Agribusiness & Applied Economics Report No. 657 February 2010

Dynamic Changes in Market Structure and Competition in the Corn and Soybean Seed Sector

William W. Wilson

Bruce Dahl

Dept of Agribusiness and Applied Economics
Agricultural Experiment Station
North Dakota State University
Fargo, ND 58108-6050

Acknowledgments

The authors extend appreciation to Cole Gustafson, Frayne Olson and Cheryl Wachenheim for their constructive comments and suggestions. Thanks also to Edie Watts who helped prepare the document.

This publication is available electronically at this web site: http://agecon.lib.umn.edu/. Please address your inquiries regarding this publication to: Department of Agribusiness & Applied Economics, P.O. Box 6050, Fargo, ND, 58108-6050, Phone: 701-231-7441, Fax: 701-231-7400, Email: ndsu.agribusiness@ndsu.edu.

NDSU is an equal opportunity institution.

Table of Contents

List of Tables

List of Figures

Abstract

The purpose of this paper is to analyze the dynamics of R&D investments, and the structure of the seed distribution sector using novel data sets that have not been used before to describe competition in these industries. The results describe four sets of issues of particular importance. One is that while all agbiotechology firms have increased their R&D expenditures, there have been sharp differences in the scope of this spending. Most important is that this has spawned the growth in what is now referred as "seeds and traits." Second, a large number of future traits will be commercialized in the coming years. A third set of results indicates that one firm grew its market share by 14% and a portion of this growth has been through acquisition. The other three majors lost market share, but the ISC (independent seed companies) grew by 10%. At the crop reporting district level, the industry concentration ratios for the four largest firms (CR4) in most regions are .5-.7. Finally, farmers purchased corn and soybean seed from 4-7 different companies in most crop reporting districts (CRD) and up to 20 or more companies in the larger producing regions.

Key words: Agbiotechnology, grain seeds, competition

Dynamic Changes in Market Structure and Competition in the Corn and Soybean Seed Sector

William W. Wilson and Bruce Dahl

Introduction

The growing dominance of genetically engineered (GE) crops in the United States and world agriculture is very apparent and important. Indeed, there has been a dramatic increase in GE crops planted not only in the United States, but also in many other countries, and not only to grains and oilseeds, but now to a number of other crops as well. Evidence is also beginning to surface that shows increasing yields, and reduced costs and risks associated with GE crops, as well as reduced or improved sustainability (reduced pesticide use). Taken together, this technology is important which along with other crop improvement technologies (e.g., marker assisted breeding, etc.), will improve growth rates in productivity that will help feed the rapid growth in consumption. As is well known, Monsanto, DuPont and others have each indicated their goals of doubling crop production and productivity growth rates by 2030 and Syngenta has recently indicated that "The 300 bushel-per-acre corn yield is now clearly in front of us" (Pillar 2009).

Firms in the agbiotechnology industry confront important strategic choices. One is with respect to spending on research and development (R&D), how that money is spent, intellectual property (IP) protection strategy, as well as technology distribution strategies. Different firms have taken clearly different approaches to these strategic decisions, particularly regarding R&D spending, and seed and trait distribution.

Research to develop GE traits is high cost, very risky, takes a substantial amount of time to develop, and subject to a great deal of uncertainty regarding trait efficiency, government approvals, market acceptability, and prospective impacts of competitor traits. Thus, firms can spend in excess of $100 million to develop a trait and for varying reasons, not have it commercialized; or, traits may be developed that have a high degree of trait efficiency and if other sources of uncertainty are reconciled, may have substantial market penetration. In part for these reasons, firms in this industry have substantial economies of scale due to the high costs of R&D. As a result, there have been many mergers and acquisitions, and there are now fewer firms in some of these functional areas.

These topics have evolved to be of particular importance for agriculture as it confronts understanding the structure and conduct of these industries. Indeed, some of these issues have been subject to recent papers,[1] some pending litigation[2] and investigations,[3] and is prompting a set of hearings by the Department of Justice on competition in agriculture markets.[4] [5] The purpose of this paper is to analyze the dynamics of R&D investments, and the structure of the seed distribution sector using novel data sets that have not been used before to describe competition in these industries.

Several major themes are developed. First, agbiotechnology companies make strategic choices with respect to how much money to spend on R&D, as well as the scope of R&D that is pursued. Ultimately, the effect of these strategic choices results in a competitive environment at a later stage with more product choices, and greater innovations than would be the case otherwise. Indeed, this evolution will be resulting in far greater choice sets for growers in the future than ever has been the case in the past. Second, patents are typically received for the highly innovative research and novel products which serve the purpose of protecting Intellectual Property (IP), as well as providing incentives for firms to continue to develop new products and innovation. Indeed, the IP and patent policy in the United States is long-lived and serves these important purposes. Third, firms make decisions regarding its strategy for trait distribution and that includes licensing as well as marketing through their own germplasm. Indeed, this choice should reflect the firm's vertical and horizontal strategy. As example, it is common knowledge that Monsanto has chosen a strategy of broad-scale licensing of its technology to other seed companies, and in some cases to its competitors. This contrasts with others who focus more on marketing GE traits through their own germplasm.

Finally, of utmost importance is the role of competition and choice for growers. In the United States, growers have choices with respect to which crop to produce, whether to use conventional or GE varieties, the choice among GE technologies, and choices among seed firms. Indeed, this has been referred to a "hyper-competitive market" in which there is no shortage of choices for growers (Economist, p. 73). This set of choices is important and is a product of the industry structure and competitive environment, and ultimately provides

---

[1] See for example, Fernandez-Cornejo (2004), Moss (2009) among others, and was the topic of an August 2009 conference sponsored by the Organization for Competitive Markets (http://www.competitivemarkets.com/index.php?option=com_content&task=view&id=1&Itemid=5).

[2] See http://www.monsanto.com/dupont-youbethejudge/ and Pioneer (2009) for a review of recent litigation, as well as transcripts an initial hearing (Monsanto Company v. EI DuPont).

[3] In October 2009, the Department of Justice initiated an investigation of Monsanto, particularly regarding antitrust rule. Monsanto has indicated it has done nothing illegal and is cooperating with the DOJ (*AgWeek* 2009).

[4] See http://localfoods.wordpress.com/2009/11/18/dept-of-justice-announces-agriculture-competition-workshop-dates.

[5] In late 2009 several articles created a case of excessive monopoly power by Monsanto (Leonard 2009) which were refuted as reported in (Fatka 2009b).

competitive pressures among firms and benefits to growers. In most other countries, growers do not have this broad array of choices which results from intense competition throughout the industry.

Background to Issues and Related Studies

R&D in Crop and Seed Technologies

Several breeding technologies exist including conventional and marker assisted breeding and genetic engineering. In some sense, these can be competing technologies, or could be complementary. In an ideal world, different technologies would be applied for different, though complementary purposes. These vary with respect to cost, time, and regulatory and market acceptance with conventional being least onerous and GE breeding more onerous. Though much attention focuses on GE technology and related IP, marker assisted breeding is highly complementary. In fact, marker assisted breeding combined with high-throughput seed chipping capabilities is thought to give Monsanto an advantage (Economist, 2009 p. 72). Most companies have indicated their participation and use of each of these technologies as they look to improve crop performance.

GE traits are costly to develop and take an extended time. Estimates are that it costs about $100 million to develop a GE trait (in the United States), including costs related to regulatory approvals. Typically, it is thought the duration to create a GE variety is about 10 years, ranging from proof of concept through to the regulatory submission, and there is uncertainty throughout the development process (Monsanto 2004).

Stacked traits have now emerged as being more advanced and capable of solving more than one crop problem. In the most recent crop years, indeed triple and quad-stacked traits dominated the market. The data reported below indicates that shares for these were 46% in 2009 for corn. Recently, stacking technology has become more important with not only triple and quad-stacked traits being routinely developed, but, now Smart-Stax (Monsanto's new release which is said to have a 5-10% greater yield) is being commercialized that will have 8 traits stacked in one variety. All of this is driven by the quest to improve seed technology, to economize on costs of regulatory approval, and distribution and to "pack as much technology into a seed as possible" (Economist p. 72).

Other studies have addressed cost of private and public R&D (Fernandez-Cornejo, pp. 47-51). Importantly, there has been a longer-term shift from public to private R&D expenditures on corn and soybeans. However, of particular importance is the focus of those expenditures. As we show below, agbiotechnology firms have taken different approaches in their research focus which has impacted their future competitiveness.

Patents and Intellectual Property Rights (IPR)

Without protection of new ideas, there is little incentive to spend time and money on researching a new process or product that would essentially be free for all to use or imitate. Debates on the economics of property rights began in the mid-19th century (Giddings & Schneider, 1999).

There are two key mechanisms that provide protection of IP in the seed sector. These include the Plant Varietal Protection (PVPA) and Plant Patents. The PVPA was authorized by Congress in 1970 and provides protection for varieties, however has both researcher and farmer exemptions. The researcher exemption allows researchers to use plant varieties in their research, while the farmer exemption allows growers to re-use seed grown from prior year in subsequent year. However, it precludes growers from selling seed to other growers. In contrast, utility patents for plant varieties do not have either the researcher or grower exceptions which results in researchers being required to license varieties to use in their research and growers cannot reuse seed. Utility patents involve publishing more exact information than does PVPA. Thus, utility patents provide more protection for varieties than does the PVPA, but release more exact information.

