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South-North Trade, Intellectual Property Jurisdictions, and Freedom to Operate in Agricultural Research on Staple Crops*

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I. Introduction

The science of agriculture has undergone a major change in the past few decades, as have the biological and medical sciences more generally. The private sector in North America and Europe has become the leader in the application of modern methods of genetic transformation that have, in combination with new information technologies (or bioinformatics), opened up entirely new prospects for advances in the function, form, and performance of plants, animals, and humans. The question remains, however, if developing countries will be able to reap the benefits of such technological changes. In agricultural biotechnology, the portion of the key technology protected as intellectual property is highly concentrated in the hands of a small number of large, multinational corporations based in North America and Western Europe.[1]

Private research will not and cannot assume the burden of ensuring the food supply of the world's poor. Even in developed countries, the now-dominant

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private-sector research efforts are concentrated on a small number of traits in crops with high commercial value. In the foreseeable future, the vast number of other crops must rely on public and other nonprofit institutions as the principal source of genetic innovations. But in agricultural biotechnology, the very intellectual property rights (IPR) associated with the surge of private biotechnology research now threaten to block public and nonprofit researchers' access to new developments. This problem plagues not only agriculture but the much larger health sciences sector as well.[2] Plant breeders in developed countries increasingly find their access to essential innovative inputs uncertain, unduly expensive, or, in some reported cases, blocked altogether.[3]

There is understandable concern in the international research and donor communities that the problems with access to intellectual property constitute a serious threat to the supply of food and fiber to the poor in the less-developed or so-called Southern countries (hereafter "South"). Many of the world's poor rely for sustenance on crops, such as rice, beans, and cassava, that are high in caloric output but largely beyond the focus of the private research sector. Furthermore, the low income elasticities of these crops mean that future commercial prospects are modest. The fact that there have been some well-publicized donations of "intellectual property" by major multinational corporations to less developed countries (LDCs) for certain noncommercial crops has not only highlighted the usefulness of these technologies but also reinforced the impression of a general lack of access to modern technological opportunities for these crops.

Major donors have expressed the need for the Consultative Group on International Agricultural Research (CGIAR) and other international and local agricultural research organizations to negotiate with major corporations to gain access to their toolboxes of enabling technologies for use in agricultural research conducted in or for less-developed economies. In reality, the concerns of LDCs and international organizations about current access to essential intellectual property are exaggerated and largely misdirected. International and national agricultural research centers have far greater freedom currently to operate in agricultural research oriented toward food crops for the developing world than is commonly perceived. They are generally able to operate in regions where most modern technologies are unprotected by IPR. Unlicensed production in the South of a crop protected only in the North is both legal and moral per se. This point is broached by J. H. Barton and J. Strauss and is the main force of Rural Advancement Foundation International (RAFI).[4]

Intellectual property (IP) might well affect trade in such a crop, however. If there is significant international trade in agricultural commodities or international transfer of the technologies used in their production, identification of valid IP concerns becomes more complex. It is the neglected spatial aspects of IP that are pivotal to the freedom to operate in agricultural research. The authors focus on these spatial aspects.[5]

II. Intellectual Property and Agricultural Biotechnologies

Intellectual properties can be protected by means of copyrights, trademarks, utility patents, plant breeders' rights, and trade secrets.[6] Intellectual property rights have a number of dimensions that are relevant here, including the requirements for obtaining the rights, the scope of what is protected, the geographical limits to the rights, and the duration of the rights. These dimensions vary according to the type of IP and the legal and administrative system of each country.

Forms of Intellectual Property Protection Used in Plant Breeding

For plant breeders, patents and plant breeders' rights are the most relevant forms of IP protection. Patents are the most critical form of protection for agricultural biotechnology and have the most effect on the freedom to operate. The main alternative, plant breeders' rights, imposes only narrow restrictions on the freedom to operate in plant breeding.

The United States and Europe have led the way in allowing utility patents for plants and, particularly, for transgenic plants. In 1985, the United States Patent Office Board of Appeals ruled that sexually propagated seeds, plants, and cultured tissue could be protected by utility patents. More recently, the European Patent Office has held that transgenic methods and plants are not per se unpatentable. Under the 1994 World Trade Organization (WTO) agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), patents are to be available for any invention in any signatory nation, whether products or processes, in all fields of technologies.[7] Among the few exclusions are patents on plants and animals other than microorganisms. The details of these exclusions are an important policy question.

Because TRIPS does not define the term "invention," countries can determine that biological matter, such as genes, are merely a "discovery" and not an invention. Indeed, some countries are implementing legislation along these lines.[8] In addition, exceptions are allowed to protect *ordre public*; to protect human, animal, and plant life; and to avoid serious harm to the environment. Article 27(3)(*b*) states that a member may exclude from patentability "plants and animals other than micro-organisms, and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes"; protection of plant varieties must be provided "either by patents or by an effective sui generis system or by any combination thereof." Many member countries of the WTO are still in the process of implementing a protection system for plants.

Much has been written about what constitutes an effective sui generis protection system and the latitude that countries have in determining the scope and content of the rights to be granted.[9] Such a discussion is beyond the scope of this article. Suffice it to say that while plant protection systems are relatively well established in developed countries, less-developed countries are currently struggling with how to comply with this provision of TRIPS. Because many developing countries are unlikely to implement effective patent protection for plants, there will likely be a great deal of variability in the rights accorded in each country.

The acceptable sui generis alternatives have not been defined but are generally agreed to include forms of plant breeders' rights (PBRs) or plant variety protection. These are traditional forms of IP protection for plants, which have been codified in most developed countries and increasingly in LDCs. While there are differences among countries in the implementation of PBRs, national laws grant protection generally to varieties that are novel, distinct, uniform, and stable. Thus, the variety must be clearly distinguishable from previous varieties, must be uniform and breed true to type, and must not have been sold previously.

The holders of a plant breeders' right have a legal monopoly over the commercialization of their varieties for a prescribed length of time, allowing for the recovery of the cost of breeding commercially valuable new plant varieties. In general, the holder controls the sale, reproduction, import, and export of new varieties of plants. Exceptions may be made, however, for both research and the use of seed saved by a farmer for replanting. Moreover, in some countries, if a protected variety is used as the basis for genetic engineering, the engineered variety may not be used without permission (e.g., through licensing) of the holder of the plant breeders' right.[10]

Breeding a new variety is not affected unless the progeny is "essentially derived" from a parent protected by PBRs. The term "essentially derived" has yet to be defined precisely by judicial decisions. Thus, if they choose, TRIPS signatories may give their plant breeders freedom to operate in their choice of parent varieties for crossbreeding by opting for PBRs as a sui generis alternative to patents. It is clear that PBRs allow initially unrestricted crossbreeding of protected varieties to produce new varieties unencumbered by PBRs protecting the parents.

Contractual and Technological Tools Used to Protect Proprietary Material

In addition to the legal protection afforded by patents, plant breeders' rights, trademarks, and so on, contractual provisions may be used to extend or establish IP rights, such as providing reagents under a restrictive technology transfer agreement. Such contracts include material transfer agreements between technology developers and third parties, which limit the transfer and use of materials, such as vectors, genes, and plants, developed by the transferrer; bag-label contracts between the manufacturer and the buyer of, for example, seed, which limit further uses of purchased material that otherwise would be allowable; technology use agreements between technology suppliers and farmers, which typically control the right to plant a given seed on a specific area of land for a certain period of time; and licenses between patent or property holder and licensee, which are negotiated grants of some or all of the holder's rights, such as allowing the use and sale of the technology.

The availability of these alternatives and their practical utility depends on the nature and enforceability of national IP and contract law.

Infringement and the Freedom to Operate

Infringement and remedies.—When any element of the plant breeders' research takes place in a country where relevant patents are enforced or when the research produced might be made, used, sold, offered for sale, or imported into such a country, it is important for plant breeders to pay close attention to freedom to operate in order to avoid infringement. Infringement of a patent involves the unauthorized making, using, selling, or offering to sell the patented invention within the territory that granted the patent or the importing of the patented invention into that same country during the term of the patent.[11] The patent right is exclusionary, and the patentee must know of the alleged infringement if she is to defend her right. Her first action on identification of an alleged infringer is typically to inform him of her patent rights and either offer to negotiate a license or ask that the infringement cease. In formulating a response, the alleged infringer must evaluate the credibility of threats of legal action and of the sustainability of patent claims in such an action. If unsatisfied by the response, the patentee can sue for relief in the appropriate court. The patentee may ask the court for an injunction to prevent the continuation of the infringement and may also ask the court for an award of damages.

