average by 2010E, on a stable surface of 90m acres. By 2020E, US corn yields are expected to reach 200 bushels/acre.

Soybean yields have lagged, but acreage is likely to expand in Brazil. Yield differential is also likely to narrow, as new technology and germplasm spreads.

Rapeseed acreage is likely to continue to expand in Europe, driven by biodiesel. Yield improvement could boost economics.

Sugar beet could be a surprise for ethanol production in Europe and tropical countries: new hybrids show strong comparables vs sugar cane.

Yield improvement will also come from better processing technologies, and better end-use yields in bioethanol. Animal feed could also be optimised with better phytase.

Conclusion: second and third generation traits will be a combination of molecular-breeding optimisation of drought/stress-tolerance, but an improvement of yields in the magnitude of 10-15% is not out of reach by 2015E. This would create value.

The R&D pipelines of the major seed companies show that a great deal of effort is being directed at what is often referred to as 'yield traits'. These traits are agronomic traits which involve complex metabolism functions including water and fertilizer intake, photosynthesis, drought and stress resistance.

Compared with the first generation of traits which incrementally increased yields as a result of better use of resources, these second generation traits could potentially boost yields by 10-15%. These traits are expected to come onto the market between 2011E and 2015E, and allow for the further development of industrial applications of plants while maintaining soft commodity prices at reasonable levels.

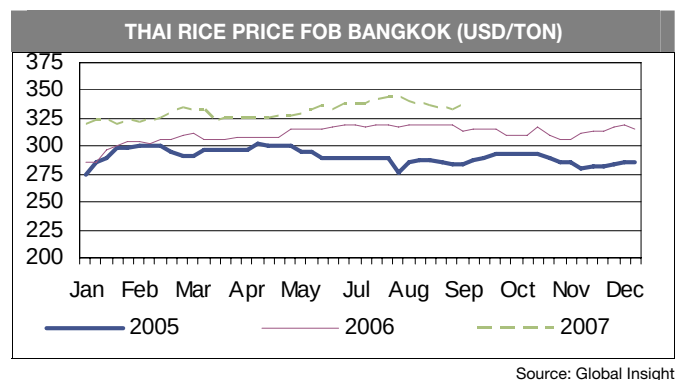
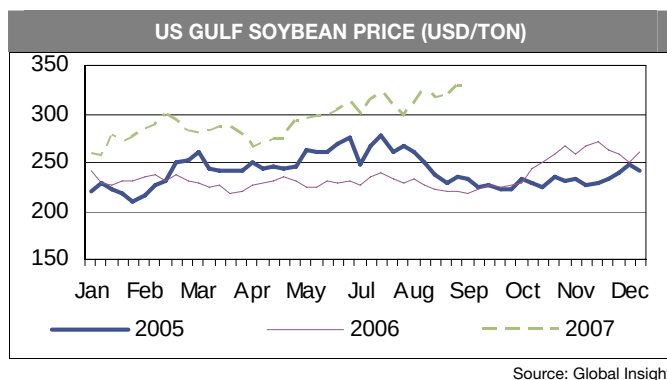
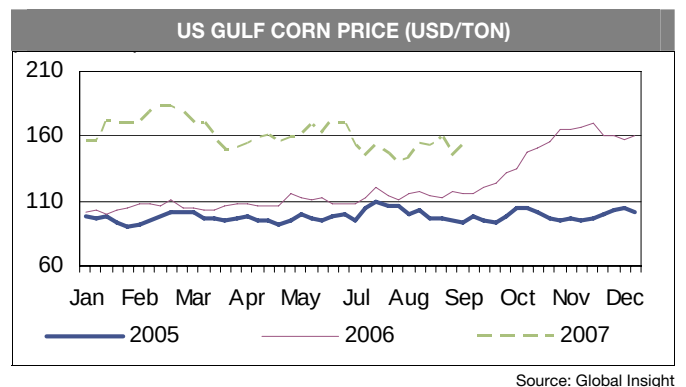
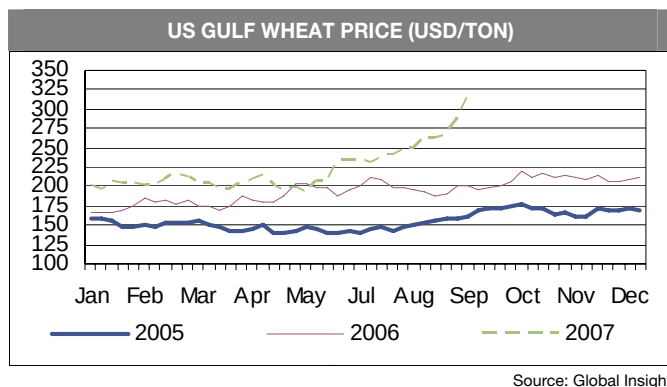
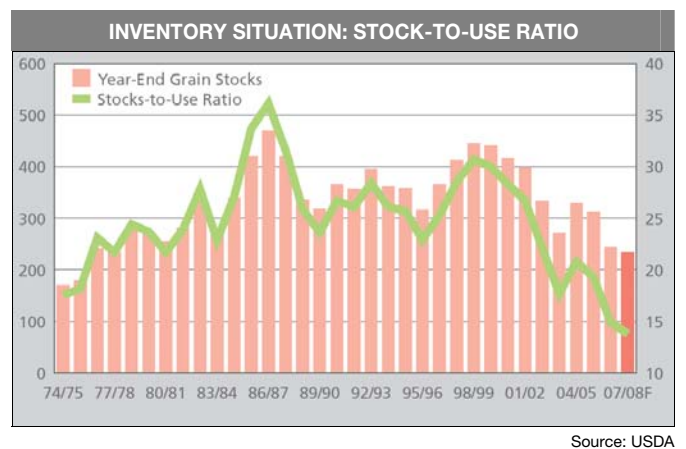
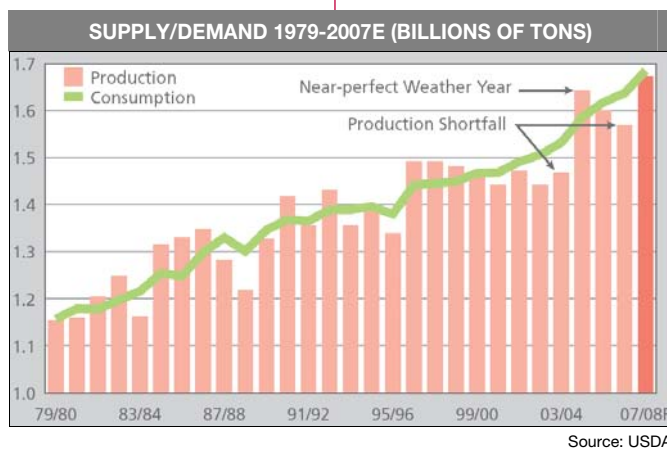
Yield traits in the spotlight...

... as consumption continues to outpace production

■ The need for higher yields

The need for higher yield has become particularly evident in 2006/07. Grain consumption has outpaced production in seven of the last eight years, the only exception being a single year of excellent growing conditions in almost every major global agricultural region in 2004/05. With growing demand for food and now a surge in the production of biofuels, the annual increase in grain consumption has grown from its historical rate of 1.2% percent to 2.0%.

That has led to a widening gap between consumption and production – one that could be exacerbated by production failures or other supply disruptions – and triggered steady inflation in crop prices, as stock-to-use ratios are at historical highs. All crop prices are clearly above the five-year average.



Biofuels: strong growth in corn, rapeseed, sugar cane and palm oil expected

Yield trend lines rising

■ Demand drivers: from food to industrial applications

The drivers of demand are well known and include demographics and increased calorie consumption as disposable income rises. We estimate this will result in 1.3%–1.5% long-term growth. On top of this growth, we have seen strong development in industrial applications, especially driven by biofuel development, which should contribute an estimated incremental 0.5–0.8% yearly growth.

Bioethanol and biodiesel have been growing strongly in all parts of the world spurred by environmental concerns over petroleum-based transport fuels, due to higher oil prices, the volatility of which is compounded by geopolitical tensions. This has triggered significant acreage expansion in key crops (corn in the US, soybean in Brazil, rapeseed in Europe and palm oil in Indonesia).

Can biofuels and food/feed applications coexist?

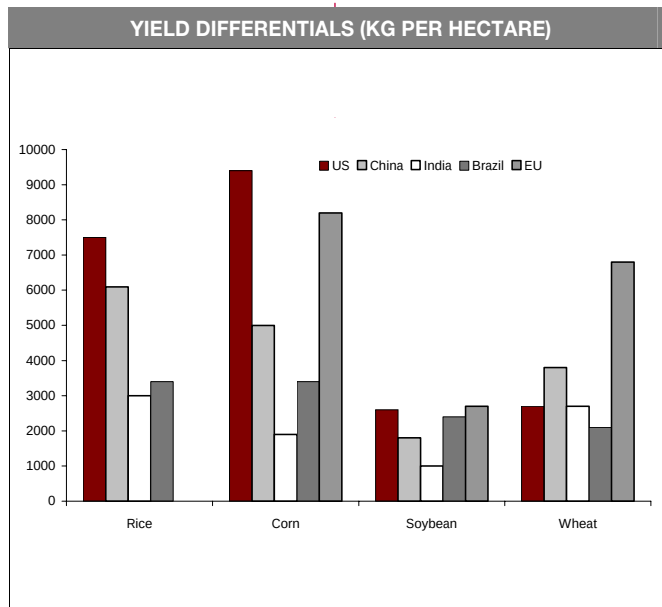
This is also a major concern, as the price of soft commodities is likely to be affected by the strong demand for biofuels and bioproducts in general. We believe that current production technologies (bioethanol from corn in the US, from sugar cane in Brazil and biodiesel from rapeseed in Europe and from palm oil in Asia) could produce enough fuel to replace 10–15% of overall transport fuel. In the US, with yield improvement through GM and enhanced germplasm (from 150 bushel/acre to 175), corn could provide enough starch to produce at least 13bn gallons of bioethanol (vs 7bn in 2007E). Bioethanol will therefore account for some 30% of corn usage. Overall acreage is expected to stay stable at between 90 and 100 million acres.

- **Better crop yields**, through biotechnology (drought-resistance will be the next blockbuster, in our view) and enhanced germplasm.
- **Better refining technologies**. Significant progress is being made towards developing better refining processes, including fractional separation of corn residues. The leading technology player, in our view, is Broin.
- **New products/technologies**. Butanol is being developed as a biofuel by BP and DuPont. The first plant will come on stream in 2007, in the UK. Butanol can be made from various sources (sugar beet, sugar cane, corn, wheat, etc). In the biodiesel field, esters from animal fats are being considered, although we do not believe this solution would significantly reduce pressure on surfaces. New crops can be used – jatropha, tropical sugar beat, etc.
- **The use of broader biomass**. This is key for going from 15% to 30%, as demonstrated in the new US DoE objectives. It is beyond the scope of this report to go into detail on how biomass can be used. In our view, the major developments will be around corn stovers. Technological feasibility has been demonstrated, and economics needs to be optimised.

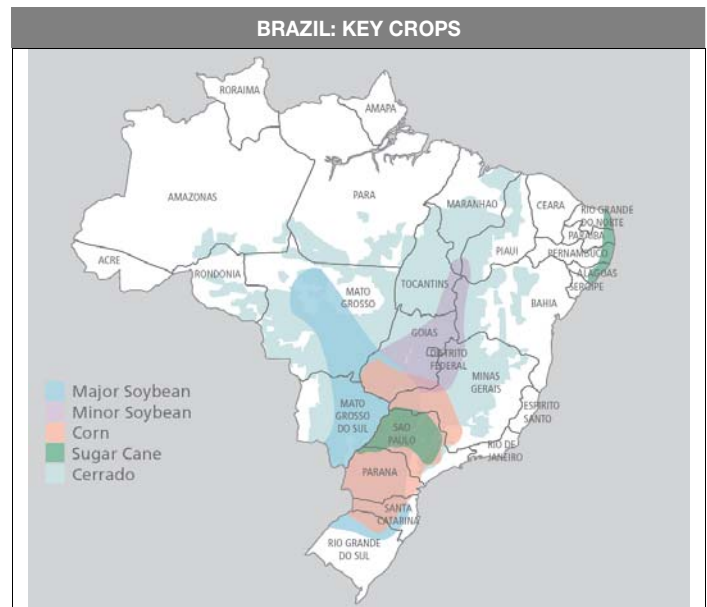
We focus here on the first point.

Yields by region

There are also significant gaps in terms of yields globally. Although part of those can be explained by climatic and soil conditions, we expect trend lines in yields to improve over the next decade, driven by increased penetration of GM in corn, cotton and soybean, increased use of more efficient crop protection products and better germplasm optimisation.



Source: USDA, Coceral, Cheuvreux



Source: Potash Corp

Brazil: surface could double over next decade

The big question: how much yield improvement is possible?

The challenge of boosting yield potential

We also expect surface to increase Brazil, the world's third-largest agricultural exporter, with significant room to grow further. According to the Ministry of Agriculture, as much as 170m hectares could be available in the Cerrado region for future crop expansion. Sugar cane acres are expected to grow from 6m to 10m hectares over the next few years in response to ethanol demand. Soybean acreage, currently 22m hectares, could also double over the next decade. We estimate that Brazil currently has some 222m hectares for breeding pastures, which could also be optimised, and 62m hectares under cultivation.

■ Is it possible? New arenas of R&D

Genetic engineering techniques are frequently proposed as ways to increase crop yields, especially in parts of the developing world affected by malnutrition and low agricultural production. However, despite 40 years of biochemical and physiological research, there have been very few cases that have directly led to improved cultivars with better yield.

This research has greatly improved our understanding of molecular traits and the factors associated with crop yields. However, the fact that there are so few examples of this research leading directly to better crop yield suggests that we should be cautious about how much molecular biology can improve crop yields in the near term.

There are two fundamental approaches to increasing yield potential:

- **increasing plants' overall physiological capacity** to produce harvestable yield under various environmental conditions (yield potential); and
- **reducing the effects of biological stresses** such as diseases, insects, and weeds that prevent plants from reaching their theoretical yield potential – that is the input traits.

Understanding and improving metabolism

The first approach depends on identifying a plant's specific function or functions that could be improved to increase yield potential. Scientists have used this approach to target particular metabolic 'control points' so that plant genes thought to limit a crop's basic yielding capacity could be targeted for improvement.

But many challenges remain...

... both technical...

... and financial

The concept of modifying a crucial biochemical or physiological step to achieve yield increase is not new. The advent of 'scientific agriculture' after World War II resulted in previously unimagined increases in crop yield. Relatively cheap fertilisers became available, and the addition of quantities of specific nutrients to the soil, especially nitrogen, was an important factor in increasing yields. So plant varieties suitable for higher-fertility conditions were developed.

Progress in research aimed at improving specific biochemical or physiological traits is nevertheless relatively slow. Researchers identified superior cultivars and established genetic heritability for some important traits that they thought were associated with yield. However, few improved varieties with enhanced yield were developed using this approach.

There are several explanations for these disappointments.

