

Seed Industry Structure Is Characterized by Growth and Consolidation

From the first ventures into the commercial production of hybrid corn seed in the 1930s, to the recent mergers and acquisitions, the seed industry has experienced extensive structural change and transition.

Early Industry Structure: 1920-1970

Until the late 19th century, most U.S. farmers depended on seed saved from their own crops cultivated in the previous year and did not purchase significant quantities of seed from commercial sources. It was not uncommon for farmers to share surplus seed with friends and neighbors. The advent and expansion of seed certification programs between 1915 and 1930 brought about large increases in the number of farmers who purchased seed from commercial traders instead of producing it themselves or obtaining it locally from neighbors. Seed certification programs provided quality assurances to farmers, leading to a rise in the role of commercial seed markets.

Most commercial seed suppliers at that time were small, family-owned private businesses lacking the financial resources necessary to pursue their own R&D activities. The primary role of seed businesses at the time was to multiply and sell seeds of varieties developed in the public domain, as R&D of improved plant varieties was carried out almost exclusively by land-grant colleges and universities, State agricultural experimental stations, and other public agencies (Duvick, 1998; McMullen, 1987).

At the end of the 19th century, the seed used in corn (the dominant field crop in U.S. agriculture) was almost entirely based on open-pollinated varieties (OPV) that farmers saved from prior crops and subsequently planted (Schor, 1994, p. 35). In the early part of the 20th century, public researchers developed high-yielding hybrid corn varieties that consistently outperformed OPVs. Capitalizing on these breakthroughs and the growing demand for hybrid seeds (and given the implicit form of proprietary rights enjoyed by hybrid corn breeders over their innovations), the private sector's role in the commercial market for hybrid corn seed increased significantly beginning in the 1930s (Duvick, 1998, pp. 198-200).

The development and diffusion of hybrid corn varieties, with their inherent capacity to protect returns to private investment, transformed the U.S. seed industry. Beginning in 1930, approximately 150 companies formed to produce hybrid corn seed and some 40 existing seed companies expanded their businesses to include production of hybrid corn seed. While most firms were established to produce and sell seed, some also instituted inhouse research and breeding programs to improve existing hybrids. As long as the lineage of a company's hybrid remained unknown to competitors or farmers, the company continued to hold a unique and marketable product until an even better hybrid was developed. By 1944, U.S. sales in the seed corn market had expanded to over \$70 million, establishing corn seed as the core business of the U.S. seed industry (Duvick, 1998, p. 199).

The early growth of the seed industry shifted corn production to hybrids swiftly and extensively; by 1965, over 95 percent of American corn acreage was planted with hybrid seed. Industry expansion also generated profits sufficient to support reinvestment in plant breeding R&D, leading to continual increases in corn seed productivity and crop yields (McMullen, 1987, p. 89). By constantly improving their products through new research, private seed firms were able to maintain the corn seed market's longrun viability. The seed industry reshaped itself primarily around large firms highly vested in the corn seed industry. The smaller firms in the industry tended to be family-run, regionally oriented firms active only in producing, distributing, and marketing varieties developed by the public sector or larger private companies (Kimle and Hayenga, 1993, pp. 19-20). The ability of farmers to save nonhybrid seeds limited the expansion of the seed industry into other agricultural seed markets, establishing corn as the historical force behind the growth of the seed industry.

Modern Industry Structure: 1970-Present

With the exception of hybrid seed firms, few companies had proprietary rights over the plant varieties

they sold as seed until the early 1970s.⁷ Most private seed firms focused primarily on cleaning, handling, storing, packaging, and selling seed developed in the public domain. The 1970 PVPA, subsequent amendments and rulings, and other actions strengthened property rights by providing proprietary rights over sexually- and tuber-propagated new plant varieties, creating an incentive for private firms to enter the seed market.

