
The evolving rights to intellectual property protection in the agricultural biosciences

Brian D. Wright*

University of California, Berkeley, USA

E-mail: wright@are.berkeley.edu

*Corresponding author

Philip G. Pardey

University of Minnesota, St. Paul, USA

E-mail: ppardey@apcc.umn.edu

Abstract: Pressures from the USA and Europe have resulted in the proliferation of stronger intellectual property protection worldwide, as a condition for continued access to world markets. The failure of crops other than soybeans, cotton, maize and canola in developed countries to benefit from the major innovations in genetic modification raises questions regarding the implications of increased intellectual property protection for development and commercialisation of staple crops for developing countries. In this paper, we review important IP-related developments relevant to the evolution of crop biotechnologies, highlighting their origins and goals, and their implications for incentives, innovation, and the structure of the crop biotechnology markets.

Keywords: biotechnology; patents; plant breeders' rights; TRIPS; monopolisation; intellectual property.

Reference to this paper should be made as follows: Wright, B.D. and Pardey, P.G. (2006) 'The evolving rights to intellectual property protection in the agricultural biosciences', *Int. J. Technology and Globalisation*, Vol. 2, Nos. 1/2, pp.12–29.

Biographical notes: Brian Wright is a graduate of the University of New England, Armidale, Australia, and has a PhD in Economics from Harvard University. He then was Assistant and Associate Professor in the Yale University, Economics Department, and is currently Professor of Agricultural and Resource Economics at the University of California, Berkeley. His research interests include the economics of commodity speculation and market stabilisation, agricultural policy, and the economics of innovation and intellectual property rights, with applications in biotechnology. He recently served on a Natural Academies Committee on Intellectual Property in Genomic and Protein Research and Innovation. He is a member of the Giannini Foundation.

Philip Pardey is Professor in the Department of Applied Economics at the University of Minnesota where he also directs the International Science and Technology Practice and Policy (InSTePP) Center. Previously, he was a Senior Research Fellow at the International Food Policy Research Institute, Washington DC, and prior to 1994 at the International Service for National Agricultural Research in The Hague, Netherlands. He studies productivity growth and technical change, and a broad ranging set of science and technology policy issues.

1 Introduction

Over the past century, agricultural research has a global record of extraordinary achievement. Contrary to the predictions of sages from Parson Malthus to Paul Ehrlich and Garrett Hardin, food supply has outstripped population growth for many decades.¹ The result is that the world population has, on average, larger body size, greater work capacity (Fogel, 2004), and longer life span. Social rates of return on agricultural research have been far higher than for most other investments, worldwide, as indicated in thousands of estimates (Table 1).

Table 1 Rates of return by commodity orientation

| Commodity orientation | Number of observations (count) | Rate of return | | |
|------------------------|-----------------------------------|----------------|-------------|---------|
| | | Mean | Minimum (%) | Maximum |
| Multicommodity | 436 | 80.3 | -1.0 | 1,219.0 |
| All agriculture | 342 | 75.7 | -1.0 | 1,219.0 |
| Crops and livestock | 80 | 106.3 | 17.0 | 562.0 |
| Unspecified | 14 | 42.1 | 16.4 | 69.2 |
| Field crops | 916 | 74.3 | -100.0 | 1,720.0 |
| Maize | 170 | 134.5 | -100.0 | 1,720.0 |
| Wheat | 155 | 50.4 | -47.5 | 290.0 |
| Rice | 81 | 75.0 | 11.4 | 466.0 |
| Livestock | 233 | 120.7 | 2.5 | 5,645.0 |
| Tree crops | 108 | 87.6 | 1.4 | 1,736.0 |
| Resources ^a | 78 | 37.6 | 0.0 | 457.0 |
| Forestry | 60 | 42.1 | 0.0 | 457.0 |
| All studies | 1,772 | 81.2 | -100.0 | 5,645.0 |

^aIncludes fishery and forestry.

Source: Alston et al. (2000)

Historically, private producers have often specialised in the provision of clean pure seed for planting many self-propagating crops. But these producers have not devoted great resources to the development of new, higher-yielding varieties. After one season at most, the farmer's own harvest competes with the breeder's supply, and the price differential necessary to encourage significant investment in research and development is too quickly competed away. The large yield-increasing innovations in the major, non-hybrid food crops were achieved by public sector and non-profit institutions including universities, government-sponsored research agencies and experiment stations, and several international crop improvement centres. The technologies were typically made available at zero cost. Though rents were obtained by early adopters and input providers, most of the benefits accrued to consumers in the form of more food and fibre at lower cost.

In the past quarter-century, a revolution in intellectual property protection has radically altered the set of opportunities for financing and encouraging innovations in crop breeding and related areas, and transformed the structure of incentives and costs related to public and private innovation. This history consists predominantly of

developed-country experience, with the USA as the leader and dominant player. Now, like it or not, most other countries have been committed by multilateral and bilateral international agreements to adopt stronger intellectual property protection. Applications of agricultural biotechnology offer them great potential benefits, but also pose significant policy challenges. Thus an overview of the experience to date of the leaders in the revolutions in intellectual property and biotechnology is relevant for the prospects for less developed economies.

In this paper, we present a retrospective on important IP-related developments relevant to the evolution of crop biotechnologies, highlighting their origins and goals, and their implications for industrial organisation and innovation incentive. Our ultimate focus is on the consequences of these developments for agricultural biotechnologies for developing countries, yet a large part of our discussion deals directly with biotech developments in the USA. This is inevitable. To date virtually all the crop biotech applications commercialised in the developed world, and in the developing world outside of China, originated in the USA (with significant European participation). The USA has also been the clear leader in innovations in intellectual property protection that the rest of the world has, to varying extents, followed.²

In assessing these global IP developments, the oft-used North–South dichotomy does not apply. Several low-income countries figure prominently in adoption and diffusion of agricultural biotechnology. China, for one, is already heavily engaged in developing independent applications and advancing them to commercialisation (Huang et al., 2002; Lei, 2004). That said, the vast majority of the developing world is far from that point, although many developing countries are now in the process of implementing new intellectual property protection regimes (Koo et al., 2004). The experience of leaders in these revolutions in agricultural biotechnology, and in relevant intellectual property protection, should be instructive for developing countries as they form their strategies for research support and administration of property rights, and for ongoing international negotiations regarding the latter.

2 The spreading revolution in intellectual property protection in agriculture³

Until the last century, plants and animals were generally considered to be products of nature. Innovations in crop varieties included introduction of plants or animals collected elsewhere. These did not qualify as inventions but as discoveries. Plants had no protection as intellectual property in any nation until 1930.