In an infringement suit, the defendant may raise the question of the validity of the patent, which is then decided by the court. The defendant may also argue that what is being done does not constitute infringement. Infringement is determined primarily by the language of the claims of the patent.[12] Owners of technology may litigate against alleged infringers, forcing the latter to incur the costs of assessed damages, and, in at least some European countries such as the United Kingdom, the patentee's legal defense if found to be infringing. Elsewhere, even a victorious litigant usually has to pay his or her legal costs. In the United States, where each party pays its own costs (barring exceptional circumstances), a minimum estimate for litigation is $500,000, and cases often cost each party several million dollars net of any damages awarded.[13] Thus, prospective inventors must beware of IP claims on which their research inputs, processes, or research outputs might infringe or be alleged to infringe. Prospective technology users may have to weigh the risk of litigation against the costs or difficulties of obtaining licenses.

As patenting becomes even more prevalent in biotechnology, the diversity of innovations utilized in developing modern cultivars (cultivated varieties) means that the number of separate rights needed to produce a new innovation proliferates. Where ownership of relevant rights is sufficiently diffuse, the multilateral bargaining problem can become impossible to resolve. This is the "tragedy of the anticommons" noted by M. A. Heller and R. S. Eisenberg.[14]

The tragedy of the anticommons can be compounded seriously by uncertainty. Those who develop new technology by building on existing technologies often know neither the extent to which the latter have been claimed as IP nor the strength of any claims. Both the conduct of research and development (R&D) and subsequent commercialization entail navigating a potential minefield of patent applications that have been filed but remain invisible pending publication by the patent office.[15] Public breeders in the United States received a nasty surprise when a patent issued to Monsanto for the CaMV 35S promoter surfaced after they had used it in the breeding of crop cultivars on the brink of commercialization. More generally, individual inventors in the United States, such as Jerome Lemelson, became notorious for continuing prosecution of patent applications for long periods of time, while others became locked into their technology, and then extracting large rents from infringements after the patent was issued.

The uncertainty emanating from submarine patents is becoming less important as the United States has harmonized with the rest of the world by awarding a patent term of 20 years from the date of filing (previously 17 years from the date the patent was awarded) as well as beginning, in November 2000, to publish patent applications within 18 months of filing. Publication may be excepted by petition, but only if the application is not the basis for an application filed in another country that does publish applications.[16] But even when claims have been published, the breadth of claims of some patents, the existence of multiple patents with applicable claims, and the slow pace of legal resolution of validity combine to make timely identification of valid and invalid claims difficult, or at least legally hazardous, especially in the United States.

IP strategies in light of the freedom to operate.—Freedom to operate is fundamental to the effective development and commercialization of any innovation and is particularly crucial in agricultural biotechnology in light of recent developments. Research licenses are often easy to obtain, but if a research program or commercialization proceeds before obtaining freedom to operate in enabling technologies, future negotiations may be placed in serious jeopardy. The negotiating position of the innovator typically deteriorates as innovation progresses.

In many situations, companies or public institutions controlling IP rights have adopted a policy of not granting a commercialization license and, instead, retain the sole right to the use of the technology for commercial development or license it exclusively to an entity that will not grant others a license. Frequently, IP owners seek unreasonable or unacceptable terms for commercial licenses. Such companies have the power to block applications of the technology by their competitors or their acquisition targets. For instance, the Centre for Legumes in Mediterranean Agriculture (CLIMA) in Australia developed a transgenic lupin cultivar with tolerance to the herbicide Basta® but have been unable to reach agreement with the developers of Basta®, AgrEvo (now Aventis), to release the plant commercially.[17] Likewise, researchers at Michigan State University developed a new turf grass containing a proprietary gene from one company and a promoter from another. Neither company would give permission for its material to be used in conjunction with that from another company, so the turf grass germplasm has been destroyed.[18]

The Freedom to Operate in Agricultural R&D for Developing Countries

It is vitally important to keep in mind that there is no such thing as an "international intellectual property right."[19] A patent or other IP right awarded in one country, for example, in the United States, does not confer property rights in the rest of the world. Patents and other IP rights are awarded by national governments, and the protection conferred extends only as far as the geographic boundaries of the country in which the right is awarded. Thus, to obtain protection in several countries, rights must be applied for and awarded in each.

There is widespread misunderstanding regarding IPR and freedom to operate in developing countries. A survey of the use of proprietary biotech research inputs at selected CGIAR centers showed considerable confusion on the part of researchers regarding the existence of relevant IPR and the freedom to operate.[20] The report itself does not distinguish local validity of IPR from the existence of IPR in some jurisdiction. As emphasized above, patents are valid only in countries in which they are issued.

Many current key technologies for plant breeding appear to be unprotected in developing countries. For example, in the case of plant transformation technology, particle bombardment technology appears to be controlled primarily by Monsanto/Agracetus and Du Pont, with a complex web of cross-licensed partners. The key *Agrobacterium* technology for plant transformation is held more diversely and in different implementations by numerous patents applied for and patents awarded in different jurisdictions (United States, Europe, Australia, Canada, and Japan) to Monsanto, the Max Planck Institute, AstraZeneca/Mogen, Novartis, Japan Tobacco, and many others.[21] The most widely used selectable markers for cereal transformation are controlled by Aventis/AgrEvo (phosphinothricin, Basta®), Monsanto (a particular implementation of the kanamycin resistance gene or G418 under control of CaMV 35S or 19S promoters), or Novartis (hygromycin resistance), which is patented or pending in Australia, Canada, Europe, the United States, Hungary, Ireland, Russia, Japan, Israel, Greece, and Denmark. Patents for Monsanto's CaMV 35S, possibly the most widely used promoter, have been granted only in the United States and Europe, and the only pending application is in Japan. Patents in the United States claiming portions of the CaMV 35S promoter are held by Rockefeller University. Thus, there are no IP restrictions on the use of these commonly employed genes in LDCs.

The freedom to operate in R&D depends on choices (especially those concerning litigation, threats of litigation, and the grant or sale of use rights) made by owners of relevant proprietary technologies. In addition to IP laws, the incentives that shape these choices are affected by an array of factors, some of which are biosafety regulations, public relations, implementation of laws, and market characteristics. Biosafety regulations are closely related to

IP in biotechnology. In particular, in some countries, official approval is required for the use, sale, and importation of transgenic crop or animal varieties. Just like IP or any other laws, biosafety regulations, and their degree of enforcement, are primarily national in nature but still affected by international treaties.[22]

The willingness of owners of agricultural technology to cede use rights, or the minimum price at which they are willing to sell the rights to others, is affected by the location and structure of crop production and, particularly, the pattern of trade. There are two sets of circumstances, often overlapping, under which the freedom to operate in agricultural research may not be under serious threat.

First, owners of proprietary technologies may be willing to allow their use gratis when targeted at commercially unattractive markets, such as subsistence use by poor producers in developing countries. For example, multinationals have given significant publicity to donations of technologies to nonprofit agricultural research agencies working on behalf of poor farmers and consumers in the developing world. Occasionally, more complex market segmentation deals are announced, in which commercially viable uses of the technology are separated from uses that are of humanitarian rather than commercial value.

