and then there were 4

is concentration affecting Biotechnology Industry R&D performance?

RESEARCH & DEVELOPMENT

The pace of consolidation in ag biotech is a cause for concern in some quarters. What will happen to R&D? And, with only four main suppliers, will farmers be able to get the biotech seed products they really need, or just the nearest thing available?

BY JAMES F. OEHMKE AND CHRISTOPHER A. WOLF

The agricultural industry has become increasingly concentrated in the last few years. This is evident in firms involved in biotechnology research and development (R&D) as well as in production agriculture. Biotechnical advances and legal changes have created a situation in which a few large companies can control the direction and pace of biotechnology R&D and use. This raises questions about the ability of these companies to influence price, and it begs the questions: Will these companies generate the full range of biotechnology innovations that society values? And, will their innovative activity reflect the value that society places on the potential outputs?

Past economic research on innovation and concentration has suggested that concentration encourages innovation. However, there is also countervailing evidence to indicate that when concentration is extreme, innovation is squelched. We focus on transgenic crop R&D to assess the level of industry concentration, the characteristics and factors that contribute to concentration, and some implications for industry performance and policy.

Building a Better Variety

Transgenic plant varieties are created by taking DNA sequences from nearly any organism — including unrelated plants, bacteria, and viruses — and inserting these sequences into the seeds

of an economically desirable plant variety. The inserted DNA transfers useful properties to the transgenic plant, such as herbicide tolerance or insect resistance.

Intellectual Property Protection for Plant R&D

Creation of a transgenic variety requires access to a useful DNA sequence, a tool to extract the sequence from the host organism, an insertion mechanism, often a "promoter" to activate the new DNA sequence (the gene construct), and usually a "marker" to distinguish seeds that have been modified from those that have not. Standard extraction, insertion, promotion, and marker tools are available, but because they are patented they are not free and, depending on the firm holding the patent, may be available only at prohibitively high prices. The objective of private-sector biotechnology research is primarily to find or create (and patent) new and economically useful gene constructs.

When the genetic material has been successfully transferred, the firm field tests the variety under U.S. Department of Agriculture Animal Plant and Health Inspection Service (APHIS) guidelines, and then, if the firm considers the trial successful, it applies to APHIS for deregulation. If APHIS grants deregulated status, then the transgenic variety may be commercialized like any traditional variety. Once a transgenic variety is deregulated, it may be (traditionally) crossed with other varieties and pass on its genetics without further involvement from APHIS.

Through 2000, APHIS had granted deregulated status to 53 different organisms developed by 17 different firms and two universities. The most popular commodities were corn (15 deregulations) and tomatoes (11). The most popular traits involved herbicide tolerance (23), insect resistance (16), and product-quality improvements (12).

The plant biotechnology industry is one of the most concentrated in the world. In 1999, only four firms had significant revenue from sales of transgenic plant seed or biotechnolo-

Intellectual Property Protection for Plant R&D

In the United States, the Plant Patent Act of 1930 and the Plant Variety Protection Act of 1970 provide protection of intellectual property residing in plants. In Diamond v. Chakrabarty, the U.S. Supreme Court allowed protection of intellectual property embodied in living tissue via utility patents. Ensuing case law extended this protection to genetic material.