2.1 Plant patents

The USA, via the Plant Patent Act of 1930, was the first country to offer intellectual property protection specifically directed at plants. Eligible plants were asexually propagated plants other than tubers. The Act gave the patentee the exclusive right, for the same limited term as utility patents, to asexually reproduce, sell or use the patented plant and its asexually reproduced progeny for the term of the patent. Plant patents could be enforced, as are utility patents, via lawsuits against infringers. This type of protection has been important in horticulture, and in particular for protecting berries, vines, fruit trees and ornamentals.

2.2 *Plant variety protection*

In 1970, protection was extended to sexually reproduced varieties in the USA via the Plant Variety Protection Act. Plant varieties that were new, distinct, uniform, and stable (that is, the progeny had the same characteristics as the parents) became eligible for plant variety protection certificates (PVPCs). The 1970 act allowed limited sales or exchanges of seed by farmers, but this feature was eliminated in a subsequent revision. However, farmers are still allowed to replant their own seed or other germplasm. The latter provision has meant that the breeder's market for seed sales is weakened by competition from farmers' own production after the first season of use (Perrin et al., 1983), if seed saving is economically feasible.

Similar protection of 'plant breeders' rights' (PBRs) in the form of plant variety protection had been introduced earlier in many European nations, following the guidelines of the international Union for the Protection of New Varieties of Plants (UPOV), established via the convention for the Protection of New Varieties of Plants, Paris, 1961. The convention, of which the USA is now a member, has been revised in 1972, 1978, and 1991. The term of protection is currently 20 years for most plants, extended to 25 years for trees and vines. This type of protection is now proliferating worldwide, as discussed below. In general, other countries offering PVPCs have not followed the USA in offering plant patents for asexually reproduced plants, but use PVPCs for this purpose.

Neither plant patents nor plant variety protection constrain use of varieties for breeding new varieties, with the exception that the UPOV guidelines extend protection to new varieties that are 'essentially derived' from an existing variety. Although not precisely defined, the term is understood to imply that a new cultivar distinguished only by genetic transformation of a protected variety, introducing one or more new genes, would be covered by plant variety protection.

Most observers would agree with Louwaars et al. (2005) that there is no strong empirical evidence that plant variety protection under UPOV has encouraged significant innovation in plant breeding of new agricultural crop varieties,⁴ although it may have had some effect on industry structure, and on the generation and registration of cultivars with economically insignificant, cosmetic variation that meets the criterion of distinctiveness necessary for grant of a PVPC.

Plant Variety Protection has been used extensively in the seed industry to control reproduction of commercial varieties (as opposed to breeding) in agriculture and horticulture, and to protect valuable newly-discovered mutations in horticulture. It has also been used to protect the parents of hybrids from unauthorised use by competitors (generally other breeders, rather than farmers, in this case) to produce commercial hybrid seeds.

Plant breeders' rights are particularly popular with breeders in Europe. In some cases, seed saving is not allowed, and royalties are collected on purchases of rootstock or seed. In other cases saving of seed or other germplasm is allowed, and farmers are assessed a royalty on output for this use of germplasm. (Both methods are used, for different types of flowers, in, for example, the Netherlands and Japan).⁵ In the case of widely dispersed cultivation of commodity crops where seed can be cheaply saved without too much deterioration, seed replanting is difficult to monitor, and it may be infeasible to sustain a private market on the basis of seed sales revenue (see Knudson and Ruttan (1988) for the case of hybrid wheat). In some marketing channels that are highly

centralised, royalties can be collected based on product sales of protected varieties. Royalties on protected cut flowers imported from Africa, Latin America and the Caribbean are collected at the centralised flower markets in the Netherlands.

In Australia, levies on output to support research and promotion are a well-established feature of commodity markets (Alston et al., 1999). Recently, federal legislation has enabled collection of End Point Royalties by bulk crop handlers including the Australian Wheat Board, based on marketed crop output of varieties with Plant Variety Protection, rather than on seed purchased or saved for planting. Seed saving is allowed, but seed transfer to other farmers is not. Compliance of up to 80% has been achieved (Fox, 2005). If high compliance can be sustained, the Australian experience might suggest that end point royalties could make plant breeders' rights a more significant and effective source of research incentives for low-value, broad-acre field crops with geographically dispersed, highly variable yield but centralised collection points.

2.3 *Utility patents*

The change in intellectual property protection most relevant for agricultural biotechnology began in the USA in 1980, when the Supreme Court confirmed in the landmark *Diamond v. Chakrabarty (1980)* decision that utility patents could be granted on eligible living organisms.⁶ Utility patents can protect novel, nonobvious and useful products or processes embodied in tangible forms, for a term renewable up to 20 years. The patent offers protection only within the country where it is granted, including protection (enforceable via lawsuits against infringers) against making, using, offering for sale or importing. The scope of protection is defined in the claims, as approved by the patent office, subject to interpretation by the courts.

In the same year, 1980, passage of the Bayh-Dole Act generalised the rights of researchers to patent inventions achieved under federal funding in non-defense areas. The Act made the patentability of plants more relevant for the public and non-profit researchers involved in plant biology and crop breeding. In 1982, enforcement of patent rights was effectively strengthened by making the Court of Appeals of the Federal Circuit responsible for appeals of patent decisions (Jaffe, 2000). These legal changes transformed the intellectual property protection environment of agricultural biotechnology in the USA. But they also constituted the opening moves in a sequence of legal changes in Europe, Japan, and other developed countries that followed, to varying degrees, the USA lead.

Pressures for strengthening US patent law and expanding its scope arose in the 1970s, and originated outside of agriculture. They arose from the concern of business interests with capturing rents on existing technology, as distinct from creation of new incentives for innovation. They reflected the pessimistic perception that the USA had lost its technological edge in the 1970s to other countries, such as Japan, and that these countries were insufficiently compensating the USA for past innovations (Dutfield, 2002).

In contrast to their role as intellectual leaders of the trade liberalisation movement since the Second World War, economists have not in general figured prominently in the initiative for stronger patent protection. They in general agree that without some public intervention the generation of new useful innovations may be suboptimal, especially if innovations can be copied or otherwise appropriated at sufficiently low cost. They also understand the argument, especially popular with lawyers, that the disclosure inherent

in a patent application is ‘consideration’ for the public in return for the grant of a temporary monopoly on the innovation as claimed in the patent. Some among them agree with a philosophical argument that the innovator has a ‘natural right’ to the innovation. But economists as a group have never given expansion of patent rights the kind of support that they have given to trade liberalisation initiatives since the time of Adam Smith.⁷

Although there is agreement that incentives are important for research and development, it is increasingly clear that the theoretical advantage of using patents (as distinct from public research, or grants or contracts to other non-profit or private-sector researchers, which had long been successfully used in agricultural research) was rather narrow and delicate, dependent on the existence of information on the value of innovations held by innovators but inaccessible to the public sector (Wright, 1983), and on the infeasibility of alternate means that might be used to elicit such information (Scotchmer, 2004a). In agriculture much of the value of innovations accrues as consumer benefits from lower-priced food and better nutrition. It is by no means obvious that evaluations of social benefits are generally less accurate in the public than in the private sector.