After 1985, plant seed producers had two methods for variety protection, PVP (Plant Varietal Protection) and PUP (Plant Utility Patents) and could actually apply for both. The joint application was resolved in 2001, when the Supreme Court in J.E.M. Ag Supply vs. Pioneer Hybrid International ruled that holding both concurrently was acceptable. Dhar and Foltz indicate that following 2001, seed companies had several choices for protecting technology including, "i) Trade secrets kept in hybrids, ii) PVP certificates, iii) utility patents, and iv) some combination of these methods."

The precedence for protecting intellectual property in agriculture seed and GE traits has evolved since 1970 (as described in Fernandez-Cornejo p. 19). The system of IP protection is now comprised of Plant Variety Protection which provides breeders the right to market a new variety for 18 years, with exemptions as described above. Utility Patents are also used for novel traits which allow patent holders to sue farmers and rivals for patent infringement. Ultimately, this is what encourages licensing agreements with growers, seed companies and in some cases competitors. As indicated in Fernandez-Corneyo, both the legal interpretation and legislative actions contribute to an IP regime that provides an extensive set of incentives to develop new plant varieties. Finally, it is also important that patent law does not require the inventor to license the patented technology to anyone, "that that patent holder has the right to exclude others from making, using or selling the patented product" (Monsanto Company v EI DuPont, p. 11).

If innovation is to be encouraged, mechanisms have to exist to protect the intellectual value of the invention. Without these protections, the future value of innovations would diminish, be more uncertain (because of the uncertainty of being able to protect the innovation) and would reduce incentives to invest in crop improving R&D. Indeed, Monsanto (and presumably other agbiotechnology companies) is said to defend its IP "fiercely" (Economist, p. 73). In fact, it is the IP protections in North America and a few other countries that have encouraged most of the crop improvement innovations to be developed in these countries first.

Measures of Concentration

A wave of mergers and acquisitions occurred in the U.S. crop seed sector in the second half of the 1990s which has resulted in a major change in the structure of these industries. This is not unlike many other industries and sectors of the agricultural marketing system which experienced like structural changes. Rausser, Scotchmer, and Simon (1999) posed motivations about mergers in the crop seed sector including to exploit complementarities of assets, to internalize spillovers, or to circumvent the impossibility of issuing complete and contingent contracts. Most strategic prescriptions on vertical control is to pursue longer-term contracts (e.g. licensing agreements,) and only if these cannot be developed (i.e. primarily, due uncertainty, bounded rationality and opportunism which makes contracting difficult, to informational asymmetries, etc.) should vertical acquisitions be pursued.

Agbiotechnology firms began purchasing seed firms because of the presumed need to own a seed firm as a mechanism for the sale of trait innovations (Chataway and Tait, 2000). Coinciding with the first GE traits, agbiotechnology firms purchased seed firms that were leaders in corn and soybean sales, but acquisitions of seed firms did not stop agbiotechnology firms from further licensing their GE traits to independent seed firms (as described below). Examples are Monsanto acquired Dekalb Genetics Corporation, Cargill's international seed business, and Plant Breeding International, while still licensing their traits to independent seed firms such as Pioneer and Golden Harvest (Chataway and Tait, 2000; Lemarie and Ramani, 2003); DuPont purchased Pioneer Hi-Bred; Monsanto also acquired Asgrow (Kalaitzandonakes and Hayenga, 2000; Fernandez-Cornejo, 2004), Channel Bio Corporation (owner of two Iowa seed companies), Seminis (Monsanto, 2005), and Emergent (the 3rd largest cotton seed company in the United States with two brands in India) which allowed it to model its brands and licensing strategy in cotton similar to corn and soybeans (Howie, 2006).[6] Because marketing of varieties to independent seed companies is an important element of a licensing strategy, the viability of this sector is critical for trait distribution on GE traits.

Different measures of concentration have been used in this industry. Traditionally, these include the number and market shares of firms (as we show below), using sales as a measure of output. However, this type of data is not typically readily available so other measures have been used.

[6] A listing (selected) of Monsanto's acquisitions is contained in Bell and Shelman (2006, p. 23) and in Fernandez-Cornejo (2004, p. 34).

Some have used market shares of patents or APHIS field trials as measures of market structure and prospective market power. However, it is important to qualify the purpose and role of these data. When a GE trait is under development, its production is regulated. Deregulation requires extensive data from field trials. To do this, firms apply for field trial permits from APHIS which allows them to plant these regulated seeds. Thus by definition, firms that have large R&D in seeds and traits would eventually require approvals to plant field trials.

Fernandez-Cornejo used APHIS field trial data to point to the growth in volume and diversity of GE traits. In fact, he motivates this as a "measure of technical success of R&D efforts" (p. 53). In contrast, Moss (p. 17) uses the same data to measure concentration appealing to a concept of "innovation competition" along with concentration in patent ownership to assess impacts of mergers. The CR4 was of APHIS approvals was derived and indicated that the top 4 firms have 50% of field trials. The conclusion was to suggest concentration in R&D is a result of barriers to entry. The claim is that much of the concentration as measured by field trials reflects the cumulative effects of mergers and the "loss of competition in innovation may have weakened incentives to innovate and lowered the quality of innovation." P. 19. Moss also uses this data (Moss, 2009 p. 17) to conclude that "concentration has increased in tandem with a period of vigorous merger activity in the 2000s (Moss, p. 19).

However, nothing exists in the APHIS procedure that creates a barrier to entry. This is simply a product of earlier R&D strategies. The more likely explanation of the APHIS field trial data relates to R&D activities of individual firms. Those with larger R&D will have a larger number of traits under development. As they approach the regulatory review process, they need to apply to APHIS for field trial permits. Some of these will be approved, some not, and of those approved, some of the trials will be successful, some not, and of those that are successful, some may become deregulated and still others may be withdrawn from commercialization. For these reasons, the APHIS data are an imprecise measure of concentration, at best.

A firm may have a large number of approved field trials on a trait and then find that it is not commercially acceptable, or it may not be deregulated, or the field trials may not be successful, nor gain approval by APHIS. In these cases, the measure would inflate the prospective CR4 and suggest concentration in the industry, and subsequently that may not be the case. This is exactly what happened in wheat. Monsanto had a large concentration of the field trials, which would lead to the conclusion that there would be potentially (excessive) concentration in that crop. For varying reasons, the trait was withdrawn and not commercialized. This illustrates that use of field trials as a measure of concentration would lead to erroneous and incorrect conclusions regarding prospective concentration. For this reason, it is not obvious this is the best measure of concentration in future output sales.

Using this data, Moss claimed that Monsanto exercised market power to foreclose rivals and ultimately to slow the pace of innovation, adversely affecting prices, quality and choice for farmers and consumer of seed products (Moss 2009 p. 1). The alleged causal connection is that the concentration in innovation, as measured by APHIS permits for field trials along with patent data, is a result of cumulative mergers and is an impediment to competition (i.e. barrier to entry). This concentration reduces the quality of innovation in transgenic seed. Further, there would be fewer transgenic seed choices, and higher commodity prices (p. 16). In summary, greater concentration affects the rate and quality of innovation, reduces the number of patents and results in fewer new transgenic products. This conclusion differs from Fernandez-Cornejo. They recognize the two conventional impacts of mergers, economies of scale and increase in market power. Their empirical results for cotton and corn found that increasing concentration resulted in a cost-reducing effect (i.e. economies of scale) that prevailed over enhanced market power.

Taken together, an alternative conclusion to this entire scheme is that the concentration of APHIS field trials is simply a product of the the timing and scope of earlier R&D expenditures.

Commercialization Strategies: Licensing and Stacking Traits

The vertical relationship between seed and agbiotechnology firms and how GE technology can be transferred from the innovator to downstream firms is important and highly strategic (Lemarie and Ramani, 2003). Traits can be commercialized by issuing an exclusive license to one downstream seed firm or by issuing a non-exclusive license to numerous downstream firms. These are important strategic choices of these firms (as developed using game theory in Wilson and Huso 2008). Indeed the combination of using licensing versus vertical acquisitions is an important strategic choice. Given the uncertainties impacting this choice, there is no doubt that the optimal combination of these would result in a portfolio of strategies (or tapered vertical integration) as a means to balance risks, costs and control.

All of these firms have varying strategies to work with vertical and horizontal partners. Syngenta recently indicated that it "has pursued a policy of working with everybody in the increasingly competitive biotech seed world" (Pillar 2009). It is also commonly recognized that on this spectrum of alternatives, that Monsanto has pursued a broad-based (*Economist*, p. 72) licensing strategy. It includes licenses to growers through its own seed firms, to independent seed companies, and to its competitors. This differs from other agbiotechnolgy companies who generally make more extensive use of marketing their GE traits through their own seed firms.

An important element of licensing refers to trait stacking which involves inserting multiple GE traits into a single variety. Companies may choose to stack their own traits into their own varieties (if they own a seed firm) and/or to license them out (out-license) to other seed firms or to other agbiotechnology companies. It has been common for traits of one firm to be stacked by a seed company with traits of another agbiotechnology firm. There are numerous examples now about trait stacking including: Pioneer HiBred International in-licenses the RR trait licensed from Monsanto and Herculex from Dow; Mycogen Seeds has a new "quad stack corn hybrid" that includes Heculex, RR, and LibertyLink; and DOW is stacking RR and Herculex. Other companies do this as well. A recent example is DuPont and Syngenta who formed a venture to "out-license seed genetics and biotech traits."

