

## STRUCTURAL CHANGE IN THE BIOTECH SEED AND CHEMICAL INDUSTRIAL COMPLEX

Marvin L. Hayenga<sup>1</sup>

In this paper, the restructuring of the seed and chemical industries is discussed. Impacts on the herbicide and insecticide markets are detailed, along with the contractual relationships between biotechnology seed suppliers and farmers. Antitrust issues raised by the recent wave of merger and acquisition activity and intellectual property rights issues are briefly discussed.

*Key words:* biotechnology; farmer technology fees; consolidation; chemical and seed industries; patent disputes

**D**ramatic changes in the seed, chemical, and grain industrial complex have been triggered in the last five years by the “coming of age” of agricultural biotechnology. Perhaps a more appropriate metaphor would be the birth and the preschool years of the first set of commercial products from recombinant DNA technology. We have witnessed much laboratory development, field testing, and seeking of regulatory approval in the United States (U.S.) and abroad in the last decade. Finally, the first significant commercial sales of biotechnology products have materialized; products like herbicide and insect resistant seed varieties in corn, soybeans, and cotton (Hayenga, 1988; Kimle & Hayenga, 1993; Carlson, Marra, & Hubbell, 1997). These sales are merely the tip of the iceberg.

Several major players in the seed, herbicide, and biotechnology complex are emerging as leading competitors, developing and marketing the early biotechnology products in the grain and oilseed industries. Monsanto has led the way with massive investments in biotechnology research, and with seed and biotechnology company mergers and acquisitions (M&As). Novartis, DuPont and Pioneer, Dow Agrosiences, AgrEvo (Hoechst/Schering), and Zeneca and van der Have are all involved in similar efforts, albeit on a reduced scale. Such efforts allow firms to maintain a competitive position. Many of these companies are also involved in major disputes over patent rights to insect resistant *Bacillus thuringiensis* (Bt) corn, Bt technology contracts, and glyphosate resistant corn technology; and in market foreclosure and monopolization issues in the herbicide market.

In what follows, some of the consequences of the associated seed company buying spree, the changing structure of the industrial complex, and the surge of litigation to resolve important intellectual property rights ownership, control, and resulting profits, are all discussed. But first, the comparative importance of the companies involved in the major seed markets is analyzed. Likewise,

---

<sup>1</sup>Marvin L. Hayenga is a Professor of Economics at Iowa State University. © 1998 Marvin Hayenga.

the growth in the use of genetically engineered seed is examined, along with the market shares of the leaders in the pesticide markets. The emerging impacts of the linked seed and chemical packages being marketed to farmers are also discussed. Finally, some of the current issues being litigated, and some of the broader issues that are likely to emerge, are considered.

### **Market Shares And Seed Industry Structure**

The on-going concentration is a result of chemical companies vertically integrating into the seed and biotechnology industries. The end-goal of such integration has been to capture profits from biotechnology innovations which, in some cases, are also complementary to their chemical technology. In addition, these moves are an effort by the chemical companies to defend themselves against their competitors' moves.

Tables 1 and 2 show estimated 1997 seed company market shares. Shares in 1998 are likely to be similar, though the dramatic success of Roundup Ready soybeans has increased Asgrow's market share a few points and reduced Pioneer's share. DeKalb Genetics (which first introduced Roundup Ready corn) and Novartis (which has had success with Bt corn) increased their seed corn market shares by 1 or 2 points in 1998. The ownership changes occurring in 1998 are reflected in tables 1 and 2.

**Table 1. North American Seed Corn Market Shares, 1997**

<b>Company</b>	<b>Percent</b>
Pioneer Hi-Bred	42
Monsanto	<b>14</b>
<i>DeKalb</i>	<i>10</i>
<i>Asgrow</i>	<i>4</i>
Novartis	9
Dow Agrosiences / Mycogen	4
Golden Harvest	4
AgrEvo / Cargill	4
Hoechst / Schering / Advanta	3
Others	20
<i>Source: Industry Estimates</i>	

Pioneer Hi-Bred International (now 20% owned by DuPont) has been the leading branded seed merchandiser in the corn and soybean markets. Pioneer's market shares exceeded 40 percent in corn and 19 percent of purchased soybean seed in the late 1990s.