Even if market-based protection of the value of innovations is considered important, surveys have revealed that firms in most sectors of US business do not identify patents as the major means of protection of the commercialisation of innovations, with the prominent exceptions of chemicals and pharmaceuticals (Levin et al., 1987; Cohen et al., 2000). Furthermore, the recent prominence of the ‘open source’ phenomenon, especially in software development, has if anything made economists more keenly aware that a system of direct monetary rewards might not in practice be the universally superior means for inducing innovation. The strong position against patent protection (and copyrights) enunciated by Boldrin and Levine (2002) is definitely outside the mainstream at present, but the critique of Jaffe and Lerner (2004) of patent protection in the USA presents views similar to those of many and perhaps most economists.

What is beyond doubt is that there is no consensus among economist regarding the global merits of the kind of strengthening of patent protection implemented in the USA since 1980 comparable to the consensus on the global merits of freer trade. Nevertheless, other developed countries have followed, to varying degrees, the USA lead in strengthening intellectual property protection, and in encouraging patenting by publicly employed or funded researchers.

2.4 The global proliferation of intellectual property protection

In developed countries the degree of patent protection available to plants and animals *per se* and other life forms varies from country to country, and is usually less strong than in the USA. Indeed, the UPOV Convention initially prohibited ‘double protection’, and until recently plants and animals have not been patentable in most countries. Though patent protection is strictly national in scope, international treaties and conventions govern various aspects of patenting. The World Intellectual Property Organization (WIPO) has a lead role in coordination and information collection. It offers an important service in assisting developing countries with implementation of patent systems. Applications in multiple countries are facilitated by the Patent Cooperation Treaty, and by the European Patent Office, the Eurasian Patent Organization, African Regional Industrial Property Office and the Organization Africaine de la Propriété Intellectuelle.

Recently there has been rapid and unprecedented proliferation of commitments to stronger intellectual property protection among less-developed economies. This trend originated outside of the international treaties and conventions traditionally associated with intellectual property, in a multilateral agreement negotiated during the 1986–1994 Uruguay Round of the General Agreement on Tariffs and Trade (GATT, now the World Trade Organization), popularly known by its acronym, TRIPS (Trade-Related Aspects of Intellectual Property). TRIPS (2002) obliges members of the WTO to implement minimum standards of protection for all major types of intellectual property rights. It carries credible means of enforcement; countries can be penalised with trade sanctions if they do not comply.⁸

It was the value of trade access, not perceptions of domestic benefits of patent protection, that induced widespread accession to TRIPS by less-developed countries. They faced the threat of loss of trade access via bilateral sanctions if they did not support this multilateral agreement.⁹

According to Dutfield (2002), the TRIPS agreement was conceived by a few executives of leading US-based multinational corporations, and its development was closely monitored and influenced by the international pharmaceutical, chemical, semiconductor, trademark and copyright industries, highly interested in obtaining more foreign royalties for their innovations. The interests of developing countries, and of food producers or consumers, do not appear to have figured prominently in the motivation, originating in the USA, for adopting TRIPS.

If economists are divided on the merits of strong patent protection globally or in wealthy countries as a group, they are even less supportive of the benefits for less developed countries of adoption of similarly strong protection. Like the USA, Switzerland, and the Netherlands, among others, in the 19th century (Lerner, 2002), less-developed countries stand to gain from freely copying technology of foreign leaders in innovation, if they are allowed to do so. Countries without strong imitative capacity might, consistent with Smith (2002), find that imports are larger in quantity and prices are lower for technologies without strong patent protection.

Some economists have seen advantages in stronger intellectual property protection as a stimulus to research and development investment, or private foreign direct investment more generally (for example Kanwar and Evenson (2003) and Lesser (2005), respectively). If these effects are important, they should be apparent in the pharmaceutical industry, where patents are recognised as unusually important. Recently, Lanjouw (2005) has studied how patent regimes affect market entry of new pharmaceuticals, and finds that for less-developed countries, strong process patents, and weak (short-life) product patents encourage early entry, but lengthening the life of product patents has not further encouraged entry. One reason for the latter finding might be that firms like to enter wealthy markets first, at high prices. Entering simultaneously in poorer markets at appropriately lower prices can incur political fallout in the wealthy market due to international price comparisons. Delay may appear more acceptable if the patent expiration date is far off. More generally, we know of no evidence of any stimulus to independent domestic innovation sufficient to offset the costs of local patenting by foreigners, who typically hold the overwhelming majority of patents in developing countries with a modern patent system.¹⁰

Regardless of its merits as policy for the developing world generally, the TRIPS agreement, as adopted, mandates that all member countries implement a patent system based on commonly accepted tenets of patentability. Leskien and Flitner (1997) provide a

detailed examination of the language of TRIPS and how it relates to plant genetic resources. Member countries are allowed to exempt from patentability several categories of inventions, including plants and animals. Microorganisms must be patentable, if otherwise satisfying patenting criteria, but ‘essentially’ biological processes may be excluded. However, the term “essentially biological processes” is not defined. Article 27.3(b) of TRIPS states that all plants may be excluded from patentability, provided the member country adopts alternative intellectual property legislation such as plant breeders’ rights or any other ‘effective *sui generis*’ system to cover plant varieties. The term *sui generis* is undefined, but generally thought to include protection of varieties via plant breeders’ rights consistent with UPOV.

The exemption for plants under TRIPS is viewed by some commentators as an important concession to developing countries, but it actually is of limited significance for innovation in plant biotechnology. In subsequent bilateral ‘TRIPS+’ negotiations with the European Union, the European Free Trade Association or the USA, and in regional free trade agreements, many developing countries have given up the alternatives available under Article 27.3(b). The process is ongoing, apparently progressing from economically small nations to others that are larger and more powerful.¹¹ Furthermore, plants containing new genetic material or produced by a novel process might be indirectly protected via a patent on that material or process, as noted by the UK Commission on Intellectual Property Rights (2002, Chapter 3).

In discussing proliferation, the distinction between formal commitments and implementation is crucial. Developing countries in general have yet to implement the protections of plants to which they have recently committed. Louwaars et al. (2005, pp.2, 3) present a detailed and informative account of the current status of implementation of strengthened intellectual property rights including utility patents, plant breeders’ rights and trademarks, in five countries, China, Colombia, India, Kenya and Uganda. They observe that

“[E]stablishing a PVP law and putting it into practice are two separate challenges. ... [S]anctions for violations are often not well defined and ... courts are not well prepared to enforce the rights. ... There is very little experience in the case study countries with the implementation of patents for plant breeding or biotechnology, with the exception of China. There is little or no case law in the case study countries relevant to the enforcement of such patents.”

