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Easing Barriers to Movement of Plant Varieties for Agricultural Development

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Jitendra Srivastava

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Abbreviations

ADB	Asian Development Bank
CIAT	Centro Internacional de Agricultura Tropical
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
IARC	international agricultural research centers
NARS	national agricultural research system
OPV	open pollinated variety
PVP	plant variety protection
SOE	state owned enterprises
TEBD	Seed Industry Association
t/ha	tons per hectare
TIGEM	Agricultural State Enterprises
TZDK	Agricultural Supply Organization
WB	World Bank

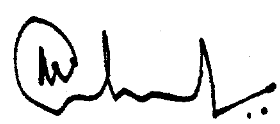
Foreword

The papers in this document come out of an international workshop on seed policies held at the World Bank in June 1995. Papers and discussions at the workshop—with prominent participation by representatives from private seed companies and developing country governments—have strong implications for Bank advice on seeds and agricultural technology transfer. Recommendations from the workshop ask donors and governments to work together to revise regulatory and policy obstacles to private technology transfer in agriculture, including especially obstacles to variety introductions.

Good policies would allow private companies of all sizes to assist with technology transfer and seed distribution to promote higher yields and crop diversification. Although government research agencies in many countries have had a major impact on farm-level technology, particularly for major crops, maintaining an adequate flow of new technology stretches the resources of even the most successful government research agencies in the largest developing countries. Even when government research is effective and well-funded, improving farmer access to private varieties can boost farm productivity and incomes. In particular, success with many minor crops, including high value horticultural crops such as fruit trees, vegetables, and flowers, is severely constrained, if not impossible, without the active participation of private seed companies to deliver the latest world-class technology.

Deregulation will be particularly important for smaller and poorer developing countries, such as in Africa and Central America. In these countries most technology must come from outside, but markets are too small to persuade companies to invest the time and money necessary to overcome regulatory barriers.

Similarly, for countries in East and Central Europe, reducing controls on variety transfer can facilitate integration of their technically advanced but isolated seed industries into the international seed industry.



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Abstract

Private seed trade can be an important channel to deliver new agricultural technology —especially new varieties — to farmers in developing countries. However, many developing countries enforce seed regulations and other policies that obstruct private companies from operating and delivering new technology. The World Bank organized an international workshop in 1995 to review seed policies and to develop recommendations to ease barriers to variety introductions into developing countries. This volume presents recommendations and selected papers from the workshop.

Papers and discussions at the workshop identified reforms to speed the flow of private seed technology into developing countries. Key recommendations advise governments to: (a) work more with the private seed industry; (b) allow private companies to introduce new varieties without prior government approval (voluntary variety registration); (c) make seed certification optional rather than compulsory; (d) give private companies access to public varieties and breeding lines; (e) establish legal processes for companies to register ownership of varieties; and (f) focus phytosanitary controls on realistic pest and disease threats, and remove other nontariff barriers on seed imports.

Foreign varieties are available for international borrowing when governments allow. Even with pervasive government limits on private variety introductions, a large share of improved varieties released in developing countries comes directly from foreign crosses, and most of the rest depends at least in part on foreign parents. Papers at the workshop demonstrate that roughly half of the wheat and a quarter of the rice varieties which government research agencies have approved and released in developing countries have come directly from foreign crosses by IRRI, CIMMYT, and other governments. Private companies similarly locate breeding in selected countries, distributing lines to other countries for testing and introduction (depending on market opportunities). Papers at the workshop describe private company strategies for maize and cotton.

Although many developing governments severely limit private seed company activities, policies are not uniform. From the early 1980s, an increasing number of developing countries have been allowing private seed companies to introduce new varieties and otherwise contribute to agricultural development. Papers at the workshop described seed policies, reforms, and impacts in India, Turkey, Peru, and Bangladesh.

1

Workshop Overview and Recommendations

David Gisselquist

The purpose of this volume is to discuss regulations governing the trade of plant varieties and to recommend steps governments could take to facilitate the movement of new plant varieties to farmers in developing countries.

Recommendations are based on papers presented and discussed at the workshop, *Easing Barriers to Movement of Plant Varieties for Agricultural Development.* The workshop, sponsored by the World Bank, brought together representatives from private seed companies, governments, and donor organizations, along with consultant and university agricultural experts.[1] Participants from private companies played a large part in workshop deliberations, challenging others to recognize difficulties in existing seed policies. Sections 2 through 4 of this volume present selected papers from the workshop dealing with regulations and recommended reforms, international sources for new seed technology, and country experiences with reform.

Seed policy reforms proposed in this volume are particularly important for Africa, a continent of relatively small countries, each of which has limited funds for public research and also small seed markets that, taken alone, are

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of limited interest to private companies. Recommendations from the workshop, as outlined in this document, challenge African governments to open borders to new varieties, giving farmers immediate access to regional technology, and also creating larger regional markets that will attract private domestic and foreign companies to enter and compete.

Policy obstacles and recommendations for reform

Workshop participants described policy obstacles to movement of plant varieties — and especially movement through private seed companies — and recommended regulatory reforms (see papers in Section 2). This sub-section summarizes the obstacles and recommendations and organizes them into eight general topics (see also table 1.1).

Lack of government contacts with private seed industry

The private international seed industry offers research, market access, policy advice, and training through multiple channels, including private seed companies and also national and international seed industry associations. The industry works with multinational organizations such as the OECD Seed Schemes and International Seed Trade Federation to manage seed trade and other aspects of the private seed industry. The private seed industries in developing countries, however, are often small, isolated from the international industry, and absent from domestic seed policy deliberations.

Recommendation 1: To foster stronger private seed industries in developing countries, governments are encouraged to establish formal contacts with their own private domestic seed industries, to bring domestic and international seed companies into seed policy discussions, and to join supporting international seed organizations (see papers by Condon and Poey in Section 2).

Compulsory variety registration

Governments of many developing countries strictly regulate introduction of new varieties, banning sale of seeds until some government agency has tested performance of the variety (often for two to six or more years) and a government committee reporting to the minister of agriculture has approved the variety. Performance tests address the question of whether or not the candidate new variety has value for farmers in cultivation and use. Performance or VCU tests often compare the candidate variety in side-by-side field trials with standard or check varieties.

Governments that control the introduction of new varieties maintain lists of allowed varieties, adding to these lists as they approve new varieties. Many governments use variety controls to block (or delay) entry of private varieties, approving only varieties coming out of public sector research programs. Often, lists of approved varieties are short and filled with relatively old varieties. In Ghana, for example, the National Seed Committee as of 1985 allowed only five improved varieties for maize, none for cassava, and two for sorghum; in Malawi, the 1991 seed list allows eleven varieties for maize (only one of which is from a private breeding program), four for soybean, and one each for sorghum and pearl millet. Typically, many listed varieties are of interest to farmers, and on the other hand popular or potentially popular improved varieties have been left off the list (for example, pajam rice in Bangladesh or magoye soybeans in Malawi). For unlisted varieties, farmer access to seed is limited to smuggling or to informal farmer-to-farmer trade.