Traditionally, stacked varieties contained two traits. Use of herbicide tolerant (HT) and insect resistant (IR) stacked traits in corn and cotton has increased since their commercialization. Monsanto offered a triple-trait stacked corn variety containing YieldGard® Plus (two traits to control corn borer and rootworm), as well as Roundup Ready® Corn 2 (YieldGard® Plus, 2004). Indeed, Monsanto concluded that stacking traits is a critical element of their commercial strategies (Monsanto 2006b) and they are (in 2004) "offering more stacked-trait products this year than ever before" (Monsanto 2004b, p. 2). More recently Monsanto is commercializing "Smart Stax" which contains eight traits and would be the new platform for commercialization.

There are numerous issues that impact these relationships. Most important are distinctions between a company stacking traits in their own seed vs. out-licensing (examples of each exist), inter-agbiotechnology firm agreements allowing stacking, and whether the traits are complementary vs. competitive. Restrictions that would apply to stacking traits would occur through the licensing agreement. It would be rare that restrictions would be placed on complementary traits, but restrictions on competing traits are common.[7] There are also issues and claims regarding the execution of these licensing agreements. It is important that the mere existence of a licensing agreement is a result of R&D expenditures that results in IP that is protected by a patent.

Licensing is particularly critical to the independent seed companies (ISC's). Indeed, without aggressive broad based licensing of patented products, these (ISC) firms would have difficulty competing and would likely diminish due to not being able to compete with GE traited varieties. Simply, licensing facilitates agbiotechnology companies a mechanism of distributing their traits without owning seed firms for 100 percent of their planned output, which would be excessively costly, risky, unnecessary and strategically unwise. It is these licensing mechanisms which allow agbiotechology firms to simultaneously protect its IP, and to pursue strategies of partial vertical integration for seed and trait distribution.

Litigation Among Agbiotechnology Rivals

Many of these issues are manifested now in a set of investigations and legal proceedings between two of the largest agbiotechnology companies, Monsanto and DuPont. Briefly, the claim involves licensing and interpretation of licensing agreements and restrictions. DuPont-Pioneer had an existing licensing agreement on Round-up Ready and was using it in their

[7] Many of these issues are discussed by the parties in Monsanto Company v. EI DuPont.

varieties. Over time DuPont-Pioneer planned to introduce Optimum GAT Herbicide Tolerance and indicated it would be more flexible and efficient than other traits. Their plan would be to retire its RR varieties and replace them with Optimum GAT. Subsequently, DuPont recognized that commercialization of Optimum GAT would be deferred because when used alone (i.e., not stacked with RR), it posed unacceptable risks to farmers.[8] Finally, DuPont recently announced that commercialization of this trait would be deferred until the mid part of the next decade.

At issue are apparent restrictive covenants in the licensing agreement. DuPont claimed that Optimum GAT for soybeans that includes the RR is a better product and thus should be allowed to stack these traits. A "stacking restriction" contained in Monsanto's licensing agreement precludes such practices. DuPont claims it has this right, whereas Monsanto is of the view that this practice violates their contract and patent rights. Recently, a legal ruling indicated DuPont had violated its contract with Monsanto (Leonard, 2010). This paper does not seek to resolve this issue but instead to indicate the intensity of competition among these firms as they seek to execute licensing strategies.

R&D Investment, Future Traits, and Innovation

Strategic Investments in R&D

There are a relatively small number of firms in the agbiotechnology industry in part due to their specialization but also due to the economies of scale in research and development. These companies spend large amounts of money on research and development on technologies that take 10+ years to develop and commercialize. Hence, they make large front-end expenditures betting on a technology that will be competitive and generate returns for a period following commercialization. For these reasons, IP protection is critical, without which the amount of investment in this type of R&D would be much less.

Agbioitechnology companies are in-part research firms that invest money to create new products or platforms for crop production. In this process, they make important strategic choices. One is how much to spend on research.[9] Some firms simply budget a percent of their revenues to research whereas others budget research for specific projects (as allegedly claimed of Monsanto). The other strategic choice is the scope of their research spending. Ultimately, spending on R&D, over time results in new technologies, the prospect of patents, and in the case of GE traits, results in a process requiring extensive field trials and if approved, results in products that can be used internally or distributed externally. The important point is that the

[8] For a complete set of references on this issue, see: http://www.monsanto.com/dupont-youbethejudge/ and http://www2.dupont.com/Media_Center/en_US/daily_news/may/article20090506a.html and more recently, see Monsanto Company v. EI DuPont.

[9] While others (e.g., Fernandez-Cornejo; Moss) make extensive discussion on public and private R&D, generally that data is dated, and importantly has not been separated by focus of the R&D expenditures.

scope of these strategic R&D decisions ultimately determines the commercial success of firms many years later.

The scope and direction of R&D expenditures is one of the important strategic decisions made by these companies. There is a clear difference between expenditures to develop agrochemicals for crop protection versus investing in research to develop seeds and traits. In the evolving competitive environment among firms in this sector, the difference in scope of R&D impacts subsequent competitive rivalry. In fact, this distinction has had a drastic impact on the structure and competitive environment now being observed in this sector.

Data on R&D by firm are used to depict the value and scope of these expenditures.[10] Figure 1 shows a summary of these expenditures for the major agbiotechnology companies on Crop Protection and on Seeds and Traits from 1990 to 2008. These are shown in nominal dollars and Figure 2 shows their total expenditures over this period in 2005 real dollars. Figure 3 shows the share of expenditures by each firm on these two strategic scopes of R&D, and their behavior through time.

In total, these firms spent about $31.2 billlion on chemistry to improve weed and insect control. During the same period, Monsanto spent over $8 billion in Seed and Trait R&D to improve weed and insect control. The firm with the next largest spending in this area was DuPont which about ½ of Monsanto's.

Bayer, Syngenta, BASF, DOW and DuPont were the firms that spent the most on Crop Protection R&D. Since about 2004 there has been a gradual increase in expenditures in these areas by some firms, but otherwise, the trends are not too noticeable.

The firm with the largest expenditures on seeds and traits is Monsanto. In fact, the *Economist* article suggested that Monsanto created this industrial sector by its focused spending. [11] This commenced following 1996 when Monsanto's R&D on Seeds and Traits increased drastically from about $200 million/year to $600 million in 1998 and another peak in 2008 at over $800 million. DuPont is the firm with the next largest spending in this category, but its level of spending is substantially less, as is that of each of the other firms.

[10] The data presented in this section is novel and has not been shown before. It was assembled from data prepared by CONTEXT (2010). The data were derived from various sources including SEC filings, annual reports, 10-K's, 8-K's and 20-F's, as well as miscellaneous investor presentations.

[11] Monsanto claims that they pioneered the "seeds and trait" evolution which has been a pillar for their strategy and is now being adapted by rivals (Monsanto 2004b, p. 1). This is a strategy that is now being adapted by rivals (Monsanto 2004b p. 1).

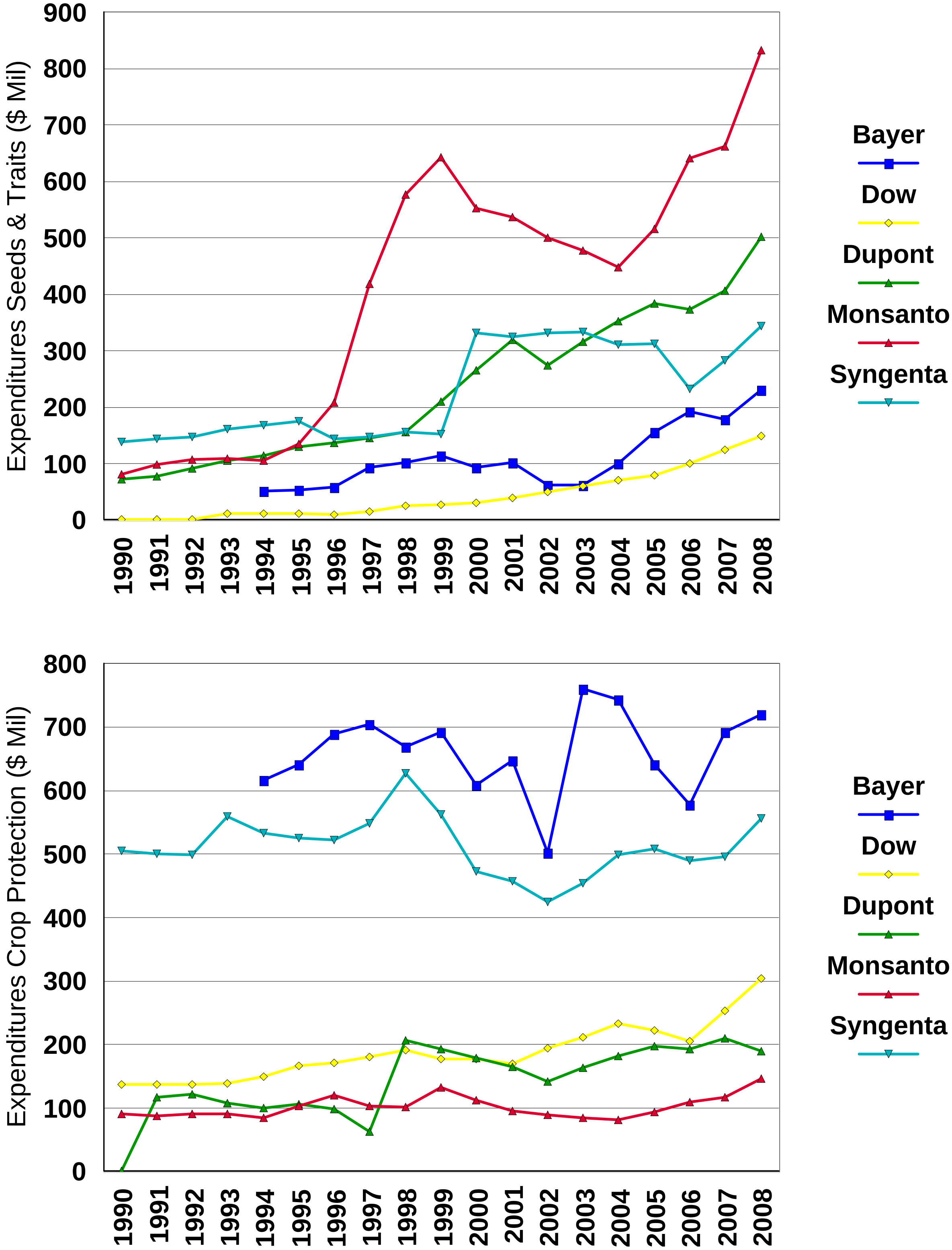

Figure 1. Expenditures for Crop Protection and Seeds & Traits, 1990-2008, Selected Firms.