**Table 2. North American Purchased Soybean Seed Market Shares, 1997**

<b>Company</b>	<b>Percent</b>
Monsanto	<b>19</b>
<i>DeKalb</i>	8
<i>Asgrow</i>	11
Pioneer Hi-Bred	19
Novartis	5
Dow Agrosiences / Mycogen	4
Stine	4
Other brands	39
Public varieties	10
<i>Note.</i> In 1997, an estimated 25 percent of soybean seed was farmer-saved, not newly purchased.	
<i>Source: Industry Estimates</i>	

Monsanto's purchases of Asgrow and DeKalb Genetics have resulted in a branded seed corn market share near 14 percent. In addition, Monsanto's purchase of Holdens gives them significant influence over germ plasm sold to other companies; Holdens' germ plasm is estimated to be part of an additional 30-40 percent of branded seed sales. The bombardment and agrobacterium gene insertion technologies patented by Monsanto and DeKalb also raise issues about the ability of potential competitors to compete in the genetic engineering race. With Monsanto's acquisition of DeKalb, Monsanto and Pioneer combined will either own or significantly influence over 90 percent of the North American seed corn market. In addition, Monsanto has license agreements for its Roundup Ready and YieldGuard technologies with other companies. These companies account for a very high share of the soybean seed market and a smaller share of the seed corn market.

Other companies have also been involved in the restructuring of the seed industry. In 1996, Novartis combined the Ciba-Geigy (one of the first marketers of Bt corn) and Northrup King seed businesses. Novartis then capitalized upon the Bt products of these companies in order to expand its corn seed market share from about 6 percent in 1995 to 9-10 percent in 1998. Dow Agrosiences recently acquired Mycogen. Mycogen has a 4 percent market share in corn seed. In addition, Dow Agrosiences recently acquired part of Illinois Foundation Seeds which provides foundation seed for another 11 percent of branded seed corn sales by other companies. AgrEvo recently acquired Cargill's domestic seed business, while Monsanto acquired Cargill's international seed business. The objectives of several companies, including Monsanto, Novartis, DuPont and Pioneer, is to develop seed with value-added traits for the food and feed markets, and to establish joint ventures to market the end products. These objectives will be achieved through companies like Optimum Quality Grain, Continental Grain, Cargill, and ADM.

The soybean market has long been considered the low margin part of the seed business. In the soybean seed market there is no hybridization to differentiate products, and a significant amount of farmer-saved seed. In addition, public varieties from universities provide low priced competition that has limited branded soybean seed profit margins (Kimle & Hayenga, 1993). Pioneer's entry into the soybean seed market in the early 1980s, and their very large corn market shares and strong dealer system, have resulted in their emergence as the leading soybean seed company in the late 1990s. Asgrow and DeKalb were strong competitors who were recently acquired by Monsanto. Asgrow has capitalized on the Roundup Ready soybean demand in order to capture the largest market share in

1998, partly at Pioneer’s expense. After the DeKalb acquisition, Monsanto seed companies account for 23-25 percent of purchased soybean seed in 1998, up five points from 1997.

The cotton seed market has long been dominated by Delta and Pine Land (Table 3). Monsanto became a competitor when it bought Calgene and Calgene’s Stoneville cotton seed subsidiary. Monsanto’s recent purchase of Delta and Pine Land (not yet approved by the Justice Department) will bring its total market share near 84 percent in 1997, and 87 percent in 1998. Because of this extremely high market share, and in an apparent attempt to avoid, objections from antitrust agencies in the U.S., Monsanto recently announced that it will divest the Stoneville operations. Stoneville’s market share has increased to 16 percent due to the combination of superior yielding varieties and its introduction of Buctril herbicide resistant cotton.

**Table 3. Cotton Seed Market Shares**

Company	1997	1998
Monsanto	<b>84</b>	<b>87</b>
<i>Delta &amp; Pine Land</i>	72	71
<i>Stoneville</i>	12	16
Other	16	13
<i>Source: Agricultural Marketing Service. (1997;1998). <u>Cotton Varieties Planted</u>. Washington, DC: United States Department of Agriculture.</i>		

### Genetic Innovation

The first generation of biotechnology products, which have achieved high commercial volumes, are primarily crop insect or weed protection innovations. These crops have enhanced input traits. Products with added value output traits are coming soon.

#### Input Traits

Industry experts expect that biotechnology-based solutions to weed, fungal, and insect problems will comprise 10-20 percent of the global \$45 billion crop protection market. Biotechnology innovations could become dominant in the next 10-20 years in some insect-control markets (Beyer & Chumley, 1998). Forty-five percent of cotton produced in 1998 was genetically engineered for insect resistance, herbicide resistance, or both.