Over the past three decades, the U.S. seed industry has been marked by transition. As recently as 1970, most seed firms were independent. During the 1970s, most small seed firms vanished, as mergers and acquisitions created a new seed industry structure dominated by large companies with primary investments in related sectors. For example, more than 50 seed companies were acquired by pharmaceutical, petrochemical, and food firms following the passage of the 1970 PVPA (Lesser, 1998). The acquiring companies were drawn to the potential profits available through the purchase of strong, well-developed seed companies. Those large corporations, many of them multinational conglomerates, possessed the resources needed to achieve scale economies in research and development. Many chemical firms entered the U.S. seed market because the agricultural chemicals market had reached maturity and profits in that sector were declining (Kimle and Hayenga, 1993, pp. 20-21).⁸ Pursuing new, high-growth opportunities, large multinational corporations specializing in chemicals and pharmaceuticals, such as Ciba-Geigy, Sandoz, Royal Dutch/Shell, Upjohn, and Celanese, entered the seed industry in the mid-1970s (Kimle and Hayenga, 1993, pp. 19-20). As a result, private sector acquisitions expanded rapidly, and, by the early 1980s, several international firms were among the top seed sellers worldwide (table 12).

⁷ Apart from corn, the only other field crops that have been successfully hybridized are sorghum and sunflower. Breeders also successfully hybridized a number of vegetable crops, such as onions, tomatoes, broccoli, cabbage, melons, and spinach, but the market shares of these crops are marginal, compared with those of corn (McMullen, 1987, p. 89; Leibenluft, 1981, p. 95). Until recently, farmers growing other major field crops remained dependent on saved seed, thus limiting the growth of seed industries for those crops: only 55 percent of the soybean acreage, 50 percent of cotton acreage, and 10 percent of wheat acreage was cultivated with purchased seed as late as 1982 (McMullen, 1987, pp. 86-87).

⁸ The chemical industry experienced its most marked growth—15 percent or more annually—during the late 1960s and 1970s. Since then, market growth has been under 10 percent and was predicted to slow in the late 1990s (Storck, 1987).

Table 12—Global seed sales of top international seed companies

Company	1983	1989	1983	1989
	<i>Million current dollars</i>		<i>Million 1989 dollars¹</i>	
Royal Dutch/Shell	650		784	
Pioneer Hi-Bred	557	840	672	840
Sandoz	319	471	385	471
Cardo	285		344	
Asgrow		270		270
DeKalb/Pfizer	187	205	226	205
ICI		250		250
SICA France Mais		170		170
Takii		170		170
Clause		159		159
Claeys-Luck	155		187	
Sakata		152		152
Upjohn	139		168	
Limagrain	130	268	157	268
Ciba-Geigy	107	148	129	148
Suiker Unie	100		121	
K.W.S.	80		97	
Cebeco	65		78	
Svalof	55		66	
Cargill	50	241	60	241

¹ Calculated using the U.S. GDP deflator.

Source: McMullen (1983), p. 94; Kimle and Hayenga (1989), p. 21.

In the early 1980s, developments in biotechnology created an additional incentive for firms to increase their R&D capacity and expand further into seed production. As the first products of crop biotechnology began large-scale extensive testing in the 1980s, the seed industry's structure underwent additional transformation. The industry again reorganized through extensive mergers, acquisitions, and joint ventures as companies sought to achieve economies of scale to offset the high costs of biotechnology R&D. Strong demand complementarities provide the rationale for joint ventures between chemical and seed businesses (Just and Hueth, 1993). An example is the case of the herbicide glyphosate and soybeans tolerant to glyphosate.

Despite these incentives, many large chemical and industrial manufacturing companies that invested heavily in the seed industry during the early 1980s are no longer in the seed business. Royal Dutch/Shell, a market leader in 1983 with seed sales topping \$650 million, sold its seed unit and had exited the seed industry completely by 1989. Other large players in the market, such as Occidental Petroleum, Upjohn, Lubrizol, and Celanese, similarly shed their seed subsidiaries. Of the 14 companies that led industry sales in 1983, only 7 occupied top global sales positions by 1989. Pioneer Hi-Bred main-

tained the leadership position in the market in 1989, followed by Sandoz, Asgrow, and Limagrain.