If the stakes are high enough, multinationals have been willing to incur a good deal of opprobrium in enforcing their IPR against farmers in Canada and the United States. Moreover, owners of IPR include specialized smaller companies, with no reputation or goodwill to protect, whose need for cash motivates them to protect their IPR wherever infringement occurs. The Enola bean and Texmati rice United States patent controversies show that Northern firms are willing to claim rights in the face of opposition from the South when the stakes are sufficiently high.[23]

One highly publicized example of the complexity of IP arrangements is the *Golden*Rice™ Vitamin A Rice Project. *Golden*Rice™ contains enhanced levels of provitamin A in the endosperm of the seed (which remains after the rice is polished), which offers potential health benefits to millions of poor farmers and consumers in developing countries. According to R. D. Kryder, S. P. Kowalski, and A. F. Krattiger, there are 70 patents associated with this technology, including both process patents (relevant to creation of the technology) and product patents (embodied in the rice itself).[24] This case has been quoted as posing a nightmare with respect to freedom to operate. AstraZeneca acquired the commercial rights to *Golden*Rice™ from Greenovations, a small German company acting as an intermediary for the inventors. In return, AstraZeneca licensed the inventors to enable the distribution of the rice on a royalty-free basis to farmers who earn less than $10,000 per year and live in developing countries, leaving the company free to explore commercial prospects for the technology.[25] In addition, Monsanto announced its intent to provide royalty-free licenses for all its technologies that support further development of *Golden*Rice™, and other IP holders have followed suit.[26] Their

TABLE 1

VITAMIN A RICE PATENT IN RICE-PRODUCING AND RICE-IMPORTING COUNTRIES

Top 15 Rice-Producing Countries	Number of Patents	Top 15 Rice-Importing Countries	Number of Patents
China	11	Iran	0
India	5	Brazil	10
Indonesia	6	Nigeria	0
Bangladesh	0	Philippines	1
Vietnam	9	Iraq	0
Thailand	0	Saudi Arabia	0
Myanmar	0	Malaysia	0
Japan	21	South Africa	5
Philippines	1	Japan	21
Brazil	10	Ivory Coast	10
United States	44	Senegal	10
South Korea	10	United Kingdom	35
Pakistan	0	France	37
Egypt	0	Indonesia	6
Nepal	0	United States	44

SOURCE.—R. D. Kryder, S. P. Kowalski, and A. F. Krattiger, "The Intellectual and Technical Property Components of Pro-Vitamin A Rice (*Golden*Rice™): A Preliminary Freedom-to-Operate Review," ISAAA Briefs no. 20 (International Service for the Acquisition of Agri-Biotech Applications, Ithaca, N.Y., 2000), table 4.

donations have engendered widespread positive publicity for the corporate donors.

Second, irrespective of whether the crop is grown on a subsistence or commercial basis and whether the technology is subject to IP protection elsewhere, anyone is free to use technologies and know-how in crops that are developed, produced, and consumed in countries where the technology is not subject to local IP protection. This fact makes it difficult to know exactly what is being "donated" in prominent cases. For example, what did poor rice consumers gain from the *Golden*Rice™ donations? Table 1 shows the top 15 rice importer countries and the number of Vitamin A rice technology patents valid in each. It is clear that for most of the developing countries on the list few or no patents associated with Vitamin A rice are valid in each. Crops traded only among countries in which the technologies are not subject to IP are not liable to claims based on the use of these technologies. For example, importation of Vitamin A rice into Iran from Bangladesh infringes no patents. Furthermore, these numbers in the table are overestimates. Some of the patents may not cover the application to Vitamin A rice, and others may be later invalidated. Nonetheless, there is a real danger that donations such as those associated with Vitamin A rice technology will encourage LDCs and international crop breeders to assume as a matter of policy that claims will not be asserted against their activities and outputs when the stakes are higher, as maintained by RAFI (2000).[27]

Our evidence indicates that developing-world crop breeders have freedom to operate with respect to crops produced in developing countries unencumbered by local IP protection of relevant inputs, processes, or products. But IP problems might affect research decisions regarding technologies destined for crops grown in developing countries unencumbered by IP restrictions if those crops are subsequently exported in a form in which infringement is detectable to countries in which IP is likely to prevail. Importers of Bangladeshi Vitamin A rice into Japan might be subject to successful prosecution for infringement of claims to any embodied material covered by Japanese patent claims. This could be so even if technologies are unencumbered by IP in Bangladesh. Note that in such cases it is the importer, not the breeder, who might be infringing on IP, but responsible breeders will take note of such problems in their innovation decisions.

The determination of freedom to operate in crop breeding requires technical knowledge, a broad business overview, a detailed understanding of all relevant patent claims in all relevant countries, an understanding of markets and national jurisdictions, and a knowledge of litigation and negotiation procedures in relevant jurisdictions. A comprehensive assessment of all these aspects is well beyond the scope of this article. In the next section, we confine our attention to global production and trade patterns as a basis for assessing the impact of developed-country IPR on producers in developing countries with no relevant IPR who use new technologies and follow recent trade patterns.

III. Production and Trade Patterns and the Freedom to Operate

Understanding the production and trade status of crops relevant to developing countries is important in ascertaining the implications of IPR and also helpful to those endeavoring to structure assignments of use rights by the private sector to public and nonprofit plant breeders, with a focus on agriculture in less-developed economies. To make the analysis concrete, we focus on crops covered by the international agricultural research centers that are members of the CGIAR. These include many of the crops most important to research agencies operating in less-developed economies, with tropical beverages being major exceptions.

Data Sources and Treatment

From the on-line FAOSTAT database of the Food and Agriculture Organization of the United Nations, harvested crop production data are reported on a calendar-year basis. Export values and quantity totals are from FAOSTAT's "Agriculture and Food Trade" domain and are classified according to the international Standard International Trade Classification (SITC, revision 2) standard. Import and export totals, from FAO's "Commodity Balances" domain, represent the total amount of each commodity traded (irrespective of its source or destination) in its primary-equivalent form.[28]

To quantify bilateral trade flows among developing and developed countries for the CGIAR crops, we used the Commodity Trade Statistics Data Base

(COMTRADE) compiled by the United Nations Statistics Division. The United Nations Statistics Division converts value-of-trade data to current U.S. dollars using exchange rates supplied by each reporting country or using a weighted-average exchange rate derived from monthly market rates. Wherever possible, trade volumes and quantities (if reported) are expressed in metric units.

We used annual SITC (revision 3) data for the period 1992–98. Presuming that trade statistics reported by developed countries are generally more reliable than those from developing countries, we estimated annual bilateral trade flows using annual trade flows among 29 developed countries treated as reporters and 168 developing countries and areas treated as partners.[29] Thus "exports from developing countries" was our estimate of the imports reported by the developed countries from developing countries. Exports are valued in "fob" (free-on-board) prices, imports mainly in "cif" (cost, insurance, and freight) prices, and thus the reported total value of imports is generally larger than the corresponding value of exports.[30]

Agricultural commodities are traded in raw or primary and various processed forms. For example, wheat is traded as grain, flour, pasta, bran, starch, and so on; soybeans are traded as grain, crude and refined oil, oil cake, and soy sauce. We compiled the COMTRADE data at the most disaggregated level available to us in the SITC 3 series, namely, the five-digit level. Most of the CGIAR crops are specifically represented at this level of disaggregation; the omissions are yams, sweet potatoes, cowpeas, pigeon peas, and plantains.[31] We recorded all identifiable forms of each CGIAR crop. These were summed to form the respective commodity trade totals. In total, 53 product categories were aggregated into 15 commodity totals. It is possible that some fraction of these commodities was traded in some form not specified in the SITC (revision 3) series, but the degree of underreporting for this reason is probably small.

International Production and Trade Totals

Using the Food and Agriculture Organization (FAO) series, table 2 summarizes the 1997 production and international trade performance of the 20 crops currently researched by the CGIAR, arranged into three country groupings—the developing countries, transition economies, and the world. Table 2, columns 1, 3, and 6, reports the 1997 quantity of exports from developing countries, transitional economies, and the world, respectively; columns 2, 4, and 7 give the quantities produced for these same regional groupings. Crops were grouped according to CGIAR "areas of research" and within each group, reported in descending order according to the quantity of production in developing countries (col. 2). At least 95% of the world's production of rice, cassava, sweet potatoes, yams, bananas, plantains, chickpeas, pigeon peas, cowpeas, groundnuts, and coconuts takes place in poor countries, as does 94% of the millet production and over two-thirds of the sorghum output (col. 2/7). Poor countries produce a smaller but still significant share (46%) of global soybean production. Pro-