Insect resistance for European corn borer in corn has been achieved by genetic insertion of the Bt gene. Bt corn reached the market in 1996, as Mycogen and Ciba-Geigy began sales, joined by a large number of competitors in 1997 and 1998. *Bacillus thuringiensis* seed corn sales reached approximately 20 percent of acreage in 1998, and are projected to nearly double in 1999, though low corn prices, combined with little corn borer pressure in 1998, may slow that growth. Total Bt corn volume is expected to reach 50-60 percent within a few years (Table 4). The extent of growth may be limited if the Environmental Protection Agency requires high levels of non-Bt corn (possibly 20-40 percent of acreage) to guard against development of resistant strains of European corn borer. The largest share of Bt corn is licensed from Monsanto (YieldGuard brand), with the rest from Dow (Mycogen), Novartis, and AgrEvo.

**Table 4. Estimated Transgenic Crop Acreage**

Percent of planted acres					
Crop	1995	1996	1997	1998	1999 (est.)
<b>Corn</b>					
• Bt		1	7	20	25-40
• RR				1	4
• LL			1	7	
<b>Soybeans</b>					
• RR		1	14	37	50+
<b>Cotton</b>					
• Bt		14	17	21	
• RR			6	28	50+
• BXN				8	
Bt is <i>Bacillus thuringiensis</i> (insect resistant), RR is Roundup resistant, LL is Liberty resistant, BXN is Buctril tolerant.					

Several companies have announced that corn rootworm resistant varieties will reach the market by 2000. These companies expect sales to expand sharply in the following few years. Since corn rootworm is a more pervasive and serious problem for corn growers, this form of insect resistant seed is likely to have an even greater impact in the seed corn industry than corn borer resistance.

Insect resistant Bt varieties in cotton have been commercially available for three years to control cotton bollworm, tobacco budworm, and pink bollworm. Cotton bollworm and tobacco budworm infestations were present in 79 percent of cotton acreage in 1997, according to the National Cotton Council. Over 20 percent of cotton acreage was sown with Bt cotton in 1998, and this acreage is increasing. The use of Bt cotton is especially high in areas where insects have developed resistance to the most commonly used insecticide sprays -- the pyrethroids.

However, there are factors which will limit the market penetration of Bt cotton seed. There have been some problems reported of incomplete bollworm control in high infestation years. A non-Bt cotton must be planted on 4-20 percent of cotton acreage to reduce chances of resistance developing in the target insects. Cotton in California is typically not infested with the prime pests which Bt cotton controls, while Texas cotton is usually treated with one spray, compared to 3-5 sprays in the Southeast. So the incentive to use Bt cotton is much less outside the Southeast.

Genetically engineered herbicide resistant seed was introduced in soybeans and cotton in 1996, and in corn in 1997. Some naturally-selected herbicide resistant varieties were available a few years earlier. The soybean seed market has been radically transformed in the last few years as Roundup Ready soybeans have jumped to over 30 percent of the market in 1998. Roundup Ready soybeans are projected to be planted on over 50 percent of acreage in 1999; possibly reaching 70-80 percent in the future. Herbicide resistant cotton seed now comprises nearly 40 percent of planted acreage, but acreage is expected to more than double in the next five years. Most of the acres are planted with Monsanto's Roundup Ready technology, but almost a million acres are tolerant to Buctril.

Herbicide resistant corn acreage (e.g., Roundup Ready corn) is still quite small. The Roundup Ready resistant seed corn market share is likely to grow at a slower pace than soybeans, and will reach no more than 20-30 percent share of acreage planted under the kinds of restrictions previously built into Monsanto's licensing agreements. The operating interpretation of the recent U.S. Department of Justice (DOJ) agreements with Monsanto, which did not challenge the DeKalb acquisition, is not yet clear. The DOJ is requiring Monsanto to remove restrictions against competing genes. These genes can be used in conjunction with Monsanto's technology. This action may increase the market share of Roundup Ready genes, though not all the acres planted with Roundup Ready genes will have Roundup applied to them. Volunteer Roundup resistant plants in corn-soybean rotations, and yield pressure from weeds in some areas that tolerate Roundup, may temper farmer enthusiasm for increasing Roundup Ready seed corn purchases.

Additional herbicide resistant corn acreage will also be planted; however, some acreage will not be planted with genetically engineered corn (e.g., imadazolinone resistant corn). And a potentially large acreage of glyphosate resistant corn may have herbicide resistance included as part of the Bt corn genetic engineering process. This stacked trait corn may not be used with the companion herbicide if the cost and effectiveness of the seed/chemical package is not competitive with alternatives.