Mergers and acquisitions, along with increased private sector R&D expenditures, continued to grow through the 1990s. According to some industry experts, the acceleration in seed company acquisitions stemmed from efforts by acquiring companies to raise their market share in a market with rich profit potential (Kidd, 1989). Some businesses active in mergers and acquisitions may also have been attempting to consolidate market share and distribution infrastructure/capacity in selected species in anticipation of new biotechnology product developments. In addition, companies may seek to acquire others to facilitate access to protected intellectual property, particularly when licensing is costly (Blonigen and Taylor, 2000).

Some firms evolved toward developing “life sciences” complexes organized around the development of such products as agricultural chemicals, seeds, foods and food ingredients, and pharmaceuticals based on applications of related research in biotechnology and genetics. Monsanto, Novartis, and AgrEvo gained a significant share of the market through such strategic behavior (Begemann, 1997) (table 13). Most of those life sciences companies, however, divested their agri-

Table 13—Estimated seed sales and shares of U.S. market for major field crops, 1997

Company	Total		Corn market share	Soybean market share	Cotton market share
	Total sales	market share ¹			
	<i>Million dollars</i>	<i>Percent</i>			
Pioneer Hi-Bred	1,178	33.6	42	19	0
Monsanto ²	541	15.4	14	19	11
Novartis	262	7.5	9	5	0
Delta & Pine Land ³	79	2.3	0	0	73
Dow Agrosciences / Mycogen	136	3.9	4	4	0
Golden Harvest	93	2.6	4	0	0
AgrEvo/Cargill	93	2.6	4	0	0
Others	1,121	32.0	23	53	16
Total	3,503	100.0	100	100	100

¹ Total market shares in this table include only corn, soybeans, and cotton.

² Monsanto acquired Dekalb in 1997 and Asgrow in 1998.

³ The merger between Monsanto and Delta & Pine Land in 1998 was called off in December 1999.

Sources: Market shares for corn and soybeans: Hayenga (1998); cotton: USDA, AMS. Total crop sales calculated from acreages and seed cost per acre: USDA's Agricultural Resource Management Survey data (1998) and *Agricultural Statistics* (USDA, 1998).

cultural operations over the past 3 years (King, 2001; Fulton and Giannakas, 2002).

The changing nature of the seed industry following the entry of large firms has been the subject of much debate. Many large firms enjoy economies of scale in R&D and have been able to subsidize seed research with resources and revenues from other corporate divisions (Butler and Marion, 1985, p. 51). The development of biotechnology has also generated opportunities for economies of scope (i.e., producing several products together at a cost less than producing them separately). According to Fulton and Giannakas (2002), once a specific gene has been isolated (e.g., a gene that confers resistance to a particular herbicide) this gene can be used in a number of crops. Furthermore, the entry of large multinational firms in the industry also expands markets, from domestic or regional to global, increasing sales volume and profits supporting R&D.

The entry of multinational firms in the seed industry may also have drawbacks. First, the relatively small size of the commercial seed market—\$5.7 billion in the United States and \$25 billion worldwide (table 2)—means that seed divisions in large firms are less likely to exert influence on corporate decisions than those divisions involved in larger markets, such as pharmaceuticals and chemicals (FIS/ASSINSEL, 2000). Second, the time-consuming nature of seed R&D requires a long-term perspective on R&D investments, which may not appeal to a firm's shareholders (Butler and Marion, 1985, p. 51). Third, and most importantly, the presence of large firms in the industry raises concerns about increasing market concentration and oligopolistic competition among and between firms (see, for instance, Leibenluft, 1981; Begemann, 1997; Kalaitzandonakes and Hayenga, 1999).