TABLE 2

PRODUCTION AND TRACE INDICATORS, 1997

	DEVELOPING COUNTRIES*					TRANSITION ECONOMIES*					WORLD*			
	Exports		Production			Exports		Production			Exports			
COMMODITY	Quantity (1,000 mt) (1)	Share Exp/Wexp (%) (1/6)	Quantity (1,000 mt) (2)	Share Pdn/WPdn (%) (2/7)	Share Exp/Pdn (%) (1/2)	Quantity (1,000 mt) (3)	Share Exp/Wexp (%) (3/6)	Quantity (1,000 mt) (4)	Share Pdn/WPdn (%) (5/7)	Share Exp/Pdn (%) (3/4)	Value (in US$ Millions) (5)	Quantity (1,000 mt) (6)	Production (1,000 mt) (7)	Share Exp/Pdn (%) (6/7)
	Cereals													
Rice	22,630	76.2	613,623	95.2	3.7	128	.4	1,203	.2	10.6	7,660	29,693	644,818	4.6
Wheat	15,268	12.1	285,793	46.8	5.3	7,374	5.8	16,427	19.1	6.3	20,641	126,093	610,546	20.7
Maize	22,639	22.4	263,992	40.6	8.6	1,884	1.9	45,215	7.0	4.2	14,069	101,016	650,113	15.5
Sorghum	809	12.7	43,619	69.4	1.9	2	.0	67	.1	3.2	769	6,373	62,822	10.1
Millet	108	46.9	26,344	93.5	.4	21	9.1	1,616	5.7	1.3	55	230	28,187	.8
Barley	1,800	7.0	24,854	16.0	7.2	2,342	9.1	47,951	30.9	4.9	3,788	25,752	154,984	16.6
	Roots, Tubers, Banana, and Plantain													
Cassava	1,220	94.2	64,909	100.0	6.8	0	.0	0	…	…	2,801	11,905	164,909	7.2
Sweet potato	55	67.7	128,363	98.5	.0	2	2.0	0	…	…	34	82	130,257	.1
Potato	970	7.2	111,747	38.6	.9	357	2.6	8,273	34.0	.4	2,553	13,494	289,345	4.7
Banana	2,137	90.1	57,616	98.4	21.1	72	.5	0	…	…	4,707	13,464	58,562	23.0
Yam	23	99.8	30,037	98.9	.1	0	…	0	…	…	18	23	30,376	.1
Plantain	143	90.9	29,629	100.0	.5	0	.0	0	…	…	58	157	29,629	.5

	Food Legumes													
Soybeans	60,626	51.5	171,570	46.4	35.3	422	.4	1,840	.5	23.0	33,522	117,802	69,961	31.8
Beans	1,848	74.5	14,559	86.0	12.7	7	.3	562	3.3	1.2	1,323	2,482	16,932	14.7
Chickpeas†	378	48.8	8,104	96.6	4.7	0	…	5	.1	…	301	775	8,389	9.2
Pigeon peas†	7	100.0	2,866	100.0	.2	0	…	0	…	…	3	7	2,866	.2
cowpeas†	20	86.5	2,383	98.0	.8	0	…	37	1.5	…	5	23	2,433	1.0
Lentils†	322	46.5	2,179	79.5	14.8	0	…	9	.3	…	329	693	2,742	25.3
	Oil Crops													
Coconut	30,005	90.6	99,708	98.4	30.1	11	.0	0	…	…	8,629	33,131	101,333	32.7
Groundnuts	3,450	75.7	60,461	94.9	5.7	37	.8	150	.2	24.7	3,650	4,560	63,702	7.2

SOURCE.—Compiled from Food and Agriculture Organization's (FAO) FAOSTAT database (2000) "Commodity Balances" for cols. 1–4, 6, and 7, available at http://apps.fao.org/. To estimate col. 5, we formed a price (i.e., unit value) by dividing the total value of exports by the corresponding total quantity for each commodity in its primary form, reported in FAOSTAT's "Agriculture and Food Trade" domain. We used this price to weight the total traded quantities reported in the Commodity Balances data obtained from Food and Agriculture Organization.

NOTE.—"Exp" denotes exports, "Wexp" denotes world exports, "Pdn" denotes production, and "Wpdn" denotes world production. All products are in crop-primary-equivalent form. In the production totals we also estimated and included production of oils and cakes that were converted in primary-equivalent form using average world conversion factors taken from United Nations Food and Agriculture Organization, "Technical Conversion Factors (Tcf) for Agricultural Commodities," available at http://www.fao.org/WAICENT/FAOINFO/ECONOMIC/ESS/tcf.htm. Within each crop class, crops are arranged in descending order of 1997 developing-world production (col. 2).

* Includes 124 developing and 27 transitional countries, and 178 countries in the world total.

† For these crops, production data were taken from the "Agricultural Production" domain of FAOSTAT (2000).

duction of cereals other than rice is more geographically dispersed. Less than 50% of the world's production of wheat, maize, and barley is grown in the developing world, with the transition economies being significant producers of barley and wheat.

For many of the crops in table 2, total exports from developing countries (whether they are exported to developed or other developing countries) represent a minor share of total developing-country production (col. 1/2). The major exceptions are soybeans, coconuts, and bananas. About one-third of the developing world's soybean production is exported, as well as one-fifth of its banana production (overwhelmingly dessert bananas); neither crop, however, is a consumer staple in the main exporting countries. Coconuts come mainly from the Philippines and are mostly exported in semiprocessed form.

South-North Trade Flows

Table 3 summarizes the annual average trade flows between developing countries and the developed world for 15 commodities for the period 1994–98, using the COMTRADE data. The table shows that developed countries are net exporters of wheat, maize, potatoes, sorghum, and lentils to the developing world and net importers of all other crops in the table.

Developing countries as a group both import and export virtually all the crops. In part, this reflects seasonal differences in production and the differences in the quality and form of the crops being traded. By total value, wheat is the major developed-country export crop with a developing-country destination—averaging more than $10.7 billion (current prices) per year (col. 1)—followed by soybeans ($4.5 billion), maize ($4.3 billion), barley ($1.1 billion), and rice ($982 million). But as a developing-country export crop to the developed world, wheat ranks a distant sixth (col. 3). The top-ranking exports from LDCs to the developed world by value are soybeans, bananas, rice, and coconuts; each crop averages more than $1 billion per year, with soybean and banana exports averaging more than $4.5 billion per year.

The middle panel of table 3 (cols. 3 and 4) shows that wheat, soybeans, and maize combined account for more than 85% of all developed-country exports to the developing world among the 15 crops listed here, while soybeans and (dessert) bananas account for about 60% by value of the developed-country crop imports from the developing world.

The bottom panel in table 3 gives the developed-country share of total imports and exports, respectively, that come from and go to developing countries. Comparatively large shares—more than 40%—of the developed world's wheat, sorghum, maize, rice, barley, beans, and soybeans exports go to the developing world. The preponderance of the developed world's banana, coconut, cassava, and chickpea imports come from developing countries. Notably, wheat and maize originating from developing countries are less than 6% and 7% of the total developed-world imports of wheat and maize, respectively. On the other hand, Southern rice comprises 48% of total Northern rice imports.

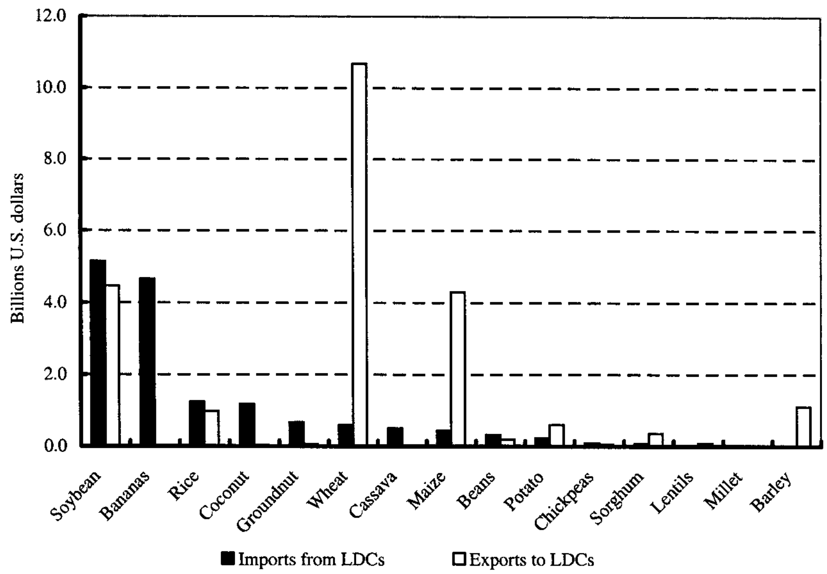

FIG. 1.—Developed-country trade with less developed countries, 1994–98 annual average. Source: Compiled from United Nations Statistical Division, Commodity Trade Statistics Data Base (1999).