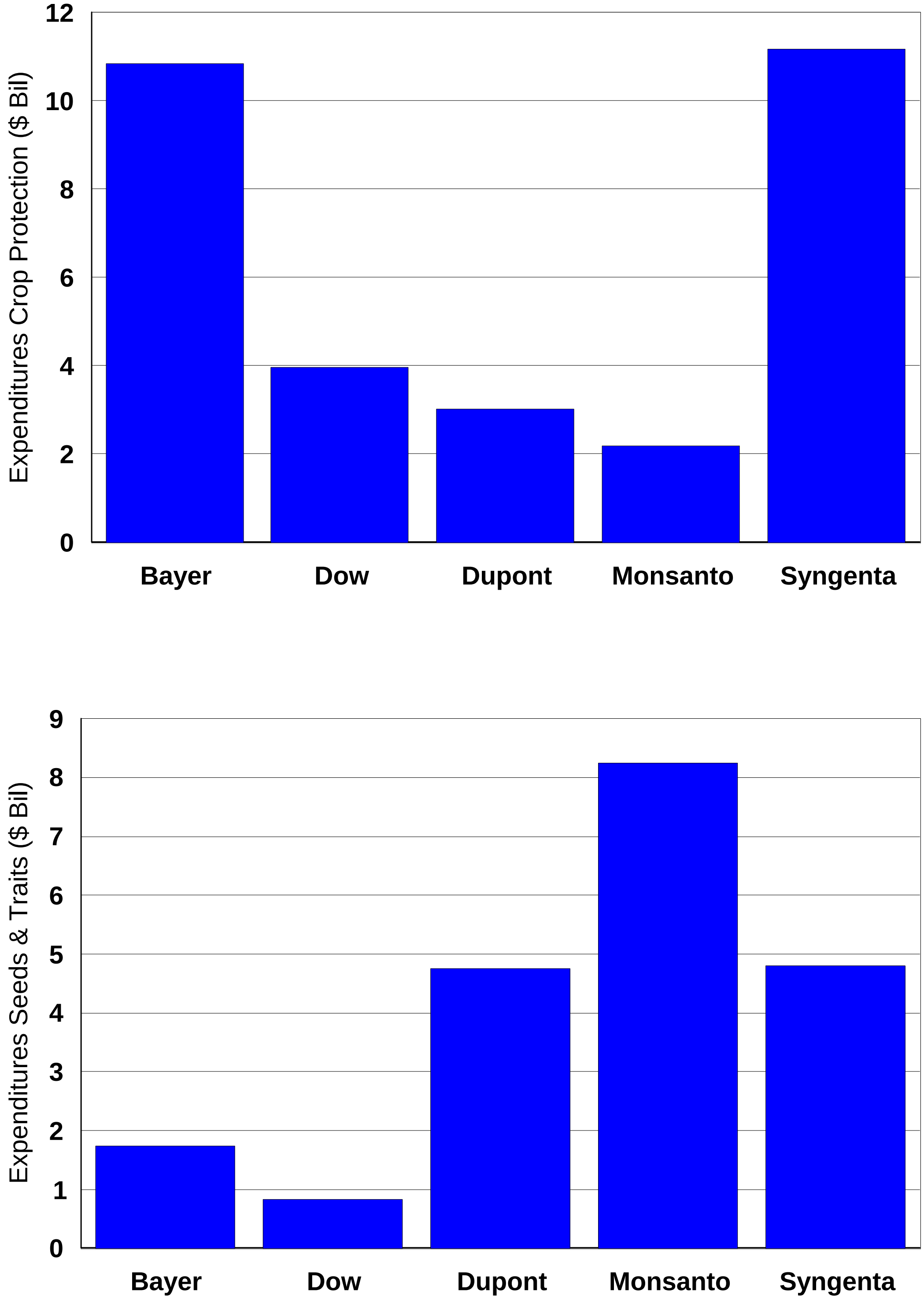

Figure 2. Expenditures for Crop Protection and Seeds & Traits, Selected Firms, Total for 1990-2008, (2005=100).

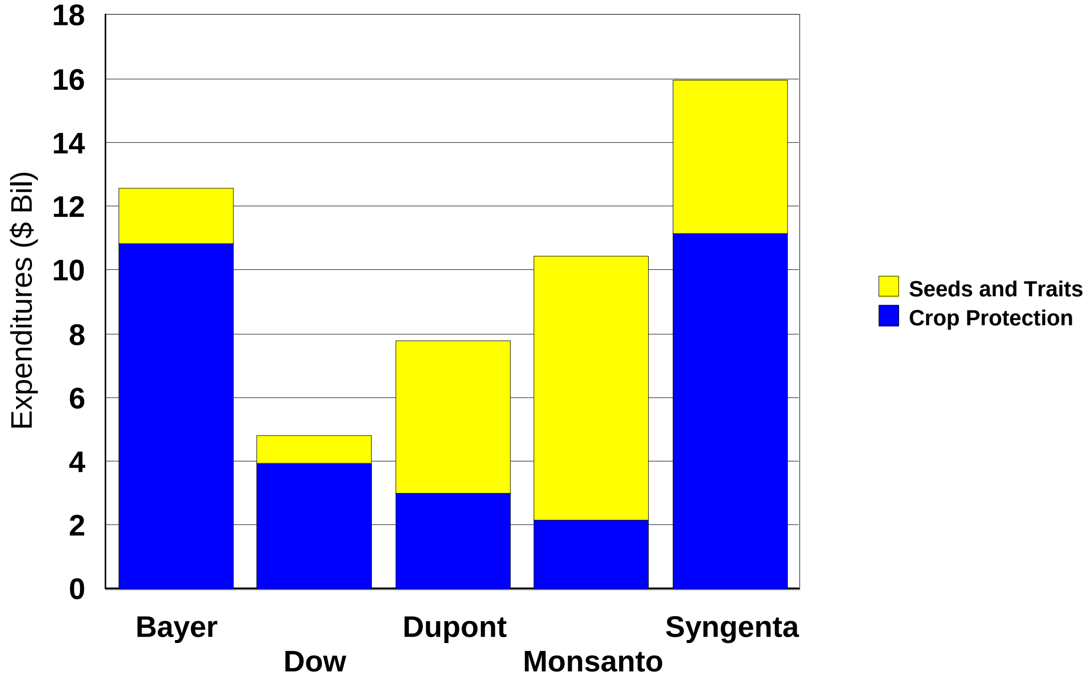

Figure 3. Expenditures for Crop Protection and Seeds & Traits, Total for 1990-2008, (2005=100).

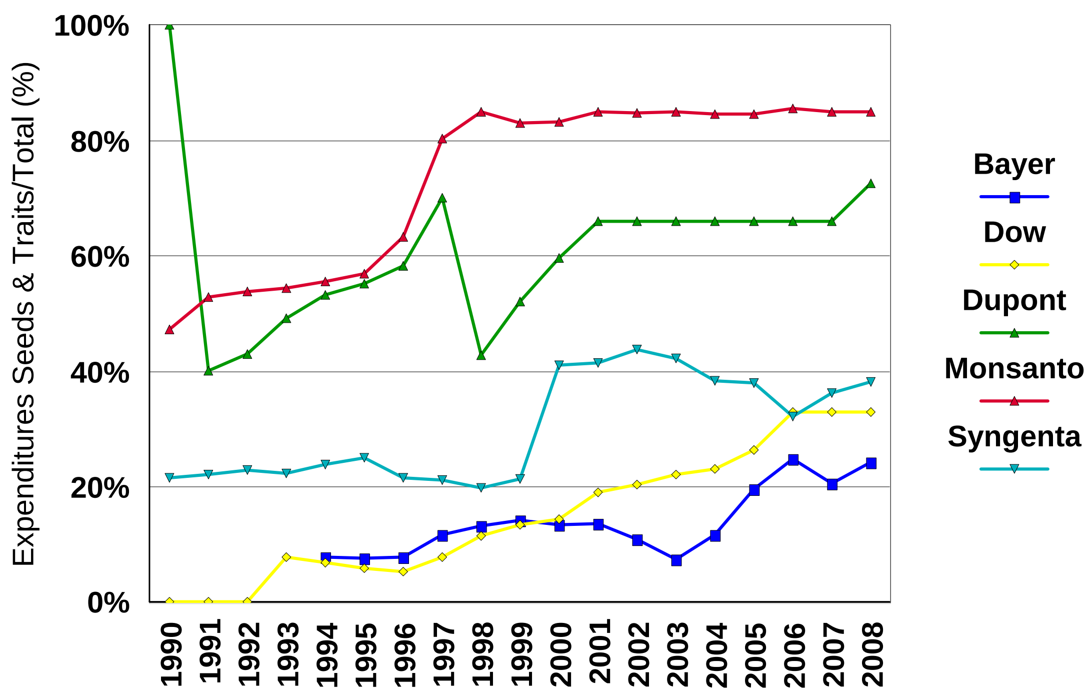

Figure 3.1 Expenditures for Seeds & Traits as Percent of Total, 1990-2008, (2005=100).