The seed market is still somewhat small in size, compared with other agricultural input markets, such as

Table 14—Global seed and pesticide sales of major multinational firms, 1999

Company	Seeds	Pesticides
	<i>Million dollars</i>	
Syngenta (Novartis/AstraZeneca)	1,173	7,030
Aventis (Hoechst & Rhone Poulenc) ¹	135	4,582
Dupont (inc. Pioneer)	1,835	2,309
Monsanto/Pharmacia	600	3,230
Dow Agrosciences	220	2,132

¹ Recently acquired by Bayer.

Source: Merrill Lynch (2000).

the pesticide market (table 14). Still, the total market value of purchased seed in the United States grew substantially in the past three decades. This growth has been particularly rapid in the seed markets for major field crops—corn, soybeans, wheat, and cotton—which constituted 70 percent of the overall seed market in 1982. These markets are dominated by a few large firms which, through strategic corporate behavior, have come to play a central role in some or all of these markets. Together, their seed sales amounted to approximately \$4 billion in 1999 (table 14).

Before discussing firm- and crop-specific details of the modern seed industry and its structure, it is useful to review the workings of the seed market, or how seeds are developed, manufactured, and distributed to farmers. Though different types of seed have very distinct production processes and markets, a fairly general description of the process is applicable across all types (see box on the process of seed production).

The Process of Seed Production, Marketing, and Distribution

Different types of seed have very distinct production processes and markets, but a general description of the overall process is applicable across most seed types. The seed firm can be viewed in terms of four separate functions: (1) Plant breeding R&D, (2) seed production, (3) seed conditioning, and (4) seed marketing and distribution.

Plant breeding. Plant breeding constitutes the foundation of the modern seed industry in that it creates a unique and marketable product through the application of science. Plant breeders develop seeds embodying such improvements as high yields, resistance to disease and pests, or traits specific to regional agroclimatic conditions. A seed's success in the market depends primarily on its improved traits, which embody the R&D effort.

The high costs associated with large-scale R&D limit it to a relatively small number of large companies and to Federal Government agencies and land-grant colleges and universities. High R&D costs require private sector varieties to be commercially viable, highly competitive, and well protected by intellectual property rights (IPR). Where each breeder holds the exclusive rights to produce and distribute his or her variety, competition tends to be based more on product performance—yield, disease resistance, quality—than price (Leibluft, 1981, p. 107). Given the size of their R&D investments, these plant breeders play a central role in managing the entire production, distribution, and marketing processes in the seed industry, resulting in extensive vertical integration of the industry (Butler and Marion, 1985, pp. 18-19). Moreover, there are economies of scale in R&D, marketing, and distribution, but there are not many economies of scale in seed conditioning (Morris, 1998).

Seed production. Seed firms with a marketable seed product typically contract out the production and multiplication processes to farmers, farmers' associations, and private firms. Breeders provide contract growers the *foundation seed* (parent seed stock produced from the original seed developed by plant breeders) to produce either more foundation

seed for continued R&D purposes, or *registered seed* for large-scale production purposes. Registered seed is contracted out in a similar manner to produce *certified seed*, sold to farmers conforming to standards of genetic purity and quality established by State agencies (Agrawal et al., 1998, pp. 104-105, Butler and Marion, 1985, p. 16). The production of certified seed requires strategic planning to ensure that market demand is adequately met. This planning may include determining the quantities of each variety to be produced; determining inventories necessary to produce in excess of forecasted demand to avoid immediate or future shortages; and reducing the risks associated with the unpredictable effects of weather conditions, disease, and pests. Production may also require estimating the quantity of saved seeds farmers will use instead of purchased seed, and the differences in quantity and type of seed demanded in different geographic markets (Leibluft, 1981, p. 109; Butler and Marion, 1985, pp. 18-19). Corn seed firms, for example, disperse seed-growing contracts throughout the United States (and to countries of the Southern Hemisphere as well) to minimize disease and weather risks and often intentionally overproduce by 25 percent of forecasted demand for the coming season to ensure adequate supply.