Even when governments manage systems of compulsory variety registration so as to allow private companies to enter the market, costs to register new varieties (fees, time, etc) limit the number of varieties that companies introduce. When this happens, farmers suffer. Companies are not able to introduce their best varieties for each agro-ecological zone (for example, Ethiopian highland, lowland, and rift valley

Table 1.1 Regulatory barriers and recommended reforms

Obstacle	*Recommended government reforms*
Lack of input from private sector into government policies	To improve seed policies, • establish formal contacts with national seed industry associations • bring national and international seed companies into seed policy discussions • join supporting official multinational organizations dealing with seeds, such as the OECD Seed Schemes and the International Seed Trade Federation
Compulsory variety registration	To encourage research and variety introductions by private companies, NGOs, and autonomous public organizations (for example, universities): • make variety registration voluntary; in other words, allow companies to sell seed of varieties that government has not tested and approved If there is too much opposition to end compulsory variety registration, then: • limit compulsory variety registration to a few major crops, leaving other crops with voluntary registration; and/or • make registration automatic for varieties that are already registered in a list of other countries
Compulsory seed certification and other quality controls	To favor quality seed and competitive markets: • offer seed certification, but make it voluntary • enforce truth-in-labelling; mandate what companies must put on labels, then prosecute if contents do not match labels
Lack of private access to public germplasm and breeders' seeds, including materials from IARCs	To encourage private research and to speed delivery of public research results to farmers: • allow anyone (companies, NGOs, etc.) to get IARC lines and other genetic materials direct from IARCs; and instruct public research agencies to pass them on at cost • establish policies for public research agencies to sell germplasm and seeds from own research at cost or for a profit
Inadequate protection for intellectual property rights in seed technology	To encourage variety transfer and research: • allow companies to sell hybrid seeds without giving the government samples of valuable parent lines (that is, allow companies to maintain physical control of parent lines) • adopt legislation allowing companies to register ownership of varieties
Unreasonable phytosanitary rules and other non-tariff barriers on seed imports and exports	To facilitate safe international seed trade: • work with multinational organizations and the private seed industry to standardize phytosanitary seed tests and to arrange transparent procedures to resolve disputes • do away with all other non-tariff barriers on seed imports and exports
Over-centralized administration of regulations	*To favor expansion and development of the informal seed sector:* • deregulate as above, particularly doing away with compulsory variety registration and compulsory seed certification • as far as possible, decentralize administration of remaining regulations to sub-national governments or local offices of central agencies
Fragmented regional markets: small countries with excessively nationalistic seed systems	To encourage expanded flows of new public and private varieties into regional markets: • do away with compulsory variety registration • remove non-tariff barriers on seed imports (except those that address phytosanitary concerns) • cooperate to study regional seed-borne pests and diseases

zones) or market niche (for example, for food or feed, early or late maturing, etc). Instead, companies choose varieties that are good in some markets and satisfactory in others. Similarly, compulsory registration makes it more expensive for companies to replace older varieties with newer and better ones. Finally, farmers do not always want the best variety. Depending on many factors, such as seed cost or availability of fertilizers, farmers may prefer varieties that would not pass official performance tests.

Most — but not all — of the participants at the workshop criticized performance tests and compulsory variety registration as costly and unnecessary and recommended alternate proven arrangements for managing the introduction of new varieties. The following paragraphs present the overall sense of the workshop in favor of doing away with variety controls; minority arguments in favor of variety controls are considered at the end of this Section.

Seed company representatives taking part in the workshop described extensive company tests of new varieties before bringing seeds to market (see paper by Ansaldo and Riley in Section 3). Companies judge seed quality on the basis of data from hundreds or thousands of plots, including demonstrations and market trials to determine performance in farmers' fields and farmer interest. Official trials, however, are often too limited in number and too poor in quality to support good decisions (see papers by Gaedelmann in Section 2 and Ansaldo and Riley in Section 3). In addition, official trials divert public and private resources from other activities, such as research and technology dissemination.

Workshop participants described alternate seed regulatory practices in various countries, providing a backdrop against which to consider compulsory variety controls in many developing countries. Jim Elgin, of the United States Department of Agriculture (USDA), described and contrasted US and EU (European Union) seed regulations (see Elgin in Section 2). In the United States, companies sell seeds of new varieties without registering them in any way and also without government tests and approvals. Registration is available as an option; a company can register a new variety by submitting its own data on the variety to a journal. Seed companies in EU countries must submit seeds of candidate new varieties to one or another EU government for two years of tests. Tests look at performance (VCU tests) and also consider whether or not seeds represent a variety (DUS tests, to see if plants are *distinct* from other varieties, *uniform*, and have *stable* characteristics over several generations).

The EU seed regulatory system is superficially similar to compulsory variety registration as practiced in many developing countries. However, the EU system has an important mitigating feature: Companies can choose to introduce a new variety through any EU government. Once approved by any one government, the variety goes into an EU *Common Catalogue*, and seeds can be sold throughout the EU. For example, seeds of a variety approved in Italy can be sold in Spain or Germany without further tests. Multiple doors to a common list give companies some leverage among governments; if one government is difficult, maybe another will be more reasonable. Also, governments are competing to keep a share of the EU's private seed industry. Finally, the EU *Common Catalogues* provide access to a large multi-country market, so that companies have strong incentives to overcome regulatory barriers.

Thus, although EU variety controls delay introduction of new varieties for several years, their impact is not at all as stultifying as single-country variety controls in small and poor developing countries such as Malawi, Angola, Madagascar, or Ghana. Even supposing that tests and decisions are reasonable and unbiased — which has often not been the case — registration procedures block entry for all varieties for which registration costs exceed expected profits from seed sale. In small and poor countries, companies may be willing to deal with the expense and bother of VCU tests and registration procedures to introduce new hybrids for major crops such as maize, but not for self- or open-pollinated varieties (OPVs) of minor crops, *with their relatively much smaller* potential seed revenues.

Other papers at the workshop made it clear that voluntary variety registration is practiced by a significant portion of the developing world; the pattern is not limited to the United States. In 1990, Bangladesh did away with compulsory variety registration for all but five crops (see paper by Gisselquist in Section 4). Agrawal (see Section 4) reports that for many years the Indian government has not required variety registration for seed sale.[2] In countries with this pattern, seed laws often recognize a class of "quality declared" commercial seed, for which governments ask that companies label seeds accurately, but do not require prior government tests of varieties or seed quality.