Monsanto made a strategic choice to accelerate its spending on Seeds and Traits in 1996. Other agbiotechnology companies increased spending on seeds and traits but did not do so until about the early 2000s. It is apparent that commencing in 2006 each of the agbiotechnology companies has further accelerated their spending on seeds and traits. As a result, Monsanto had a lead on its rivals by about 5-6 years. Further, given it takes about 10+ years to develop and commercialized traits, these data suggest Monsanto would have a lead in the commercialization of new traits by about 5+ years.

Finally, the portion of total R&D expenditures further illustrates the scope of these strategic decisions. Figures 3 and 3.1 shows that Monsanto clearly is pursuing seeds and traits which is their dominate area of spending. All of the others spend a greater portion on Crop Protections relative to seeds and traits. Over time, shares of expenditures on seeds and traits by each of the firms have increased. Of the firms, Dow has shown a continued increase in the percent of expenditures to seeds & traits over time, while most of the other firms reflect short period shifts followed by periods of more stable expenditures.

In summary, these data show that the competitors to Monsanto focused their R&D expenditures on agrochemicals until at least the early 2000s. Since then, they have shifted with greater funds being directed to seeds and traits. Monsanto spent lesser on agrochemicals, and more on seeds and traits; competitors are also spending on seeds and traits, though lesser, and lagged. These results are not only strategically significant, but also provide a more likely explanation as to why Monsanto has a larger share of APHIS field trials than others.

Future Traits

A result of this competition has been an escalation in the number of choices available to farmers in the United States. For illustration, the number of corn hybrids increased by 82 percent from 1998 to 2008; and the choice of soybean varieties increased by 14 percent (each including both biotech and non-biotech). This observation differs from some claims that there has been reduced innovation in the seed sector.

One of the outcomes of these competitive pressures that drive strategic choices is that there has been an escalation of the number and diversity of products developed and in varying stages of the process of being commercialized. This has resulted in highly innovative product choices for growers and consumers and is a result of the competitive environment that drives R&D strategic choices. This contrasts with the claim by Moss that the quality and quantity of innovation is reduced.

GE soybeans were first offered in 1996 in limited amounts with about 17% of the area in 1997 and grew to 91% for 2009. Corn did not reach 75% adoption until 2008. In recent years there has been an escalation in the area planted to stacked traits, particularly for corn. Further access to this technology by growers in the United States has allowed them a distinct first mover-advantage relative to growers in other countries. The reason for this is that the protection of IP has encouraged firms to focus their research on traits that are in countries that have a high degree of IP protection.

One way to examine the prospective competitive environment is on planned or anticipated traits that are at varying stages of development, deregulation or pre-commercialization. Data on these were assembled from various sources to illustrate the future competitive environment in traits and are shown in Table 1. Information provided in this table likely captures known traits under development, though it may not be exhaustive due to the anecdotal release of information related to trait development. Nevertheless, it is certainly representative.[12] These observations were also recently echoed by the President of Syngenta who indicated that "We're heading into an era where there will be so many new technologies that the old standbys, like Roundup Ready, will gradually lose their hold and will be replaced by dozens of different options for the farmer (Pillar, 2009).

The results illustrate a number of important points. First, a large number of traits are anticipated to be commercialized in the next 10 or more years. For corn and soybean, there are 21 and 22 new GE traits, respectively. Second, in many cases the forthcoming traits would result in competing solutions for the same problem. Third, some of these are producer traits, some are processor traits and others are consumer traits. Though producer traits dominated early commercialization, as the market matures, focus of trait development has expanded to consumer and processor traits. Fourth, a number of these are being developed jointly by multiple developers.

The dynamics of R&D competition are clear when examining the anticipated timing of competing traits. As examples: 1) several forms of HT being planned; 2) several forms of drought resistance being developed, with Monsanto potentially being first to market, followed by Syngenta and later by Pioneer/DuPont; and 3) Nitrogen use efficiency will be commercialized first by Monsanto, then Pioneer and Syngenta. Of course, there is uncertainty as to the exact timing which depends on trait review, deregulation and commercialization which will vary and have to adapt as these processes ensue. There is an even more diverse set of traits to be commercialized for soybeans. With these unique traits, they will ultimately provide choices to producers and compete for producer's plantings and processors adoption.

[12] Commercialization depends on many factors, including successful conclusion of regulatory process. The release of DuPont's Optimum HT was moved to the mid-decade based on the recent announcement by DuPont (12/4/09).

Table 1. Traits in the Deregulation and Pre-Commercialization Phase

Year	Corn Traits			Soybean Traits		
	Developer	***Trait***	***Trait Type***	***Soybean Developer***	***Trait***	***Trait Type***
2009	Monsanto	VT Triple Pro	Production	Bayer	Liberty Link	Producer
				Monsanto	RR2	Producer
2010	Syngenta	Broad Lep MIR 162	Production	Pioneer/ DuPont	High Oleic	Consumer
	Monsanto/ DOW	Smart-Stax	Production	Monsanto	High Stearate	Consumer
	Syngenta	Corn Amylase	Processor	Pioneer/ DuPont	GAT/Glyphosate-ALS	Producer
	Monsanto/ BASF	Drought Tolerant	Producer	Monsanto	Omega-3	Consumer
2011	Syngenta	Drought Tolerant	Producer	Bayer	Glyphosate & isoxazole tol.	Producer
	Monsanto/ BASF	High yield	Producer	Monsanto, Pioneer/DuPont	High Beta-Conglycinin	Consumer
	Pioneer/ DuPont	Increased yield	Producer		High Stearate	Consumer
	Pioneer/ DuPont	Improved feed	Processor	Pioneer/ DuPont	Low-Phytate	Consumer
	DOW	Herbicide Tol	Producer	Monsanto	High-oil soy	Consumer
	Syngenta	RW Dual Mode of Action	Producer		Dicamba Tolerant	Producer
	Pioneer/ DuPont—12/4/09	Optimum HT	Producer		Low Sat	Consumer
	Pioneer/ DuPont	Triple-mode Herb. Tol.	Producer		Bt/RR2Y	Producer
	Monsanto/ BASF	Nitrogen Utilization	Producer		Modified 7S Protein FF	Consumer
	Syngenta	Increased Ethanol	Processor		Omega-3 (EPA/DHA	Consumer
	Pioneer/ DuPont	Nitrogen Utilization	Producer	DOW	Herbicide tol.: 2,4-D and aryloxyphenoxy propionate herbicide	Producer
	Pioneer/ DuPont	Drought Tolerance	Producer	Monsanto/ Pioneer	Disease	Producer
201X	BASF	Improved feed	Processor		Soybean Cyst Nematode	Producer
	Pioneer/ DuPont	Increased Ethanol	Processor		Rust	Producer
	Syngenta	Insect Traits	Producer	Syngenta	Disease Resistance	Producer
	Syngenta	Nitrogen Utilization	Producer	Monsanto/ Pioneer	Disease Resistance Soybean Cyst Nematode	Producer

Source: Adapted from industry sources, and as summarized recently by Sipple at the CNMA (available at http://www.canadagrainscouncil.ca/public/CGCDocument/www_view_public?dgid=2). The estimated commercialization pipeline of corn and soybean biotech events was prepared by the U.S. Grains Council and the American Soybean Association, November 2007. Updated March 2009

Finally, it is important that these are highly innovative and a result of the strategic choices made by competing agbiotechnology firms as much as 10 years earlier. These innovations far exceed that which were available from conventional breeding and are a result of the benefits of GE technology, the competitive environment among firms and the protection of IP. Indeed, prior to the advances in GE technology, at best seed and breeding firms sought advances in yields, and to a much lesser extent quality and the industry mostly relied upon targeted geographical purchases to improve product quality. Thus, these innovations are a virtue of the technology, competition among firms and a result of their strategic R&D choices.

Commercial Distribution Strategies and Concentration in Seed Sales

This section uses commercial data to describe measures of market structure in these industries. Attention focuses on pricing, as well as market shares at the national, and sub-national levels. [13]

Trait Prices

As a result of the wide array of choices, growers can choose the right products for their farming operations. Concern is sometimes raised about trait pricing, and particularly in reference to differentials among alternative bundled products. To illustrate current values, we created broad averages of these which are shown in Table 2.

Results indicate that all seed prices have increased through time. Conventional (non-traited) seed cost have the lowest price at $106/acre in 2008. In comparison, the average seed cost for traited corn was $155/acre. While these increases are apparent, they are less than many of the other inputs in agriculture during the same period (e.g., fungicides and fertilizer increased 266% and 518% respectively during the period 2000-2009).

Table 2. Values for Conventional and Traited Corn Varieties ($/unit)

	2004	2008	Change (%)
Conventional	83	106	27
Traited	97	155	59
Most Popular Choice (by acres planted) Inclusive of Triple and Quad Stacked Traits			**% of Acres**
Trait 1		171	43
Trait 2		161	20
Trait 3		147	19
Non-traited		113	13

Source: Derived from data contained in dmrkynetec

[13] Data presented in this section were from the dmrkynetec data on agricultural input spending. Specifically, the data used for the calculations in 4.1 and 4.2 were derived from this data; and the maps and figures shown in sections 4.3 were derived from data from the dmrkynetec data.