The production of both registered and certified seed through contract growers is closely managed by seed firms to ensure that the desirable plant characteristics are carried through to subsequent generations, and to prevent open pollination, disease or pest infestation, or other types of problems that could affect product quality. Contract growers are carefully selected by seed firms and are provided with technical assistance or supervision. Seed firms closely control all stages, from seedbed preparation and planting densities to the timing of input application (Agrawal et al., 1998, pp. 106-107).

Seed conditioning. Once harvested, certified seed is conditioned for sale to farmers, a process that typically includes

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drying, cleaning, and sorting the seed; treating the seed with insecticides and fungicides; and packaging the seed for distribution and sale (Krull et al., 1998, p. 133; *Seed World*, 1999, p. 41). Seed is also subject to inspection under various State programs to ensure that the final product meets certain quality standards. This inspection may include tests for purity, germination, presence of noxious weed seeds, and moisture content.

Seed marketing and distribution. Large seed firms play a direct role in marketing and distributing their end product to regional, national, and international markets. Many firms also license or outsource marketing and distribution to private firms and individuals to improve access to local markets (Butler and Marion, 1985, 16). Local distribution is typically run by independent agents, such as farmer-dealers, farmers' associations, company salespeople, and private wholesalers and retailers. Different distribution channels are used in different regions and markets. In the Midwest, for example, most corn seed is sold to farmers by part-time farmer-dealers who have received training directly from the seed firm. In the South, corn seed sales are channeled through agricultural supply stores. On large farms throughout the country, seed company salespeople sell straight to farmers (Leibenluft, 1981, p. 109).

Seed pricing. The market price of seed incorporates the costs associated with development, production, marketing, and distribution. In the long run, the price must be responsive to the farmers' willingness to purchase while at the same time ensuring a profit margin that provides an attractive return on capital to investors. Furthermore, the price depends on the competitiveness of the particular seed market, and the pricing behavior of those firms that hold large shares of the market.

R&D costs account for an important portion of the market price for seed, particularly for hybrids or transgenic seeds over which private firms own exclusive proprietary rights. In recent decades, private sector R&D costs have been rising with the application of new technologies, and much of the increase in seed prices has been associated with this trend (Krull et al., 1998, pp. 133-134). R&D costs vary

among the different seed markets. For example, the corn seed market depends extensively on private sector R&D and passes these costs on to farmers, while the wheat seed market depends largely on public sector research, which is almost cost-free to farmers.

Seed production is another major cost, contributing up to about a quarter of the seed price, but the share of these production costs varies as the marketing and distribution costs change. Production costs include paying farmers to grow seed for exclusive resale to the seed firm. Contract growing typically requires that the seed firm pay a margin above the commodity market price for the seed to ensure that optimal growing conditions are maintained to produce a good quality product (Agrawal et al., 1998, p. 115). For example, for corn, a contract payment formula may be $R = 1.1(P_{ch} - 0.08)[2(y - y_{av}) + 185]$, where P_{ch} is the expected price of the commodity, such as a futures price, y is the farm corn yield (given a certain nitrogen application and weather) and y_{av} is the regional average yield (also given nitrogen application). Thus, the grower payment is based on an adjusted yield that is equal to a typical yield of 185 bushels per acre plus twice the difference between the farm yield and regional average yields. The grower receives an additional bonus of 10 percent to make the contract desirable (Preckel et al., 1997).

Seed conditioning and treatment may account for around 15 percent of the seed price. This process benefits from scale economies arising from the relatively intensive use of capital equipment.

Advertising, promotion, and distribution are other major costs. These costs vary with the stage of the product cycle and their share may account for more than 20 percent of the seed price. Advertising and promotion are necessary to distinguish a seed firm's product from other firms' products on the market, to educate dealers on the best crop management practices to ensure high seed productivity, and to induce farmers to adopt the firm's particular seed. Distribution costs include costs of transportation and communication between production facility, wholesalers, retailers, and farmers, as well as storage costs (including financial costs) if seed is held as inventory between seasons (Krull et al., 1998, pp. 133-134; Agrawal, 1998, p. 120).