Implementation is clearly a daunting task in many countries.

In some cases, however, effective enforcement of foreign patent claims on transgenic crops is being established. For example, an agreement was recently reached between Brazil and Monsanto whereby a payment of 88 cents per kilogram will be collected for herbicide tolerant seeds embodying Monsanto’s patented herbicide tolerance technology. Earlier, soybean producers in southern Brazil agreed to a 2% royalty for soybeans collected in the local market, for herbicide-tolerant soybeans incorporating Monsanto’s technology. (St. Louis Business Journal, September 30, 2005.) Attempts to collect a similar royalty on beans produced in Argentina, where the technology is unpatented, but widely adopted (Qaim and de Janvry, 2002) have met with significant resistance. The fact that foreign competitors do not have to pay what US farmers pay for the Monsanto technology has prompted US farmers to press for enforcement of royalties overseas (US General Accounting Office, 2000).

3 The evolution and diffusion of agricultural biotechnology

In the 1970s, breakthroughs in the UK and the USA, including the Nobel Prize-winning work of Cohen and Boyer on recombinant DNA, heralded the birth of a worldwide revolution in biotechnology. Their key innovation was patented in 1980, but licensed widely at low cost. In the 1980s and early 1990s, the environment was uniquely favourable for innovations in agricultural biotechnology. Funding for the basic science on which it relies was, as it continues to be, dominated by generous US federal government allocations to the National Institutes of Health. Opportunities for innovation abounded. Most of them, unencumbered by prior intellectual property claims, were freely and globally available for exploitation, with successful outcomes patentable under the new intellectual property regime.

Multinational pharmaceutical firms transformed themselves into 'life science' conglomerates, divested of commodity chemical divisions, in anticipation of synergies between newly integrated agricultural biotechnology activities and their pharmaceutical divisions. The life science firms formulated strategies involving sales of crop protection traits to seed producers via arms-length IPR transactions. Seed producers were to become retailers of crop protection beyond natural genetic resistance. A few large seed producers also began their own biotech initiatives.

Agricultural biotechnology startups proliferated in the 1980s and 1990s in the USA, financed by venture capitalists, often built around patented innovations produced by university scientists in their laboratories, and licensed exclusively to the startup. Non-profit institutions, and their researchers, came to view the returns on their agricultural biotech research in a new light.

The joint result of the new legal and scientific opportunities was a proliferation of new applications of biotechnology in agriculture and related industries. By 1996, technologies had been developed that offered insect resistance in corn, cotton, and potatoes, and herbicide tolerance in soybean, corn and canola. A long shelf-life tomato had also been developed and marketed, and the Chinese had developed a transgenic tobacco.

Technical and quality problems killed the US market for transgenic potatoes and tomatoes.¹² Public skepticism about genetically modified foods, especially in Europe, discouraged further development of transgenic tomatoes and tobacco, and hindered the spread of transgenics to Europe and other countries.

On the other hand, transgenic corn and soybean were adopted widely, especially in North and South America, and transgenic cotton has spread to China, Australia, India and Argentina, among other countries. The rapid diffusion of these innovations, applied on over 200 million acres in 2004 across countries at very different stages of development (James, 2004), is a tribute to their effectiveness as perceived by farmers in many different environments, and to the performance of the private-sector innovators and input providers who have brought these technologies to farmers' fields, aided by intellectual property protection.

4 The structural implications of proliferating intellectual property claims

Patents create the clearest incentives for research when there are no prior IPR claims on the inputs or methods used, or on the results of their use. Such 'freedom to operate' was

broadly available in the 1980s. In effect, the value that the patentee captures could include any contributions of previous, unprotected research. As intellectual property protection of agricultural biotechnology has evolved, it has become evident that existing patents and other means of IPR protection are changing the structure as well as the performance of the institutions involved in agricultural biotechnology research

Breeding is a cumulative science, and seeds accumulate innovations. The number and diversity of innovations utilised in modern cultivar development, and incorporated in the germplasm, can be large. The spread of intellectual property protection on such innovations has meant that germplasm is often covered by a large number of intellectual property claims on these innovations, including key process technologies required to bring about the genetic transformations embodied in the seed. The transgenic vitamin A rice technology, currently under development as Golden Rice[®], is a well-publicised example (Kryder et al., 2000).¹³

As patents on key technologies or materials including genes, markers, promoters, and means of transformation proliferate, the restrictive force of monopolies conferred by these patents becomes increasingly evident. In addition to the aggregate value of the rent transfers to prior patent holders, the costs of actually consummating licensing deals can be very significant. These include the costs of discovering the existence, nature and ownership of prior patents and patent applications. (Indeed it might not be possible to ascertain the nature of patent applications at any cost, until they are published, at least eighteen months after application.) They also include the costs of negotiating rights to use or acquire the relevant intellectual property in a dynamic market where the number of negotiating parties is small, and values are not clearly established and constantly changing.

Financing and managing the quest for freedom to operate in the necessary inputs and processes (for example, genes, promoters, markers, and transformation technology) has been a real challenge, especially for smaller firms. For example, many millions of dollars and much managerial effort has been spent on legal disputes over proprietary technology related to control of insect pests using transgenic plants expressing *Bt* genes. At one point, as Barton (1998) showed, there were at least 26 separate active legal cases involving transgenic *Bt* technology in the USA. Multiple conflicts over *Bt* continue. Jones (2005) reports on six US cases related to *Bt* that were decided in 2004 or still active in early 2005. In September 2005 the US Patent Number 6,943,282 was granted, covering transgenic *Bt* in plants. This seemingly broad patent was filed in 1988, but delayed by an 'interference' at the US Patent and Trademark Office. (That is, there was a conflict between two different patent applications regarding the rights to the innovation.) It now can be in effect until 2021. Similarly, conflicting claims to one of the two main means of plant transformation were in dispute and unresolved in the European Union and the USA until 2004. It is no coincidence that many of the corporations involved in plant biotechnology chose attorneys, not plant breeders, biologists or marketers, as their CEO's.

In the 1990s, life science conglomerates realised that access to elite germplasm could be at least as important as access to the relevant biotechnology in commercialising the new herbicide-tolerant or insect-resistant varieties. Moreover, the significance of the transaction costs associated with licensing among producers of biotechnology inputs, and between such producers and seed breeders, was becoming more and more apparent. Strategies involving repeated arms-length licensing of transgenic technologies, protected by IPR, to seed breeders were seen as increasingly problematic.