- The anticipated benefits were sometimes simply not transferable to the field situation. The activity of a metabolic pathway can be enhanced or diminished, but it may be irrelevant in increasing crop yield.
- Molecular modification often had a greatly diminished effect on crop growth as its influence moved up through a crop's organisational hierarchy, from the molecular level to the level of the organelle, cell, organ, plant and crop. Biochemical compensation by other pathways may also moderate the effect of the original modification.
- It is difficult to carry a concept of genetic variation from the process level through to the development of a viable commercial variety. The rare successes in the past in developing crop varieties using this approach illustrate that this research requires integrated, multidisciplinary teams with career and financial commitments to sustain long-term research efforts lasting 12 to 15 years.

Possible target traits for genetic transformation²

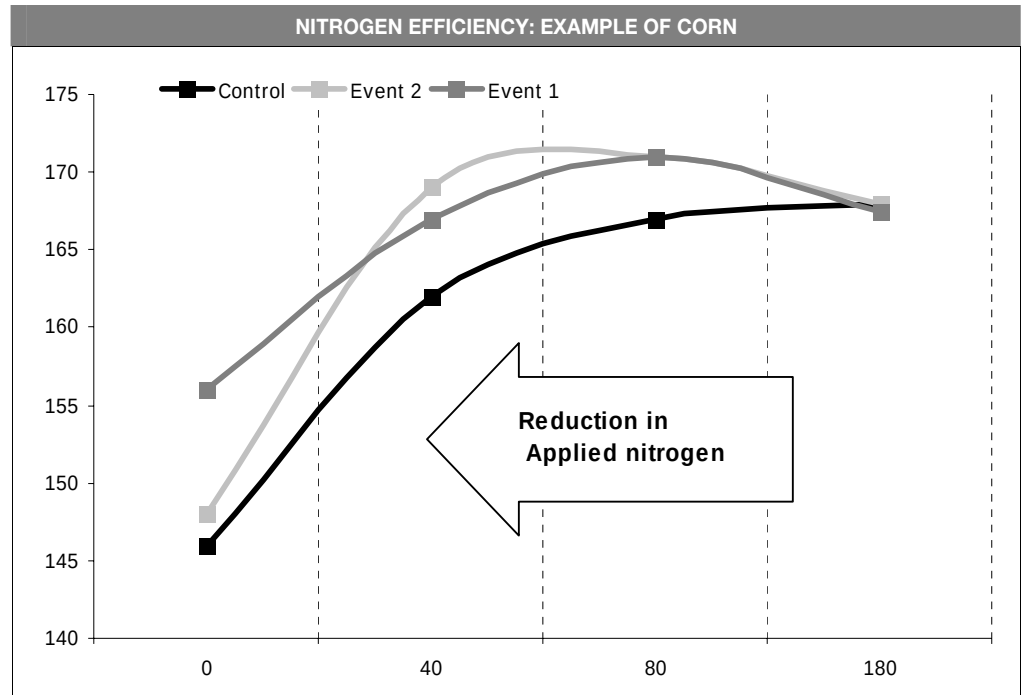
Nevertheless, this is now the focus of large, focused companies and biotechnology tools.

1. Photosynthesis improvement. Photosynthesis is the process by which plants use sunlight to assimilate carbon. Considerable early excitement was generated as genetic lines with superior leaf photosynthetic activity were identified and the photosynthetic capacity was successfully bred into progeny lines of several crops, including corn, wheat and soybean. Disappointment followed when these 'improved' lines failed to produce yield increases: the benefits of improved photosynthesis at the cellular and leaf level do not translate directly into larger grain yield. In particular, improved photosynthesis – which boosts carbohydrate production – may lead to larger vegetative growth, which will increase the plant's demand for nitrogen. Unless the plant can take up more nitrogen from the soil, grain yield may actually decrease. This is because the limited supply of nitrogen may end up producing bigger plants rather than more grain. The plant's needs for resources such as carbohydrates, nitrogen and sulphur need to be addressed together.

2. Nitrogen assimilation: optimisation of fertilizer use. In the past, a plant's nitrogen accumulation has been a crucial feature of yield increases. Usually, this has resulted from making more nitrogen available to plants (for example, by applying nitrogen fertilisers to the soil), and by breeding new plant varieties that can take up and store more nitrogen. A key factor in these successes has been improving the amount of accumulated nitrogen that gets stored in the grain, rather than being 'locked up' in the plant's vegetative tissues.

² Trends in Plant Science, 9, Sinclair et al, *Crop transformation and the challenge to increase yield potential*, 2004

A target for genetic engineers has been to increase nitrogen-use efficiency. However, efforts to improve a plant's nitrogen metabolism by changing its genome are unlikely to succeed because plant biochemistry is already extremely 'efficient' in nitrogen uptake and use. It may be difficult to improve whole plant traits because it seems unlikely that engineering a single gene or even a few genes can easily manipulate these traits.



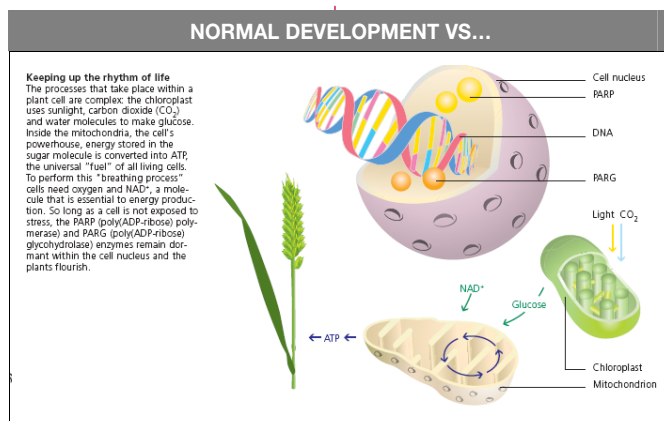
Source: Monsanto

3. Seed growth. Increasing seed growth rates and overcoming the problem of seed-embryo abortion is also a key focus. However, researchers have found that plants are well endowed with redundancies and backups to optimise grain production in a range of environments. Plants tend to compensate for an increase in one factor by decreasing others. Research has shown that in a community of plants, if one seed is growing more quickly, the plant compensates by changing the number of seeds or the duration of seed growth, resulting in little or no increase in overall yield.

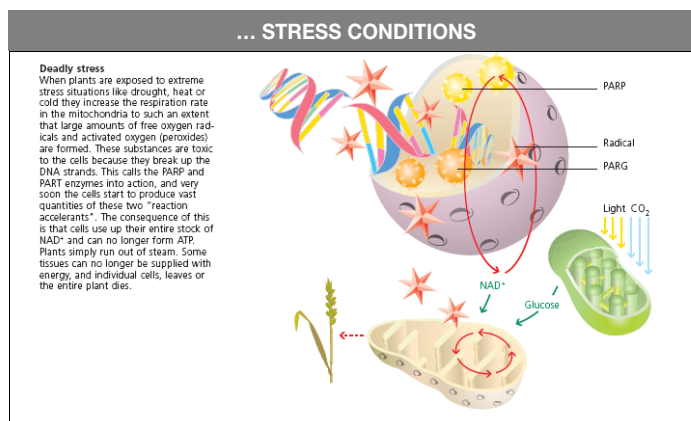
In a few isolated cases, researchers have succeeded in improving seed growth rates by genetically engineering plants to be less sensitive to phosphorus feedback inhibition in the grain. However, they found that seed growth was accompanied by increases in the growth of individual plants. As a result, there was no change in the overall harvest index (the ratio between the harvested grain and the total accumulated crop mass) for rice and only a small increase in wheat.

4. Drought stress: potentially the most important trait. Water plays a crucial role in the survival of plants by fulfilling the roles of solvent, transport medium and evaporative coolant as well as providing energy to drive photosynthesis, the natural plant process that synthesises organic food. Under drought conditions the loss of water in the plant protoplasm may result in the concentration of ions in the protoplasm to toxic levels resulting in possible protein denaturation and membrane fusion and negatively impacting plant metabolism.

**Access to water is key
for survival and yield**



Source: Bayer



Source: Bayer

40% of farming is carried out in arid or semi-arid regions

Water deficiency is a severe limiting factor in several countries and impacts both the food production and the economies of these countries. Approximately four tenths of the world's agricultural land is in arid or semi-arid regions with transient droughts causing death of livestock, famine and social dislocation. Several agricultural regions rely on irrigation to maintain yields. Crop plants that can make the most efficient use of water and maintain acceptable yields have an advantage in these regions. How efficiently a crop uses water directly influences yield potential, but it is not very flexible because of the physical and physiological characteristics of gas exchange in leaves (transpiration). Although there has been some success in improving water-use efficiency in wheat, any major increases in yield still depend on more water being available. This means that the crop must access more soil water in dry-land conditions. It is estimated that 20-30% of harvests are lost due to droughts globally. With the recent increase in droughts globally (due to global warming?), this has become an important focus of R&D.

Several mechanisms of drought and stress tolerance in plants are being investigated and research is currently underway to elucidate the mechanisms by which plants can survive during periods of water deficit. Several drought-tolerant plants occur naturally. Molecular biology tools can assist in the screening and identification of new drought-tolerant plants and varieties. Corn variety ZM521, for example, yields up to 50% more food than traditional varieties under drought conditions.

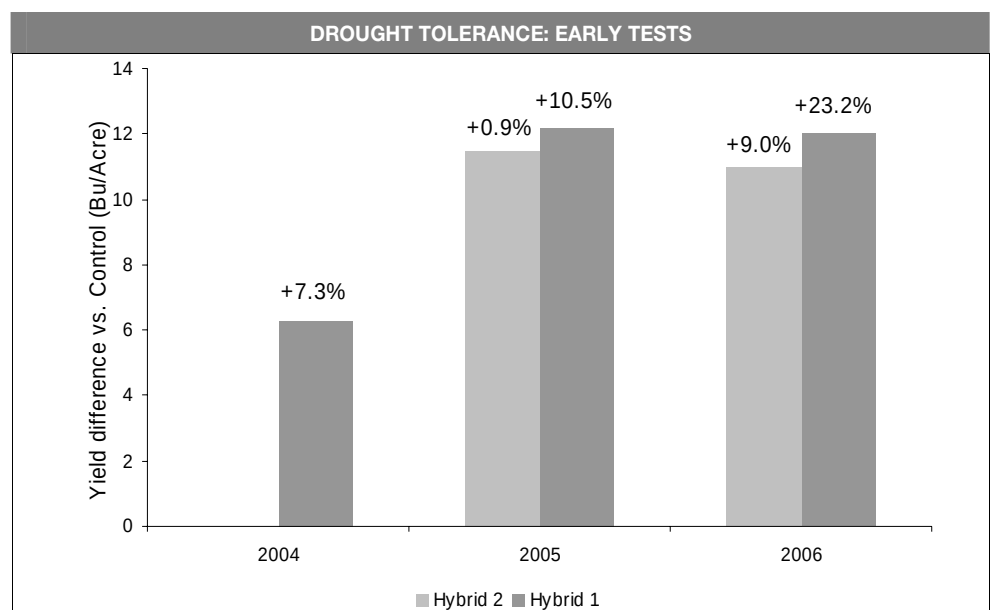
A 1998 paper published in Science outlines how plants endure periods of drought without dying. The plant hormone abscisic acid (ABA) can impact on plant control and development by mediating control of stomatal aperture in leaves. Abscisic acid is controlled by the ERA1 gene and by inhibiting the gene's action; a plant becomes supersensitive to drought. Suppression of the gene, hence closure of the stomata, enables control of water loss so that plants can last longer despite the onset of adverse conditions.

This study spawned several research programmes into drought stress and tolerance by genetic manipulation and had led to a collaboration between the University of Toronto (UT) and Performance Plants Inc. Testing is underway to apply this drought tolerance mechanism for canola and technology is being developed in other major species including corn, soybean, cotton, ornamental plants and turf grasses with a commercially available drought-tolerant corn expected to be available by 2010.

Outside the UT, the ABA mechanism of drought tolerance has attracted much research attention as a potentially useful trait in selecting for drought tolerance in crops. Apart from the ABA mechanism, several other studies are being conducted to identify other mechanisms and genes related to drought tolerance and their biological functions. The primary mediators of cellular responses to water deficit and their order of importance are still unknown: cellular water status, turgor, bound water, hormones (mainly ABA), cellular membrane functions or other agents. It is also not clear how cells perceive cellular water deficit and how cellular water deficit is transduced and transcribed into the various consequences of this stress. Furthermore, it has not been clearly established which of these responses are stress-adaptive and which are expressions of system degradation. The working hypothesis underlying current research in this area recognises multiple signal transduction pathways between stress perception and gene expression.

At plant and crop level, the important repercussions of water deficit are effects on plant phenology, phasic development, growth, carbon assimilation, assimilate partitioning and plant reproduction processes. These major effects account for most of the variation in crop yield caused by drought stress.

Much biochemical and physiological research has focused on drought tolerance, to enable plants to survive long periods of drought. However, for most annual grain crops, a drought severe enough to threaten the plant's survival will inevitably result in such a low yield that survival is a moot point.



Source: Monsanto

**GM technologies not
really appropriate for
yield traits**

**Can we put a cactus
drought-resistance
trait inside corn?**

**Route to market
extremely long!**

Conclusion

In our view, yield traits as described above are polygenic in nature and the interactions between metabolism cycles are extremely complex. Therefore, there is probably no point in trying to use inserted genes from so-called 'resurrection plants' to sustain food production during stress (cold, heat, drought, nutrient deficiency).

The rare successes of increasing crop yield potential by altering a targeted physiological trait may offer important lessons for achieving success using GM techniques. It is clear that the existence of genetic diversity for a particular trait – whether from natural diversity or transgenic techniques – is only a small, first step in achieving measurable yield improvements for farmers. The challenges have been to understand the altered trait's effect on crop performance in the field and to exploit the trait in a crop-breeding programme. In our view, there are some crucial R&D requirements in achieving success using the physiological approach:

1. Early assessment of the potential beneficial trait. Early in each programme, the researchers gave considerable attention to understanding and documenting the trait of interest under field conditions, rather than relying on extrapolations from laboratory study. Under what conditions would the trait be beneficial? What is the impact of trait expression on crop performance?

Integrating genomics, mapping and physiology might enable scientists to develop molecular hypotheses that begin at the top of the trait hierarchy rather than in the laboratory. Input from whole-plant physiologists and agronomists will be needed to make an early assessment of how proposed genetic modifications might improve the plant. It may also be advisable to use systems analysis technology to make an early assessment of the proposed GM trait or the crop's economic or commercial viability.

2. Effective phenotyping of genetic modifications. A crucial challenge in using a transgenic approach to improve yield is forecasting what will happen when a transformed trait is expressed. Trait expression depends on both the physical environment in which the plants grow and the genetic environment into which the trait has been inserted and phenotypic expression requires extensive field-testing, including evaluating plant performance and yield in a cropping situation. This is likely to increase demand for rapid and inexpensive methods for phenotyping plants, especially for traits that do not have a readily visible expression.

3. Multi-disciplinary effort. Different disciplines throughout the research effort must collaborate, including crop physiologists, agronomists and breeders. These three disciplines are still important and necessary in developing GM plants offering new genetic variability. The molecular genetic approach merely adds a further layer to this team. Indeed, system and environmental analysts may need to be involved as well, to assess where and when the expression of a GM trait might be commercially beneficial.