The trade flows between the developed and developing worlds are summarized graphically in figure 1, with commodities sorted in descending order, from left to right, according to the total value of developed-country imports from the developing world (table 3, col. 3). The trade balance for developing countries for these 15 CGIAR commodities is negative overall (table 3, col. 5), mainly because of substantial developed-country wheat and maize exports to the developing world. The only really sizable exports from LDCs to developed countries are soybeans and bananas, followed well behind by rice, coconuts, and groundnuts.

Not only are developing-country exports of staple foods to the developed world concentrated in a few commodities, but the preponderance of exports originates from comparatively few countries. Just nine less-developed countries shipped 76% of the 15-crop total exports to the developed world (table 4). Soybeans, the number one LDC export crop by value to the developed world (nearly 34% of the 15-crop total), came mainly from Brazil and Argentina, where they are not staple foods but, rather, cash crops for export. A sizable share of developing-country rice exports to the developed world was from Thailand (59% of total LDC rice exports to the developed countries), bananas came mainly from Costa Rica and Ecuador (each about 20% of total LDC-to-developed-country banana exports), and coconut exports were principally from the Philippines. Generally, more than 50% of total LDC exports to the developed world for each crop originated from just one or two countries, and for each—Brazil, Costa Rica, Ecuador, Colombia, and Panama—over

TABLE 3

DEVELOPED-COUNTRY TRADE, 1994–98 ANNUAL AVERAGE

	EXPORTS		IMPORTS		BALANCE OF TRADE	
	To LDCs (1)	Total (2)	From LDCs (3)	Total (4)	With LDCs (5)	Total (6)
	Annual Trade Flows (1,000 US$)					
Soybean	4,466,762	10,440,702	5,145,713	11,118,853	(678,951)	(678,151)
Bananas	3,555	888,659	4,651,434	5,379,999	(4,647,879)	(4,491,339)
Rice	982,054	2,305,332	1,242,062	2,596,468	(260,008)	(291,136)
Coconut	28,675	197,949	1,177,257	1,331,826	(1,148,582)	(1,133,877)
Groundnut	63,764	491,664	669,741	1,095,247	(605,976)	(603,583)
Wheat	10,676,906	21,261,677	600,116	11,400,189	10,076,789	9,861,488
Cassava	893	45,440	507,791	562,058	(506,898)	(516,618)
Maize	4,293,828	9,192,626	434,742	5,823,624	3,859,086	3,369,001
Beans	199,408	472,547	326,179	664,494	(126,772)	(191,947)
Potato	601,064	4,154,037	236,214	3,732,855	364,850	421,182
Chickpeas	60,390	76,105	92,021	106,974	(31,631)	(30,870)
Sorghum	355,282	745,732	82,319	530,640	272,963	215,093
Lentils	83,322	162,396	21,826	95,439	61,496	66,956
Millet	3,216	32,231	16,590	51,609	(13,373)	(19,378)
Barley	1,103,922	2,433,878	4,618	1,443,621	1,099,303	990,257
Total	22,923,040	52,900,975	15,208,623	45,933,896	7,714,417	6,967,078
	Share of Commodity Total					
Soybean	19.49	19.74	33.83	24.21		
Bananas	.02	1.68	30.58	11.71		
Rice	4.28	4.36	8.17	5.65		
Coconut	.13	.37	7.74	2.90		
Groundnut	.28	.93	4.40	2.38		

Wheat	46.58	40.19	3.95	24.82
Cassava	.00	.09	3.34	1.22
Maize	18.73	17.38	2.86	12.68
Beans	.87	.89	2.14	1.45
Potato	2.62	7.85	1.55	8.13
Chickpeas	.26	.14	.61	.23
Sorghum	1.55	1.41	.54	1.16
Lentils	.36	.31	.14	.21
Millet	.01	.06	.11	.11
Barley	4.82	4.6	.03	3.14
Total	100	100	100	100
	Share of Respective Import and Export Total			
Soybean	42.78	100	46.28	100
Bananas	.40	100	86.46	100
Rice	42.6	100	47.84	100
Coconut	14.49	100	88.39	100
Groundnut	12.97	100	61.15	100
Wheat	50.22	100	5.26	100
Cassava	1.97	100	90.34	100
Maize	46.71	100	7.47	100
Beans	42.2	100	49.09	100
Potato	14.47	100	6.33	100
Chickpeas	79.35	100	86.02	100
Sorghum	47.64	100	15.51	100
Lentils	51.31	100	22.87	100
Millet	9.98	100	32.15	100
Barley	45.36	100	.32	100
Total	43.33	100	33.11	100

SOURCE.—Compiled from United Nations Statistics Division Commodity Trade Statistics Data Base (1999).
NOTE.—Crops are arranged in rank order of total imports from less developed countries (LDC; col. 3). Negative balances in parentheses.

TABLE 4

Developing-Country Exports to the Developed World—Top Nine Countries, 1994–98 Averages

Origin	All CGIAR Commodities	Soybeans	Bananas	Rice	Coconut	Groundnut	Wheat	Cassava
Annual average exports by value (1,000s of US$ per year):								
Brazil	3,068,757	3,044,148	2,852	1,207	1,406	10,003	1,077	510
Argentina	2,099,760	1,501,520	…	1,047	1,013	227,653	12,932	…
Thailand	1,279,176	3,553	6,003	728,786	8,492	…	76,411	433,047
Philippines	1,018,158	1,890	320,658	67	683,466	…	9,010	2,502
Costa Rica	983,076	107	957,633	…	712	…	646	23,891
Ecuador	975,244	…	974,634	…	…	…	58	372
China	942,887	187,176	3,581	142,723	837	209,950	138,909	2,277
Colombia	669,144	…	666,268	…	261	42	1,746	…
Panama	442,198	…	440,780	…	…	…	…	45
All other	3,730,224	407,321	1,279,025	368,233	481,069	222,093	359,328	45,148
Total	15,208,623	5,145,713	4,651,434	1,242,062	1,177,257	669,741	600,116	507,791
Share of country total (%):								
Brazil	20.18	59.16	.06	.1	.12	1.49	.18	.1
Argentina	13.81	29.18	…	.08	.09	33.99	2.15	…
Thailand	8.41	.07	.13	58.68	.72	…	12.73	85.28
Philippines	6.69	.04	6.89	.01	58.06	…	1.5	.49
Costa Rica	6.46	0	20.59	…	.06	…	.11	4.7
Ecuador	6.41	…	20.95	…		…	.01	.07
China	6.2	3.64	.08	11.49	.07	31.35	23.15	.45
Colombia	4.4	…	14.32	…	.02	.01	.29	…
Panama	2.91	…	9.48	…	…	…	…	.01
All other	24.53	7.92	27.5	29.65	40.86	33.16	59.88	8.89
Total	100	100	100	100	100	100	100	100
Share of commodity total (%):								
Brazil	100	99.2	.09	.04	.05	.33	.04	.02
Argentina	100	71.51	…	.05	.05	10.84	.62	…
Thailand	100	.28	.47	56.97	.66	…	5.97	33.85
Philippines	100	.19	31.49	.01	67.13	…	.88	.25
Costa Rica	100	.01	97.41	…	.07	…	.07	2.43
Ecuador	100	…	99.94	…	…	…	.01	.04
China	100	19.85	.38	15.14	.09	22.27	14.73	.24
Colombia	100	…	99.57	…	.04	.01	.26	…
Panama	100	…	99.68	…	…	…	…	.01
All other	100	10.92	34.29	9.87	12.9	5.95	9.63	1.21