National Data on Market Shares

The lower portion of the table shows average values for the most popular technology choices, including their market share. It is clear that there is differentiation within this market, and grower's choice of seed with more effective technology is apparent despite the higher price relative to other technology choices.

National market shares for corn seed sales are shown in Table 3 for the major firms (without attribution to specific firm names due to confidentiality). Data in this table illustrates the source of growth by firm. These are important since there have been claims that firms are monopolizing this industry through acquisitions and innovation concentration, and that independent seed companies are being eliminated.

Table 3. Changes in Corn Market Shares: 1998 and 2008

Company/Brand	Change
Firm 1	-10
Firm 2	+14
Firm 3	-9
Firm 4	-5
Independent (or Regional) Seed Cos (ISC's)	+10

Source: Derived from data contained in dmrkynetec

The results do not support these claims. Firm 2 has grown its market share by 14% and a portion of this growth has been through acquisition. Second, the loss in market share of the other three majors is apparent. Finally, and of particular importance is the growth of the ISC (independent seed companies, or regional seed companies). As illustrated here, their market share has grown by 10 percent.

In summary, the losses to three of the firms were in part to another major, but also to the ISC's. Finally, the data do not support claims that consolidation has "eliminated the numerous independent seed companies" (Moss, p. 13). In contrast, this sector has flourished, and in fact, is likely an important beneficiary of broad-based licensing to GE traits.

Crop Reporting District Results

Competition for seed sales is ultimately at the sub-national level, and impacted by the competitive structure in individual regions. This is a result of bundles of traits developed by vertically integrated seed companies as well as a product of licensing strategies of agbiotechnology firms and their licensees, including their own seed units, independent regional seed firms, as well as licenses to their competitors (as discussed above).

This section shows data on market shares (CR4) at the CRD (crop reporting district) level for the years, 1998 and 2008 (see Figures 4-9 for corn and soybeans and for changes through time).[14] The results indicate that there is variability in the CR4's across regions, and through time. Of particular importance are that first, the CR4s in most regions are .5-.7 i.e., the top 4 seed selling firms have 50-70% of market which is comparable to many other segments of the agricultural marketing system. Second, for both corn and soybeans, there have been changes from 1998 to 2008. The average CR4 (i.e., average across CRDs) for corn changed from 83 to 76% between 1998 and 2008; the comparable values for soybeans indicated a change from 68 to 70%. [15] Specifically, the level of concentration has decreased in the case of corn indicating more competition in the more recent period. That for soybeans was essentially unchanged.

The data were also summarized by measuring the number of seed firms in which producers purchased seed. These data were only available at this level for 2008 at the CRD level. See Figures 10 and 11.[16]

Results illustrate a number of important facts. First for most CRDs, each of the major competitors are represented, including Pioneer, Monsanto, Syngenta and Mycogen. Second, as is apparent, there is a positive relationship between the number of firms and the amount of production in each CRD (though not shown). Simply, for CRDs with greater production, there are more firms that sell seed. There is a minimum threshold of about 4 for each crop (there are only a few observations with fewer than 4 firms). Third, and of particular importance, during 2008, farmers purchased corn seed from a minimum of 4-7 different companies in most CRDs with some of the CRDs with greater production having as many as 21-30 seed companies; and purchased soybean seed from a minimum of 4-7 firms and larger producing regions had as many as 16-22 seed firms.

Thus, even though the GE traits may be dominated by only a few firms, these results illustrate or suggest that there is fairly wide distribution of these traits. The mechanism by which this occurs is through licensing. It is critically important that Monsanto chose to broadly license its biotechnology traits, primarily to independent seed companies, as well as to a lesser extent its competitors. This is not universally true across all agbiotechnology companies, but its impact is important since it provides choice to growers. Indeed, had it not been for this broad

---

[14] Values shown in white indicate data were missing or not reported for 1 or both years from that CRD.

[15] Some CRDs had missing values and these were excluded from this derivation. These figures are simple averages; and the results were comparable with weighted by total expenditures.

[16] Specifically, responses from the dmrkynetec data were grouped by seed companies with common ownership which were treated as a single company (e.g., all Monsanto owned brands were only counted once).

based licensing strategy, there would be far fewer seed companies providing technologies to growers than is actually observed.

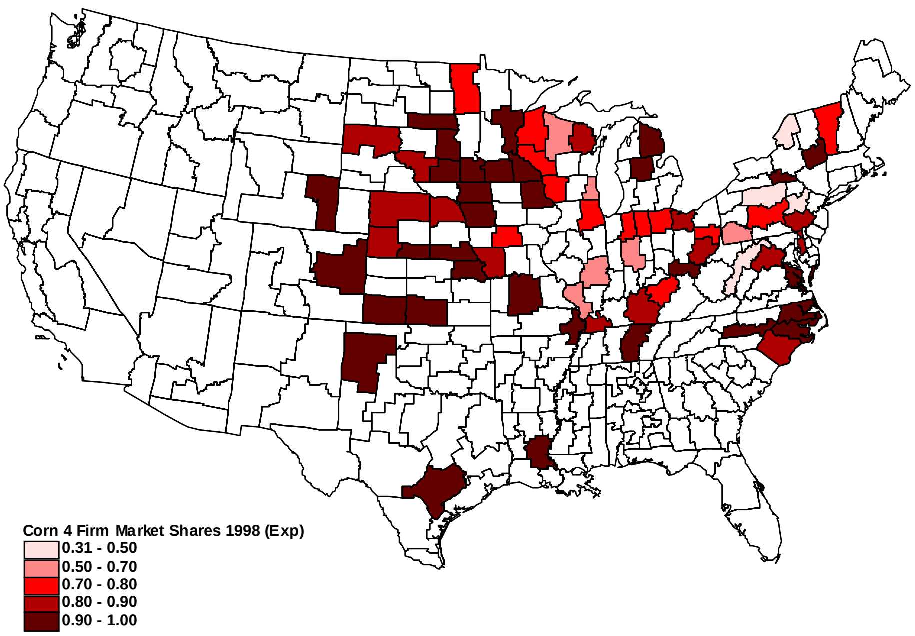

Figure 4. Corn 4 Firm Market Shares for Expenditures, 1998.

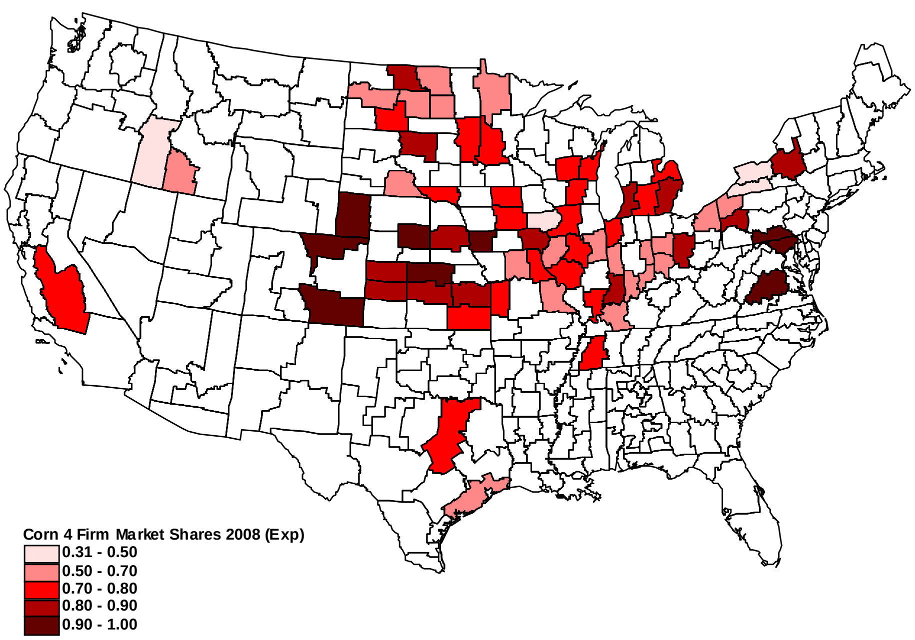

Figure 5. Corn 4 Firm Market Shares for Expenditures, 2008.

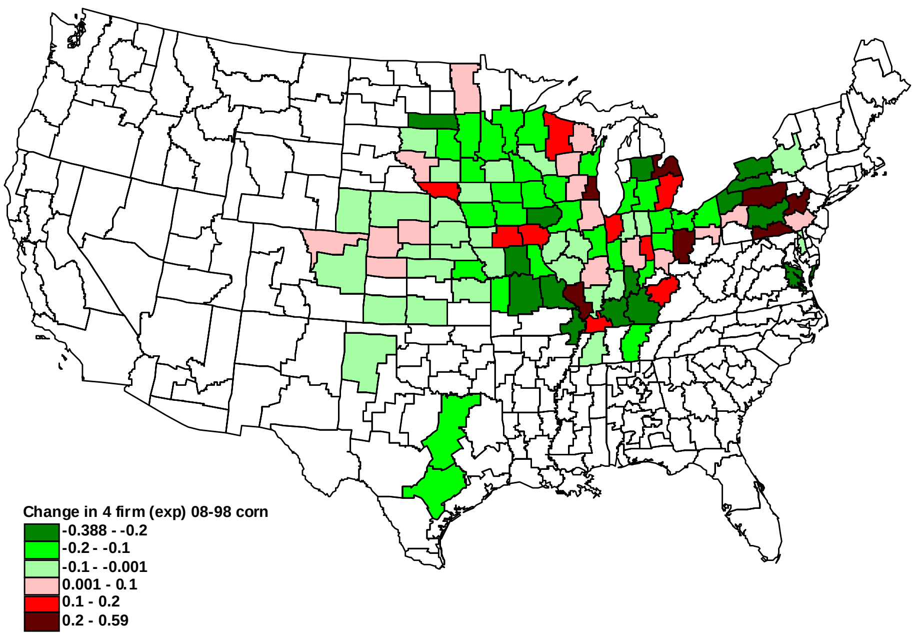

Figure 6. Change in Corn 4 Firm Market Shares for Expenditures, 2008-1998.