4. Long-term financial commitment. Successful development historically took 12 to 15 years to move from the initial studies of a physiological trait to the release of a commercial variety with improved yield. Syngenta developed its CRW trait in around seven years. Although the molecular genetics approach can speed up some of the steps involved, additional efforts to fully document the consequences of introducing a new trait could well offset this gain. The financial commitment required for this long-term team research is likely to be the most important factor of success. We see a deepening gap between the companies that can afford this research and those that can't.

Several MAS techniques are being developed for the improvement of polygenic traits

50% time reduction to develop new plant varieties

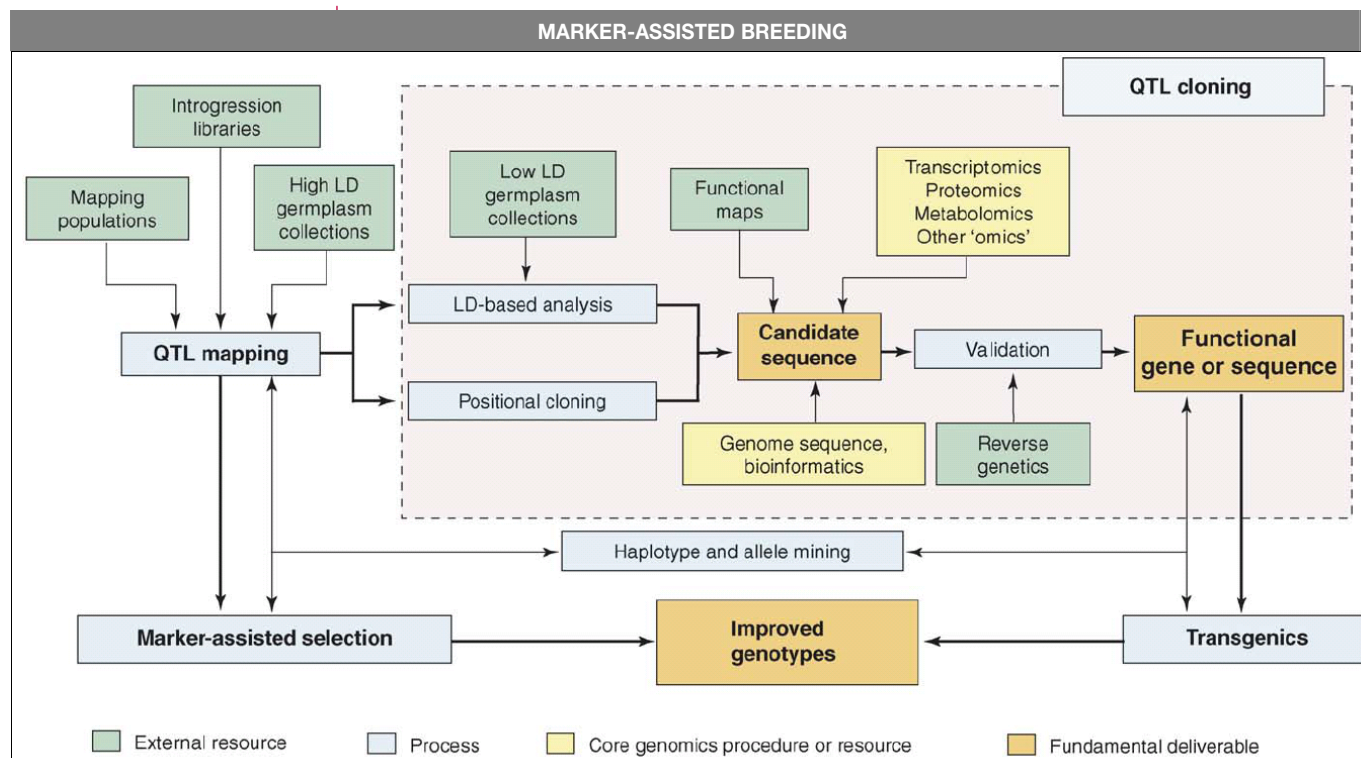
■ Marker-assisted breeding revolution

It is not the purpose of this report to describe the technology in detail, but it is worth taking a brief look at marker-assisted selection (MAS), which allows for exponential acceleration of classical breeding.

Advances in the development of molecular tools have allowed for improved identification, mapping and isolation of genes in a wide range of crop species. Initially, markers called restriction fragment length polymorphisms (RFLPs) were used to construct linkage maps for several crop species, including corn, tomato and rice. Later the polymerase chain reaction (PCR) revolutionised molecular marker assays because of their ease of use and suitability for automation. The idea behind MAS is that there may be genes with significant effects that may be targeted specifically in selection. Such genes are called major genes located at QTL (Quantitative Trait Loci). They can be detected and mapped on the genome. Following the pattern of inheritance at such QTL can assist in selection.

While MAS is emerging as a promising new agricultural technology with broad applications (fruit, vegetables, flowers, field crops, etc), the limits of transgenic technology are becoming increasingly apparent. Most of the transgenic crops introduced into the field express only two traits, resistance to pests and compatibility with herbicides, and rely on the expression of a single gene. As we have said, yield traits touch a large part of the metabolism and therefore require the optimisation of a large part of the genome! The coding for drought tolerance for example is incredibly complex, involving up to 60 genes, all interacting in a subtle and complex way.

Rapidly accumulating information about crop genomes is allowing scientists to identify genes associated with traits such as yield, and then scan crop relatives for the presence of those genes. While GM techniques transfer a gene from an unrelated species into the genome of a food crop to increase yield, resist pests or improve nutrition, MAS is designed to locate desired traits in other varieties or wild relatives of a particular food crop, then crossbreed those plants with existing commercial varieties to improve the crop.



Already some successful commercial applications

Using MAS, researchers can upgrade classical breeding, and cut the time needed to develop new plant varieties by 50% or more by pinpointing appropriate plant partners at the gamete or seedling stage.

Using MAS, researchers in the Netherlands have developed a new lettuce variety resistant to an aphid that causes reduced and abnormal growth. Researchers at the US department of agriculture have used MAS to develop a strain of rice that is soft on the outside but remains firm on the inside after processing. Scientists in the UK and India have used MAS to develop pearl millet that is tolerant to drought and resistant to mildew. The crop was introduced into the market in India in 2005. Using MAS, Syngenta has developed several new fruit and vegetable varieties with better consumer appeal – Dulcinea watermelons, various tomatoes and sugarbeet. Part of Monsanto yield improvement for its GM corn hybrids is in our view also linked to germplasm improvement via MAS.

There is still much work to be done in understanding the interaction between single genetic markers and complex genetic clusters and environmental factors, all of which affect the development of the plant and produce desirable outcomes such as improved yield and drought resistance. The following table shows the state of R&D for drought tolerance and the mapping of various metabolism pathways and the localisation of major genes and their QTLs.

Less risky than GM!

MAS also greatly reduces the risk of environmental harm and potential adverse health effects associated with GM crops. Not surprisingly, MAS technology is being looked at with increasing interest within the European Union, where public opposition to GM food has remained resolute. In a recent speech, Stavros Dimas, the EU's environment commissioner, noted that 'MAS technology is attracting considerable attention' and said that the EU 'should not ignore the use of 'upgraded' conventional varieties as an alternative to GM crops.

WHOLE PLANT AND CROP DROUGHT TOLERANCE QTL RESEARCH

Trait	Species	Population	Type	QTL numbers	Reference
Rainfed field performance in several locations	Barley	Barke x HOR11508 (H.Spontaneum)	DH	80	Talamè et al. 2004
Relative water content	Barley		RIL	9	Teulat et al. 2003
Seedling desiccation tolerance	Barley	Mona x H. spontaneum	F4	7	Zhang et al. 2005
Flowering parameters under drought, ASI	Corn	Ac7643S5 X Ac7729/TZSRWS5	F2	7	Ribaut et al. 1996
Plant height, ear number, days to silking, yield	Corn	SD34 X SD35	F3	5	Agrama and Moussa 1996
QTL x environment interaction	Corn		F2-F3-		Vargas et al. 2006
Grain yield and components under stress	Pearl millet	H77 x PRLT 2/89-33s	various		Yadav et al. 2002
Dehydration avoidance and dehydration tolerance traits	Rice	Indica x Japonica	RIL	27, 36 and 38	Yue et al. 2006
Dehydration avoidance and dehydration tolerance traits	Rice	Introgression lines from O. rufipogon	lines	12	Zhang et al. 2006
Dehydration avoidance and dehydration tolerance traits	Rice	IR 58821 x IR 52561	RIL	18 to 38	Manickavelu et al. 2006
Dehydration avoidance traits	Rice	Bala x Azucena	RIL	17	Price et al. 2002
Leaf rolling, leaf drying, RWC, growth rate	Rice	IR64 X Azucena	DHL	42	Courtois et al. 2000
Morphological and physiological traits	Rice	IR64 X Azucena	DHL	15	Hemamalini et al. 2000
Morphological and physiological traits	Rice	Bala x Azucena	RIL	24	Gomez et al. 2007
Productivity, water status, roots	Rice	Indica x Upland	RIL	39	Bing Yue et al. 2005
Yield and its components under drought	Rice	Bala x Azucena	RIL	31	Lafitte et al., 2004
Yield and its components under drought	Rice	Upland cv x Lowland cv	RIL	Several main effect	Zou et al. 2006
Yield and its components under drought	Rice	Introgression Indica lines		36	Xu et al., 2005
Yield, biomass, Osmotic adjustment, roots	Rice	CT9993 x IR62266	DHL	47	Chandra Babu et al. 2003
Yield, yield components, panicle sterility etc'	Rice	CT9993 x IR62266	RIL	77	Jonaliza et al. 2004
Yield under drought at reproductive stage over 2 years	Rice	Vandana X Way Rarem	RIL	1	Berniera et al. 2007

Source: Various

Drought tolerance

Back-of-the-envelop
calculation: USD18bn
in the US alone

■ A USD20bn market?

All the seed players are extremely bullish on the potential of these new areas of plant biotechnology. The market potential for these traits could be worth USD20bn by 2015E mostly driven by drought-tolerance (2011E) and nitrogen-efficiency (2015E). This would come on top of the current USD6.2bn of input traits market.

The first new traits should arrive on the market in 2011E and will focus on drought-tolerance. Both the GM and the MAS route are being pursued by the major players, led by Monsanto and Syngenta.

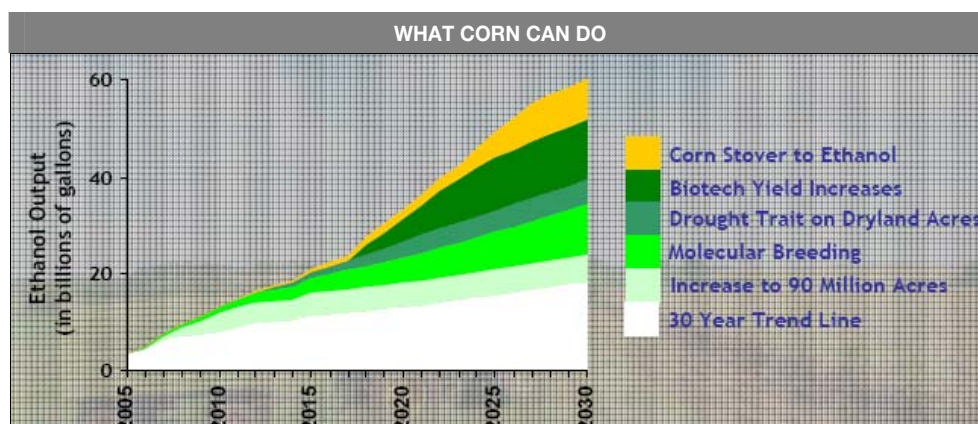
BASF/metanomics is more focused on discovery, and the recent deal with Monsanto (see next chapter) should enable BASF to monetise its R&D efforts. **DuPont/Pioneer** has recently developed several hybrids with exceptional drought tolerance and high-yield potential. New products coming to market soon will share a parent inbred from the 120-day Pioneer® brand hybrid 33D11. This hybrid has shown it can reduce water intake when needed and still maintain overall plant health and yield potential. **Syngenta** is pursuing both GM technology (we believe it is in partnership with Performance Plants, Canada) and MAS. Corn is targeted, although Performance Plants has used its technology on canola. Monsanto is targeting 2011 for its drought-tolerant corn.

Market potential

If yields of corn are improved by 10% (in other words, from 180 to 200 bushel/acre, and assuming a constant USD3 per bushel, biotechnology would improve farmer revenues by some USD20 per acre. If we assume that the corresponding traits could be planted on the 90m acres, the overall market could be worth USD18bn. The benefits are likely to be shared with farmers (traditionally 50%-50%). BASF forecasts second-generation traits to reach USD50bn by 2025.

No more trade-off between food and industrial applications?

Factoring in the potential yield improvement of crops, plus the development in plant-based industrial processes, Monsanto believes that without cellulosic ethanol but with 90 million acres, 24bn gallons of ethanol could be produced by 2015E, based on 30% of current surface and an increase of surface thanks to drought resistance corn – estimated at 5-6m acres in the US. Corn has already been gaining in the South, where cotton has traditionally been planted.



Source: Monsanto Ag Outlook Forum

Our view is that mid-term 15 billion gallons is achievable through the traditional corn conversion processes (on 90m acres), but the 36 billion gallon target for 2022E will require the development of cellulosic ethanol by 2015E. The infrastructure is currently being put in place (13 billion refining capacity should be available by 2010E).

Europe and RoW clearly differ in the appreciation of the risks of GM crops...

... and this is accentuated by the lack of risk-assessment

III – GM crops raise various risks

There is clear divergence between Europe and the US in terms of the risk assessment of GM crops. Some European states are still very reluctant to authorise commercialisation of GM seeds. Europe imposed a five-year moratorium, which ended in 2004, but was relayed by the safeguard clause implemented by several countries to stop commercialisation. Potential risks are ecological, sanitary, economical and ethical in nature. Regulatory risks for producers include labelling, approval procedures and consumer distrust.

Due to the lack of insurance, dissemination and contamination risks create liabilities and conflicts between different types of agriculture.

While GE crops pose an inevitable ethical debate, gene transfer risks give rise to public health concerns, although these have never been demonstrated.

The lack of long-term, independent scientific studies and uncertainty over the results of clinical studies on the impact of GM on health are the main basis of mistrust from European consumers

It will take years to alter the perception of GM crops, although actual GM surface in Europe has been increasing sharply over the past few years, driven by Spain.

Although GM crops open up interesting possibilities and considerable prospects for progress, so far, the main benefits are currently for farmers, with improved working conditions and reduced constraints, but no real gains for consumers.

As a result, most environmental associations are against the development of GM crops – even violently opposed, in the case of organisations such as Greenpeace or Friends of the Earth. Indeed, while benefits have been identified, these associations and a large portion of European opinion believe that the risks are poorly understood and barely quantified.

Moreover, the recent WHO report states that 'at present, no conclusive evidence on environmental advantages or costs can be generalised from the use of GM crops. Consequences may vary significantly between different GM traits, crop types and different local conditions including ecological and agro-ecological characteristics'. The most recent data that we depicted in Chapter 1, based on a 10-year trend, shows nevertheless positive impacts.