#### End Product Traits

The primary value-added trait corn on the market today is high oil corn developed by DuPont, which is marketed through the new DuPont-Pioneer joint venture -- Optimum Quality Grains. This product is not genetically engineered. Approximately 2 percent of corn acres were high oil corn in 1998. This acreage is growing rapidly.

There are a number of genetically engineered varieties of corn and soybeans that will be entering the commercial market on a small scale in 2000. These products will come from several companies. These products are likely to include: high lysine, methionine, and tryptophan corn (i.e., corn with better amino acid balance); high oleic, low linoleic soybean oils (i.e., soybean oils with more shelf life); high stearic oils; improved amino acid mix in soybeans; and industrial products from corn or soybeans. Nutraceuticals that involve food health claims will become prevalent in the future.

Value-added traits will be "stacked" with herbicide and insecticide resistance traits to provide higher value seed, which offer lower costs or higher yield, and increased value of the end product. These cost savings will be shared with all contributors (or the innovation will not survive commercially). The introduction of value-added crops is likely to involve contractual links among the seed company, the farmer, the elevator, and the end user in order to segregate the value-added product from standard commodities and to capture its added value. This is the model being followed with Optimum Quality Grain's identity-preserved high oil corn.

### **Herbicide And Pesticide Market Consequences**

#### Leading Companies

The leading companies in the soybean herbicide market were American Cyanamid and Monsanto in 1997. American Cyanamid was the industry leader, treating over 65 percent of soybean acreage, followed by Monsanto (30 plus percent), DuPont (25-30 percent), Dow and BASF (15-20 percent each). Since more than one herbicide is usually used (probably an average nearer to two applications), these percentages differ significantly from market shares, which are close to half the percentages noted

above. The American Home Products and Monsanto merger, which was recently canceled, would have led to very high concentration in the soybean herbicide market, with the two leading competitors combined approaching half of total market volume.

The corn herbicide market is dominated by Novartis, which has over a 30 percent market share, followed by Monsanto, DuPont, and BASF (with shares in the 10-20 percent range). Cotton herbicide market leaders in 1997 were Novartis and DuPont with over 20 percent market share each, with Monsanto, Dow, FMC, and American Cyanamid near 10 percent each.

Entomologists estimate that half of corn acreage is treated with insecticides, primarily rootworm and European corn borer. The corn insecticide markets for the treatment of rootworm are led by Zeneca, Dow, American Cyanamid, and Bayer. Zeneca and FMC lead in the much smaller corn borer insecticide market (primarily pyrethroids). The leading cotton insecticide companies now also facing declining sales due to Bt cotton are Zeneca, FMC, Bayer, and American Cyanamid.

#### Impact of Biotechnology on Insecticide Markets

The use of insect resistant corn and cotton has led to reduced insecticide use. Typically, approximately 5-15 percent of corn producers sprayed for European corn borer (ECB) control before the introduction of Bt corn. The acreage treated for ECB in 1998 dropped by approximately 2 million acres, a 30 percent reduction from the previous year, due to low ECB populations in 1998 and the substitution of Bt corn varieties. Bt insecticide sprays declined from approximately 10 percent of the acreage to near zero. More reductions are expected as Bt corn use becomes prevalent, though farmers using Bt seed are more likely to spray their non-Bt refuge acres with pyrethroids as they see yield differences due to the insect pests. Broad spectrum insecticides will be affected less.

Corn rootworm soil insecticides comprised over 80 percent of corn acreage treated with insecticides in 1998, approximately 1/3 of all corn acreage. The corn rootworm resistant varieties will begin to have a much more dramatic effect on the insecticide market after 2000. These introductions could sharply reduce insecticide use on corn if resistance to the genetically engineered toxins does not develop in unmanageable ways. The combination of insect resistant technologies by the year 2005 seems very likely, and may dramatically reduce corn insecticide market volumes, reduce chemical industry profits, and result in many companies exiting the market.