	Maize	Beans	Potato	Chickpeas	Sorghum	Lentils	Millet	Barley
Annual average exports by value (1,000s of US$ per year):								
Brazil	4,843	1,733	967	…	…	…	…	…
Argentina	232,611	59,104	…	…	55,287	…	7,508	…
Thailand	4,008	17,752	616	…	166	140	…	…
Philippines	168	…	126	…	…	…	…	…
Costa Rica	…	…	42	…	…	…	…	…
Ecuador	…	19	…	…	…	…	…	…
China	69,438	161,587	3,490	63	8,548	5,999	8,217	91
Colombia	521	120	85	…	…	…	…	…
Panama	380	…	…	…	…	…	…	…
All other	122,774	85,864	230,887	91,957	18,318	15,687	865	4,527
Total	434,742	326,179	236,214	92,021	82,319	21,826	16,590	4,618
Share of country total (%):								
Brazil	1.11	.53	.41	…	…	…	…	…
Argentina	53.51	18.12	…	…	67.16	…	45.26	…
Thailand	.92	5.44	.26	…	.2	.64	…	…
Philippines	.04	…	.05	…	…	…	…	…
Costa Rica	…	…	.02	…	…	…	…	…
Ecuador	…	.01	…	…	…	…	…	…
China	15.97	49.54	1.48	.07	10.38	27.48	49.53	1.97
Colombia	.12	.04	.04	…	…	…	…	…
Panama	.09	…	…	…	…	…	…	…
All other	28.24	26.32	97.74	99.93	22.25	71.88	5.21	98.03
Total	100	100	100	100	100	100	100	100
Share of commodity total (%):								
Brazil	.16	.06	.03	…	…	…	…	…
Argentina	11.08	2.81	…	…	2.63	…	.36	…
Thailand	.31	1.39	.05	…	.01	.01	…	…
Philippines	.02	…	.01	…	…	…	…	…
Costa Rica	…	…	0	…	…	…	…	…
Ecuador	…	0	…	…	…	…	…	…
China	7.36	17.14	.37	.01	.91	.64	.87	.01
Colombia	.08	.02	.01	…	…	…	…	…
Panama	.09	…	…	…	…	…	…	…
All other	3.29	2.3	6.19	2.47	.49	.42	.02	.12

SOURCE.—Compiled from United Nations Statistics Division Commodity Trade Statistics Data Base (1999).

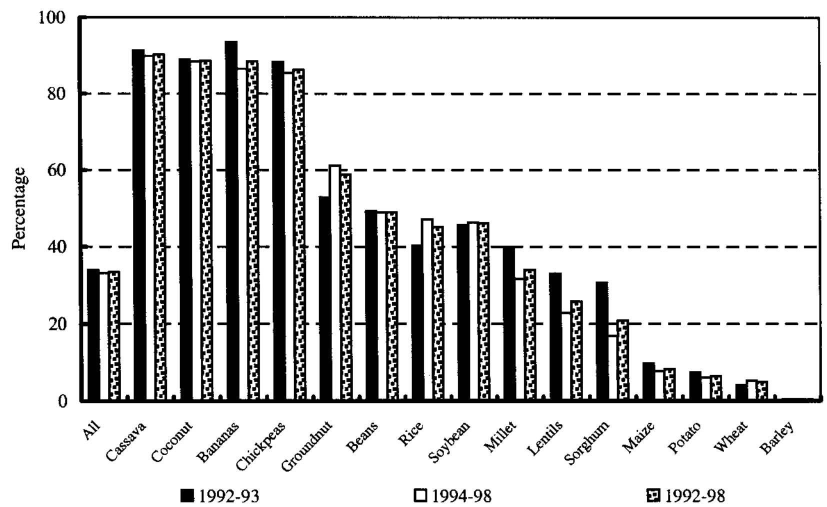

FIG. 2.—Share of developed-country imports originating from less developed countries, 1989–98. Source: Compiled from United Nations Statistical Division, Commodity Trade Statistics Data Base (1999).

97% of these exports involved just one of the crops considered. Over 80% of the exports of the commodities under consideration come from Thailand and Argentina and involved just two such commodities—rice and cassava in the case of Thailand, and soybeans and groundnuts in the case of Argentina.

A detailed investigation of region-to-region, country-to-region, and country-to-country trade flows for the 15 CGIAR crops reinforces the finding described above that comparatively few LDC countries account for most of the total LDC exports to the developed world. Additionally, most of these LDC exports go to Western Europe (about 64%), followed by the United States (16%) and Japan (11%). Western Europe is the principal developed-world destination for developing-country exports for all but three CGIAR commodities—the exceptions being wheat, sorghum, and barley. The overall value and pattern of South-North trade has been geographically stable recently, with approximately one-third of the imports for developed countries coming from LDCs since 1992. Moreover, just nine LDCs accounted for about three-quarters of the shipments of CGIAR crops to Northern countries for the years 1992–98, with Brazil, Argentina, Thailand, Philippines, and China being the biggest exporters. The composition of South-North trade has changed. The value of wheat and rice exports from the LDCs to the developed countries grew rapidly, by over 10% and 6% per year, respectively, since 1992. In contrast, LDC exports of barley, beans, cassava, chickpeas, lentils, maize, millet, potatoes, and sorghum to the developed world declined. These crop-specific patterns of trade over the 1992–98 period are reflected in figure 2.

Processed Products, Infringement, and Detectability

Intellectual property claims can pertain not only to products but also to processes (e.g., methods for making a plant and methods for processing it) and the processed products themselves. Many commodities are traded in processed form. The COMTRADE data show that about 60% (by value) of LDC exports of coconuts to the developed world are in the form of oil and about 54% of soybean exports are so traded. In contrast, bananas and rice are shipped almost entirely in raw form, in which IP should be more readily detectable. To successfully litigate against the importation of crops that were developed with locally protected IP, it is necessary for the litigant to establish the use of the IP. The use of modern biotechnologies can be discerned in seeds and fruit parts but not necessarily if the crop is shipped in processed form. Tests based on protein or DNA, including sensitive polymerase chain-reaction-based (PCR) diagnostic methods, are largely, if not wholly, incapable of detecting substantive components of protected technologies in oils, carbohydrates, purified proteins, or some extracts.

The law is unsettled regarding the reach of infringement of method claims to products resulting from these methods of producing or processing a crop. For example, an imported product made by a patented process may not be infringing if it is materially changed by subsequent processes (such as shipping oil derived from soybean varieties, the creation of which is subject to process patents). However, relying on public policy arguments espoused in legislative history, the U.S. Federal Circuit Court in *Bio-Technology General Corp. v. Genentech Corp.* found infringement even though a product was materially changed.[32] Furthermore, the burden of proof requirements may favor the patentee. In the United States, the presumptions are that a product is made from a patented process when there is a substantial likelihood of it and that the patentee made a reasonable effort to determine the process actually used. On the other hand, the use of processes protected by IP to produce a traded commodity is likely to be difficult to verify. It then becomes the alleged infringer's burden to prove that the process was noninfringing.

In summary, the production and trade evidence reveals that:

1. Exports from developing to developed countries of staple food crops are insignificant in relation to domestic agricultural production, to total agricultural exports from developing countries, or to developed-country imports, except for a few commodities from a small number of developing countries.
2. The developing countries as a group account for more than 95% by weight (and for quite a few of these crops more than 98%) of the world's production of rice, millet, cassava, sweet potato, yam, banana, plantain, chickpeas, cowpeas, pigeon peas, groundnuts, and coconuts. They also account for over 65% of the world's production of sorghum, beans, and lentils.

3. Soybeans, coconuts, bananas, lentils, and beans are the only crops of the 15 studied for which more than 10% of developing-country production is exported.
4. Just two crops (soybeans and bananas) account for 64% of LDC crop exports by value to the developed countries and just four countries (Brazil, Argentina, Ecuador, and Costa Rica) account for 42% of the South-North trade in these two crops. Together with exports of rice and coconuts, these products comprise 80% of the South-North trade total. Most of the rice and coconut shipments from the South destined for the developed world come from Thailand and the Philippines, respectively.
5. Western Europe is the principal destination for South-North trade in nine of the top 10 developing-country crop exports—specifically soybeans, bananas, rice, coconuts, groundnuts, cassava, maize, beans, and potatoes. Wheat is the only exception; exports from LDCs are shipped mainly to North America and Japan but are dwarfed by wheat trade in the reverse direction from North America to LDCs.

Soybeans, the most valuable developing-country export crop, is of minor importance in most LDC research portfolios and is not a staple crop in Brazil and Argentina, which, together, account for 79% of South-North trade in this crop. But given the significance of the value of soybean exports and the role of biotechnology in soybean breeding, a few comments on these are in order. In 2000, genetically modified soybeans occupied 95% of soybean acreage in Argentina.[33] Roundup resistant seeds reputedly smuggled from Argentina were planted on an estimated 8% of Brazilian soybean acreage in 1999.[34] This occurred notwithstanding the fact that such seeds are still outlawed in Brazil.[35] Roundup Ready® soybean technology is not patented in Argentina, although seeds with this technology are generally protected by plant breeders' rights under Argentina's 1974 seed law.[36] Thus, it is legal for Argentine seed companies to breed new cultivars using glyphosate tolerance genes without licensing agreements with Monsanto, although the shipment into the United States of soybeans grown from such seeds could make importers liable to litigation.