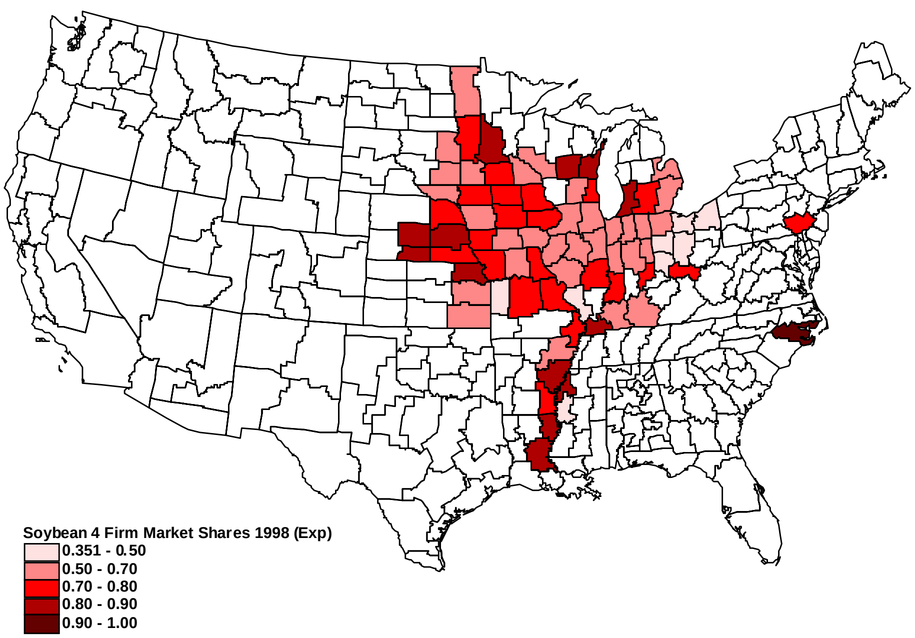

Figure 7. Soybean 4 Firm Market Shares for Expenditures, 1998.

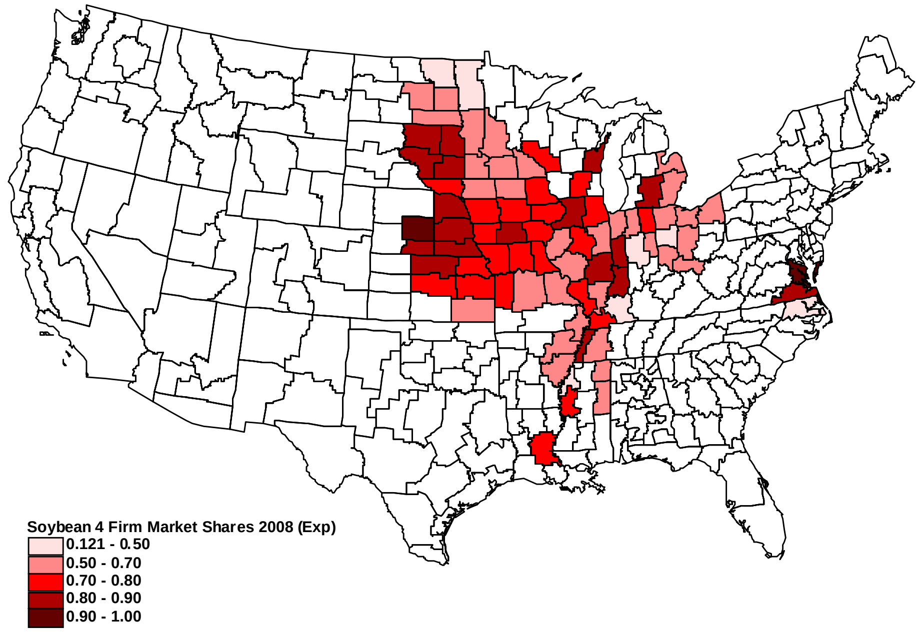

Figure 8. Soybean 4 Firm Market Shares for Expenditures, 2008.

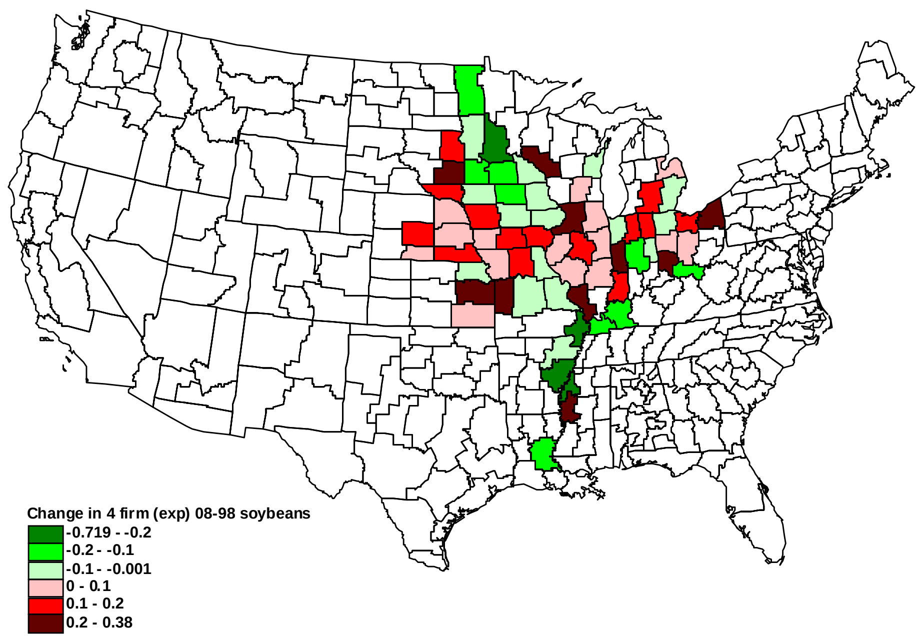

Figure 9. Change in Soybean 4 Firm Market Shares for Expenditures, 2008-1998.

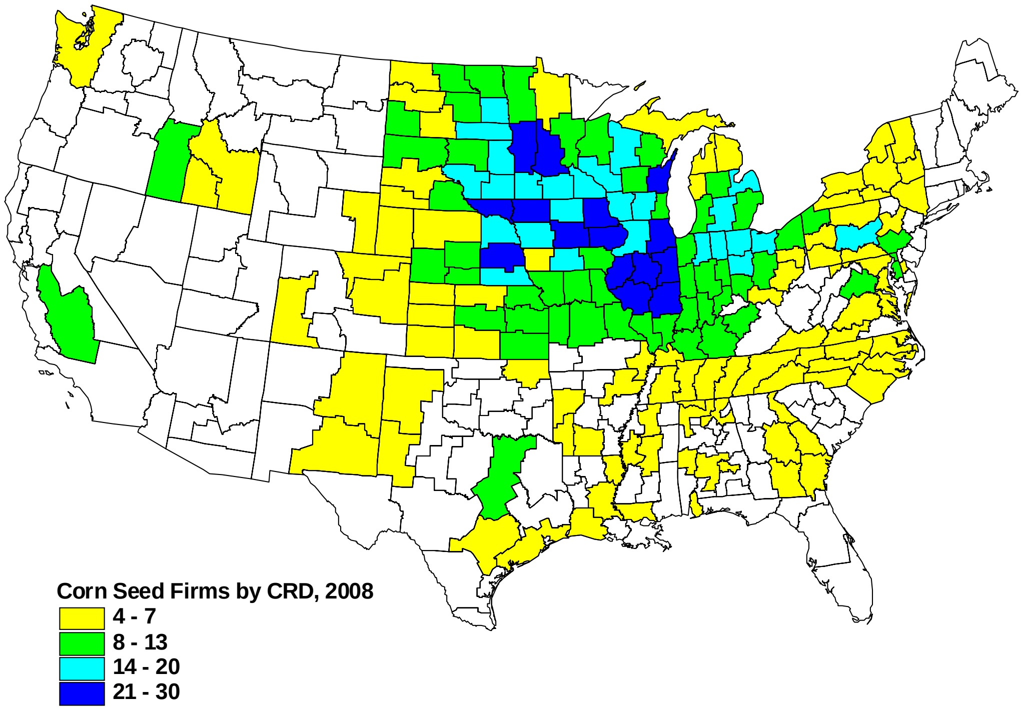

Figure 10. Corn Seed Firms by Crop Reporting District.