By 1995, before seed producers had significant transgenic sales, the most far-sighted producers of crop protection chemicals had turned to a strategy of integrating forward into the retail seed market. A wave of high-priced acquisitions of independent seed producers began. Now the same companies that produced crop protection chemicals that were complements or substitutes for the transgenic herbicide tolerance and insecticidal traits also transformed the germplasm, produced the seed and sold seed to the farmer. This concentration happened very quickly. Its speed is indicated by de Janvry et al. (2000) who report that in 1994 individuals and independent biotechnology firms held 77% of US patents related to *Bt*, whereas just five years later, in 1999, six integrated firms held 67% of *Bt* patents, of which 77% were obtained by acquisition of smaller biotech and seed firms. By 2002, according to King and Schimmelpfennig (2005, p.84), six firms controlled over 40% of all private-sector agricultural biotechnology patents, as classified in USDA data, issued through 2000. Each of these firms had acquired most of those patents via mergers and acquisitions of seed companies and biotechnology firms, many of them small start-ups formed in the hope of eventual acquisition. Adjusting for subsequent mergers, four firms held almost half of these patents issued by 1999 (Brennan et al. 2005).

By 1999, life science companies were becoming disenchanted with agriculture, because of low commodity prices, lack of anticipated technical synergies with human health biotech, and adverse consumer reaction to genetically modified foods, especially in Europe. In successive waves of conglomerate mergers, life science firms divested their agricultural divisions from their commodity chemical and pharmaceutical interests, but concentration in inputs related to agricultural biotechnology continued to increase. Formation of startups in plant biotechnology, other than those focused on specialised genomics or production of pharmaceutical products using plants, dwindled.

Thus a sequence of acquisitions, divestitures and mergers¹⁴ has integrated the chemical and biotechnological inputs related to crop protection and genetics, resulting in a highly concentrated crop seed biotechnology industry focused, at least until now, on soybean, maize, cotton and canola research conducted mainly in developed countries. This phenomenon was largely driven by attempts to get around contracting problems associated with assembling the IPR necessary for creating and commercialising new biotechnologies, and to capture the maximum value inherent in novel output traits (Graff et al., 2003).¹⁵ Conglomerates also sought to defend the market price of crop protection services formerly offered only in chemical form and now threatened by alternative sources of protection embodied in the DNA of the seed, and generally to protect and if possible increase the market value of crop protection and other services in the face of rapid technological change.

Concentration in the global agricultural biotechnology industry is inevitable, given the high fixed cost and low variable costs associated with the technology. The top firms spend impressive sums on research and development, led by Monsanto which regularly has spent more than one half a billion dollars per year; several more spend around half this sum on agricultural biotechnology research and development. Given these commitments, it is clear that the industry must have the market power necessary to charge well above short run marginal cost if it is to survive.

Some observers have been concerned about the possibility of monopolisation of these markets for some time (Wright, 1998). However, very high concentration of access to key enabling technologies and of field trials of certain crops (an indication of innovation market share), has occurred with little public intervention, even in jurisdictions such as

the USA where antitrust enforcement has historically been strong.¹⁶ Interventions that have occurred there have focused on the evolution of domestic market structure, and have had at most a modest effect.¹⁷ In these cases, domestic regulatory actions aim to strike a balance between innovation incentives for leading firms and the maintenance of some competition to ensure more efficient use of new technologies for the crops at which they are targeted.

Though concern that monopolisation has proceeded too far is, belatedly, spreading (see for example Brennan et al. (2005), which presents Herfindahl-Hirschmann Indices and concentration ratios as measures of market power), in economic terms the transgenic technologies have generated large economic value, the majority of which appears to go to farmers or consumers. Monopolisation has only a second-order efficiency effect within the markets for the major transgenic crops on which the private sector is focused, including maize, soybean, cotton and canola. The leading agricultural biotechnology firms at present see insufficient prospective returns in most other agricultural or horticultural crops, whether in developed countries where such crops have been called 'orphans' (analogous to 'orphan drugs', pharmaceuticals with relatively small prospective markets) or in developing countries.¹⁸

If biotechnology innovations are to be implemented for these other crops the public and non-profit sectors will have to continue to shoulder the bulk of the burden. Here the first of two key issues is whether the public and non-profit breeders of crops neglected by the private sector can get any access at all (monopolised or not), for innovation and commercialisation purposes, to the key technologies and information held by the leading firms in agricultural biotechnology. The second is whether biosafety regulations will impose insurmountable barriers to commercialisation of successful innovations that might be achieved for orphan crops in developed economies, and for the crucial food staples and most other crops in developing economies. The issues appear to be fundamentally similar in both cases, so the experience with orphan crops in developed countries, considered in our companion paper (Wright and Pardey, 2005), is relevant to the prospects facing less-developed countries in the newly global intellectual property environment.

5 Conclusion

The revolution in intellectual property rights is changing the structure of incentives and opportunities for innovation in agricultural biotechnology worldwide. Although strong protection has been established in a number of developed countries, the successfully commercialised innovations generated in such countries are dominated by a small set of herbicide tolerant and insect resistant technologies generated in North America, focused on the handful of important crops with high appropriable value, including maize, cotton, soybeans and canola.

Though increased concentration of market power and a decline in new entrants are legitimate concerns, these new markets are being successfully served by multinational firms in a number of countries. Rapid diffusion and adaptation has also occurred in developing countries prior to the adoption of more effective intellectual property protection, indicating that new, stronger IPRs are not essential for effective operation of private seed markets in importing, adopting and adapting existing genetically modified

traits. However effective IPRs are in some cases essential for effective rent transfer to foreign technology providers.

For the larger set of crops of lower appropriable value (or crops grown in markets that are more costly to service), the picture is quite different. ‘Orphan’ crops have not attracted sustained private-sector attention, even where strong intellectual property protection is well established. Private incentives generated by intellectual property protection have not been sufficient to generate successful commercialisation of genetic modification for these crops, even in countries such as the USA where consumer opposition to transgenics has been relatively muted.

Publicly funded R&D is likely to continue to be the main source of biotechnology innovations for most non-hybrid crops other than soybean, cotton and canola, in developed economies, even if they have strong intellectual property protection regimes. Upstream enabling innovation will continue to be geographically concentrated, and largely publicly funded, benefiting from externalities of huge allocations to biotechnology for human health in the USA.

Experience thus far in lead countries indicates that the new intellectual property protection environment poses many challenges, and raises new, yet unresolved, funding, IP access and freedom to operate issues for applications of biotechnology beyond the handful of crops of interest to the major private-sector innovators. The implications for applications of biotechnology in developing countries under the new intellectual property regimes are the subject of our companion paper (Wright and Pardey, 2005).