More importantly in our view, the 'equivalent'-food concept in the US has allowed the development of GM food. The preferred approach of the industry has been to use compositional comparisons between GM and non-GM crops. When they are not significantly different, the two are regarded as 'substantially equivalent', and therefore the GM food crop is regarded as safe as its conventional counterpart. This ensures that GM crops can be patented without animal testing. However, substantial equivalence is an unscientific concept that has never been properly defined and there are no legally binding rules on how to establish it.

Persistent scientific uncertainty due to the lack of long-term independent clinical studies – and preserved by the companies involved in GM themselves, as they believe that it is part of their competitive advantage – has prompted governments to take precautionary measures.

■ Economic risks

Labelling and precautionary principles: two regulatory risks

Given the concerns expressed by public opposition to GM, EU and international trade regulations are based on two main principles – freedom of choice and labelling – that are closely intertwined.

At international level, the Cartagena Protocol mandates that GMO products traded between countries (if at least one of these states ratified the Protocol) must be stored in packages bearing the label 'may contain GMOs'.

It also includes the right for nations to implement the precautionary principle, by imposing bans or restrictions on the import and use of GE organisms when there is a lack of scientific certainty due to insufficient relevant scientific information and knowledge.

At European level, the main regulation is the EU1830/2003 and amending Directive 2001/18/EC concerning the traceability and labelling of GMOs and the traceability of food and feed products produced from these GMOs. Labelling of food products is now mandatory, with producers having to mention GMOs in the list of ingredients whenever the product contains more than **0.9% of GMOs per ingredient**. Moreover, when the presence of a GMO is not fortuitous (or technically avoidable), the product has to be labelled even if it contains less than 0.9% of GMOs. In addition to restrictive labelling, companies face a protracted and uncertain seed authorisation process for food applications. It is worth noting that none of these apply to animal feed applications (meat, milk or eggs production).

A long and uncertain authorisation procedure in Europe

Companies need to carry out effective testing studies in order to avoid longer delays. This in turn suggests that only companies with strong R&D capabilities and financial muscle can sustain GM development.

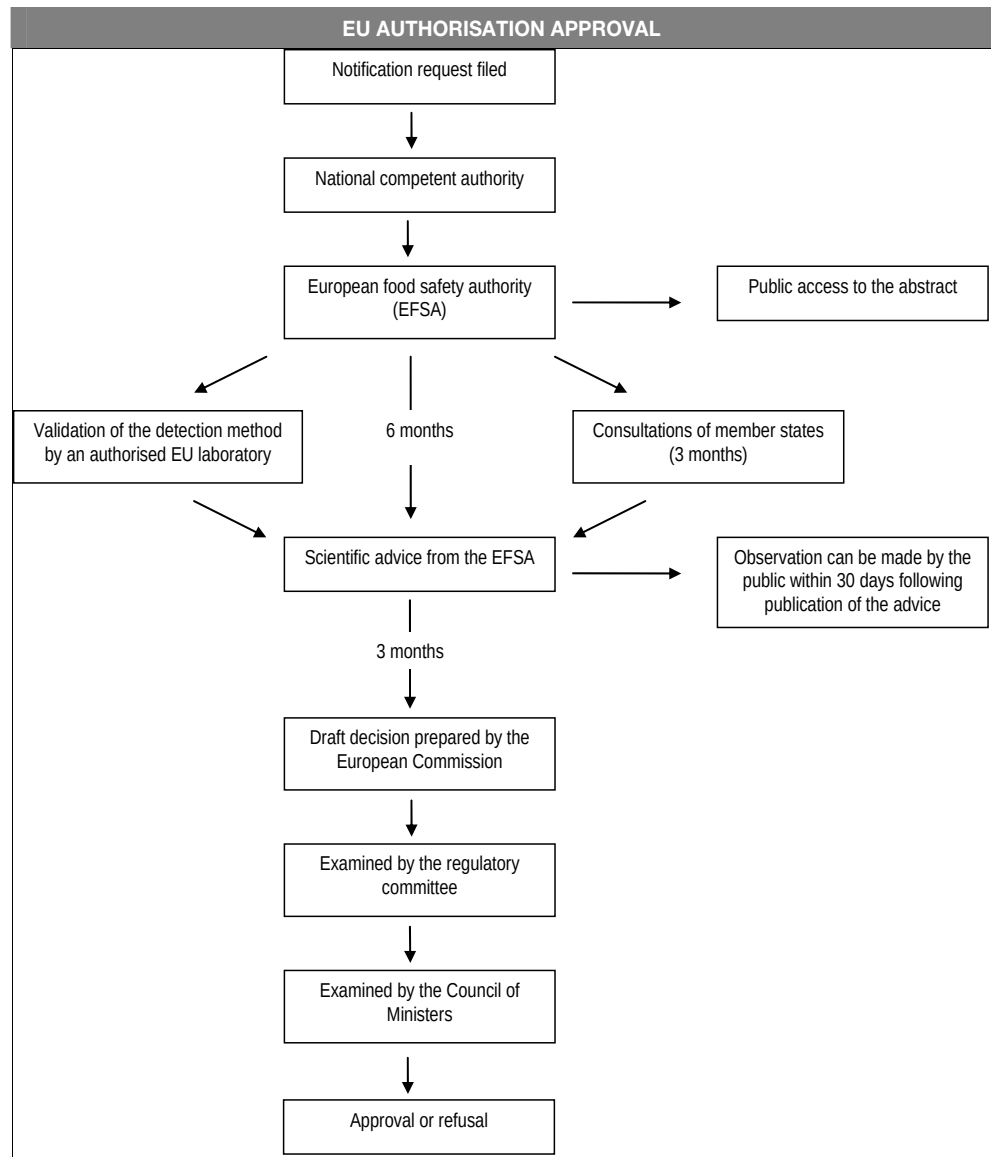
A company that wishes to market a GMO or a product derived from or containing GMOs in Europe, has first to obtain marketing authorisation (Directive 2001/18/EC on the deliberate release into the environment of genetically modified organisms, repealing directive 90/220/EEC). The approval decision is adopted at EU level after a scientific assessment of all risks and advice from all the member states. This authorisation is valid throughout the EU. The public has access to abstracts of requests for authorisation and advice presented by scientific committees. The public is consulted on each request made for marketing authorisation. Approval is valid for ten years.

So far, only a limited number of GMOs have been authorised on the market for cultivation, including Monsanto's NK603 and Syngenta's Bt11.

The authorisation procedure introduces an environmental impact assessment. It also includes a safeguard clause: when a member state has justifiable reason to consider that a GMO, which has received written consent for placing in the market, constitutes a risk to human health or the environment, it may provisionally restrict or prohibit the use and/or sale of that GMO on its territory. However, the burden of proof falls on the state! Therefore, the precautionary principle alone cannot be used as justification for banning a GMO.

The European Food Safety Authority (EFSA) assesses the safety risks of food for human or animal consumption. It thus provides scientific advice to European institutions and member states and is at the origin of decisions to authorise or block the commercialisation of a GM product. The group assesses available scientific data on GM products at the request of the European Commission (e.g. GM rice LLRICE601), and provides the latter with advice on the risk to human health and the environment. For example, NK603 "Roundup Ready" corn, rapeseed GT73 and corn MON863 are considered to be as safe as conventional corn and rice. The agency may also conclude that it does not have enough data to establish an opinion.

**Member states may
provisionally block
GMOs**



Source: French Government

Controversial products...

...spark intense debates between European countries, Brussels and the WTO

The most virulent debate concerns corn produced by Monsanto, namely Bt MON863, which was approved by the EFSA following tests on rats. Scientists from CRII-GEN (a French committee for independent research and information on genetic engineering) have opposed EFSA's positive conclusion, in light of the effects on the liver and kidneys of rats fed with the corn, and consider that tests of just 90 days on the mammals were not long enough. CRII-GEN calls into question EFSA's methodology in this case.

Monsanto's corn MON810 is prohibited in several European countries (Germany, Austria, Greece, Italy, Switzerland, Hungary, Poland and very recently France), which have exercised the safeguard clause in the EU Directive.

However, the European Commission is currently caught in the crossfire: either it can ask countries such as Austria to lift their moratorium on the commercialisation of MON810 and Bayer T25 corn and anger the 14 countries that support the moratorium, or it can retract its request and risk reprisals at the WTO, which deems the safeguard clauses illegal. It appears that Austria will be asked to lift its moratorium on the commercialisation of GM corn, although it can maintain its moratorium on the cultivation of GM crops.

**European distrust of
GMOs...****...does not stem from
fear of technology**

In addition, following decisions made during the recent 'Grenelle' environmental consultation, France has opted to suspend the commercial cultivation of GMOs and will therefore apply the EC's safeguard clause on MON810.

Consumer distrust: is GM food safe to eat?

A European survey in 2006 showed that a vast majority of Europeans (73%) are against GM food, whereas half are in favour of gene therapy, 52% in favour of pharmacogenetics and 55% in favour of nanotechnology. It appears that support for GM food has decreased since 1996 in the EU-15 (from 78% to 48% in the Netherlands, 49% to 12% in Greece, etc.). For most Europeans, GM food appears to serve no useful purpose, to be morally unacceptable and to be a risk for society (Eurobarometer 2006).

Note that this distrust of GMOs does not stem from fear of technology, as shown by the above survey. Indeed the vast majority of Europeans are in favour of other new technologies (nanotechnology, pharmacogenetics and gene therapy).

Conclusion

There are many (divergent) opinions but fairly scarce data on the potential health risks of GM food crops, even though these should have been tested for and eliminated before their introduction. Moreover, the scientific quality of what has been published is, in most instances not up to expected standards. If, as claimed, our future is dependent on the success of the promise of genetic modification delivering wholesome, plentiful, more nutritious and safe GM foods, the inescapable conclusion of this review is that the present crude method of genetic modification has so far not delivered these benefits and the promise of a superior second generation is still in the future. Although it is argued by some that small differences between GM and non-GM crops have little biological meaning, it is clear that most GM and parental line crops fall short of the definition of 'substantial equivalence'. We clearly need novel methods and concepts to probe into the compositional, nutritional/toxicological and metabolic differences between GM and conventional crops and into the safety of the genetic techniques used in developing GM crops if we want to put this technology on a proper scientific foundation and allay the fears of the general public.

The development of GM in Europe is clearly dependent on consumer approval of the technologies. Seeds companies therefore face a commercial risk, especially if consumer attitudes change in the Americas, the largest markets for GM technologies, though they are limited as they can also provide conventional seeds. The impact on margins will clearly be important at Monsanto, the largest player with close to 90% market share in the technologies. Syngenta, DuPont are relatively small players which could switch back to conventional seeds with very limited impact on margins. It is also important to know that some 80% of GM crops go into animal feed and industrial applications, with limited impact from public opinion.

Different countries...

Problem of segregation

Compensation funds

■ Socioeconomic risks: dissemination

The development of GM crops is eventually driven by consumer demand, and all the confusion between scientific experts and toxicology departments is not helping informed decision-making. Other risks include dissemination.

Accidental dissemination, or adventitious presence

The responsibility regime falls within the competence of each member state. If there is no specific GMO accountability regime, the normal regime applies.

Austria, Germany, Nigeria, Norway and Switzerland have all adopted legislation that covers public and private sector liability. For Austria and Switzerland, the responsibility lies with producers (e.g. Monsanto), whilst Germany places the responsibility on operators (i.e., the farmers). Lastly, while South Africa applies the principle of end-user or consumer responsibility, Slovakia places the burden of responsibility on users, which includes all natural persons using the genetic technologies apart from the end user.

In the absence of insurance, this risk creates liabilities...

In order to be labelled GMO-free, a product has to contain less than 0.9% GMOs. Yet cross-pollination from neighbouring fields of transgenic corn depends largely on the location of the GMO and non-GMO fields with regard to prevailing winds, their shape and relative size, and the ecology of the local landscape.

Whilst the dissemination of grain and pollen is variable, it is nonetheless inevitable.

Coexistence thus depends on both the location of the fields and the type of crop: sugar beet and cotton are less sensitive to cross-pollination than rapeseed, which disseminates very well. This depends notably on the reproducible nature of the plants, i.e., whether the pollen is distributed by insects (entomophilous species) or the plant is wind-pollinated (anemophily). Crop rotation is also a means to avoid contamination.

The issue of coexistence relates to segregation measures taken at farm or regional level to ensure that farmers can provide EU consumers with a choice of GM or non-GM harvests that comply with EU labelling standards.

According to guidelines published by the European Commission, it should be the responsibility of farmers who bring innovation (i.e. GM) into a region to take measures and, where necessary, change practices to ensure coexistence. For instance:

- Cleaning harvesting machinery;
- Introducing isolation distances between GM and non-GM fields (25 metres at European level, 50 metres in France, 150 metres in Germany); it would have been also interesting to establish safety distances according to the local landscape, which differs widely by region and has a major influence on genetic dissemination;
- Planting buffer strips of non-GM corn plants around GM corn plots.

The economic consequences of mandatory isolation distances (and of mandatory buffer strips) is the opportunity cost of not being able to grow GM corn in part of the farm. This cost is the difference in farmers' gross margin between GM corn and the alternative crop planted, which most likely will be conventional non-GM corn.

This difference, estimated empirically for Spain (25-metre isolation distance), is an average of EUR84 per hectare at national level. In addition, mandatory isolation distances or buffer strips directly affect costs due to the need to source inputs (seeds) and organise plantings for two crops instead of one.

Non-technical coexistence measures could also be imposed by EU member states on GM crop growers such as fixed levy on each hectare of cultivated GM crop to create compensation funds.

The US system could lead to absurd situations

Currently, insurance coverage for economic damage resulting from adventitious presence is not available in the EU (European Commission, COM (2006)).

As Swiss Re, one of the leading reinsurers, acknowledges, “for the insurance industry, genetic engineering is potentially one of the most particularly exposed technologies of the future”.

...and conflicts between different types of agriculture

Despite these precautions, certain types of agriculture are more exposed to this risk. This is the case for organic farming, in which product certification is based on the absence of GMOs. Above all, the type of consumers targeted often hesitate to buy products containing the slightest trace of GMOs, given that the extra cost is significant.

However, with no assurance that no contamination is possible between GMO and organic crops, the certification process automatically puts these two forms of agriculture in direct opposition — even if some organic farmers are starting to take an interest in these new crops in order to make up for loss of yield due to the non-use of pesticides.

The French draft law transposing the EU Directive (2001/18/EC) covers the economic damage i.e., ‘the loss of value of the product resulting from the difference between the selling price of the harvest subject to the labelling obligation and that of the same product not subject to such an obligation.’

This law provides that any farmer who grows a genetically modified species with marketing authorisation has to take out a financial guarantee, under an insurance policy or, conversely, pay a tax contributing to a compensation fund managed by the French body, the ONIGC (national inter-professional industrial agriculture office).

The fund is also built up through contributions paid by professional and inter-professional bodies involved in obtaining, producing or selling genetically modified, seed, plants or seedlings.

Patenting living organisms: the risk of dependence

Intellectual property rights (IPR) enable companies to appropriate and limit access to resources by farmers, who cannot save and reuse seeds. The major fear is the alleged IPR infringement caused by GMO contamination of traditional crops.

A traditional farmer was sued by Monsanto in 1998 for having infringed the company's patent by growing and selling contaminated plants (*Monsanto Canada vs. Schmeiser*).