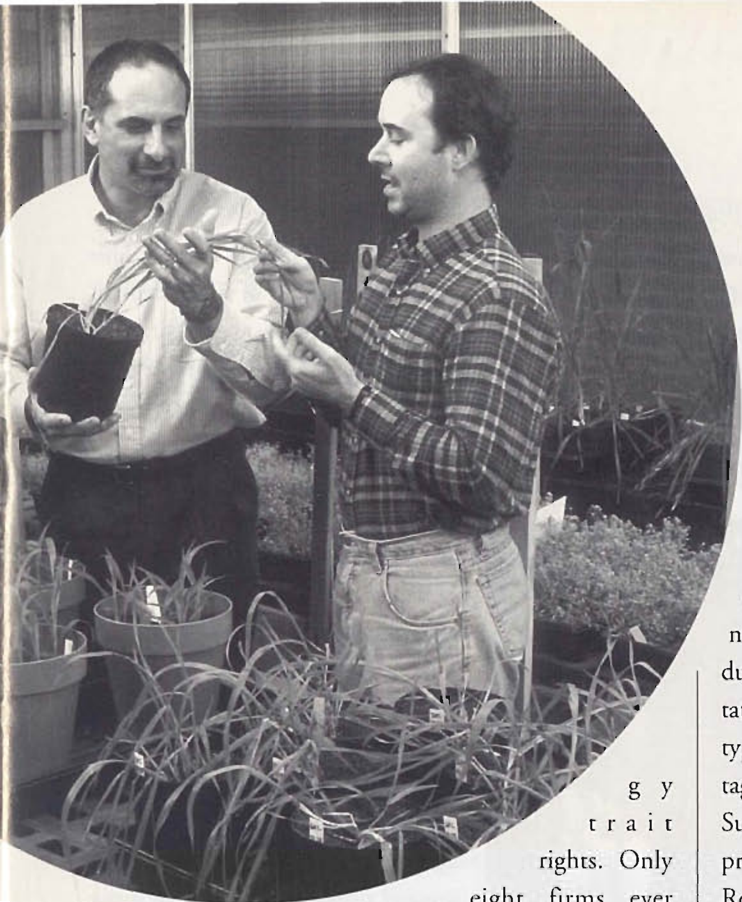
Patents on plant varieties were opposed by some for fear of enhancing the economic power of seed companies. This economic power was forecasted to result in increased genetic uniformity, incentives to restrict information and materials, increased requirements of capital to conduct R&D favoring larger companies at the expense of smaller companies, mergers and acquisitions that increase concentration, and higher seed prices. This proved untrue for the Plant Variety Protection Act (Butler and Marion), but these concerns have recently resurfaced with respect to transgenic plant innovations.

The Gene Gun and Incentives to Innovate

Techniques to insert genes into cells are patentable processes. Perhaps the most popular technique is the "gene gun" which literally shoots recombinant DNA into plant cells where it can be incorporated into the chromosomes of that plant. The gene gun was developed at Cornell University, which sold the technology rights to DuPont in 1990.

With the purchase of the gene gun technology, DuPont became the gatekeeper for many existing and future biotechnologies that depend on gene insertion. Lacking a licensing agreement, which may include a significant portion of future profits, many technologies are no longer commercially viable. Thus, the expected profits of any technology that depends on the gene gun may be reduced or blocked by DuPont.

The ownership of basic technologies can decrease societal welfare in two ways. First, rather than build from existing basic technologies, resources may be dedicated to finding substitute basic technologies. Second, the property rights ownership of basic technologies may remove incentives to build applications that use these technologies. The gene gun is just one example of property rights affecting the incentive to innovate.



Does concentration compromise innovation? Some observers fear that the small number of firms involved in plant biotechnology R&D will limit future product innovations available to farmers.

photo courtesy of USDA/ARS

g y trait rights. Only eight firms ever successfully deregulated a herbicide tolerant (HT) variety of any crop (based on APHIS data), and only four of these currently exist as firms with independent technologies. The three crops with the largest acreages planted to transgenic varieties are corn, cotton, and soybeans.

Does Concentration Compromise Innovation?

The nature of biotechnology raises some unique concerns about how industry concentration affects the pace of innovation. In biotechnology, the idea that the next innovation will replace the previous innovation (as, for example, the compact disc has largely replaced the audio cassette) does not appear to be true. Instead, the next innovation often "stacks" new biotechnology traits on top of those developed earlier.

For example, HT corn has not been replaced by corn that makes herbicides obsolete. The following innovation is corn that is both HT and insect resistant (IR). Consequently, in biotechnology subsequent innovations depend crucially on the patented materials from the previous innovation(s), as well as the patented techniques for transgenic manipulation.

The real concern is not that Monsanto will charge "too much" for HT corn, but that future innovation will be curtailed because only Monsanto can add to the stack. If all commercially available HT corn varieties rely on one of two gene constructs, is there an incentive for other firms to create the next variety of transgenic corn?

The answer depends in large part on the number of genetically different varieties that are available to improve upon. Prior to transgenic biotechnology, a number of seed companies conducted research to produce varieties with desirable characteristics such as adaptation to regional growing conditions. Research of this type seems to be declining as an additional yield advantage is desirable only if the variety is also HT and/or IR. Success with HT varieties creates demand for herbicides, providing companies such as Monsanto, which produces Roundup®, an incentive to conduct that research.