Recommendation 2: Governments are encouraged to make variety registration voluntary, allowing companies to sell seeds of new varieties on the basis of company decisions alone (see the first four papers in Section 2). Official performance tests could continue on a strictly voluntary basis, and governments could maintain lists of recommended varieties as a source of information for farmers and for the seed industry, though companies would be allowed to sell seed of varieties that are neither tested nor listed.

As second best solutions, governments could:

- limit compulsory variety registration to one or two crops that are important for food security or the economy, leaving companies free to introduce varieties for all other crops without government interference (see paper by Gisselquist in Section 4 describing seed regulatory reforms in Bangladesh);

or

- go to multi-country variety lists; any government acting on its own could do this by announcing that it will automatically accept varieties registered in a specified list of other countries.

During the 1990s, governments of many developing countries have been reviewing and revising seed regulations. Whether or not to make variety registration compulsory has been one of the issues on the table. For example, the Southern African Development Community (SADC) and the Commonwealth Secretariat organized a 1994 workshop on SADC seed policy in Harare, Zimbabwe. Acting on the basis of an expert report that did not discuss the option of voluntary variety registration (Dixit and Swarup 1993), the workshop endorsed compulsory variety registration and national variety lists for all SADC countries (Commonwealth Secretariat and SADC 1994, p 11). This unfortunate position was somewhat mitigated by another workshop recommendation that "laws should provide reciprocal recognition of varieties amongst countries since this would facilitate regional seed trade" (Commonwealth Secretariat and SADC 1994, p 2). As discussed above, the workshop's recommendation for compulsory variety registration with a multi-country SADC variety list is a second-best solution. Taken together, all eleven SADC countries (Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe) have a population of only 140 million.

During the 1990s, advances in bio-engineering led to development of transgenic varieties (plants modified to include genes from other species) for commercially significant crops, including maize and cotton. Bio-engineered varieties offer valuable advantages, such as improved resistance to pests through incorporation of genes that instruct plants to produce biopesticides. But experts raise questions about public health and environmental impacts of bio-engineered crops — for example, widespread planting of cotton with the gene to produce Bt toxins could induce resistance to Bt (a useful biopesticide) in pest populations. Also, transgenic genes could escape into wild populations when crops are planted in their Vavilovian centers.

The workshop did not develop any specific recommendations for regulating introduction of transgenic varieties. Since transgenic varieties are so new, there is no consensus on public health and environmental risks. Currently, OECD countries regulate transgenic varieties more stringently than varieties from conventional breeding. However, regulations in OECD countries are in a state of flux, and can be expected to evolve rapidly over the next decade. Governments of developing countries can generally be encouraged to follow the lead of OECD countries to design regulations and to approve specific varieties or genes.

Compulsory certification and seed quality tests

Paralleling differences in their approach to variety registration, governments follow different regulatory strategies to promote seed quality. Elgin describes and compares US and EU systems (see Elgin in Section 2). The United States addresses seed quality through truth-in-labelling, allowing companies to set their own quality standards and to carry out their own tests, asking only that companies label seeds with accurate information on variety, germination, purity, inert matter, etc. In the United States, official certification (by state not federal agencies) is voluntary. The EU, however, demands compulsory certification: companies must arrange for government officials to visit all seed production plots to check that seeds are of the correct variety and to test all seeds for quality (germination rate, etc).

In many developing countries, including India and Bangladesh (see papers by Agrawal and Gisselquist in Section 4) certification is voluntary, as in the United States. But many other developing countries follow the EU pattern, making certification compulsory for all commercial seed.

Compulsory certification boosts seed production costs. Also, the expense and paperwork involved in arranging for government officials to visit seed plots and to test seed lots are barriers to entry into the formal seed sector.

At the workshop, endorsements for voluntary certification came from donor staff, a USDA seed expert (see Elgin in Section 2), and private sector participants (see papers by Condon and Poey in Section 2). Venkatesan makes a strong case for voluntary certification (Venkatesan, p 35):

> A seed law which provides for "optional" certification would encourage seed production in the informal sector and would make the certification agency "earn" its honor, rather than having it given to it by a government fiat; if farmers develop confidence in the agency, they might be prepared to pay a higher price for "certified" seed.

Poey (see Section 2) advised that governments "'audit' or confirm that companies maintain adequate quality control," but cautioned that "certification should by no means substitute for each company's own internal quality control measures."

> *Recommendation 3: Governments are encouraged to make official seed certification available but voluntary.* Also, a truth-in-labelling approach allows governments to promote seed quality and to control fraud with minimal interference in competitive private markets (see end of this section.)

Unrealistic phytosanitary rules and other non-tariff trade barriers

Seed imports are important for introducing new varieties and for keeping seed costs down. Often, imports help a company to introduce new varieties to a market; once the size of a market is determined, locally produced seed is normally cheaper and replaces imported seed. Even so, companies can have difficulty managing annual fluctuations in seed production and demand, leading to unmet demand or large inventories that are expensive to carry. Occasional seed exports and imports help companies hold down costs and hence seed prices.

Papers and discussions at the workshop criticized unrealistic phytosanitary rules as barriers to seed trade (see papers by Condon, Gaedelmann, and McGee in Section 2). To address the risk that imported seeds may introduce new pests and diseases, virtually all governments set detailed crop-by-crop rules about how imported seeds are to be treated, from which regions or countries seed imports are not allowed, etc. While there is no debate about the principle of phytosanitary controls, experts argue that many specific existing rules do not address realistic threats, but are rather an excuse to block seed imports. Also, current rules often overlook real threats.

Recommendation 4: To facilitate safe seed trade, governments are encouraged: (a) to focus phytosanitary systems on realistic pest and disease threats; and (b) to work with international organizations and private seed trade associations to establish transparent procedures to appeal and arbitrate disagreements about seed rules and decisions.

Many governments protect domestic seed industries with systems of import permits that require importers to get prior approval from ministries of agriculture for each order. Tariffs on seeds, however, are characteristically low and are seldom a significant trade barrier. The more actions taken to protect domestic seed industries, the less competitive the seed industries tend to become, and this effect is greater for smaller countries. With protected seed industries, farmers get lower seed value for cost.

Recommendation 5: To favor competitive domestic seed industries, governments are encouraged to do away with other non-tariff barriers on seed trade (that is, barriers that have nothing to do with phytosanitary concerns).