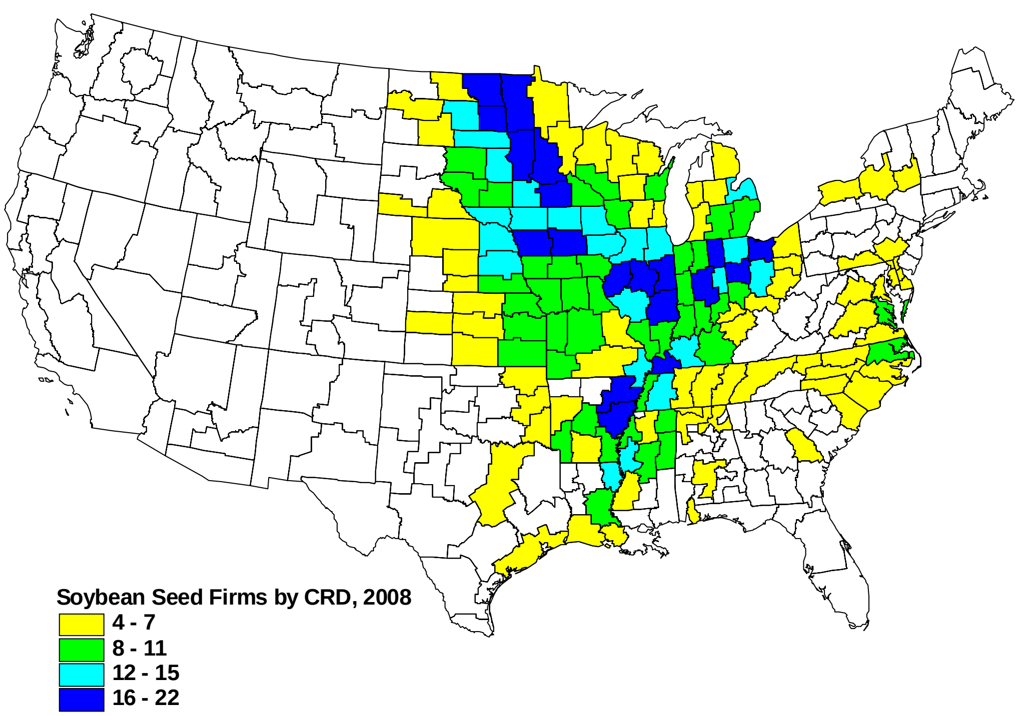

Figure 11. Soybean Seed Firms by Crop Reporting District

Summary and Discussion

Agbiotechnology has become very important to agriculture and its impacts are apparent. It is particularly important in the United States which typically benefits first from the technology (in part due to its IP protection regime), has the greatest and fastest penetration of traits. However, similar innovations are ensuing in other countries and crops. Of importance is that through this technology, as well as others, the major agbiotechnology firms are of the view they can double yields by 2030.

This has resulted in one of the major technological changes in agriculture in recent decades, and is resulting in a change in the structure of these industries. Numerous changes are occurring and are being challenged in a number of fronts. For purposes here, four sets of issues are of particular importance. One is that there has been substantial growth in R&D expenditures in this sector. Second, this growth has resulted in developing technology and Intellectual Property (IP) that needs protection. In the United States, there are several mechanisms in which IP can be fairly efficiently protected. Third is that these industries have become more concentrated, in part, this is due to consolidation. Finally, firms have pursued different strategies of distribution for its technologies. Most important is that of licensing which is now common. Some companies have pursued broader based licensing to seed companies, as well as its competitors, whereas others have pursued less broad-based strategies. Ultimately, this is the mechanism that allows firms to protect its IP, and to induce investment in developing new technology. Finally, some disputes are now erupting among firms regarding their interpretation of licensing agreements.

The analysis in this paper uses novel data sets to illustrate a number of important points. One is that while all agbiotechology firms have increased their R&D expenditures, there have been sharp differences in the scope of this spending. Most of the firms were agchemcial companies and concentrated their spending on chemical solutions to crop production problems. Monsanto was the first to shift their funding to "seeds and traits." This shift was very important strategically, and only later did some firms make like shifts. However, this lag gave Monsanto a first-mover advantage in this technology. Second, there are a large number of future traits that will be commercialized in the coming years. Indeed, these traits are not dominated by any one firm, many offer competing solutions, some are focused on producers, but others on consumers and processing. These would be considered as highly innovative and a result of the competitive structural technical environment for this industry.

A third set of results are shown that depict industry concentration. The results indicate that one firm grew its market share by 14% and a portion of this growth has been through acquisition. The other three majors lost market share, but the ISC (independent seed companies) grew by 10%. At the crop reporting district basis, the CR4s in most regions are .5-.7. The average CR4 (i.e., average across CRDs) for corn changed from 83 to 76% between 1998 and 2008; the comparable values for soybeans indicated a change from 68 to 70%. Finally, each of the major competitors is represented for most CRDs, and during 2008, farmers purchased corn and soybean seed from 4-7 different companies in most CRDs and up to 20 or more companies in the larger producing regions.

The regime of seed and traits has now evolved to be an important aspect of agriculture. This has resulted in a high degree of choices for growers. Since agbiotechnology firms have pursued licensing of traits to growers, seed companies and in some cases to competitors, the number of choices has escalated. Growers have choices about what crops to grow, which technology to use, which companies' technology to plant, and choices among competing seed firms. This set of choices is critical and results in an intensely fierce competitive environment. Indeed if it were not for competitive battles in R&D spending and broad-based licensing strategies, growers would have fewer choices, and the independent seed company sector would likely diminish in its role.

References

AgWeek. 2009. "Monsanto Investigation." *AgWeek*, Grand Forks, ND, Oct 12, 2009, p. 7. Gr

Bell, D and M. Shelman. 2006. "Monsanto: Realizing Biotech Value in Brazil." Case Study (9-507-018), Harvard Business School, December 15.

Chataway, J., and J. Tait. 2000. Monsanto monograph. In *PITA project: Policy influences on technology for agriculture: Chemicals, biotechnology, and seeds* (Annex C11). Retrieved November 4, 2004, from PITA Project Web site: http://technology.open.ac.uk/cts/pita/AnnC11-mono-monsanto.pdf

CONTEXT, 2010. *Plant Science Industry R&D Analysis*, West DesMoines, Iowa.

Dhar, Tirtha and Jeremy Foltz. 2005. The Impact of Intellectual Property Rights in the Plant/Seed Industry. In Seeds of Change. Oxon, UK: CABI Press.

dmrkynetec 2009. Agriculture market studies, St. Louis and available at http://www.dmrkynetec.com/Contact-Us/Americas.aspx

Fatka, J. 2009a. "Monsanto seeks investigation into DuPont activities, *Feedstuffs*, August 31, 2009, p. 4.

Fatka, J. 2009b. "Monsanto stands behind practices," *Feedstuffs*, December 28, 2009, p. 6.

Fernandez-Cornejo, J. The Seed Industry in U.S. Agriculture, USDA ERS Ag Information Bulletin, No. 786, 2004. : http://www.ers.usda.gov/publications/AIB786/

Economist 2009. "The Parable of the Sower: The debate over whether Monsanto is a corporate saint or sinner," *Economist*, Nov 21 2009, pp. 71-73.

Giddings, L.A., and S.A. Schneider. 1999. Economic Dimensions of Intellectual Property. Arlington, VA. Nathan Associates Inc.

Howie, M. 2005. "Monsanto continues spree: Emergent may be last big buy." *Feedstuffs*, p. 7, February 28.

Kalaitzandonakes, N., and M. Hayenga. 2000. Structural change in the biotechnology and seed industrial complex: Theory and evidence. In W.H. Lesser (Ed.), *Transitions in agbiotech: Economics of strategy and policy* (pp. 217-227). Storrs, CT: Food Marketing Policy Center.

Lemarie, S., and S. Ramani. 2003. *An analysis of vertical relationships between seed and biotech companies*. Paper presented at the annual meeting of the American Agricultural Economics Association, Montreal, Canada. July 27-30.

Leonard, C. 2009. “Monsanto Monopoly?”, *AgWeek*, December 28, 2009, p. 29.

Monsanto. 2004a. Product Pipeline. Retrieved March 24, 2004 from http://www.monsanto.com/monsanto/layout/sci-tech/prod_pipeline/ productpipeline.asp#phase3

Monsanto Company. 2004b. *Annual Report*. St. Louis, MO, November 3.

Monsanto Company. 2005. “Monsanto Company to Acquire Seminis, Inc., a Leading Vegetable and Fruit Seed Company.” January 24, 2005. Online. Available at http://www.monsanto.com/monsanto/layout/media/04/05-10-04.asp. [Accessed January 2005.]

Monsanto Company. 2006a. “Dow Agrosciences and Monsanto Reach Global Agreement, Creating New Choices for Farmers.” January 18. Online. Available at http://www.monsanto.com. [Accessed January 2006.]

Monsanto Company. 2006b. “Stacked Traits.”March 23. Online. Available at http://www.monsanto.com. [Accessed March 2006.]

Monsanto Company v. EI Dupont 2009. “Transcript of Proceedings,” Eastern District of Missouri Eastern Division, No. 4:09-CV-00686-ERW, available at http://www.monsanto.com/pdf/dupont_legal/oral_hearing_transcript.pdf

Moss, D. 2009. Transgenic Seed Platfoms: Competition between a Rock and a Hard Place?, American Antitrust Institute, Oct 23, 2009.

Pillar, D. “Monsanto-Pioneer Squabble May Build Syngenta Market,” *Des Moines Register*, Nov 25, 2009.

Pioneer Press Release. 2009 “DuPont Alleges Anti-Competitive Conduct by Monsanto” WILMINGTON, Del., May 5, 2009 available at http://www.pioneer.com/web/site/portal/menuitem.f3825e23adca22214c844c84d10093a0/

Rausser, G., S. Scotchmer, and L. Simon. 1999. Intellectual Property and Market Structure in Agriculture. Paper Presented at the Meeting of the International Consortium on Agricultural Biotechnology Research. Rome Italy.

W. Wilson and S. Huso. 2008. "Trait Stacking, Licensing, and Seed Firm Acquisitions in GM Grains: A Strategic Analysis." *Journal of Agricultural & Resource Economics*, Vol. 33, No. 3 (December 2008) pp. 382-401.