In Europe, plant species are protected by the COV (*Certificat d'Obtention Végétale*, or plant variety protection certificate), which is an intellectual property right reserved for species created through plant breeding. Created in 1961 under the International Convention for the Protection of New Varieties of Plants, it guarantees the breeder:

- protection for the name of the invention; and
- a virtually exclusive monopoly on the sale of seeds for a period of 20 to 30 years.

The COV authorises the farmer, under certain conditions, to reuse part of his crop to seed his own plots of land the following year (“farm seed”).

It also creates the possibility of breeding new species from a COV-protected species whereby this new variety can be placed on the market without its inventor owing anything to the holder of the COV in question. However, this new species must be able to exist independently of the initial species. This is the exemption in favour of the breeder.

The COV allows researchers free use of the protected species in their work. Therefore, in Europe, the risk of lawsuits in the event of intentional contamination is not high.

**Unsuitable crops,
knowledge loss and
risks of dependence:
risks for emerging
countries are
significant**

**No clear conclusion
regarding biodiversity**

**Crossing the barrier of
living orders: the
ethical issue**

However, some opponents claim that for GM crops made for biofuel purposes, the fact that resources are all handled by very few giant companies creates another phenomenon of dependency, similar to the dependency on oil and specific countries, which biofuels were precisely intended to prevent.

The UN Food and Agriculture Organisation (FAO) has also expressed reserves on the 'molecular fracture' between North and South countries as most research efforts are focused on crops in developed countries (soy, corn, cotton) and ignore the five most important crops for semi-arid tropical regions: sorghum, millet, pigeon peas, chick peas and groundnuts.

The risk is dependence on multinationals for the annual food supply for the majority of the population.

This risk is compounded by the fact that using private seed contributes to the loss of traditional farmers' knowledge in the selection of good seed from previous harvests.

■ Environmental and public health risks

Increasingly standardised crops, a risk for biodiversity

Loss of biodiversity – disappearance of certain insects:

A UK study in 1999 showed that some herbicide-resistant GM crops, such as corn, are better for animals and neighbouring plant species than traditional crops, whereas the effect is the opposite for beet and rapeseed crops. This was the largest study ever realised.

In spite of the lack of clear conclusion of the impacts of GMO on biodiversity, one can still regret the fact that increase used of standardised crop will represent a loss of vernacular species.

Studies assessing the hazard for pollinating insects, ruminants or the overall ecosystem conclude less that there is a GMO-specific danger than risks resulting from conventional agricultural practices: the intensive use of pesticides and herbicides, mono-crops, etc.

Genetic engineering: ethics and public health issues

A final ethical concern involves the crossing of the barrier between the animal and vegetable kingdoms: the insertion of a fish gene into a strawberry is not only a technical issue but also a moral one.

At present, no genetically modified animal has been placed on the market, but research has been carried out on sterile transgenic fish in order to reduce the risk of spread, hence predation competition and genetic pollution. The research involves:

- growth rate modification;
- resistance to viruses;
- tolerance to the environment: salinity, temperature;
- "decorative" attributes, e.g. fluorescence.

Beyond the ethical issues raised by these manipulations between various natural kingdoms, it seems that here again, the public is likely to be more tolerant if it perceives the real interest in its usage, which is not really the case at present.

According to the French inter-ministerial site on GMOs, the risks that GMOs are likely to present include risks to human health via toxicity or allergic reactions and risks to the environment such as the destabilisation of certain ecosystems (the StarLink incident).

Threat of public health scares

Apart from the environmental threat of using strong herbicides, resistance is a major problem...

Because of the lack of epidemiological studies, public health risks have not been assessed on a very long-term basis. Indeed, the results of existing 90-day studies have not found any significant health impact. Some scientists claim that 90 days are not sufficient and tests should be extended to two years, as it is the case for pesticides. GMs accompanied with two-year clinical studies would no longer be profitable. However, experts do not agree on the relevance of longer studies, as other conventional foods do not have to undergo tests whereas some of these have been proven to be very unhealthy (palm oil, hydrogenated fats, high-fructose corn syrup, etc). In terms of health, GMs seem to be a case of 'not being able to see the woods for the trees'.

The most recent food-related public health scares – BSE ("mad cow" disease), foot-and-mouth disease, avian influenza – have created a feeling of insecurity and cast doubt on food safety. BSE, caused by a prion (a protein that can mutate from a normal form into a pathogenic form via a change in its structure), has successfully crossed the species barrier. Only cattle fed with animal meal (which violates the herbivorous nature of cattle) are affected.

GMOs, which integrate genes from different kingdoms, initially limited to genetic modification, raise ethical problems similar to the BSE crisis and have sparked numerous questions that are worthy of discussion and consideration.

Moreover, despite clear food labelling in Europe, the lack of traceability for livestock that are fed GM plants could boost public opposition.

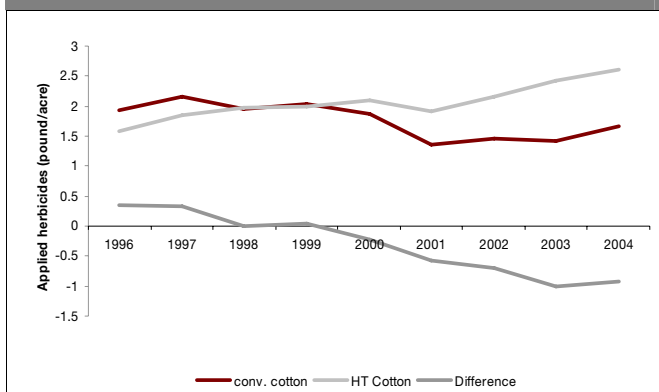
Strengthening resistances

The use of stronger herbicides and insecticides in plants:

There is no unanimity among studies as to the effect of GMOs on the quantity of herbicides used. Some GMOs lead to reduced use of herbicides, others increase their consumption.

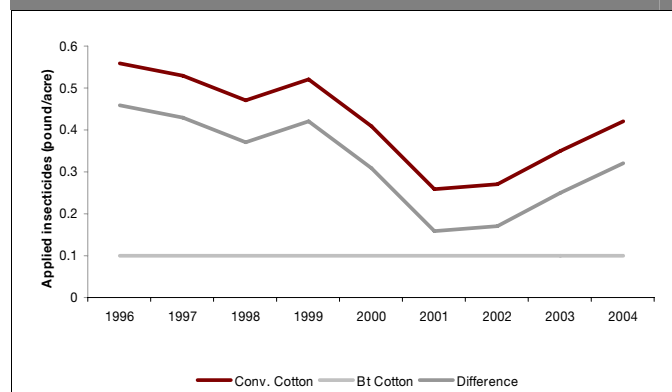
- HT (herbicide tolerant) crops are designed to enable farmers to spread broad-spectrum herbicides to which the crops will be resistant. Doses for HT crops tend to increase with time: weeds adapt to the increasing use of herbicides, and thus become less sensitive (or even totally resistant) to the herbicide used. However, in the case of traditional crops, the quantity of herbicide used declines as more effective products are used (less spread, smaller quantities applied).
- The price of glyphosate-based herbicides has declined sharply.
- Similarly, the impact of GMOs on the quantity of the insecticides used is not uniform. It seems that Bt corn and Bt cotton are the only GMOs at present that enable a real reduction in the amount of pesticide used.

AVERAGE USED OF HERBICIDES ON COTTON



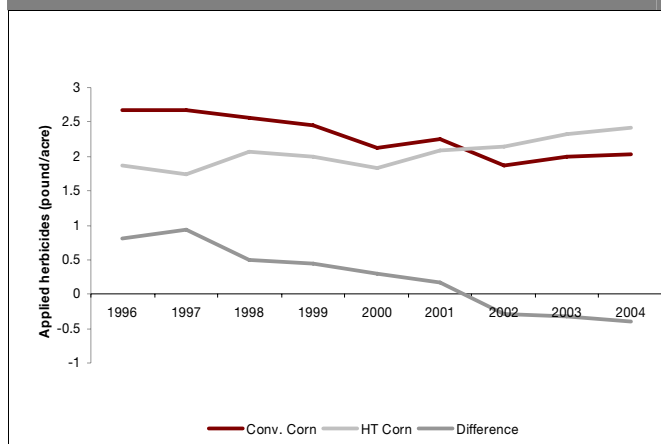
Source: USDA

AVERAGE USED OF INSECTICIDES ON COTTON



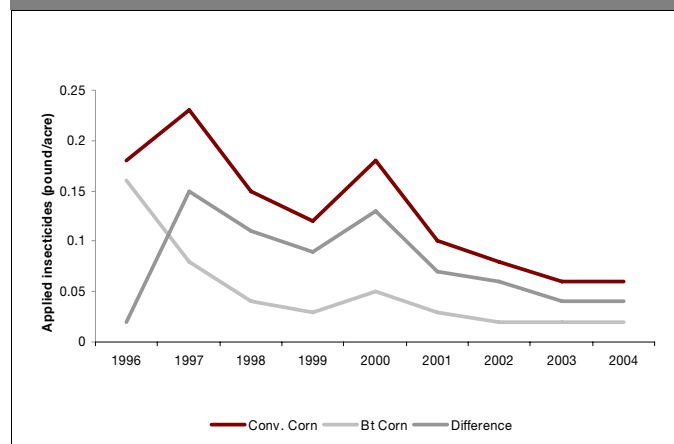
Source: USDA

AVERAGE USED OF HERBICIDES ON CORN



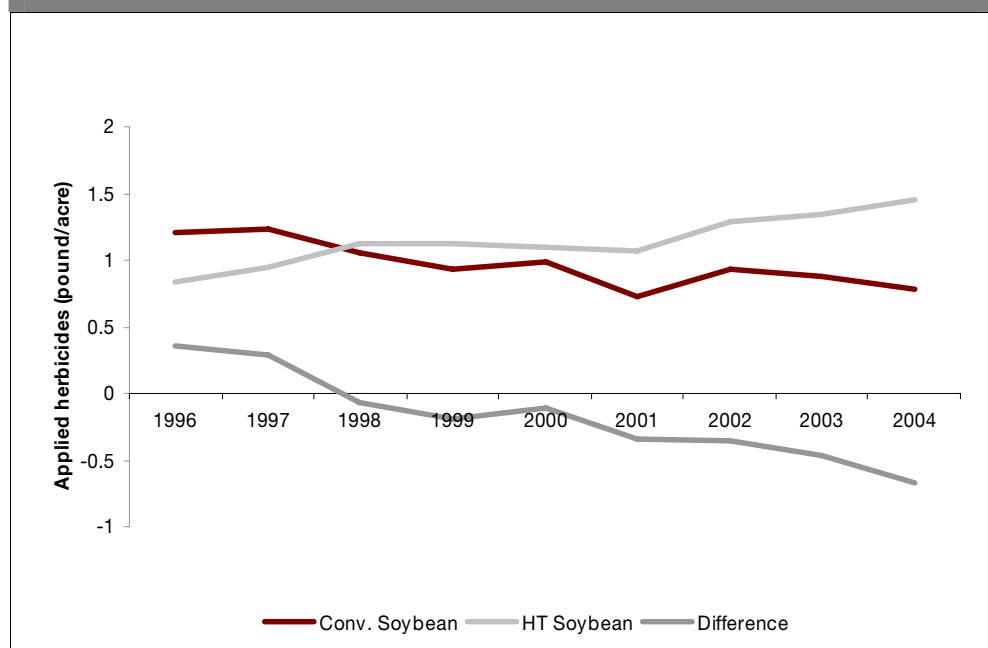
Source: USDA

AVERAGE USED OF INSECTICIDES ON CORN



Source: USDA

AVERAGE USED OF HERBICIDES ON SOYBEAN



Source: USDA

Stronger herbicides also increase the risk of pollution. Glyphosate, for example, endangers groundwater³.

Moreover, increased use of ultra-strong herbicides such as Round Up increases the risk of resistant weeds (glyphosate-resistant weeds have been reported in Australia, the US, Malaysia, Chile, etc, in reaction to Roundup Ready GE crop fields).

³ The substitution of GM crops with glyphosate in place of traditional crops could reduce environmental contamination from herbicides in the short term.

In the long term, however, studies have shown that AMPA, a glyphosate metabolite, could accumulate more substantially in soil, which would result in an increase in quantities detected in water, while this molecule is already one of the most often detected (IFEN, 2004).

Furthermore, in the case of widespread use of glyphosate, weeds could become resistant, a phenomenon that has already been observed (Perez & Kogan, 2003), and would imply the use of additional herbicides.

Moreover, the doses used for this study are average levels, whereas in some cases more than four or five glyphosate weedings are necessary (CETIOM), which would lead to high concentrations over and above those resulting from non-agricultural uses of this herbicide. There could also be effects on the biological functioning of soil, as the results concerning glyphosate's impact on microflora are not clearly established.

Source: INRA

**...could it be tackled
by crop rotation?**

The use of plants containing insecticidal genes has also contributed to the appearance of resistant insects.

The phenomenon of resistance that results from the pressure of breeding (broadly speaking, only individuals with resistant genes will reproduce and constitute in the future a large proportion of the population) could be reduced by crop rotation.

Moreover, it is well known that pesticides are dangerous to human health. ARTAC (the French association for research and treatment against cancer) issues regular reminders that pesticides pose the greatest danger to human health.

Finally, GE crops often contain genes giving resistance to antibiotics as marker gene. If these genes are transferred to bacteria, they may weaken or nullify the effectiveness of antibiotic treatment.

Conversely, Directive 2001/18/EC provides that GMOs which contain genes expressing resistance to antibiotics in use for medical or veterinary treatment are taken into particular consideration when carrying out an environmental risk assessment, with a view to identifying and phasing out such markers by 31 December 2008 in the case of marketable GMOs and 31 December 2004 for GMOs placed on the market for any other purpose.

IV – The players

Monsanto, with seed and trait sales of USD4bn in 2006/07, is the clear leader in GM seeds. We estimate that it has captured 24% of the North American corn branded seed market, and more than 90% of the GM traits.

Syngenta, with some 10.5% of the branded US corn seed market and 10% of the soybean US seed market in 2006, is in a position to launch its proprietary platform in corn, and recent deals with Pioneer (GreenLeaf, Optimum GAT) should help narrow the gap with Monsanto.

DuPont/Pioneer, after strong performances and market share gains in the 1980s, has lost ground to Monsanto.

Consolidation is very likely, as access to technology and germplasm will have an increasing impact on value propositions for farmers.

■ Monsanto

Brief history

Monsanto spun off its chemical activities in 1997 (Solutia) and instead acquired biotech firms such as Calgene. It already entered the seed market in 1996 when it formed a strategic alliance with DeKalb Genetics. Continuing on from this, Monsanto purchased a 40% stake in DeKalb in the first half of 1998 for USD2.5bn. This gave Monsanto an important outlet for its Roundup Ready and YieldGard varieties.

Acquisitions in seeds have helped penetration of GM technologies...

In September 1996, Monsanto acquired Asgrow Agronomics for USD240m. Asgrow Agronomics has 45% of its sales in soybeans. In January 1997, Monsanto agreed to buy Holden's Foundation Seeds for USD1.02bn. This acquisition along with other key deals has given Monsanto key channels of distribution for its GM technologies. In July 1998, Monsanto acquired Plant Breeding International Cambridge (PBI) for USD525m. PBI, a UK-based company, specialises in the breeding and marketing of winter wheat, barley, rapeseed, potatoes and other crops. In 2005, Monsanto acquired Seminis, the leading F&V seed company. This year, Monsanto acquired Delta and Pineland for USD1.9bn. DLP is the leading US seed cotton, with growing business in India and Latin America. Monsanto tried to acquire DLP in 1998, but dropped the plan in early 2000, due to concerns expressed under the Anti-Trust Law and the terms on offer. Monsanto is the No1 seed producer in the US and South America, with a No1 position in cotton.