Even without any policy interference to protect domestic seed industries, seed import costs heavily favor in-country production in most circumstances. For example, even with liberal seed import regimes, imports into Thailand and Chile supplied only about 1 to 3 percent of planted seed in the mid-1980s (FAO 1987, p 307; Pray 1990, p 195). Nevertheless, in some circumstances a case can be made for modest tariffs to protect domestic seed production for major crops. For example, with devaluations, inflation, and price interventions in fertilizer and maize markets, relative maize seed prices in Malawi, Zambia, and Zimbabwe in the mid-1990s diverged widely and fluctuated rapidly. In such circumstances, unrestricted and untaxed seed imports could devastate seed production in one or several countries, undermining stable domestic supply of seed for major food crops. Currently, Malawi and Zambia limit seed imports with non-tariff barriers; in general, tariffs would be preferable.

Weak intellectual property rights

Participants at the workshop argued that weak protection of intellectual property rights in many developing countries inhibits private sector introduction of new varieties. Depending on the crop and country, seed companies have a number of options to protect intellectual property rights in seed technology (see Gaedelmann in Section 2).

For crops such as maize and sunflower, companies can package breeding advances into hybrid seed, which is produced from two or more parent lines and which will not produce equivalent seed in the next generation. With hybrids, companies have biological protection (through physical control of parent lines), which can be reinforced with legal protection in a number of ways (for example, as trade secrets, through contracts with seed growers, or by registering variety ownership through PVP or patent law), depending on what laws are available in a country.

For other crops such as potatoes and cotton, for which breeding advances are packaged into non-hybrid seed (which anyone can use to produce more seed of the same variety), companies have no alternative to legal protection through PVP or patent laws. If these are not available, a company is not able to block other companies from multiplying seed for sale.

Two recommendations come out of workshop discussions on intellectual property rights:

> *Recommendation 6: Governments are encouraged to stop requiring companies to submit samples of hybrid parent lines before allowing seed sale (for example, as conditions for variety registration, seed certification, etc).* These demands undermine biological protection for hybrids. Companies fear that governments will make valuable parent lines available to breeders in government agencies or other companies. In recent years, these demands have blocked private companies from introducing hybrids into many countries, including China and Zambia.

> *Recommendation 7: Governments are encouraged to adopt PVP laws consistent with the 1978 or 1991 Convention of UPOV (Union for the Protection of New Plant Varieties).* UPOV is an international treaty organization, for which membership requires passage of an acceptable PVP law. PVP laws consistent with either Convention allow a company to register ownership of a variety and then to block other companies from selling seeds of that variety. The 1991 Convention more strictly limits farmer's privilege (the amount of seed a farmer can produce for own use or sale) and close breeding (see Gaedelmann in Section 2).

As part of the latest GATT accords, governments agree to "provide for the protection of plant varieties either by patents or by an effective *sui generis* system or any combination thereof" (Trade Related Intellectual Property Rights [TRIPS] Agreement, part 2, section 5, article 27, para 3[b]). With respect to plant varieties, recommendation 7 asks governments to satisfy their obligations under TRIPS by joining UPOV. Clauses in the TRIPS agreement give developing countries five to ten years to comply.

Lack of private access to public lines

In years past, government research agencies routinely channeled breeders' seed to seed parastatals for seed multiplication and sale. With a trend away from seed parastatals, government research scientists look for new arrangements to multiply seed of new public varieties. For example, the Ministry of Agriculture in Malawi organizes growers to take and multiply seed for sale back to the Ministry, which then offers it to farmers.

Government supervision of seed multiplication, as in Malawi, can be expensive and unnecessary. Instead, governments can demonstrate new varieties and at the same time offer breeder's seed for sale, leaving to farmers and private seed companies the task to multiply and sell. If a variety will not go under such conditions, then arguably it is not interesting to farmers and not worth further promotion.

Public research agencies also have germplasm and lines from research that are not suitable for release as varieties. To support private research and to encourage widest use of these materials, governments can make standard policies to sell them on request and at cost.

However, some public materials may have a high market value. In such cases, exceptions can be made to allow agencies to sell or license them for whatever the market will bear, particularly if materials are expected to go into international trade.

Germplasm and lines from international agricultural research centers (IARCs), such as the International Rice Research Institute (IRRI), are another resource that can support private as well as public research. Donors sponsor IARC research for the benefit of farmers and consumers in developing countries. IARCs freely distribute their germplasm and lines (many of which are suitable for immediate release as varieties without any further breeding) to government research agencies. However, governments of many developing countries claim monopolies on IARC materials, denying access to resident private companies. With monopoly power, public research agencies have delayed and even blocked introduction of new varieties from IARC lines; for example, Turkish scientists blocked introduction of CIMMYT wheat in the 1960s.

Recommendation 8: Government research agencies are encouraged to establish standard arrangements to sell germplasm and breeder's and foundation seeds to private companies. Standardizing commercial arrangements provides a framework for public-private cooperation, supporting in-country private research and expeditiously channeling advances from public sector research into farmers' hands.

Recommendation 9: Governments are encouraged to allow resident private companies free access to IARC germplasm and lines. India, for example, allows resident companies direct access to ICRISAT materials on the same terms as government research agencies.

Over-centralized administration of seed regulations

In many developing countries, the formal commercial sector, public and private together, provides less than 10 percent of planted seed, while the informal sector, including farmer saved seed and farmer-to-farmer sales, accounts for most planted seed. The large size of the informal seed sector is a symptom of dualism in the economy in general and for seeds in particular. Governments can break down this dualism by making it easier for informal seed producers to establish links with government agencies and to move into the formal sector.

Informal seed producers are often skilled and respected medium- or large-scale farmers. If regulations and government agencies allow, many of these informal producers will expand operations and join the formal private seed industry. Some regulatory obstacles are common to all sectors (for example, requirement to register as a company, which entails paying VAT or other taxes). In the seeds sector, any number of regulations, such as compulsory seed certification, can serve to reinforce dualism. Some of these regulatory obstacles can be simply removed (for example, seed certification can be made voluntary), while others cannot. This leaves governments with a problem: how to lower barriers so that a significant share of informal seed producers can grow into formal seed companies?

Decentralization seems to be part of the solution: Peru's recent strategy to work with private seed companies through committees at department level (a level of sub-national government equivalent to provinces or states) facilitated the emergence of more than 150 small seed companies in the early 1990s (see paper by Cortes in Section 4). In India and Turkey (see papers by Agrawal and by Gisselquist and Pray, respectively, in Section 4), sub-national governments have responsibility for important aspects of seed regulation as well; in both countries, private seed industries include large numbers of local companies.

Recommendation 10: To enable informal seed producers to graduate into the formal seed sector, governments are encouraged: (a) to cut seed regulations; and (b) as far as possible to decentralize administration of remaining regulations to states or other sub-national governments that are more accessible to small seed producers.