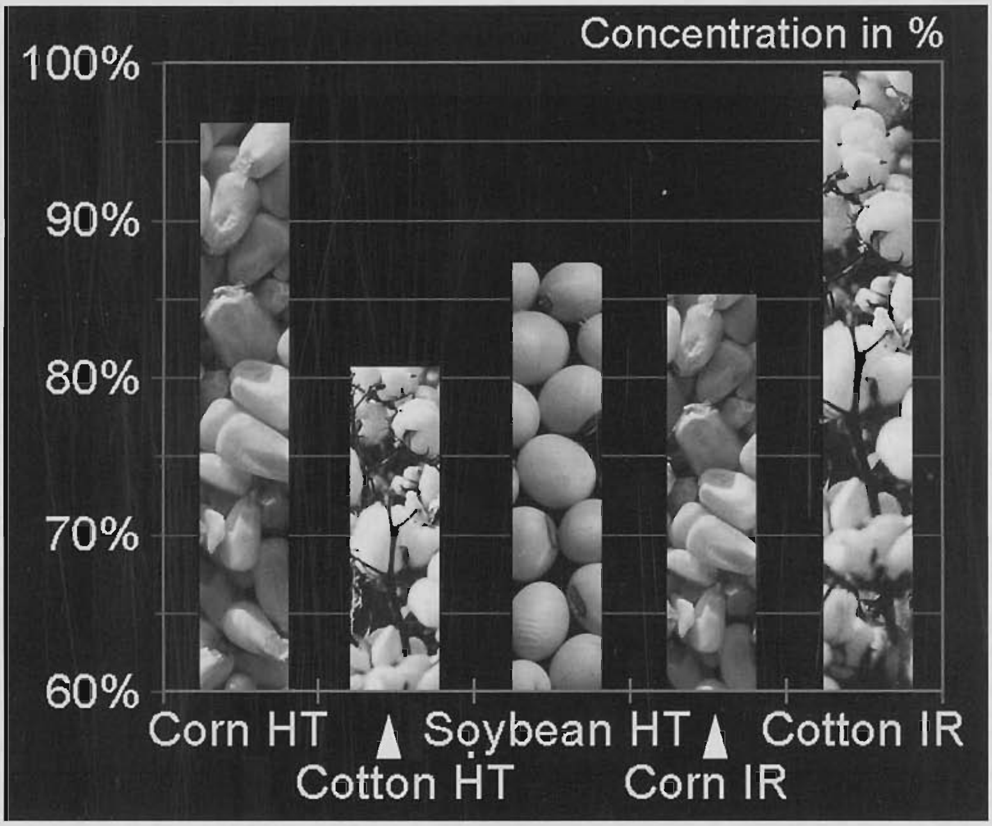
Will an independent R&D company improving on an HT variety be able to purchase from or sell the commercialization rights to a large company like Monsanto, which owns the gene construct for that herbicide tolerance, at a profit-making price? The answer depends partly on the concentration of HT gene constructs in the biotechnology R&D industry.

We would like to examine the number of gene constructs undergoing field trials. By using the gene construct measure, we answer the question of whether the small firms are contributing significant independent innovations, or are simply testing or replicating gene constructs already discovered by the major firms. Unfortunately, gene construct data are usually proprietary and not reliably available. However, closely related information is the phenotype of the tested variety. For example, the corn phenotype of glyphosate (a type of herbicide) tolerance can be readily associated with one of the two gene constructs that convey this tolerance.

The proportion of field trials in the industry's most popular phenotype categories through the end of 2000 provides a concentration measure. For HT corn, 96 percent of the field trials were to confer one of four phenotypes (Figure 1). That is, 96 percent of HT corn field trials relied on gene constructs owned by one of four firms. Eighty-six percent of the HT soybean trials also confer one of these phenotypes, and 81 percent of the HT cotton trials were for one of four phenotypes. The two most common phenotypes in IR corn and cotton trials accounted for 85 percent and 99 percent of IR corn and cotton trials, respectively (for IR, the correspondence between phenotype and gene construct is less direct as there are multiple transgenes that may be utilized). Explicitly accounting for the limited number of gene constructs in the areas of herbicide tolerance and insect resistance shows that concentration in these innovation markets is much greater than is indicated by concentration measures that rely only on firm numbers (Brennan, Pray, and Courtmanche).