Cotton has a large number of pests, so insect resistance to a few will not necessarily eliminate insecticide use in cotton. Bt cotton has resulted in approximately 20 percent fewer acres being sprayed with pyrethroids. *Bacillus thuringiensis* cotton has extremely high market shares in the lower Southeast where most acres were previously sprayed several times, and in Arizona where the pink bollworm is a problem. According to the National Cotton Council, the potential future Bt cotton acreage can be expected to be the current acreage plus some portion of the 6.9 million acres (there are 10 million plus acres infested) still treated for bollworm and budworm in 1997. Over 2 million acres in Texas were treated with single sprays, so Bt cotton would not be an economical alternative. Requirements for refuge acreage sown with non-Bt cotton to limit the buildup of Bt resistant insects places additional limits. Projected refuge acreage ranges anywhere from 4 to 20 percent of total acreage. So it is likely that less than 40 percent of total cotton acreage will be the effective upper limit for Bt cotton.

### Impact of Biotechnology on Herbicide Markets

Herbicide resistant seed is dramatically affecting the soybean herbicide market. It is having less effect in the cotton market and is just beginning to affect the corn herbicide market. The biggest market impact from seed and chemical packages occurs where the weed control from prior herbicide programs is not effective. Roundup is cost-effective for a broad spectrum of weeds which it controls effectively (especially in the case of soybeans). The number of soybean acres treated with Roundup doubled in 1998. Accordingly, most competitors had their market share drop by one-third to one-half. American Cyanamid, the market leader, had the greatest volume reduction.

In the cotton herbicide market, Monsanto has moved up from supplying a very small share of the market several years ago, to having approximately 10 percent of the market in 1997. All of this increase is due to sales of Roundup. While this percentage share is much lower than the Roundup Ready cotton acreage planted, apparently there is a narrow window of opportunity for Roundup application to cotton without causing aborted bolls; hence, there is lower overall use of Roundup. Bromoxynil (BXN) resistant cotton seed has been marketed successfully by Stoneville. Eight percent of cotton acres were planted with bromoxynil in 1998. The recent EPA registration of that herbicide in 1998 is likely to increase the market volume of BXN cotton, and of the bromoxynil herbicide.

Roundup tolerant corn varieties are generally expected to represent 20-30 percent of the seed corn market by 2005. Several major seed companies have not obtained licenses for Roundup Ready technology, or for alternative glyphosate tolerance technology in seed corn. These companies include Pioneer, Mycogen, and Cargill. The fact that these three companies have not obtained licenses has a number of interesting implications. First, the potential growth of Roundup sales in the corn market may be significantly limited. Second, it may reflect a relatively smaller perceived benefit from using Roundup Ready corn versus soybeans. Pioneer has a less restrictive license for corn. The greater yield impact of heavy weed pressure on young corn compared to young soybeans may make Roundup plus a Roundup Ready seed technology fee a less desirable package compared to traditional elite hybrids, when combined with some good, inexpensive herbicide packages used in soybeans. Third, if these companies do become Roundup Ready licensees, or otherwise obtain glyphosate tolerant corn technology, they could significantly expand the glyphosate tolerant seed corn volume and the corresponding use of glyphosate herbicides. So far, the Roundup Ready corn varieties have not led to much change in herbicide market shares, but the potential for moderate shifts away from other herbicides seems likely if the Roundup Ready varieties ultimately make up a quarter of the market.

Monsanto's Roundup patent protection expires in 2000. As a result, Roundup prices have been declining in anticipation of lost patent protection and new entrants into the glyphosate herbicide market. Other herbicide competitors have also lowered prices to remain competitive with the very effective seed and chemical packaging by Monsanto. Expanded glyphosate competition and lower market prices can be expected if companies like Dow, Zeneca, and Rhone Poulenc Agro enter the U.S. market with glyphosate herbicides in 2000.



## **Seed And Chemical Market Linkages**

Monsanto's use of restrictive contracts has been an innovative way of capturing a significant share of the value of patented innovations. Growers buying Monsanto's insect or herbicide resistant seed have to sign contracts guaranteeing no reuse of seed in the following year. This restriction has especially added sales in soybeans where use of farmer-saved seed is significant. Further, the herbicide resistant seed cannot be treated with any other glyphosate herbicide than Roundup, one of the restrictions which potential glyphosate competitors are objecting to.

Growers must pay technology fees to the seed company which collects them for Monsanto and receives a small handling fee. These technology fee list prices ranged from \$32 per acre for Bt cotton, to \$5 per unit for Roundup Ready soybeans. The per unit fee for Roundup Ready soybeans increased to \$6.50 when Roundup herbicide prices dropped by \$10 per gallon in late 1998. A \$6 per acre fee is charged for Roundup Ready corn. However, a rebate of \$6.50 per acre is given for using Monsanto pre-emergence herbicides in the first year of introduction. A \$35 per unit fee is charged for Bt corn, though technology fees or premiums actually charged were typically in the \$15-30 per unit range. Some Bt competitors charge less without a contract or a separate technology fee identified. Lower corn borer populations, and very low corn market prices in 1998, have led Monsanto to announce lower Bt technology fees for 1999 (\$24 per unit).