In a search of Patent Cooperation Treaty applications and issued United States and European patents, we found only three directly related to transgenic bananas. Several others recite banana viruses and detection methods. However, there is IP pertaining to biotechnologies in commercially grown bananas because of patents with claims that encompass bananas (e.g., claims to monocots). The three principal fruit types of the genus *Musa* are dessert bananas, cooking bananas, and plantains. The vast majority of bananas exported by LDCs are dessert bananas. Cooking bananas and plantains are important in terms of production and consumption but not in terms of exports. International (nonprofit) plant-breeding research deals with all three *Musa* types, although CGIAR research is mostly confined to cooking bananas and plantains.

An important South-North trade development noted above is the rapid rise in rice exports from LDCs to developed countries. Of all Northern rice imports, almost half now originate in Southern countries and, in particular, from Thailand, India, China, and the Netherlands Antilles.[37]

In summary, the trade data suggest that freedom-to-operate problems are most likely—among the crops under consideration—to arise in soybeans, bananas, and rice. However, soybeans are not, at present, a staple commodity in the major exporter countries, nor are they a focus of international agricultural research organizations working in or on behalf of the developing world. The types of bananas that dominate as an LDC food crop and consumer staple do not figure significantly in trade. Rice is a staple par excellence, but the percentage of rice output traded to the North is very small.

IV. Conclusion

At present, crop breeders in less-developed countries have substantial freedom to operate regarding research on most crops of greatest significance for food security in poor countries. Intellectual property rights over biotechnologies relevant to agriculture are held mainly in (and are therefore mainly relevant to) rich-country jurisdictions. Intellectual property rights in the North affect farmers in the South (and, indirectly, the LDC breeders who supply them with modern cultivars) if they export infringing products to the North. However, South-North trade in the food staples is limited overall as well as in terms of the number of crops and the number of less-developed countries involved in any significant sense. Intellectual property rights–based limitations on export markets for food staples that embody technologies protected only in the North should not, in general, be considered an important impediment to the use of these technologies in such crops in the South.

This does not mean that freedom to operate is not an issue for LDC research or production for those few staples for which exports of agricultural staples to Northern countries constitute a significant share of a Southern country's total exports. Problems may also arise for traders of Southern cash crops destined for Northern markets, such as horticultural products, tropical beverages, or dessert bananas.

Undue concern about the freedom to conduct LDC research (or research by those working on behalf of LDCs) is misdirecting policy and practical attention away from the major current constraints on research on food crops for the South. There is an increasingly serious lack of investment in Southern research and a lack of local scientific skills needed to take advantage of the rapidly advancing stock of complex modern biotechnologies, whether they are protected by patents or not. Biotechnology is challenging the adaptive capacity that has enabled poor countries to benefit from the advances in plant genetics and other relevant technologies in the past half-century, and lagging public resources are not being replaced by private-sector investments. Failure to invest in the capacity needed to evaluate, access, and regulate the technologies being developed in the North is currently a far greater constraint than freedom to operate. The current confusion over this issue itself illustrates the lack of capacity that researchers and decision makers have for handling questions relating to IPR and freedom to operate in LDC plant breeding.

For the future, the form of implementation of the TRIPS agreement with respect to plant-breeding technology, domestically and in important export markets, is a crucial issue for LDC policy makers. Where patenting of plant and other life-forms is allowed, the extent of patenting of key biotechnologies in the South will grow, threatening the freedom to operate of LDC researchers and freedom to trade in LDC agricultural products, both South-North and South-South. This issue ranks with the implementation of farmers' rights as an important policy concern for plant breeders, farmers, and the food consumers of the South, but domestic freedom to operate is generally the dominant IPR issue. Exports of important food staples that dominate agriculture are not important growth drivers in most developing countries.

Misconception of their present freedom to operate is a threat to the effectiveness with which breeders of food crops for the South can bargain for access to the scientific outputs from the more than $10 billion of private spending (1993 prices) on agricultural R&D in 1995 in Organization for Economic Cooperation and Development countries.[38] Institutional innovations bridging the private-public divide are beginning to emerge.[39] It behooves all parties to have a proper picture of the present degrees of freedom regarding Southern agricultural R&D in order to strike effective deals when tapping Northern IP on behalf of the world's poor, to know when such deals are not needed, and to recognize what is being surrendered in choosing plant patenting rather than plant breeders' rights in implementing the TRIPS agreement.

Notes

* The authors are listed alphabetically. Eran Binenbaum is a lecturer in the School of Economics at the University of Adelaide; Carol Nottenburg is chief legal officer and director of intellectual property at CAMBIA (the Center for the Application of Molecular Biology to International Agriculture); Philip Pardey is a professor in the Department of Applied Economics, University of Minnesota; Brian Wright is a professor in the Department of Agricultural and Resource Economics, University of California, Berkeley, and a member of the Giannini Foundation; and Patricia Zambrano is a senior research assistant at the International Food Policy Research Institute. Stephen Stohs, Bonwoo Koo, and Yuan Liang provided excellent research assistance, and Agapi Somwaru (U.S. Department of Agriculture, Economic Research Service) collaborated with us in compiling the trade data. We thank Per Pinstrup-Andersen and Richard Jefferson for their especially helpful comments on earlier drafts. Research for this article was made possible, in part, by grants from the Swedish International Development Agency (Sida) and the Giannini Foundation.

1. See http://www.cambia.org/.

2. See M. A. Heller and R. S. Eisenberg, "Can Patents Deter Innovation? The Anticommons in Biomedical Research," *Science* 280 (May 1, 1998): 698–701; and, e.g., National Institutes of Health, "Report of the National Institutes of Health Working Group on Research Tools" (National Institutes of Health, Bethesda, Md., June 4, 1998), available at http://www.nih.gov/news/researchtools.

3. B. D. Wright, "Public Germplasm Development at a Crossroads: Biotechnology

and Intellectual Property," *California Agriculture* 52, no. 6 (1998): 8–13; R. K. Lindner, "Prospects for Public Plant Breeding in a Small Country" (paper presented at the ICABR [International Consortium on Agricultural Biotechnology Research] Conference, Rome, June 1999); F. H. Erbisch, "Challenges of Plant Protection: How a Semipublic Agricultural Research Institution Protects Its New Plant Varieties and Markets Them" (paper presented at the workshop on the Impact on Research and Development of *Sui Generis* Approaches to Plant Variety Protection of Rice in Developing Countries, International Rice Research Institute, Los Baños, Philippines, February 16–18, 2000).

4. See J. H. Barton and J. Strauss, "How Can the Developing World Protect Itself from Biotech Patent-Holders?" *Nature* 406, no. 6,975 (2000): 455; and RAFI, "In Search of Higher Ground: The Intellectual Property Challenge to Public Agricultural Research and Human Rights and 28 Alternative Initiatives," Occasional Paper Series 6, no. 1 (Rural Advancement Foundation International, Winnipeg, September 2000), available at http://www.rafi.org/documents/occ_higherground.pdf.

5. The trade-related spatial issues discussed here were addressed in a pilot study with less comprehensive data by Eran Binenbaum and Brian Wright, "On the Significance of South-North Trade in IARC Crops," appendix in "Mobilizing Science for Global Food Security: Report of the CGIAR Panel on Proprietary Science and Technology," no. SDR/TAC:IAR/98/7.1 (Technical Advisory Committee of the CGIAR, Rome, 1998), app. C-3, available at http://www.worldbank.org/html/publications/mtm98/tc9871.pdf.

6. Other forms of IP protection, such as design patents, are not dealt with here.

7. Article 27 of the TRIPS Agreement. This and all subsequent references to TRIPS legal articles are taken from General Agreement on Tarrifs and Trade (G.A.T.T.) Secretariat, *The Results of the Uruguay Round of Multilateral Trade Negotiations: The Legal Texts* (Geneva: GATT Secretariat, June 1994).