Acknowledgement

The authors thank the University of California, Berkeley, the Giannini Foundation, the University of Minnesota, and the International Food Policy Research Institute for financial support, and Carol Nottenburg, Bonwoo Koo, Greg Graff, Sara Boettiger, Richard Jefferson, the late Jenny Lanjouw, and Ruth Uwaifo for helping shape our ideas on this topic.

References

- Alston, J.M. and Venner, R.J. (2002) ‘The effects of the US plant variety protection act on wheat genetic improvement’, *Research Policy*, Vol. 31, pp.527–542.
- Alston, J.M., Harris, M.S., Mullen, J.D. and Pardey, P.G. (1999) ‘Agricultural R&D policy in Australia’, in Alston, J.M., Pardey, P.G. and Smith, V.H. (Eds.): *Paying for Agricultural Productivity*, Chapter 5, Johns Hopkins University Press, Baltimore.
- Alston, J.M., Marra, M.C., Pardey, P.G. and Wyatt, T.J. (2000) *A Meta Analysis of Rates of Return to Agricultural R&D: Ex Pede Herculeum?*, IFPRI Research Report No 113, Washington DC.
- Barton, J.H. (1998) ‘The impact of contemporary patent law on plant biotechnology research’, in Eberhard, S.A., Shands, H.L., Collins, W. and Lower, R.L. (Eds.): *Intellectual Property Rights III Global Genetic Resources: Access and Property Rights*, CSAA Miscellaneous Publication, Crop Science Society of America and American Society of Agronomy, Madison, pp.85–97.
- Binenbaum, E., Nottenburg, C., Pardey, P.G., Wright, B.D. and Zambrano, P. (2003) ‘South–North trade, intellectual property jurisdictions, and freedom to operate in agricultural research on staple crops’, *Economic Development and Cultural Change*, Vol. 51, No. 2, January, pp.309–335.

- Boettiger, S., Graff, G., Pardey, P.G., van Dusen, E. and Wright, B.D. (2004) 'Intellectual property rights for plant biotechnology: international aspects', in Christou, P. and Klee, H. (Eds.): *Handbook of Plant Biotechnology*, Chapter 56, John Wiley and Sons, Chichester, pp.1090–1113.
- Boldrin, M. and Levine, D. (2002) 'The case against intellectual property', *American Economic Review*, Vol. 92, No. 2, May, pp.209–212.
- Brennan, M., Pray, C., Naseem, A. and Oehmke, J.F. (2005) 'An innovation market approach to analyzing impacts of mergers and acquisitions in the plant biotechnology industry', *AgBioForum*, Vol. 8, Nos. 2–3, pp.89–99.
- Butler, L.J. (1996) 'Plant breeders' rights in the US: update of a 1983 study', in van Wijk, J. and Jaffe, W. (Eds): *Proceedings of a Seminar on the Impact of Plant Breeders' Rights in Developing Countries Held at Santa Fe Bogota, Colombia, 7–8th March*, University of Amsterdam, Amsterdam, pp.17–33.
- Butler, L.J. and Marion, B.W. (1985) *The Impacts of Patent Protection on the US Seed Industry and Public Plant Breeding*, University of Wisconsin, North Central Regional Research Bulletin No. 304, Madison, WI.
- Canadian Food Inspection Agency (CFIA) (2002) *10-Year Review of Canada's Plant Breeders' Rights Act*, Canadian Food Inspection Agency, available at <http://www.inspection.gc.ca/english/plaveg/pbrpov/10yenglish.pdf>.
- Commission on Intellectual Property Rights (CIPR) (2002) *Integrating Intellectual Property Rights and Development Policy*, Dsprint/redesign, Enfield.
- Cohen, W.M., Nelson, R.R. and Walsh, J.P. (2000) *Protecting Their Intellectual Assets: Appropriability Conditions and Why US Manufacturing Firms Patent (or not)*, NBER Working Paper no. 7552, National Bureau of Economic Research.
- de Janvry, A., Graff, G., Sadoulet, E. and Zilberman, D. (2000) *Technological Change in Agriculture and Poverty Reduction*, University of California, Berkeley, Concept paper for WDR on Poverty and Development 2000/2001, pp.6–7, Accessed from <http://www.worldbank.org/poverty/wdrpoverty/background/dejanvry.pdf>.
- Diez, M.C.F. (2002) 'The impact of plant varieties rights on research: the case of Spain', *Food Policy*, Vol. 27, pp.171–183.
- Dutfield, G. (2002) 'Trade, intellectual property and biogenetic resources: a guide to the international regulatory framework', *Background Paper for the Multi-stakeholder Dialogue on Trade, Intellectual Property and Biological and Genetic Resources in Asia*, International Centre for Trade and Sustainable Development (ICTSD), Geneva, April.
- Ehrlich, P.R. (1968) *The Population Bomb*, Ballantine Books, New York.
- Fogel, R.W. (2004) 'Health, nutrition and economic growth', *Economic Development and Cultural Change*, Vol. 52, No. 3, pp.643–658.
- Fox, P. (2005) *Personal Communication*, Grain Biotech Australia, Western Australia.
- Frey, K.J. (1996) *National Plant Breeding Study I: Human and Financial Resource Devoted to Plant Breeding Research and Development in the United States in 1994*, Special Report 98, Iowa Agriculture and Home Economics Experiment Station, Iowa State University, Ames, Iowa.
- Graff, G.D., Rausser, G.C. and Small, A.A. (2003) 'Agricultural biotechnology's complementary intellectual assets', *Review of Economics and Statistics*, Vol. 85, No. 2, pp.349–363.
- Hardin, G.J. (1977) *The Limits of Altruism: An Ecologist's View of Survival*, Indiana University Press, Bloomington.
- Huang, J., Rozelle, S., Pray, C. and Wang, Q. (2002) 'Plant biotechnology in China', *Science*, Vol. 295, 25th January, pp.674–677.
- Jaffe, A.B. (2000) 'The US patent system in transition: policy innovation and the innovation process', *Research Policy*, Vol. 29, pp.531–557.