Figure 1: Trial Concentration

The columns in the graph depict the percentage of biotech varieties owned by one of the four major plant biotech firms.



Patents, Performance, and Policy

Patents and intellectual property protection on research inputs and processes affect incentives to use these processes for further innovation. Applications that use patented technologies give bargaining power to the patent owner. Therefore, these applications may not realize their true value, discouraging further applications by any firm other than the patent holder. This protection also affects the distribution of R&D capital. Rather than focusing on building applications for existing basic technology, companies have an incentive to find a basic replacement technology before proceeding with research on applications. If firms substitute redundant basic technology R&D for new applications, then the rate of technical progress is reduced.

Concentration in the biotechnology R&D industry also raises issues about trait stacking — issues analogous to those in recent antitrust litigation faced by Microsoft. The antitrust allegations against the software giant centered around "tying" sales of the Windows Explorer® internet browser with the sale of the Microsoft Windows® operating system. Similarly, agricultural biotechnology companies search for transgenic plants that allow, and often encourage, the use of the inputs that they own. For example, Monsanto R&D produced Roundup Ready® crops.

Stacking Up Features – and Prices

Stacking transgenic traits may or may not be driven by market considerations. For example, suppose a farmer wishes to purchase high-lysine corn only if it is also Roundup Ready. In this case, stacking the high-lysine and herbicide-tolerant traits in the same variety is certainly of benefit. However, if the farmer was concerned only about lysine content, while Monsanto was selling only Roundup Ready high-lysine corn, then this stacking would be expensive overkill for the farmer.

In the Microsoft case, the Department of Justice asked whether the operating system could be purchased without the browser. For biotechnology, the question becomes: Will farmers/consumers be able to choose the stack of transgenic traits most suitable for them? Or, will industry concentration stifle the development of useful traits and lead to a "one-size-fits-all" situation?

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Concentration raises concerns about noncompetitive pricing, and the extraction of all benefits from the adopter. However, evidence suggests that farmers are reaping significant benefits from transgenic crops in the form of lower production costs (Falck-Zepeda et al.). This suggests that concentration issues are more important to the R&D market than to the product market, at least to date.

In traditional markets, free entry can provide an antidote to the negative social consequences of concentration and noncompetitive pricing. In biotechnology, the intellectual property protection of R&D processes and the stacking of newly discovered traits onto already patented organisms may provide significant barriers to entry. Thus, it becomes critically important to look at concentration and competition in the innovation market.

The policy issues surrounding this phenomenon are difficult to assess and involve trade-offs. Without the property rights that allow the innovator to profit, there is less incentive to innovate. However, these property rights also allow and encourage the concentration we find in transgenic plant R&D.

The questions that future analysts must ask include: Are we (producers and consumers) getting sufficient R&D in the transgenic plants of all types and market sizes? Is the ownership of basic technologies — such as the gene gun — limiting incentives to innovate? Do companies pursue technological innovations only in markets of major commodities (for example, corn, cotton, soybeans)? And, can public research funding alleviate some of the incentive issues?

For More Information

Brennan, Margaret F., Carl E. Pray, and Ann Courtmanche. "Impact of Industry Concentration on Innovation in the U.S. Plant Biotech Industry." Paper presented at the conference Transitions in Agbiotech: Economics of Strategy and Policy, Washington, DC, June 1999.

Butler, L. and B. Marion. "The Impacts of Patent Protection on the U.S. Seed Industry and Public Plant Breeding." North Central Regional Research Publication 304. September 1985.

Falck-Zepeda, Jose Benjamin, Greg Traxler, and Robert G. Nelson. "Surplus Distribution from the Introduction of a Biotechnology Innovation." *American Journal of Agricultural Economics* 82(May 2000):360-69.

Oehmke, J., D. Weatherspoon, C. Wolf, A Naseem, M. Maredia, and A. Hightower. "Is Agricultural Research Still A Public Good?" *Agribusiness* 16(Winter 2000): 68-81.

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