Small countries, fragmented markets

Private seed companies balance expected profits against costs when considering whether or not to enter a market or to introduce a new variety. For smaller and poorer countries, potential profits are relatively small, so that even very modest regulatory barriers may completely block private companies from entering or introducing new varieties, particularly self- and open-pollinated varieties of minor crops. For example, private seed companies in India, with a population of 900 million, have relatively strong incentives to introduce new varieties because the market is so large. In contrast, seed markets in Malawi and Zambia, with populations of roughly 10 million each, are only about one percent as large as in India; hence, incentives for private companies to enter and to introduce new varieties are relatively low. Throughout sub-Saharan Africa, only a small minority of countries has more than 15 million people, and only one exceeds 100 million.

One strategy for relatively small countries in Africa (and also Central America) to improve farmer access to new varieties is to create regional markets for seed technology, whose size would attract private companies. Similarly, creating regional markets would give farmers unimpeded access to varieties from public breeding in multiple regional countries.

> *Recommendation 11: African governments are encouraged to create regional markets for seed technology by: (a) doing away with compulsory variety registration and consequent single-country lists of allowed varieties; (b) moving towards regional PVP registration; (c) cooperating to study regional seedborne pests and diseases; and (d) doing away with non-tariff barriers (except reasonable phytosanitary controls) on regional seed trade.*

International flows of new seed technology

Farmers in industrial countries have access to a steady and large flow of new varieties for all major and minor crops, including vegetables, and fruits. In 1993 alone, the OECD's *List of Cultivars Eligible for Certification* added more than 400 new varieties for maize and more than 100 each for sugar beet, wheat, and sunflower (this list may not be complete, since US law allows companies to sell seeds of varieties which are not listed).

Corresponding to this steady flow of new varieties, older ones fall out of favor. In industrial countries, the expected market life for a new variety is less than ten years. Steady advances in breeding achieve yearly increases in yields and other improvements so that even very successful varieties soon lose their market appeal as even better ones come available.

Thinking of the supply of new varieties as a flow rather than single varieties has implications for agricultural development strategy. For a developing country, the challenge is not to introduce particular new technologies—such as a handful of improved varieties for a few major crops—but rather to improve farmer access to the flow of new seed technology from laboratories and research plots throughout the world.

Certainly, only a portion of the world's flow of new varieties is relevant for any particular developing country, depending on environment and other considerations. However, with the expansion of public and private sector breeding programs in low latitudes over the last several decades, the share of world seed technology suitable for developing countries has increased over time. For wheat and rice, direct international variety transfers have accounted for a large share of improved varieties introduced into developing countries (see papers by Maredia, Ward and Byerlee and by Evenson and Gollin in Section 3). For hybrid maize and cotton, private companies have varieties suitable for many ecological zones and market preferences, such as white maize for sub-tropical regions of Africa (see papers by Ansaldo and Riley and by Pallin in Section 3). More than 40 percent of Pioneer Hi-Bred's maize research locations are in developing countries, at low latitudes that facilitate breeding for other developing countries. Depending on market size, companies will also breed for specific country or regional markets if the company's existing varieties are not satisfactory.

The potential contribution of foreign varieties depends in part on a country's size. Small countries share ecological zones with neighbors, have small seed markets, and small government research budgets. If farmers in small countries such as Malawi are to gain access to an equivalent flow of new varieties as available to farmers in larger and more populous countries such as Brazil, Mexico, the United States, or India, then international variety transfer will necessarily supply most of those varieties.

Country experiences with reform

Over the past fifty years, developing countries have practiced a range of seed regulatory regimes, with some such as Thailand more open all along and others such as Ghana consistently closed. Also, in some countries, such as Chile and Mexico, regulatory reforms have moved countries from closed to open policies. This range of experience provides information about the impact of regulatory systems and other conditions on seed industries and agricultural development.

Papers presented and distributed at the workshop described regulatory reforms and their impact in India, Turkey, Peru, and Bangladesh.

India

India for many years pursued self-sufficiency and socialism, discouraging seed imports and foreign companies while promoting public sector seed production and trade. In many other developing countries, similar policies left farmers with a short and often poor selection of varieties. In India, however, several mitigating factors limited the damage to farmers. First, variety registration has been voluntary, so that no single committee or agency has had authority to decide which varieties can be introduced (except that a Cotton Control Act empowers government to decide which cotton varieties can be grown, but that Act is not enforced [World Bank 1997b, vol 2, annex 2, p4]). Second, agriculture is a state subject, so that autonomous state research organizations are able to make their own decisions about breeding and variety release. Third, seed certification has been voluntary, which lowers barriers to entry and seed production costs for private companies. And finally, India is a large country, with a population greater than all of Africa or Latin America.

Even before regulatory reforms from the end of the 1980s, Indian farmers had access to seeds of several thousand varieties for major and minor crops from thousands of breeders in federal and state agricultural research organizations and universities, and there was a large and competitive domestic private seed industry as well. Compared to current systems in most African countries, the Indian seed system even before reform was far superior. Even though most breeding was in the public sector, it was competitive rather than centrally controlled. Varieties could follow market demand from one state to another. Private companies could introduce new varieties—from other states or countries or from own research—without having to seek government approval, and they could sell seeds across state borders. In contrast, in much of Africa, governments control variety introductions and discourage cross-border trade, limiting farmers to public sector varieties bred and released in single countries, most of which are smaller than an average Indian state.

India's long experience with voluntary variety registration and seed certification provides solid evidence that even in poor countries farmers do not suffer when governments allow farmers and markets—rather than government regulators—to assess variety performance and seed quality. A 1997 World Bank report prepared with FAO assistance states that for India (World Bank 1997a, p 16):

> . . . voluntary certification of notified varieties (ie, those released officially through the variety release system) and

> truthful labeling of hybrids and other seed produced by the private sector (ie, voluntary variety registration and seed certification) provides adequate protection to consumers without unduly inhibiting producers. This system should be retained.

India's primary seed and economic reforms from the late 1980s included: improved private company access to varieties from public breeding (through sale of breeders' seed); reduced entry barriers for foreign vegetable varieties (through seed imports); and reduced entry barriers for foreign seed companies. With these new policies, private companies have improved the menu of varieties available to Indian farmers, introducing foreign varieties as well as new varieties from expanded in-country research. From 1988 to 1995, the cumulative number of varieties released by private companies from in-country research more than doubled to about 300.

Turkey

Prior to 1980, Turkey similarly favored self-sufficiency and socialism in the seed industry. Government parastatals dominated seed production and trade. However, the situation was more closed than in India; government research was centrally controlled, and variety registration and seed certification were compulsory. With all these restraints, farmers had access to few interesting varieties for many crops, and private commercial seed production was extremely limited.

Entering the 1980s, widespread smuggling of vegetable seeds and government inability to popularize hybrid maize demonstrated the failure of existing policies to give farmers access to advanced technology. Also, millions of Turks had travelled to Western Europe and had seen how things work in industrial market economies. Although general macroeconomic reforms from 1980 had liberalized trade and investment, special regulations continued to block private seed production and trade.