- Jaffe, A.B. and Lerner, J. (2004) *Innovation and Its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What To Do About It*, Princeton University Press, Princeton, NJ.
- Jaffe, W. and van Wijk, J. (1995) *The Impact of Plant Breeders' Rights in Developing Countries*, Inter-Am Institute for Co-operation on Agriculture, University of Amsterdam, Amsterdam.
- James, C. (2004) *Global Status of Commercialized Biotech/GM Crops: 2004*. Brief No. 32-2004, International Service for the Acquisition of Agri- Biotech Applications, Ithaca.
- Jones (2005) *Patent Challenges to Ag Biotech Technologies in 2004*, ISB News Report, February.
- Kalton, R.R., Richardson, P.A. and Frey, N.M. (1989) 'Inputs in private sector plant breeding and biotechnology research programs in the United States', *Diversity*, Vol. 5, No. 4, pp.22–25.
- Kanwar, S. and Evenson, R. (2003) 'Does intellectual property protection spur technological change?', *Oxford Economic Papers*, Vol. 55, pp.235–264.
- Kasler, D. and Lau, E. (2000) 'At Calgene, a harvest of uncertainty, promise and peril: the future of biotechnology', *The Sacramento Bee*, May 7, 2000. Accessed 13th November, <http://www.sacbee.com/news/projects/biotechnology/>.
- King, J.L. and Schimmelpfennig, D. (2005) 'Mergers, acquisitions, and stocks of agricultural biotechnology intellectual property', *AgBioForum*, Vol. 8, Nos. 2–3, pp.83–88.
- Knudson, M.K. and Pray, C.E. (1991) 'Plant variety protection, private funding, and public sector research priorities', *American Journal of Agricultural Economics*, Vol. 73, No. 3, pp.882–886.
- Knudson, M.K. and Ruttan, V.W. (1988) 'Research and development of a biological innovation: commercial hybrid wheat', *Food Research Institute Studies*, Vol. 21, No. 1, pp.45–68.
- Koo, B., Nottenburg, C. and Pardey, P.G. (2004) 'Plants and intellectual property: an international appraisal', *Science*, Vol. 306, November, pp.1295–1297.
- Koo, B., Pardey, P.G., Qian, K. and Zhang, Y. (2006) 'An option perspective on generating and maintaining plant variety rights in China', *Agricultural Economics*, forthcoming.
- Kryder, D.R., Kowalski, S.P. and Krattiger A.F. (2000) *The Intellectual and Technical Property Components of Pro-vitamin A Rice (Golden Rice): A Preliminary Freedom-to-Operate Review*, International Service for the Acquisition of Agri-biotech Applications (ISAAA) Brief No. 20, ISAAA, Ithaca, NY.
- Kubo, K. (2005) *Personal Communication*, Department of Agricultural and Resource Economics, University of California, Berkeley, and Institute of Developing Economies, Japan External Trade Organization.
- Lanjouw, J. (2005) 'Patents, Price Controls and New Drugs: How Policy Affects Global Market Entry', University of California, Berkeley, 19th April, Mimeo.
- Lei, X. (2004) 'China could be first nation to approve sale of GM rice', *Science*, Vol. 306, No. 5701, 26th November, pp.1458–1459.
- Lerner, J. (2002) '150 years of patent protection', *American Economic Review Papers and Proceedings*, Vol. 92, May, pp.221–225.
- Leskien, D. and Flitner, M. (1997) 'Intellectual property rights and plant genetic resources: options for a *sui generis* system', *Issues in Genetic Resources No. 6*, International Plant Genetic Resources Institute, Rome, June.
- Lesser, W. (2005) 'Intellectual property rights in a changing political environment: perspectives on the types and administration of protection', *AgBioForum*, Vol. 8, Nos. 2–3, pp.64–72.
- Levin, R.C., Klevorick, A.K., Nelson, R.R., Winter, S.G., Glibert, R. and Griliches, Z. (1987) 'Appropriating the returns from industrial research and development', *Bookings Papers on Economic Activity*, Vol. 3, pp.783–831.
- Louwaars, N.P., Tripp, R., Eaton, D., Henson-Apollonio, V., Hu, R., Mendoza, M., Muhhuku, F., Pal, S. and Wekundah, J. (2005) *Impacts of Strengthened Intellectual Property Rights Regimes on the Plant Breeding Industry in Developing Countries: A Synthesis of Five Case Studies*, A study commissioned by the World Bank, executed in 2004.

- Machlup, F. (1958) *An Economic Review of the Patent System*, Study No. 15 of the Sub-committee on Patents, Trademarks, and Copyrights of the Committee on the Judiciary, US Senate, 85th Congress, 2nd Session, Washington, DC.
- Marra, M.C., Pardey, P.G. and Alston, J.M. (2002) *The Payoffs to Agricultural Biotechnology: An Assessment of the Evidence*, EPTD Discussion Paper No. 87, International Food Policy Research Institute, Washington, DC, January.
- Moschini, G.C. (2004) 'Intellectual property rights and the world trade organization: retrospect and prospects', in Anania, G., Bohman, M., Carter, C. and McCalla, A. (Eds.): *Agricultural Policy Reform and the WTO: Where Are We Heading?*, Book chapter, Edward Elgar Publishing, Cheltenham, UK, pp.474–511.
- Perrin, R.K., Kunnings, K.A. and Ihnen, L.A. (1983) *Some Effects of the US Plant Variety Protection Act of 1970*, Economics Research Report No. 46, Department of Economics and Business, North Carolina State University, Raleigh, N.C., August.
- Perrin, R.K. (1994) 'Intellectual property rights in agricultural development', Anderson, J.R. (Ed.): Chapter 27 of *Agricultural Technologies Policy Issues for the International Community*, CAB International, Wallingford, UK.
- Plant, A. (1934) 'The economic theory concerning patents and inventions', *Economica*, Vol. 1, pp.30–51.
- Pray, C., Oehmke, J.F. and Naseem, A. (2005) 'Innovation and dynamic efficiency in plant biotechnology: an introduction to the researchable issues', *AgBioForum*, Vol. 8, Nos. 2–3, pp.52–63.
- Qaim, M. and de Janvry, A. (2002) 'Genetically modified crops, pricing strategies, and farmers' adoption. The case of Bt Cotton in Argentina. *American Journal of Agricultural Economics*, Vol. 85, No. 4, pp.814–828.
- Qaim, M. and Traxler, G. (2005) 'Roundup ready soybeans in Argentina: farm level, environmental, and welfare effect', *Agricultural Economics*, Vol. 32, pp.73–86.
- Ryan, M.P. (1998) *Knowledge Diplomacy: Global Competition and the Politics of Intellectual Property*, Brookings Institution, Press, Washington DC.
- Scotchmer, S. (2004a) *Innovation and Incentives*, MIT Press, Cambridge, MA.
- Scotchmer, S. (2004b) 'The political economy of intellectual property treaties', *Journal of Law, Economics and Organizations*, Vol. 20, pp.415–437.
- Smith, P. (2002) 'Patent rights and trade: analysis of biological products, medicinals and botanicals, and pharmaceuticals', *American Journal of Agricultural Economics*, Vol. 84, No. 2, pp.495–512.
- TRIPS (2002) *Agreement on Trade-Related Aspects of Intellectual Property Rights, Part II. Standards Concerning the Availability, Scope and Use of Intellectual Property Rights*. World Trade Organisation, http://www.org/english/tratop_e/trips_e/t-agm3_c.htm.
- US General Accounting Office (2000) *Biotechnology: Information on Prices of Genetically Modified Seeds in the United State and Argentina*, Report to the Chairman, Subcommittee on Risk Management, Research and Specialty Crops, Committee on Agriculture, House of Representatives, January, GAO/RCED/NSIAD-00-55.
- Wright, B.D. (1983) 'The economics of invention incentives: patents, prizes, and research contracts', *American Economic Review*, Vol. 73, No. 4, pp.691–707.
- Wright, B.D. (1998) 'Public Germplasm development at a crossroads: biotechnology and intellectual property', *California Agriculture*, Vol. 52, No. 6, pp.8–13.
- Wright, B.D. and Pardey, P.G. (2006) 'Changing intellectual property regimes: implications for developing country agriculture', *Int. J. Technology and Globalisation*, Vol. 2, Nos. 1/2, pp.93–114.
- Wright, B.D., Pardey, P.G., Nottenburg, C. and Koo, B. (2006) 'Agricultural innovation: economic incentives and institutions', Chapter in Evenson, R.E., Pingali, P. and Schultz, T.P. (Eds.): *Handbook of Agricultural Economics*, Vol. 3, Elsevier, Amsterdam, forthcoming.