The technology fees or seed premiums are typically subject to substantial discounting based on early purchase, volume discounts, and package deals for other seed or chemical products from the same company. In 1997-98, some biotechnology products sold at no premium in a very competitive marketplace and a large amount of free seed was offered in some areas in order to buy market share.

As more competitors bring substitute technologies to the market these technology fees are expected to decline. Seed and chemical package deals often result in discounts from these fees as Monsanto, and competitors with other herbicide resistant seed varieties, link prices paid for seed and chemicals to purchase volumes of both products. The idea is to tie the seed customer more closely to the chemical product.

Another innovative feature of Monsanto's licensing strategy is demonstrated through their Roundup Ready corn licensing contracts. Seed companies are provided substantial financial incentives to have Roundup Ready corn sales reach at least 2 percent of total sales by 2000, and 85% of all herbicide tolerant sales by 2002 (Freiberg, 1997). This could make it difficult for competing herbicide resistant seed technologies or herbicide companies to enter the market, or to expand their volume if Roundup Ready corn is broadly licensed by several seed companies. Restrictions have been placed on the other traits that can be stacked with Roundup resistant traits. Further, Monsanto decides the grower technology fee which will be charged each year by the seed companies selling licensed Monsanto technology. This restriction will last until 2007. These contractual restrictions may be subject to individual company negotiation and may change over time -- possibly as part of the DOJ agreement reached in early December. These restrictions were likely a major factor influencing Pioneer's announcement in 1998 that it would not license the Roundup Ready corn technology from Monsanto.

## **Legal Issues**

There are a multitude of cases where companies are using the courts to establish or protect their turf in the seed and chemical markets. The legal issues are related to the ownership of, and infringement on, intellectual property rights. In addition, antitrust and breach of contract issues have arisen. This litigation is driving up legal bills for all concerned. Since commercial biotechnology products are just beginning to be major revenue producers in the crop sector, the companies involved in the litigation are trying to establish their claim to revenues. These companies have had to wait a long time for commercialization. In addition, they have spent large amounts of capital on high risk research and development investments, with little payoff.

### Antitrust

There are antitrust issues in both the seed and the herbicide markets. The antitrust issues first arose in the seed industry with Monsanto's recent additions of several seed companies to its portfolio as a means of more effectively capturing the future value of its biotechnology innovations. The Delta and Pine Land acquisition is still under review by the U.S. Department of Justice. The extremely high share (71 percent) of the cotton market from the Delta and Pineland acquisition has forced the announced divestiture of the Stoneville cotton seed company (16 percent), already owned by Monsanto. In December 1998, the Department of Justice did approve the acquisition of DeKalb after Monsanto negotiated some give-backs to help insure adequate competition in the seed corn market.

The bombardment and agrobacterium gene insertion technologies patented by Monsanto and DeKalb are the two best methods for genetic engineering in corn. Thus, control of both could foreclose potential competitors from developing biotechnology seed corn. To get Department of Justice approval of the DeKalb acquisition, Monsanto had to license its agrobacterium insertion process to the University of California and allow sublicenses to other companies. Further, Monsanto had to remove restrictions, for a seven year period, on the biotechnology innovations from other companies which its technology (sold through Holdens) can be used in conjunction with. It is not clear whether this applies only to Holdens' germ plasm or to the broader array of Monsanto technology being licensed through Holdens; the implications could be quite different. These concessions should provide competitors, especially smaller companies without significant research and development capabilities, with a greater ability to compete in the short run, and provide enough time for Monsanto's competitors to develop alternative sources of competitive technologies or germ plasm.

The Monsanto influence in the agricultural chemical market is greatly expanding because of its herbicide tolerance technology. Monsanto is using its herbicide tolerance patents, and related contracts with seed companies and farmers, to protect it against competitors moving into the glyphosate market. Monsanto is beginning to give companies licenses to produce glyphosates and allow these companies to apply them to Roundup Ready crops in mixtures with their own chemicals (e.g., Novartis and Cheminova, with first sales expected in 2001).