Officials in Turkey's Ministry of Agriculture pushed through seed regulatory reforms in the early 1980s. In designing seed reforms, government officials sought advice from private companies as well as the International Finance Corporation (which sub-contracted advice to the Industry Council for Development). Turkey removed seed price controls, encouraged foreign seed companies to enter, and modified but did not abandon compulsory variety registration (that is, the government allowed companies to do their own variety trials, cut testing to two years, approved most varieties submitted for registration, and expanded use of "production permits" to allow companies to sell seeds of unregistered varieties).

With reforms, the number of improved varieties available to farmers increased dramatically — for example, from 1982 to 1987 the number of improved varieties for sunflower increased from three to thirty, and for soybeans from two to more than forty. From the early 1980s, private companies have introduced most new varieties, most of which have been direct transfers from foreign countries. Turkey shares latitudes with many industrial countries, and has been able to source new varieties from the United States and European countries as well as from Mexico and other countries at lower latitudes.

From the early 1980s, the private seed industry increased from a very few firms focusing on vegetables to approximately eighty a decade later. Most major multinationals have a presence through joint ventures and licensing, although there are also a few subsidiaries. As of the mid-1990s, private companies dominate commercial seed sales for maize, sunflower, potatoes, soybeans, and vegetables, while parastatals dominate seeds for wheat, barley, and cotton. Sugarbeet seed is dominated by a joint venture.

It is difficult to measure the impact of Turkey's 1980s regulatory reforms from aggregate data on crop agriculture, since many other factors such as changes in macroeconomic policies get in the way. However, it is possible to see impact of reforms on specific crops. Regressions in the paper by Gisselquist and Pray in Section 4 show a roughly $100 million increase in annual net farm income from maize due to seed reforms. Other estimates show smaller increases in income from vegetable and seed exports due to seed reforms.

The paper also considers possible costs or losses to the domestic seed industry and to farmers due to seed reforms. Despite entry of multinationals, domestic seed companies have increased seed production and sales. Increases in seed exports suggest that Turkey's seed industry has been able to compete in international markets as well. Finally, evidence suggests that farmer losses from inappropriate varieties have been lower with post-reform private seed trade than with pre-reform public seed trade, and seed quality has not been a problem.

Peru

Toward the end of the 1980s, Peru took several steps to shift seed production from the public sector to a competitive private sector: specifically, it eliminated two seed production parastatals and created public-private committees in multiple departments (a division of the country equivalent to state or province) to assist development of private seed enterprises.

Reforms at the end of the 1980s facilitated the emergence of more than 150 new seed producers through the mid-1990s. Regional seed committees arrange (voluntary) seed certification and in some cases have seed drying and processing equipment available for seed producers to use. These regional seed committees have been accessible to even very small seed producers, lowering barriers to entry into the formal sector. A large majority of new seed companies have less than ten hectares in seeds (see table 4.12).

Bangladesh

Through the 1980s, Bangladesh enforced compulsory variety registration, maintaining lists of allowed varieties for all crops, including vegetables and tree crops. For major and minor field crops, lists consisted almost entirely of varieties released by public sector research institutes; for vegetables, variety lists protected monopolies and oligopolies for private companies having sole agent contracts with foreign seed companies.

Toward the end of the 1980s, renewed interest in crop diversification—along with general interest in privatization and liberalization—stimulated the Ministry of Agriculture to re-examine seed policies to see what could be done to speed entry of new varieties through private seed companies. This review led to a Ministry of Agriculture seed policy paper that recommended seed trade liberalization to give farmers in Bangladesh access to the best varieties available in world markets. Acting on internal recommendations, the Ministry of Agriculture used its authority under existing seed legislation to issue orders ending controls on varieties allowed for import and trade.

The Ministry exempted five crops from these reforms, maintaining compulsory variety registration for rice, wheat, jute, sugarcane, and potatoes. Some experts defended variety controls for these major crops with the argument that a poor or disease-susceptible variety could have wide impact on production. This logic is not entirely convincing, because poor varieties would be unlikely to gain popularity. The government has mechanisms other than compulsory variety registration to limit area planted to varieties with severe disease susceptibility (for example, extension advice or even short lists of varieties not allowed). Probably the real reason for continuing variety controls for only five crops was that these were of most interest to public sector scientists, and reformers felt the need to defuse opposition from that quarter.

Since the early 1990s, private companies and several non-governmental organizations (NGOs) have been testing and introducing new varieties for sunflower, maize, other field crops, and vegetables. Companies have also lobbied for relaxing variety constraints on potato imports.

In several respects, 1990 seed reforms in Bangladesh can serve as a model for reforms in other developing countries. First, the Ministry of Agriculture introduced reforms through internal Ministry orders, with authority from existing seed legislation. Standard seed legislation in many countries gives ministries of agriculture authority to control seed imports, to notify or otherwise list crops for which compulsory variety registration is necessary, and to exercise judgement and authority in other areas of seed regulation. Introducing change through ministerial orders is easier and quicker than trying to design and draft new seed legislation. Amendments or even new seed laws may be called for in some cases (for example, to introduce plant variety protection), but these take time.

Second, reforms emphasized seed trade liberalization rather than privatization, removing barriers to private seed import and variety introduction, but leaving contentious debates about parastatal seed production to be decided over time. With the emphasis on liberalization, farmers gain improved access to seeds and varieties through private sector channels without losing access to seeds through public channels. Virtually the only opposition to 1990 seed reforms in Bangladesh came from public sector scientists. Seed trade liberalization allows private companies to enter and expand; over time expansion of the private seed industry can be expected to change the character of the debate about parastatal seed production. Further, leading with seed trade liberalization rather than privatization does not threaten the stability of (public sector) seed supply for major crops.

Reservations about regulatory reform

During the workshop, participants discussed reservations or questions as potential obstacles to reform:

- *Are appropriate varieties available?* Some experts argue that seed regulatory reform is not worth worrying about since varieties must be locally bred for climates, tastes, and other specific conditions in each country.

- *Will farmers lose from poor varieties and seeds?* Some experts argue that farmers in developing countries will lose if governments relax compulsory variety registration and compulsory seed certification; although markets can regulate seed quality in developed countries, conditions are different in developing countries, so that more stringent regulatory measures are appropriate.

- *Will technology transfer damage in-country research?* Many government scientists worry that government financial support for public research will fall if private seed companies are allowed to introduce new varieties for major crops.

Are appropriate varieties available?