8. Decision 486, Article 15, promulgated by the Andean Community (Bolivia, Colombia, Ecuador, Peru, and Venezuela), deems that biological material that exists in nature or can be isolated from any life form is not an invention. See Commission of the Andean Community, *Decision 486: Common Intellectual Property Regime* (Lima, September 14, 2000), available at http://www.comunidadandina.org/ingles/treaties/dec/D486e.htm.

9. See, e.g., D. Leskien and M. Flitner, "Intellectual Property Rights and Plant Genetic Resources: Options for a *Sui Generis* System," IPGRI Issues in Plant Genetic Resources, no. 6 (International Plant Genetic Resources Institute, Rome, June 1997), available at http://www.ipgri.cgiar.org/publications/pubfile.asp?ID_PUB=497.

10. UPOV Convention, 1991 Act. Details available from UPOV (International Convention for the Protection of New Varieties of Plants) of December 2, 1961, as revised at Geneva on November 10, 1972, on October 23, 1978, and on March 19, 1991. We accessed http://www.upov.int/en/publications/conventions/1991/act1991.htm for this study in October 2000.

11. Furthermore, TRIPS allows a patent owner to prohibit importation of products made by processes patented in the importing country. See World Trade Organization, Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), Article 28.1(*b*), available at http://www.wto.org/english/docs_e/legal_e/27-trips.doc.

12. In Europe, as well as some other countries, the validity of a patent grant can be challenged within the European Patent Office but only for a limited time after the patent is allowed. This procedure, known as an opposition, is an inter partes proceeding between the patentee and the challenger. United States patent law does not allow opposition but instead has a limited reexamination proceeding, which reexamines the patent only with regard to prior art not considered during examination.

13. J. Lerner ("Patenting in the Shadow of Competitors," *Journal of Law and Economics* 38 [October 1995]: 470) reports that for every 100 U.S. biotechnology patents there are six patent suits, an extremely high figure relative to other areas of

technology. He further estimates that patent litigation in the United States Patent Office and the federal courts initiated in the year 1991 led to total legal expenditures of US$1 billion in 1991 dollars compared with US$3.7 billion spending by firms on basic research in that year. Note that the cost figure excludes litigation in state courts.

14. Heller and Eisenberg (n. 2 above).

15. Such patents are sometimes called "submarine patents."

16. Some exceptions to publishing are allowed in the United States but are not expected to have a major impact in agricultural biotechnology.

17. M. Ewing, of CLIMA, personal communication, June 2000.

18. Erbisch (n. 3 above).

19. While the focus here is on patents and plant breeders' rights, we are mindful that international treaties, especially for copyrights, can bind parties to granting "full faith and credit" to the rights holder of another member country, thus, in effect, providing international protection.

20. J. I. Cohen, C. Falconi, J. Komen, and M. Blakeney, "Proprietary Biotechnology Inputs and International Agricultural Research," ISNAR Briefing Paper no. 39 (International Service for National Agricultural Research, the Hague, 1998).

21. For a comprehensive description of agrobacterium-mediated transformation technologies and related IP aspects, see C. Roa-Rodríguez and C. Nottenburg, "Agrobacterium-mediated Transformation" (CAMBIA, Canberra, 2001), available at http://www.cambiaip.org/Whitepapers/Transgenic/Whitepaper_1/AMTupdate_Feb02/Summary1.htm.

22. For example, the Biosafety Protocol, agreed on in Montreal in January 2000.

23. In September 1997, a Texas company, RiceTec, was issued a patent on "Basmati rice lines and grains" obtained from crossing a Pakistani basmati variety with an American semidwarf (short stature) strain. In August 2000, 15 of the patent's 20 claims were struck down by the U.S. Patent and Trademark Office (USPTO) after a reexamination instigated by the Government of India, and the "Basmati" name was dropped from the patent title. In April 1999, U.S. patent number 5,894,079 was issued to Larry Procter for the "Enola" bean variety of Mexican origin, giving Procter's firm exclusionary rights in the United States over all *Phaseolus vulgaris* (dry bean) varieties having a particular shade of yellow. On December 20, 2000, CIAT (an international agricultural research center engaged in bean breeding located in Colombia) filed a reexamination with the USPTO challenging all 15 of the patent's claims. Both cases gained wide publicity as examples of biopiracy and misappropriation of traditional knowledge.

24. R. D. Kryder, S. P. Kowalski, and A. F. Krattiger, "The Intellectual and Technical Property Components of Pro-Vitamin A Rice (*Golden*Rice™): A Preliminary Freedom-to-Operate Review," ISAAA Briefs no. 20 (International Service for the Acquisition of Agri-Biotech Applications, Ithaca, N.Y., 2000).

25. N. Tait and M. Wrong, "Deal Offers Free GM Rice to Poor Farmers while Rich Have to Pay," *Financial Times* (London) (May 16, 2000), as reproduced by Ag Biotech Infonet, http://www.biotech-info.net/deal_offers_free_rice.html.

26. Monsanto, "Monsanto Adds Support for 'Golden Rice': Opens Its Genome Sequence Data to Worldwide Research Community," news release (August 4, 2000), available at http://www.monsanto.com/monsanto/media/00/00aug4_goldenrice.html.

27. RAFI (n. 4 above).

28. Our regional grouping of countries generally follows FAO (United Nations Food and Agriculture Organization), FAOSTAT data files, http://faostat.fao.org/cgi-bin/nph-db.pl?subset=agriculture, accessed March 2000, with the exception that we classified Hong Kong and Singapore as developed countries, while FAOSTAT groups them with developing countries.

29. Transition economies—principally the countries that formed part of the former Soviet Union and Eastern Europe—are not included in any of the bilateral trade flow

evidence based on UNSD (United Nations Statistics Division), COMTRADE data files, 1999 (accessed April 2000).

30. The exceptions are Canada, Mexico, and Australia, whose imports are reported in "fob" prices.

31. Yams and sweet potatoes are lumped under "other roots, tubers" along with other products. Pigeon peas and cowpeas are most likely included under "other legumes." Plantains are grouped under "bananas fresh or dried."

32. See 38 USPQ2d 1321 (Fed. Cir. 1996), in which the claim at issue recited a method of constructing a cloning vehicle, and the imported product was a protein produced from a host cell containing the cloning vehicle. Compare this case to Eli Lilly & Co. v. American Cyanamid Co., 38 USPQ2d, 1705 (Fed. Cir. 1996), in which the Federal Circuit held that an imported compound produced by a claimed method for an intermediate compound was not infringing.

33. C. James, "Global Status of Commercialized Transgenic Crops: 2000," ISAAA Briefs No. 21 (International Service for the Acquisition of Agri-Biotech Applications, Ithaca, N.Y., 2000), p. 9.

34. See B. Feder, "Rocky Outlook for Genetically Engineered Crop," *New York Times* (December 20, 1999), p. 9; and American Society of Agronomy, "Brazil Wants GMOs Gone," accessed for this study at http://www.asa-cssa-sssa.org/dbrief/, in February 2000.

35. This was confirmed in a recent decision of the Regional Federal Court in Brazil against Monsanto, which can appeal the decision to the Supreme Tribunal of Justice, Brazil's Supreme Court. See J. L Rich, "Seed Setback for Monsanto," *New York Times* (August 10, 2000), p. C3.

36. United States General Accounting Office, *Biotechnology: Information on Prices of Genetically Modified Seeds in the United States and Argentina* (Washington D.C.: GAO, January 2000), p. 6, reports that "Monsanto's 1995 application for a patent for Roundup Ready soybeans in Argentina was rejected. Monsanto appealed the decision, and an Argentine court overturned the rejection. Monsanto has petitioned for reconsideration of the patent application; as of December 1999, the application was pending."

37. According to FAO, the Netherlands Antilles does not grow measurable amounts of rice. Its Northern exports consist largely of transshipments from nearby Latin American countries such as Suriname.

38. See P. G. Pardey and N. M. Beintema, "Slow Magic: Agricultural R&D a Century after Mendel," IFPRI Food Policy Report International Food Policy Research Institute, Washington, D.C., October 2001).

39. See C. Nottenburg, P. G. Pardey, and B. W. Wright, "Accessing Other People's Technology for Non-profit Research," *Australian Journal of Agricultural and Resource Economics* 48, no. 3 (2002): 389–416.