Notes

¹Notwithstanding that the Green Revolution, offering rapid and historically unprecedented increases in the yield of staple food crops in developing countries, was well underway, in his 1968 book, *The Population Bomb*, the eminent ecologist, Paul Ehrlich predicted that in the 1970s,

“the world will undergo famines—hundreds of millions of people are going to starve to death in spite of any crash programs embarked upon now. At this late date nothing can prevent a substantial increase in the world death rate”
(Ehrlich, 1968, p.xi)

The biologist Garrett Hardin (1977), famous for coining the term “The Tragedy of the Commons” to describe the very real problems that can arise when there is open access to exploitation of a natural resource, published *The Limits of Altruism* in 1977 in support of a ‘tough-minded’ approach that recognised that countries like India had exceeded their ‘carrying’ capacity.

²Worldwide, the minimum standards for the rights on offer are shaped by the Trade Related Aspects of Intellectual Property (TRIPS) agreement that came into effect in 1995 as part of the Uruguay Round of multilateral trade negotiations under the auspices of the World Trade Organization. In a growing list of developing countries, stronger rights have been put in place as a consequence of bilateral trade negotiations, as noted below.

³For a more detailed discussion of issues touched on here, see Boettiger *et al.* (2004) and Wright *et al.* (2006).

⁴Studies of effects in the USA include Perrin *et al.* (1983), Butler and Marion (1985), Kalton *et al.* (1989), Knudson and Pray (1991), Butler (1996), Frey (1996) and Alston and Venner (2002). Other papers consider the effects of plant variety protection in Argentina (Jaffe and van Wijk, 1995; Qaim and Traxler, 2005) Canada (Canadian Food Inspection Agency, 2002), Spain (Diez, 2002), the UK (Perrin, 1994) and China (Koo *et al.*, 2006).

⁵See Louwaars *et al.* (2005, p.34) and Kubo (2005)

⁶Patentability of plants and animals, among other life forms, was subsequently confirmed by Patent Office Board of Appeals decisions (*ex parte* Hibberd (1985) and *ex parte* Allen (1987)), and affirmed by the Supreme Court in *Pioneer Hi-Bred International v. J.E.M. Ag Supply Inc.*, 2001.

⁷See Plant (1934) and Machlup (1958) for classic reviews of the case for patents from a British and an US perspective, respectively.

⁸For more on TRIPS and its implications for agriculture, see Moschini (2004).

⁹Ryan (1998) discusses, from a US viewpoint, how bilateral trade sanctions by the USA under Section 301 of the Trade Act (which defined failure to protect IPR as an unfair trade practice), made credible by their actual imposition on Brazil, helped bring the developing countries to the negotiating table.

¹⁰Scotchmer (2004b) correctly identifies the benefits for less developed countries of national treatment (non-discriminatory treatment of foreign patent applicants, as mandated by the Paris Convention) and worldwide protection, relative to a system with neither. But she does not consider the alternative that combines national treatment with weaker protection in developing than developed countries.

¹¹Nations that reportedly have committed to patenting of plants and animals, not mandated under TRIPS, include Jordan, Morocco, Laos, Mongolia, Singapore, Sri Lanka, Chile and Nicaragua. Others have committed to intellectual property protection beyond the TRIPS requirements. See <http://www.grain.org/rights/tripsplus.cfm?id=68>.

¹²As Marra *et al.* (2002) describe,

“The Flavr-Savr[®] tomato, genetically engineered to delay softening so the tomato could ripen on the vine and retain its ‘fresh picked’ flavor, was introduced commercially in the USA in 1994. It was a scientific success, but a colossal business failure. Although the tomatoes achieved the delayed-softening and taste-retention objectives of their developers, yields were poor, mechanical handling equipment turned most of them into mush before they got to market, and consumers weren’t willing to pay enough of a premium over conventional fresh tomatoes to cover costs. The seeds of the biotechnology protests started with the Flavr-Savr[®], too, when Jeremy Rifkin managed to persuade the Campbell’s Soup Company not to use biotech tomatoes in its products.” (Kasler and Lau, 2000)

¹³For a critical analysis of this example, see Binenbaum *et al.* (2002).

¹⁴For a summary of selected mergers and acquisitions in the US and European agricultural chemicals, biotechnology, seeds and food/feed industries, see Pray *et al.* (2005, Table 2, p.60).

¹⁵In contrast to some other high-technology industries such as microelectronics, patent pools have not been a major part of the response of the private sector in agricultural biotechnology, though certain key technologies have been shared among a few firms.

¹⁶Between 2000 and 2004, 52% of all US Department of Agriculture regulated crop field trials, public and private, have been carried out by Monsanto. (See Information Systems for Biotechnology website: <http://www.nbiap.vt.edu/cfdocs/fieldtests1.cfm>).

¹⁷Interventions include Monsanto’s commitment to the US Department of Justice to divest its agrobacterium transformation technology for corn, as a condition for the acquisition of DeKalb. The technology was placed under the control of the University of California. It is our understanding that this technology has never been licensed to an innovator. Other antitrust interventions prevented a Monsanto merger with the cotton seed firm, Delta and Pine Land, and ensured continued access of breeders, for a limited period, to the corn germplasm of Holden’s Foundation Seed after its acquisition by Monsanto.

¹⁸There are however signs of increasing interest in applications of biotechnology in non-food ornamentals and turf grasses in wealthy countries. Note also that Monsanto recently acquired Seminis, a leading horticultural germplasm breeder.