After WWII, the insight that breeding for low latitudes and other specific conditions was necessary to generate varieties suitable for developing countries led to establishment of the International Rice Research Institute (IRRI) and other international agricultural research centers (IARCs) as well as donor support for national agricultural research systems (NARS).

Despite the substantial number of public as well as private breeding programs for low latitudes that have been established over the past forty years, some experts continue to argue that climate, diseases, tastes, and other factors inhibit transfer of varieties among developing countries so much that regulatory reform would have little or no impact. Papers in Sections 3 and 4 confront this argument, demonstrating that varieties are available and do move when regulations allow.

Several workshop participants argued that whether or not varieties move, a case for regulatory reform can be built on the premise that reform does no harm. However, that approach may not be sufficient to change policy; unless one can make a case that private introductions of new foreign varieties (or varieties from private research in-country) will follow regulatory reform, inertia may be easier. Donors might not be interested to push reform if experts thought it would have no impact.

For a developing country, the potential impact of foreign varieties coming in through direct transfer (with in-country screening, but without further crosses) depends on many factors, including size of country, quality of in-country breeding programs, quality of foreign research in comparable latitudes, and other circumstances. Measures of agro-ecological distance (see Maredia, Ward and Byerlee in Section 3) compare average performance of local vs foreign varieties; however, it is not the average that is transferred, but rather the individual.

A farmer wants the best variety for a particular field and cropping pattern. The chance that public sector in-country research supplies that variety decreases for smaller countries, minor crops, and less effective public research systems. Turning the question around, what is the chance that a new variety will exhaust its market potential within one country? That will similarly depend on the size of the country, the share of cultivated area planted to the crop, and the extent and quality of research in countries with comparable environments.

Further studies on variety movement might look at share of new varieties borrowed vs bred in-country for major and minor field crops and vegetables, based on planted area, size of country, etc. Data on source of varieties (domestic vs foreign) for developing countries that regulate variety movement could be compared with similar data on source of varieties for countries in the EU and states in the United States or India, where seed laws allow varieties and seeds to move freely across country or state boundaries. Vegetable seed companies which distribute international seed catalogues might be willing to share data on international markets for individual varieties.

Will farmers lose from poor varieties and seed?

Advocates for compulsory variety registration and compulsory seed certification for developing countries argue that companies cannot be trusted to offer good varieties and seed, that they might try to sell bad varieties to recoup breeding costs, and that they may sell bad seed (low germination rate, etc). This was a minority position at the workshop, with most participants favoring markets and alternate regulatory strategies to ensure good varieties and seeds.

Arguments to deregulate seed markets do not turn on whether or not companies are to be trusted. Markets work because farmers will stop buying seed from companies offering poor varieties and poor quality. Also, even without compulsory variety registration and seed certification, governments have other options to reinforce market rejection of poor varieties and poor quality seed (see table 1.2).

The hypothesis that farmers will lose if governments do not directly control variety and seed quality can be tested against experience in developing countries such as India, Bangladesh, Thailand, and many others with voluntary variety registration and seed certification. Such a test has not been done. Instead, advocates for government controls cite selected anecdotes to show that companies sell bad seed. Examined closely, most of these anecdotes can be reinterpreted to show that public agencies buy bad seed. For example, the government of Bangladesh imported low quality maize seed from a Thai company around 1990. That governments often buy bad seed (from private companies as well as from parastatals) demonstrates that they cannot be relied on to make good decisions about variety and quality, and if anything supports arguments against compulsory variety registration and certification.

Furthermore, risks are not all on one side. In evaluating what might happen with seed deregulation, risks of loss from poor varieties and poor quality seeds can be balanced against risks of foregone gains from suppressed new varieties or continued reliance on relatively poor quality farmer-saved and parastatal seed if seed reforms are not implemented.

Finally, arguments that farmers might lose from poor varieties and poor quality seed can

Table 1.2 Government options to limit farmer risks
(Consistent with voluntary variety registration and seed certification)

Risk	*Government options to promote quality seed*
Poor variety	• promote free entry for companies and varieties, to ensure that farmers have choice within a competitive market • advise farmers about variety performance, generally recommending better varieties, but possibly discouraging some (for example, because of disease susceptibility) • continue government breeding
Mis-labelled variety or mixture of varieties	• follow a truth-in-labelling strategy: require companies to name the variety (if it is a registered variety) on the label; if a package is mis-labelled, the government has a legal basis on which to prosecute
Poor germination, presence of weed seeds, other analytic measures of low quality	• follow a truth-in-labelling strategy: require companies to state minimum germination, maximum percent of weed seeds, etc., on the label; if contents do not match the label, the government can prosecute; and/or • set minimum germination rates and other standards for various crops (this is more restrictive than truth-in-labelling)
Seed imports introduce pests and diseases	• enforce phytosanitary rules to block seeds with pests and diseases (note: this allows imports of unregistered varieties and uncertified seed)

be considered against the percent of planted seed coming from the formal private sector. In the poorest countries where markets supposedly work least efficiently (and where opponents of seed regulatory reform argue that farmers face the greatest risk) the percent of planted seed coming through private formal channels seldom exceeds low single digits. In short: losses with deregulation are undocumented and not balanced against losses due to over-regulation; governments have alternate instruments; and risks of farmer loss from seed deregulation are grossly overblown.

Will technology transfer damage in-country research?

This is a general question that applies to industrial as well as agricultural technology. Probably the best answers to date come from research on the impact of India's industrial technology policy on technology transfer. Before late-1980s reforms, India discouraged commercial technology imports in industry, hoping to stimulate in-country research. Other developing countries have followed similar policies.

In a paper distributed at the workshop, Brian Fikkert presents evidence that India's protectionist policies worked poorly: controls on the purchase of foreign technology led to small increases in in-country research but had relatively large negative impacts on company profits. In other words, buying foreign technology is more efficient than trying to duplicate it.

However, the debate over whether or not to buy foreign industrial technology has been less about the benefits of foreign technology than about the terms on which it is introduced. Those opposing commercial transfer (that is, technology purchase) have most often wanted to get the same technology through non-commercial transfer (for example, pirating and education).

In agriculture in developing countries, opposition to private technology transfer has been more general and more persistent than in industry. In many countries, public sector scientists have opposed all private variety introductions, without making distinctions among commercial transfers (varieties acquired through payment of royalties), non-commercial transfers (for example, foreign public varieties acquired free of cost), and introduction of new varieties from private in-country research. Government scientists may be motivated in part by perceived self-interest, fearing that budget cuts for public sector research will come with seed regulatory reforms, as happened in Turkey, Mexico, and Chile. Seed reforms also challenge the status of government scientists as benefactors and protectors of peasant farmers.