In 1998, Zeneca claimed that Monsanto engaged in unfair competition by foreclosing other glyphosate producers from testing their products on Roundup Ready soybeans, requiring farmers to use only Roundup on the Roundup Ready soybeans, and restricting seed companies licensing Roundup Ready soybean technology from selling much of a competitor's glyphosate. Is this a significant foreclosure of potential competition which outweighs the rights of Monsanto to capture the benefits of its patents? Pioneer is also a party to the Zeneca lawsuit, seeking a judgment that it did not breach its license

agreement with Monsanto by providing Roundup Ready soybean seed to Zeneca for testing other glyphosate herbicides on the Roundup Ready varieties.

Rhone Poulenc Agro has charged that Monsanto's contracts with Roundup Ready licensees restrict competition and prevent entry in the corn herbicide market. Rhone Poulenc Agro claims that financial incentives offered to seed companies make it highly desirable to produce only glyphosate resistant corn. Further, the tying arrangements between the farmer's Roundup Ready seed and herbicide use are a barrier to entry for other herbicide producers. Monsanto does not allow competing herbicides even to be tested on Roundup Ready corn.

### Intellectual Property

Seven different companies are involved in lawsuits over Bt corn. These disputes are primarily over who has controlling patent rights or contractual rights to use the technology. Those companies claiming patent rights to specific genes, specific processes, or general concepts like insect resistance in corn, include Monsanto, DeKalb, Mycogen, Novartis, and Plant Genetic Systems (AgrEvo). In addition, there are suits alleging breach of contract in the patent and licensing rights to Roundup resistant technology. There have been several court decisions in these cases. They are briefly summarized below.

In February 1998, Mycogen lost a patent infringement suit against Monsanto, DeKalb, and Delta and Pine Land. A jury decided that Mycogen did not prove that it was the first to invent the Bt technology, so the other companies could continue to use the technology in several crops, and gain licensing revenues from their technology.

Mycogen filed suit against Monsanto alleging failure of Monsanto to license Bt corn technology and glyphosate resistant corn, cotton, and canola technology under a contract with Agrigenetics (a subsidiary of Lubrizol) which Mycogen had bought. Monsanto claimed that the license was not transferable. A March 1998 jury verdict against Monsanto awarded Mycogen \$172 million.

Monsanto sought damages and injunctive relief against Mycogen Plant Science and Ciba-Geigy Seed Division (now Novartis Seeds) for infringement of a Bt insect resistant patent. These companies used Bt technology in their seed without getting a license like all other companies. A jury verdict in June 1998 found that while the patent was literally infringed by the defendants the patent was not enforceable due to two defenses. Thus, the use of the Bt genes by Mycogen and Novartis could continue in competition with Monsanto's licensed products. Monsanto asked the judge to set aside the verdict. DeKalb has a similar suit against Mycogen and Pioneer, claiming that DeKalb's broad patent for Bt corn is superior to Pioneer's gene gun technology patent.

In yet another court case, Novartis lost a patent-infringement lawsuit it had filed against Monsanto Company and co-defendant DeKalb, over a patent for genetically engineered corn. In November 1998, a jury decided Monsanto and DeKalb did not infringe the patent held by Novartis since January 1997, and that the Novartis patent was invalid. Hence, Monsanto and DeKalb can continue selling and licensing their Bt corn. Novartis had asserted that all insect-resistant corn made using Bt technology was covered by the broad claim of the patent for corn transformation and insect protection. Novartis plans to appeal the verdict.

Another interesting case that is still in process deals with Monsanto's right to glyphosate resistant technology. In 1997, Monsanto commercially introduced corn containing a gene from DeKalb

providing glyphosate resistance. Rhone Poulenc Agro filed suit against Monsanto and DeKalb contending that they did not have a right to license, make or sell corn products using Rhone Poulenc Agro technology for glyphosate resistance. DeKalb had sublicensed to Monsanto glyphosate tolerant technology previously licensed from Rhone Poulenc Agro. Rhone Poulenc Agro alleged that DeKalb fraudulently failed to disclose information about the true value of the their glyphosate resistant germ plasm which had been tested by DeKalb, making the rights more valuable than they received. If Rhone Poulenc Agro prevails, this could have significant financial implications; potential license fees for 20 million acres or so of corn each year could be very large.