... DeKalb in corn, Asgrow in soybean, DLP in cotton

In addition to the above acquisitions, Monsanto also entered into a number of agreements with both seed companies and genomic research institutions. The most recent one is the R&D collaboration with BASF/metanomics. Monsanto also has a 50/50 JV with Cargill (Renessen) for improving corn processing technologies and developing usage of new enhanced crops.

Current offering

With a market share of more than 90% in genetically modified seeds, Monsanto is a leading producer for the corn, soybean cotton, and fruit & vegetable markets, as well as a strong competitor in crop-protection chemicals due to its glyphosate Roundup non-selective herbicide. Monsanto reports two segments:

- Agricultural Productivity (43% of sales, 30% of EBIT), which encompasses the herbicide, bovine hormone and swine genetics products,
- Seed & Genomics (57% of sales, 70% of EBIT)

Key product lines include:

- **Corn seeds and traits** (estimated 20% share, No2 behind Pioneer). Monsanto has gained share steadily over the past seven years, mostly due to enhanced yields, more rapid introduction of double- and triple-stacked biotech products, and the roll-

up of regional seed companies in its ASI subsidiary. We estimate Monsanto has taken 20% of the global market, and roughly 34% in the US (including 10% for ASI).

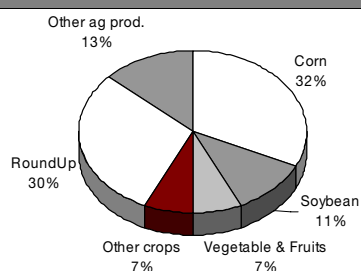
MONSANTO: CORN ACREAGE, 1996-2007E

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007E
Single-trait acres												
US RR corn trait	0	0	0.9	2.1	2.6	3.4	5.6	6.9	8.3	10.9	11.1	13
US YG CB traits	0	2.3	11.4	15.4	14.6	14.3	18.2	20	24.2	18.8	12.3	9
US YG rootworm trait	0	0	0	0	0	0	0	0.4	1.1	0.9	0.7	1
US RR stacked/non-mon. traits	0	0	0	0	0	0	0	0	0	0.5	1.3	8
Total US Single-trait acres	0	2.3	12.3	17.5	17.2	17.7	23.8	27.3	33.6	31.1	25.4	30-31
RR corn trait-other markets	0	0	0	0.1	0.1	0.2	0.2	0.3	0.2	0.4	1.3	2
YG CB traits-other markets	0	0	0	0.6	1.1	2	3	3.7	4.3	6.2	5.5	7
Total WW single-trait acres	0	2.3	12.3	18.2	18.4	19.9	27	31.3	38.1	37.7	32.2	39-40
Double-trait acres												
US YG corn borer/RR	0	0	0	0	0.1	1.2	2.2	5.1	8	11.1	12.6	14
US YG rootworm/RR	0	0	0	0	0	0	0	0	0.7	1	1.9	2
US YG plus	0	0	0	0	0	0	0	0	0	0.9	1.6	1
Total US double-trait acres	0	0	0	0	0.1	1.2	2.2	5.1	8.7	13	16.1	16-17
YG corn borer/RR-other	0	0	0	0	0	0	0.1	0.1	0.2	0.2	0.3	1
Total WW double-trait acres	0	0	0	0	0.1	1.2	2.3	5.2	8.9	13.2	16.4	17-18
Triple-trait acres												
US YG plus/RR	0	0	0	0	0	0	0	0	0	1.3	5.8	18
Total US triple-trait acres	0	0	0	0	0	0	0	0	0	1.3	5.8	17-18
Total WW triple trait acres	0	0	0	0	0	0	0	0	0	1.3	5.8	17-18
Total mon. trait corn acres												
Total abs. US corn trait acres	0	2.3	12.3	17.5	17.3	18.9	26	32.4	42.3	45.4	47.3	63-66
Total abs. WW corn trait acres	0	2.3	12.3	18.2	18.5	21.1	29.3	36.5	47	52.2	54.4	73-76
Trait -specific summaries												
Total US YG CB traits	0	2.3	11.4	15.4	14.7	15.5	20.4	25.1	32.2	32.1	32.3	41-42
Total US YG RW traits	0	0	0	0	0	0	0	0.4	1.8	4.1	10	21-22
Total US RR traits	0	0	0.9	2.1	2.7	4.6	7.8	12	17	24.8	32.7	55-56
Total US corn traits	0	2.3	12.3	17.5	17.4	20.1	28.2	37.5	51	61	75	118

Source: Monsanto

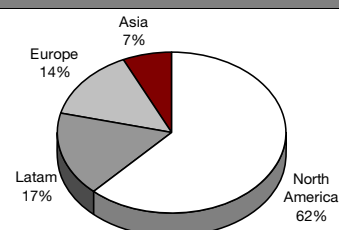
- **Soybean seeds and traits (No2).** Monsanto is the global leader in the soybean market, followed by DuPont. We believe DuPont is still the leader in the US.
- **Cotton (No1).** With its USD1.5bn acquisition of Delta and Pine Land, and the related sale of the Stoneville and NextGen brands, Monsanto has established itself as leader in the US cotton market, with a share of around 50%, followed by Bayer (35% estimated, but fastest growing).
- **Fruit & vegetables (No1).** Monsanto has approximately 20% of the global USD3bn fruit and vegetable seed market, followed by Syngenta (10%) and six regional players (together 40% of the market).
- **Crop-protection chemicals (No4).** Roundup non-selective herbicide remains the industry leader, with some USD2.8bn of sales in 2007E (31% of total 2007E sales). Generics have gained market share, but we have seen a stabilisation due to formulation and bundling.

MONSANTO 2007E SALES BY BUSINESS LINE



Source: Cheuvreux

MONSANTO 2007E SALES BY REGION



Source: Cheuvreux

Financials and outlook

In 2007, Monsanto had sales of USD4.9bn in seeds and gross profit of USD3bn, resulting in a gross margin of 60.7%.

MONSANTO: 2007 SEEDS AND GENOMICS RESULTS

To end August 2007 (USD m)	Sales	Gross profit	GP margin
Corn	2807	1721	61.3%
Soybean	901	588	65.3%
F&V	612	267	43.6%
Cotton and others	644	438	68.0%
Total	4964	3014	60.7%

Source: Monsanto

In the past three years, Monsanto's revenues have grown by around 30%.

MONSANTO: REVENUES, 2004-07

(USD m)	2004	2005	2006	2007
Seeds and genomics sales	2320	3252	3978	4964
		40%	22%	25%
Gross profit	1369	1982	2433	3014
GP margin	59.0%	60.9%	61.2%	60.7%
EBIT	196	374	794	905
EBIT margin	8.4%	11.5%	20.0%	18.2%
Total sales	5423	6294	7294	8563
		16%	16%	17%
Gross profit	2527	3004	3519	4286
GP margin	46.6%	47.7%	48.2%	50.1%
EBIT	603	742	1177	1611
EBIT margin	11.1%	11.8%	16.1%	18.8%

Source: Monsanto

At its recent Investors Days, Monsanto updated its medium-term outlook for Seeds and Genomics. The group believes it has the potential to double its growth profit to USD8bn by 2012E, mainly with the development of Seeds and Genomics. All seeds lines are expected to contribute.

Monsanto expects to increase 2004 gross profit by a factor of six, to USD3.8bn (2.2x on 2007E GP). Gross profit will be driven by strong penetration of triple-stack corn and, from 2010E, by the launch of *SmartStax* platform. Internationally, Monsanto expects continued market share gains in Europe and Latin America.

**Corn potential:
SmartStax platform
and international**

Fruit and vegetables

Seminis has been underperforming on portfolio pruning, but should return on a 6% CAGR for the next five years, 2 percentage points above market growth. Focus will be on high-yielding species for protected cultures (higher premium). Monsanto expects to double its 2007 gross profit (USD267m) by 2012E, leading to a gross profit margin of 65% vs 44% currently.

Soybean: RR2Yield by 2010E

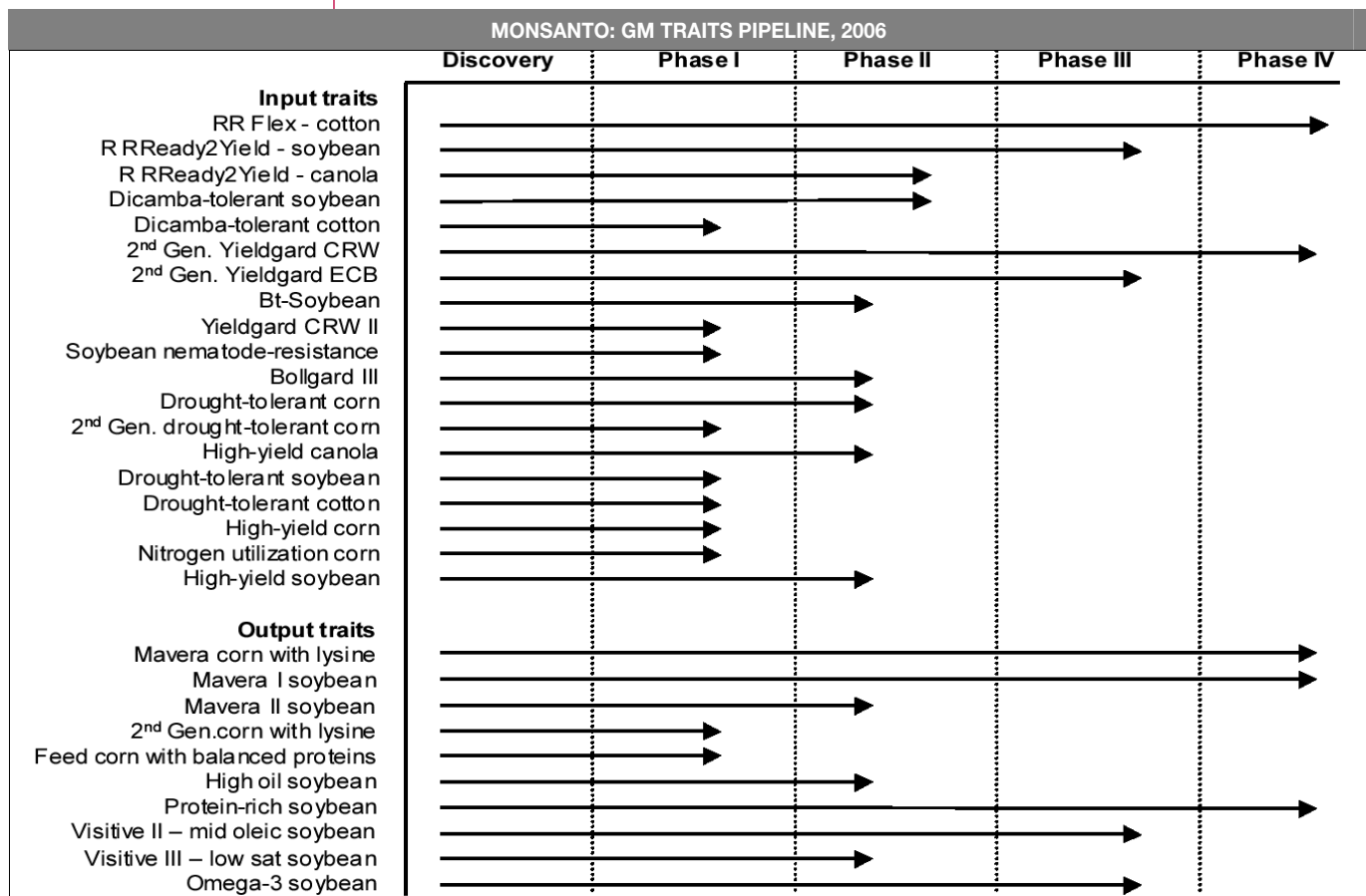
Here also, Monsanto believes it can double gross profit vs 2004 or multiply by 1.5x vs 2007 (USD588m). Main drivers are RR2Yield and Latin America further GM penetration.

Cotton: recovery of market shares

Monsanto wants to recover DLP's lost market shares (9%), despite the disposal of Stoneville to Bayer. It expects to increase 2007 gross profit by a factor of 1.8 (USD267m in 2007) by 2012E, driven by a recovery of market share, international development (India) and rollout of second-generation technologies.

R&D pipeline: yield improvement traits

Monsanto is expecting some USD5b in sales (75% value created) from a range of 'yield traits' for corn and soybeans. This is in line with a potential market for 'yield traits' at USD15bn-20bn by 2025



Source: Monsanto

■ DuPont/Pioneer

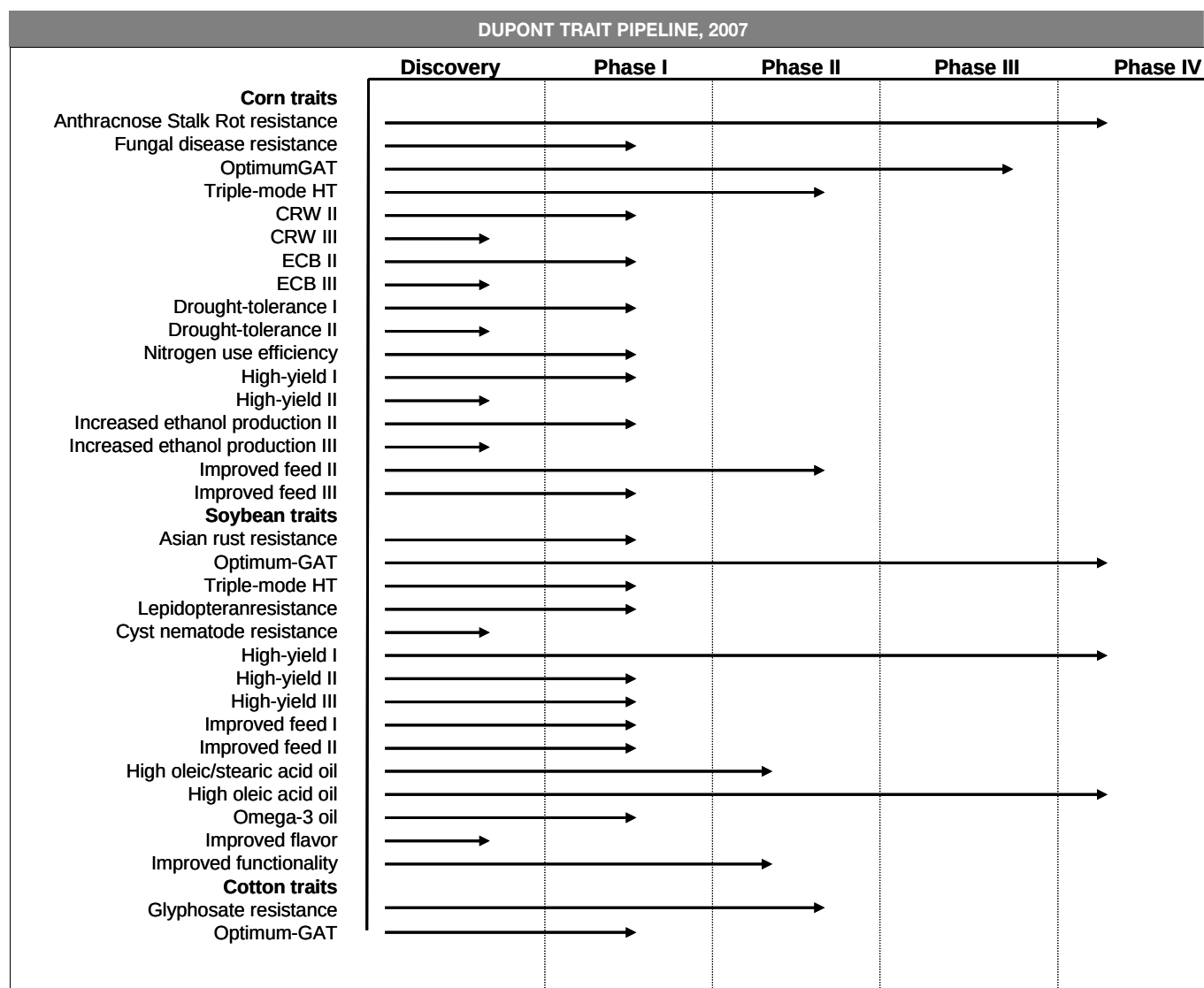
With the acquisition of Pioneer in 1999, DuPont entered the seed market with the leading company in corn and soybean. It has also a strong crop protection portfolio. Combined Ag and Nutrition sales reached USD6bn in 2006, generating EBIT of USD725m. The segment includes Crop Protection Products (CPP), Pioneer Seeds, Nutrition & Health and packaging activities (Liqui-Box).

In our view, Pioneer accounts for 42% of divisional sales (USD2.5bn) and CPP for 36% (USD2.1bn). DuPont's CPP division is heavily dependent on herbicides – and sulphonylurea chemistry – which accounted for 72% of sales in 2006 (insecticides 17%; fungicides 11%). In terms of crops, vegetables and speciality end-markets account for some 42% whereas corn and soybean account for only 22%. Geographically, 60% of sales are made outside North America, with Europe, Middle East & Africa accounting for 29% in 2003.

Pioneer, acquired in two stages (20% in 1997; 80% in 1999) for 5x sales and around 20x EBITDA, is the largest corn seed producer and distributor in North America, with sales of USD2.5bn in 2006. Corn accounts for 72% of sales, soybean 18%. Pioneer has a strong conventional and GM seeds business, with the broadest proprietary germplasm for corn, but also soybean.

Although DuPont has a large pipeline, Optimum-GAT is the next important trait for Pioneer, as it will efficiently compete with Monsanto's RR traits. This trait has been developed by Maxygen's Verdia and Pioneer, and is based on a different mode of action using glyphosate detoxification, including sulphonylureas tolerance. DuPont has consequently decided to acquire Verdia, for USD64m. Optimum-GAT will be used in soybean (2009E), corn (2010E) and cotton.

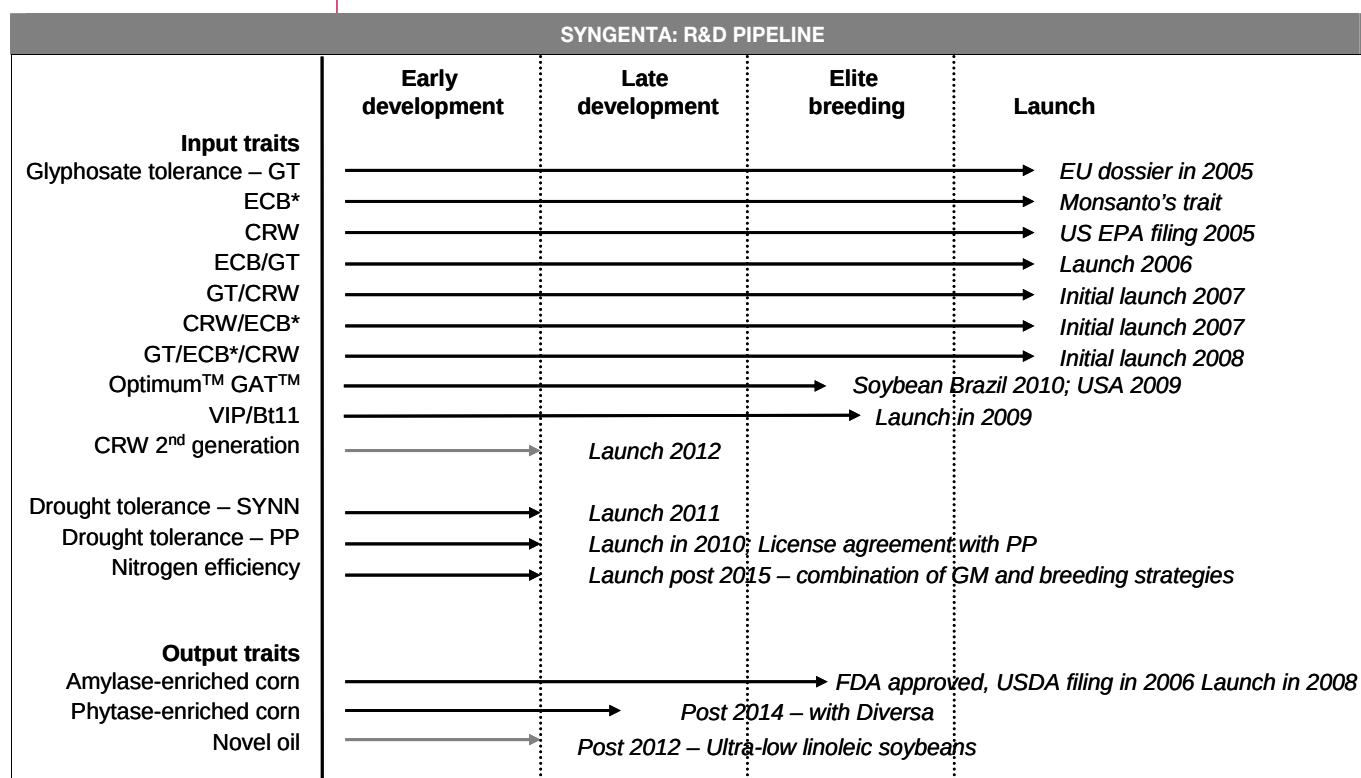
DuPont and Evogene recently announced a research collaboration to improve drought stress tolerance primarily in corn and soybeans. Under the agreement, DuPont business Pioneer Hi-Bred has exclusive rights to several genes discovered by Evogene for improving these traits.



Source: DuPont

■ Syngenta

Syngenta has also built its seed business through acquisitions, with the most recent acquisitions of Golden Harvest and Garst (corn and soybean) in 2004, Emergent genetics (vegetables) in 2006, Fischer (flowers), Zeraim Gedera (vegetables) and Sanbei (China, corn - 49% stake) in 2007. Syngenta is the largest player in flower seeds, No2 in fruit and vegetables and No3 in corn/soybean. The company has also signed a five-year R&D collaboration with the Institute of Genetics and Developmental Biology of Beijing University on all key traits that would come out from this collaboration, with global commercialisation rights.



Source: Syngenta

Plant Performance licensing on drought tolerance

Syngenta has developed its own proprietary GM corn platform, having bought GA21 herbicide tolerance from Bayer and launched its own corn rootworm (CRW) last year. It will have some 600,000 acres of proprietary triple-stack corn next year.

It also has signed a licence agreement with DuPont for its second generation HT based on both glyphosate and sulphonylurea herbicides, which will be deployed on corn and soybean. It has also, as already described in the previous chapters, developed a GM corn specifically engineered for bioethanol production, with higher levels of amylase.

Syngenta has entered into a licensing agreement with Performance Plants Inc., Canada for development of drought-tolerant corn and soybeans using Performance Plants' Yield Protection Technology™. This trait should enable plants to withstand dry seasons without suffering yield drag under normal moisture conditions. Syngenta also expects that its trait will enable growers who irrigate to use less water and offer the opportunity to convert marginal acres into more productive cropland.

Deal with ROH to develop Invinsa for heat stress reduction

Syngenta and Rohm and Haas recently signed a global alliance in the development of methyl-cyclopropene for resistance to heat stress in key field crops. Methyl-cyclopropene (*Invinsa*) blocks the action of ethylene.⁴ Its potential has been demonstrated in different regions, on different crops (wheat, corn, soybean). Improvement in yields with spraying with *Invinsa* have been demonstrated to generate a yield improvement of some 10-15%. This 'chemical' solution could create a market of USD1bn over the next three years.

Financial and outlook

Syngenta recently disappointed on the profitability of its seeds business, but this is clearly related to the pre-investments needed to launch triple-stack corn on a larger scale by 2009-2010E and to secure the development of future pipeline. The seeds R&D/marketing expenses will rise from USD661m in 2006 to some USD825m by 2009E.

We believe Syngenta's triple-stack corn shows at least as good a performance as Monsanto's and is likely to be utilised in at least 50% of the current market for Syngenta (about 10 million acres).

SYNGENTA: SEEDS, 2006-12E

(USD m)	2006	2007	2008E	2009E	2010E	2011E	2012E
Seeds sales							
Corn	550	635	630	665	700	740	785
Soybean	235	215	240	250	260	270	280
Other field crops	309	335	348	360	367	375	382
F&V	649	735	845	880	915	952	990
Total	1743	1920	2063	2155	2242	2336	2437
Gross margin analysis							
Corn	25%	19%	21%	25%	30%	36%	42%
Soybean	36%	36%	36%	36%	37%	37%	38%
Other field crops	60%	60%	60%	60%	60%	60%	60%
F&V	65%	65%	67%	68%	68%	69%	70%
Total	48%	46%	48%	50%	51%	53%	56%
EBITDA margin							
Corn	1%	-10%	-15%	-5%	0%	8%	14%
Soybean	5%	4%	5%	6%	7%	7%	8%
Other field crops	17%	17%	17%	17%	17%	18%	18%
F&V	16%	16%	16%	17%	17%	18%	18%
Total	9.1%	5.0%	5.4%	8.9%	10.5%	13.6%	15.6%

Source: Cheuvreux

⁴ Ethylene is an important hormone that plays a role in the ripening of fruit and the senescence of flowers. Environmental cues can induce the biosynthesis of the plant hormone. Flooding, drought, chilling, wounding and pathogen attack can induce ethylene formation in the plant.

■ Dow Agrosiences (DAS)

Dow Agrosience is a wholly owned subsidiary of The Dow Chemical Company and was formed in 1998 after Dow purchased the remaining shares of its joint partner Eli Lilly. The joint venture between Eli Lilly and Dow was formerly known as DowElanco. Dow's commitment to biotechnology was exemplified by the formation of a new company in September 1998 called Advanced AgriTraits LLC. The strategy of the new company involves developing the company's own technology and forming alliances with other companies to expand its biotechnology base in a cost-effective way.

DAS formed a strategic partnership and controlling interest in Mycogen in 1996. Mycogen is the sixth largest Seed Company in the US. Mycogen is the biotech arm of DAS and concentrates on agronomic traits for new plant varieties, and DAS has numerous agreements with many different companies. These are for mostly concerned with crops such as corn and canola. At the end of 1997, Dow signed an agreement with Seed Genetics Inc. to develop, market and license high oil corn inbreds using DowElanco's technology (now DAS), as well as biotech traits as they become available. In 1998 Dow formed an alliance with three major companies, Performance Plants Incorporated, BioSource Technologies Inc. and Illinois Foundation Seeds all of which are in genomics. In 1999, Dow formed a joint venture with Danisco to develop new varieties and hybrids that will increase the value of canola to customers.

In 2006, DAS launched four new products, including two new insect-protection traits for corn (Herculex[®] RW *Rootworm Protection* and Herculex XTRA *Insect Protection*). Herculex RW gives growers a high level of powerful season-long protection against corn rootworm. Herculex XTRA provides the broadest spectrum, above- and below-ground in-plant insect protection available. Cotton growers will have an expanded offering of PhytoGen[™] varieties with WideStrike[™] *Insect Protection* combined with the Roundup Ready[®] herbicide-tolerant trait.

Current research goals also include development of proprietary herbicide tolerance traits for various crops. Currently referred to as DAS Herbicide Tolerance, this innovative new technology will provide tolerance to multiple classes of herbicides in many different crop species, enabling farmers to pick and choose between weed-fighting products. Dow AgroSciences estimates launch timing for this technology at 2012 for corn and 2013 or 2014 for soybeans. DAS also intends to combine its herbicide tolerance traits with the Herculex[®] *Insect Protection* family of traits – providing growers with the broadest-spectrum of in-plant insect protection and the best herbicide tolerance package available.

DAS and Exelixis Plant Sciences recently announced an important research collaboration agreement, which includes the purchase of selected assets by DAS affiliate Agrigenetics Inc. The agreement is focused on the development of new tools for gene discovery and validation of novel crop traits. The asset purchase by Dow AgroSciences includes certain intellectual property and physical assets used for crop trait discovery.

DAS continues to expand its global corn germplasm portfolio and corn business with the acquisition by its affiliate Agrigenetics, Inc. of Duo Corn, a corn germplasm company focused primarily on early maturing germplasm silage applications for northern climates. Duo Corn is based in Rossum, Netherlands and more recently Agromen Tecnologia, Brazil.

■ Bayer Bioscience

Bayer is the largest producer of crop protection agents, with sales of EUR4.6bn in 2006. It is also present in seeds and biotechnology through its division BioScience, which had sales of EUR342m in 2006E. Bayer recently upgraded its target for the business, planning to reach sales of a EUR1bn by 2017E.

Bayer gained access to seeds and biotechnology traits via the acquisition of Aventis Crop Science in 2002. Bayer CropScience's BioScience business group includes two business units, Nunza and Crop Improvement. Bayer CropScience also owns 15% of KWS KgaA.

The BioScience business group's vegetable seeds business, Nunza, is based in the Netherlands, comprising two companies, Sunseeds (in the Americas) and Nunhems (in Europe and the rest of the world). Its main crops are carrots, onions, melons, leeks, asparagus, tomatoes, cucumbers and salad vegetables. In total, Nunza markets 2,500 varieties of 28 species around the globe. The main crops are carrots, onions, tomatoes and leeks. Nunza is relatively small in the context of the USD3bn seeds market, but this is still a fragmented sector, with Monsanto (2007 sales of USD612m and 20% of the market), Syngenta (USD500m; 17%) and Limagrain (USD450m including Vilmorin retail vegetables seeds) being the largest players.

BioScience is present in rice, canola and cotton seeds and biotechnology traits.

Rice

Arize® rice seed

Improving yields is the principal challenge for the rice community internationally. Hybrid rice seed enable farmers to achieve significant yield improvements over open-pollinated or 'inbred' varieties. Arize hybrid rice yields above the best performing inbred varieties and at least on par with competitive hybrids.

Canola

InVigor® canola seed

Canola is a variety of rapeseed, and has found strong growth in Canada and Europe due to its oil content and renewed interest in biodiesel growth. Its main characteristics are:

- hybrid vigour resulting in top yields;
- superior agronomic characteristics (crop establishment, plant size, disease tolerance, overall environmental response);
- vigorous early season growth;
- competes aggressively against weeds;
- uniform growth.