## **Implications**

The seed industry is getting much more concentrated as seed and chemical companies (Monsanto, DuPont, Novartis, Dow, and AgrEvo) are on an acquisition binge. Acquisitions and joint ventures are a means to better capturing the benefits of the new biotechnology that is finally beginning to be commercialized in the crop sector. Yet the increasing dominance of a few major players, and the biotechnology and chemical patent restrictions on what competitors can do, raise questions regarding the potential for too much market power in parts of the seed and chemical industries. Several antitrust issues in the seed and chemical markets concern the potential damage to competition from removing major competitors from already concentrated seed markets; for example, in the corn and cotton markets. In addition, private sector challenges are emerging regarding seed industry contractual linkages that limit potential competitors from entering some herbicide market segments or gaining too much market volume if they do enter.

The legal arena is populated by many of these companies trying to establish or defend their turf in these important agricultural markets. The antitrust and patent right issues being tried in the courts will have significant implications for the seed and chemical industries' structure and performance, and individual companies' profits and losses in this economic and legal arena. Monsanto is a key player in many of these suits. Monsanto's won/lost record will make significant differences in how even the competitive playing field will be, who can become a player, and who will capture the benefits from the crop production and marketing system. So far, Monsanto has a mixed record on patent claims and contract disputes, and several major cases remain to be tried. The antitrust agency review of the Delta and Pine Land acquisition is currently scheduled to be completed in early 1999. If the merger is contested, or significant remedial actions are required, this may be a very important influence on the cotton seed industries' competitive structure. The implications of the remedial concessions by Monsanto in the DeKalb acquisition are still unclear.

In the longer run, the new products and processes emerging from the biotechnology, seed, and agrochemical complex will probably emulate the pharmaceutical industry, and gradually displace the entrenched technologies and companies. But the patent and contract linkage minefield will have to be successfully traversed or overflowed, which requires both significant luck and large investments to be a successful competitor in these industries.

The herbicide markets are just beginning to feel the potential repercussions from the commercialization of the first generation of agricultural biotechnology products, with the soybean herbicide market as the leading, and potentially the most dramatic, indicator. The Monsanto Roundup resistant technology is rapidly becoming dominant in soybeans and cotton, and major shifts in market share from virtually every other competitor (especially American Cyanamid, the largest soybean herbicide supplier) to Monsanto are occurring. Soybean herbicide prices have plummeted as a result of the Roundup Ready soybean success. The rapidly growing market share for Roundup Ready cotton has stimulated a much

smaller increase in Roundup use (now up to a 10 percent market share). This is expected to grow as less stress-sensitive varieties engineered with the Roundup Ready gene hit the market. Roundup Ready corn is still in its infancy, but it is expected to have a significant impact in the seed corn and corn herbicide markets, though substantially less than in the soybean seed and herbicide markets.

Insecticide use in corn and cotton is dropping, a potential environmental benefit from the first biotechnology crop introductions. The corn insecticide market volume is dropping as a consequence of Bt corn, but the dramatic drop will happen when effective corn rootworm resistant seed becomes commercially available in a few years. Cotton insecticide use is dropping as a consequence of Bt cotton achieving 20+ percent market share, but cotton production remains a chemical-intensive industry dealing with many pests.

The value-added traits for food and feed, and even for industrial markets, will be stacked with input traits in a variety of combinations which will need to be segregated and identity-preserved to capture the enhanced value of the end products. This will lead to contract production and marketing systems for the resulting grains, oilseeds, and their derivative products. These products will radically change our marketing system -- a topic for another paper.

## **References**

- Beyer E. & Chumley F. (In Press). Crop protection industry: Retooling for a new tomorrow. In Neurotox '98: Progress in neuropharmacology and neurotoxicity of pesticides and drugs. London: Pesticides Group of the Society of the Chemical Industry.
- Carlson G., Marra M., & Hubbell B. (1997). The new 'super seeds': Transgenic technology for crop protection. Choices (Third Quarter), 31-36.
- Freiberg, B. (1997). The Monsanto contracts: Are they good or bad? Seed and Crops Digest, 48 (3), p. 3.
- Hayenga, M. L. (1988). Biotechnology in the food and agricultural sector: Issues and implications (Agricultural Issues Center Issues Paper No. 88-5). Davis, CA: University of California, Davis.
- Hayenga, M.L., Thompson, L.C., Chase C., & Kaaria S. (1992). Economic and environmental implications of herbicide-tolerant corn and processing tomatoes. Journal of Soil and Water Conservation, 47 (5), 411-418.
- Kimle, K.L. & Hayenga, M.L. (1993). Structural change among agricultural input industries. Agribusiness: An International Journal, 9, (1), 15-27.