Cotton

FiberMax® cotton seed

The acquisition of Stoneville from Monsanto, a forced disposal after the acquisition of Delta and Pine Land (DLP), puts Bayer very close to Monsanto in terms of US market share. The acquisition does not include Stoneville's NexGen franchise, a regional cotton seed business in Texas and other assets related to the NexGen business. Although the acreage of cotton in the US is in our view likely to decline over the next five years in favour of corn/soybean, Bayer FiberMax has been the fastest growing seed business, gaining market share from both Stoneville and DLP. We estimate that Bayer will have some 30% of the US market.

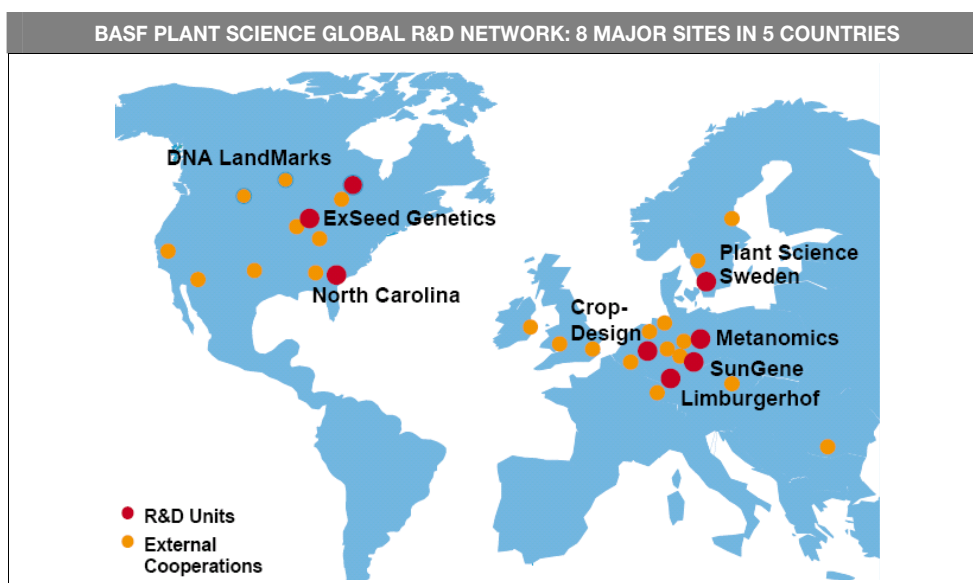
Evogen collaboration

Bayer has also signed several collaboration agreements, like the one with Evogene to increase the productivity and yield of a Bayer CropScience core crop, especially with regard to stress conditions such as drought. Under a recently signed agreement, Bayer CropScience, has exclusively licensed the rights to certain genes discovered by Evogene which have demonstrated improved plant yield and other performance enhancements in various plant species.

■ BASF

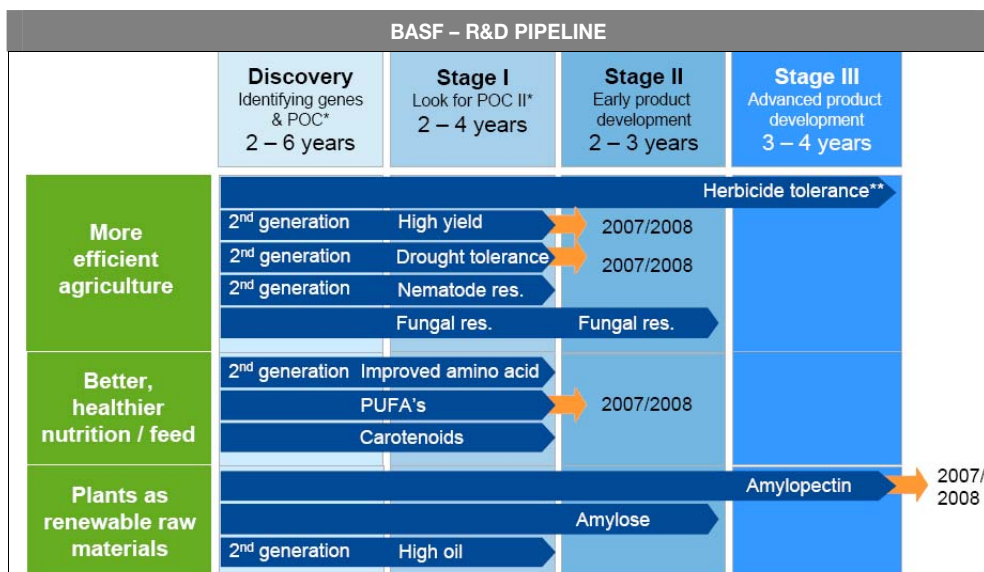
Although BASF has no presence in seeds, it has developed significant capabilities in plant science, through the acquisition of Metanomics in 1998 and CropDesign (a spin-off of Flanders Institute of biotechnology) in 2006. It now has more than 700 employees in R&D, 40 collaborations globally including more than 100 external researchers.

BASF's strategy, as a latecomer to the sector, is to focus on metabolic profiling and detailed understanding of the relationships between genome and metabolism. Profiling includes more than 1,000 metabolites targeted and 9,000 metabolome signals screened. Currently, BASF is working on Arabidopsis as a plant model (mustard family). Phenotypic analysis is carried out with CropDesign high throughput technology (100,000 plants analysed per year).



Source: BASF

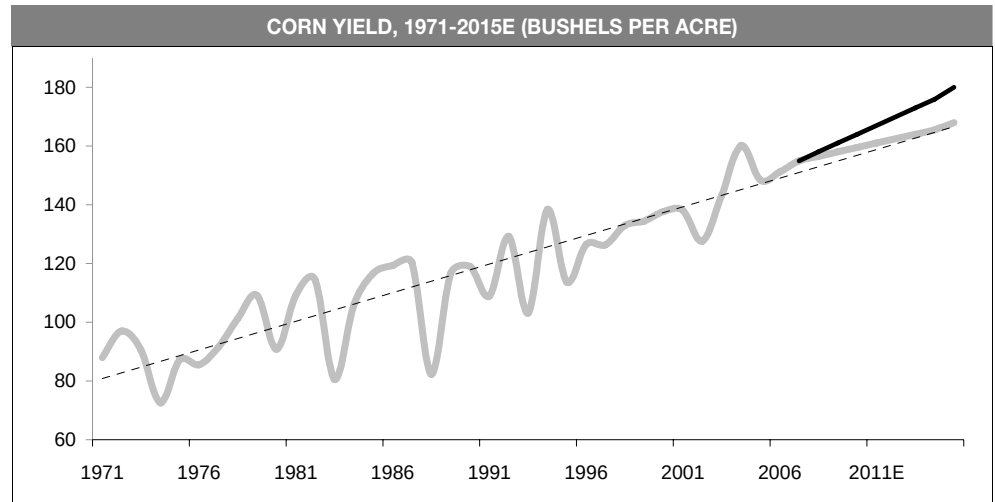
BASF plans to spend more than USD150m on Plant Science R&D, with a focus on R&D collaboration with Monsanto (some USD70m p.a.) and on key projects such as nutrition and renewable materials for industrial applications, as shown in the following chart.



Source: BASF

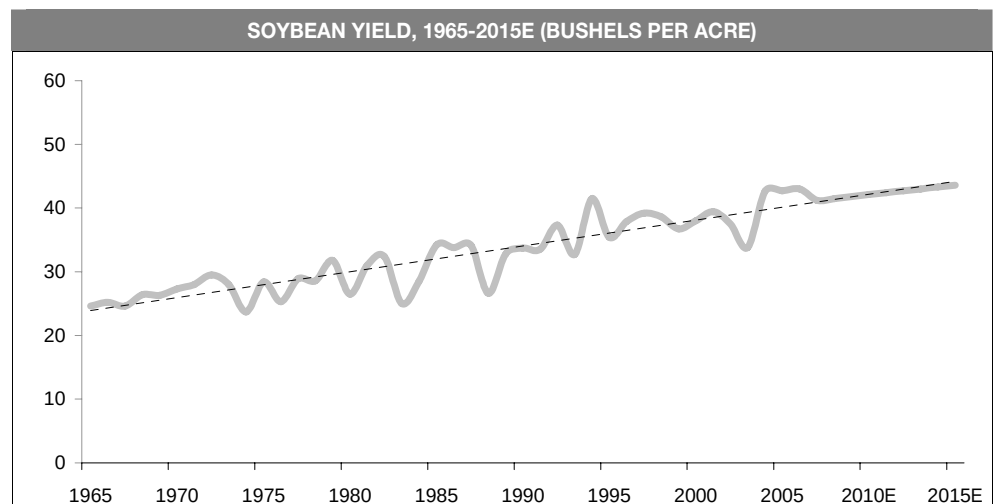
V— US corn and soybean: historical yields

US corn has shown strong yield improvement, essentially driven by conventional breeding by strong companies such as Pioneer and DeKalb. In 1971, the average yield was 80 bushels per acre, and we estimate that 2007E yield should be around 145 bu/acre.



Source: USDA, Cheuvreux

But while corn has taken giant leaps forward in average bushels per acre, soybean yields have advanced in small steps. Between 1930 and 2003, average corn yields jumped nearly sevenfold, from 20.5 to 142.2 bushels per acre. In the same period, average soybean yields nearly tripled, from 13 to 33.4 bushels per acre. National soybean yields have hovered around 40 bushels per acre for about a decade.



Source: USDA, Cheuvreux

**Why the widening gap
between corn and
soybean?**

Among the main reasons for the divergence between corn and soybean are genetic differences between the two crops and the greater attention being paid to corn research. Soybeans have about half the DNA of corn, but soybeans are much more difficult to genetically cross than corn genes. Corn is more efficient at turning sunlight into energy (photosynthesis) than soybeans and, although soybean plants generally handle environmental stresses better than corn, soybeans tend to lose more grain – or fail to make it altogether – than their kernel-producing fieldmate.

Corn breeding is clearly easier

Corn is a determinate plant. It grows, develops, sets an ear and produces a tassel, but does it only once. That means that if field conditions are good during the important phases of development, high yields can be achieved. Soybean, on the other hand, is an indeterminate plant. It continuously produces more pods and more flowers during development. If stress hits early in development, soybeans can make up any reproductive losses, such as aborted flowers and aborted pods, later in plant development. Because of that, soybean yields are more stable than corn. But the number of flowers and the number of small pods that actually never develop seeds clearly limits the potential yield.

Experts agree: breeding work in corn is easier than it is in soybeans.

- **Easier, controlled pollination.** Controlled genetic crosses between two corn plants are much simpler than crossing soybeans. In soybeans, this is very difficult because the male parts of the plant have to be removed by hand (the plant is "emasculated"). In corn, all that needs to be done is to put pollen on the silks of the plant and bag it up so that no other pollen gets in. This is controlled pollination.
- **Product of the cross.** Crossing two plants in soybean results in one flower and, potentially, three or four seeds, but in corn it leads to an entire ear, or hundreds of seeds. Genetically, the probabilities are in favour of corn!
- **More efforts focused on corn.** There are about 600 public/private breeders concentrating on corn, but only 160 focusing on soybeans. Between 1998 and 2003, corn research funded by a science-based federal agency received USD106m while soybean research received just USD15m.

Future soybean research should address the pod abortion puzzle and other yield-restricting problems. These issues include:

- **Leaf canopy.** If science can find a way to manipulate the canopy to increase light availability to the soybean plant, higher yields should be possible. The same was found to be true with corn in research conducted about 40 years ago. Leaves on today's corn hybrids grow upright, where they used to grow out and down.
- **Genetic variation.** The available soybean germplasm, which is used to produce new soybean varieties, is less diverse than corn and many other field crops. Because genetic variation is limited, the introduction of disease- and pest-resistant genes into new soybean cultivars occurs less often.

VI – Technical glossary

Biotechnology

According to the draft Protocol on Biosafety, modern biotechnology means the use of methods other than those of traditional breeding and selection to i) apply in vitro nucleic acid techniques and/or ii) fuse cells beyond the taxonomic family in order to overcome natural physiological reproductive or recombination barriers. Biotechnology is currently applied in the health sector (antibiotics, insulin, interferon), in the agri-food system (micro-organisms, plants and animals), and in industrial processes such as waste recycling. Biotechnology and genetic engineering are often used interchangeably (see below).

Bacillus thuringiensis (Bt)

Bacillus thuringiensis (Bt) is a soil bacterium that produces toxins against insects (mainly in the genera Lepidoptera, Diptera and Coleoptera). Bt preparations are used in organic farming as an insecticide.

Bt crops

Bt crops are genetically modified to carry genetic material from the soil bacterium Bacillus thuringiensis. Crops containing the Bt genes are able to produce certain Bt-toxins, thereby providing protection against insects during the growth-stage of the plant.

Canola

Canola is a type of rapeseed developed and grown in Canada. It is a registered trademark, corresponding to specified low contents in erucic acid in oil and in glucosinolates in meals equivalent to double 0 in the EU. It has initially been obtained by conventional breeding, but in recent years, GM herbicide tolerant varieties have been developed.

Genetically modified food

Foods and food ingredients consisting of or containing genetically modified organisms, or produced from such organisms.

Genetically modified organism (GMO)

An organism produced from genetic engineering techniques that allow the transfer of functional genes from one organism to another, including from one species to another. Bacteria, fungi, viruses, plants, insects, fish, and mammals are some examples of organisms the genetic material of which has been artificially modified in order to change some physical property or capability. Living modified organisms (LMOs), and transgenic organisms are other terms often used in place of GMOs.

Germplasm

Germplasm is living tissue from which new plants can be grown: seed or another plant part such as a leaf, a piece of stem, pollen or even just a few cells that can be cultured into a whole plant. Germplasm contains the genetic information for the plant's heredity makeup.

Herbicide-tolerant (HT) crops

The insertion of a herbicide tolerant gene enables farmers to spray wide-spectrum herbicides on their fields killing all the plants but the HT crop. The most common herbicide-tolerant crops (cotton, corn, soybeans and canola) are tolerant to glyphosate and to glufosinate-ammonium, which are the active ingredients of common wide spectrum herbicides. There are also HT rapeseed and cotton which are tolerant to bromoxynil.

Living modified organism (LMO)

According to Biosafety Protocol, an LMO is any living organism possessing a novel combination of genetic material obtained through modern biotechnology. A living organism is biological entity capable of transferring or replicating genetic material.

Plant breeding

Plant breeding is the use of techniques involving crossing plants to produce varieties with particular characteristics (traits) which are carried in the genes of the plants and passed on to future generations. Conventional/traditional plant breeding refers to techniques other than modern biotechnology, in particular cross-breeding and back-crossing.

Segregation

Segregating implies setting up and monitoring separate production and marketing channels for GM and non-GM products.

Traceability

Traceability measures covering feed, food and their ingredients include the obligation on feed and food businesses to ensure that adequate procedures are in place to withdraw feed and food from the market where a risk to the health of the consumer is posed. Operators should keep adequate records of suppliers of raw materials and ingredients so that the source of the problem can be identified.

Transgenic plants

Transgenic plants result from the insertion of genetic material from another organism so that the plant will exhibit a desired trait.