With seed regulatory reforms, governments spend less on variety performance tests and compulsory certification programs; hence, there is no inherent reason for reforms to come with budget cuts for public research. With private companies introducing new varieties, returns to public research could increase or decrease; presumably, returns will fall in some areas (for example, maize breeding) and rise in others (for example, research on soil fertility). Competition and communication between public and private researchers could improve management of public research institutions. Nevertheless, public sector agricultural scientists are right to worry about budget cuts because governments may cut research budgets despite evidence of high returns and effective management.

Conclusion

Seed policy is an area in which rapid reform is possible. Some of the most important policy obstacles to variety movement — such as compulsory variety registration for specified crops — take the form of government orders from ministries of agriculture, and these can be removed expeditiously through new orders from the same ministries. However, ministers of agriculture may be reluctant to act on technical matters without support from agricultural experts.

Thus, the challenge for reform involves: raising awareness of current seed policies that damage agricultural development and offering designs for reforms to put matters right. This publication aims to do both.

Introducing regulatory reform through government orders leaves existing seed laws in place. Whether or not these laws are ideal, leaving the task of changing seed laws aside until a competitive private seed industry has emerged and is able to take part in policy debates can often be good strategy. Without the persistent presence of an active and interested private seed industry association, it is doubtful that well-meaning experts will be able to design and push through reasonable, open, and workable seed laws and amendments.

Notes

1. Three divisions of the World Bank — International Trade, Agriculture and Forestry, and Training — provided financial and administrative support.

2. Although the government has allowed the sale of domestically produced seeds without variety registration, other regulations have blocked seed imports and discriminated against foreign seed companies. For example, majority foreign-owned seed companies are required to certify all seed, even seed produced in India; this entails prior variety registration. Reportedly this rule is not consistently enforced. From the late 1980s, India has eased barriers to introduction of new varieties through imported seed.

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2

Regulations and Recommendations for Reform

In many developing countries, seed regulations discourage seed companies from entering markets and doing what they can to introduce new varieties and to deliver seeds to farmers. Some of the same regulations also discourage efforts of NGOs and autonomous public sector organizations, such as universities, to introduce new varieties to farmers.

A number of speakers at the workshop described regulatory barriers and/or proposed reforms. In this Section, the first contribution, by Jim Elgin, describes and compares EU and US seed regulations. The next three papers analyze regulations and offer recommendations for reform from various private sector points of view, including: the American Seed Trade Association, a US foundation seed company with international sales, and private seed companies in developing countries. The fifth paper, by Denis McGee, describes shortcomings and proposes solutions for phytosanitary regulations in developing countries.

Robert Tripp provides a general overview of seed regulations and reforms with special attention to public sector breeding and variety release. To improve seed technology generation and transfer, Jitendra Srivastava proposes policy and regulatory reforms that address "the specific needs of all private players."

Comparing EU and US Seed Regulatory Systems

Jim Elgin

Governments of the EU (European Union) and United States have different seed regulatory systems, as shown in the following table. The US system is more open, favoring competition, lower seed costs, and ease of entry for new seed companies and varieties.

Table 2.1 Comparing EU and US seed regulations

EU (European Union) Seed Regulatory System	*US Seed Regulatory System*
1. Variety registration is mandatory. Companies are not allowed to sell seeds of a variety until the variety has been registered.	1. Variety registration is voluntary. Seeds of all varieties can be sold, whether or not they have been registered. Voluntary registration is available through public description of the variety in a journal.
2. Governments or their agents test new varieties to decide whether or not to register them; that is, whether or not to allow seeds of the variety to be marketed.	2. Companies do their own tests. Each seed merchant decides what to market based on his or her own criteria; the merchant's integrity is at stake. For voluntary registration, variety descriptions are from breeder's own data, without any official review. Subsequent court cases challenging ownership of a variety could lead to review of published data.
3. EU Common Catalogues lists all varieties approved for sale. Catalogues list varieties registered in any one EU country. Seeds of listed varieties are allowed for sale in all EU countries.	3. There is no list of registered or approved varieties, since seeds of all varieties are allowed for sale.
4. Registration establishes legal rights. Every registered variety is owned by a company or other party that pays fees for registering and maintaining registration.	4. Voluntary registration or patents establish legal rights. However, not all varieties are registered or patented. Some seeds are sold of varieties for which there is no owner.
5. Seeds must be certified in order to enter the market.	5. Seed certification or official quality tests are not required for seeds to enter the market. However, all seeds must be labelled with information on species, variety (if known), and seed analysis information (germination, purity, weed seeds, inert matter, etc.)

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Recommendations to Increase the Flow of New Seed Technology to Farmers in Developing Countries

Mark Condon

The seed industry encourages the following reforms to increase rates of introduction and adoption of new seed technology by farmers in the developing world:

1. *Donors and developing country governments should promote integration of emerging or developing seed industries into the international private seed industry, as follows:*

   (a) Developing countries are asked to recognize that each country is one of many potential markets for investment and trade, and that companies choose where to work and to invest. Therefore, from a competitive perspective, developing countries need to evaluate their regulatory systems, investment requirements, comparative advantages in seed breeding and production, and other factors that encourage or discourage attention from the world seed community.

   (b) Developing country governments are encouraged to seek membership in the following international organizations. Membership will often entail restructuring of private seed industries and trade along patterns consistent with the international private seed industry.

   (i) *OECD Seed Schemes, International Seed Testing Association* (ISTA), and *Association of Official Seed Certification Agencies* (AOSCA, a US agency). Joining these groups would encourage seed testing and certification programs that are acceptable to major seed trading countries, which would facilitate seed exports.

   (ii) *International Seed Trade Federation.* Membership entails the adoption of trade rules and arbitration procedures already accepted by fifty four countries, which would facilitate seed trade with those countries. Membership would also provide exposure to seed breeding, producing, and trading organizations in other member countries.

   (iii) *Union for the Protection of New Plant Varieties* (UPOV) and *International Association of Plant Breeders for the Protection of Plant Varieties* (ASSINSEL). Membership in UPOV entails adoption of plant variety protection legislation consistent with UPOV's 1978 or 1991 convention. Membership in ASSINSEL provides a framework for technical and legal consultations to improve intellectual property rights for seed technology.

   (iv) *International Plant Protection Convention* (IPPC) and regional organizations such as *North American Plant Protection Organization* (NAPPO), *European Plant Protection Organization* (EPPO), etc. Membership in IPPC would foster rational and transparent

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phytosanitary standards and procedures, which would facilitate international seed trade. Membership in an existing or new regional phytosanitary organization would further facilitate international seed trade, especially regional trade.

(v) *Food and Agriculture Organization* (FAO). Industrial and developing governments work together through FAO to determine policies on issues related to preservation and distribution of germplasm.

(c) Donors are encouraged to work more closely with private seed trade associations as follows:

(i) Private seed trade associations in industrial countries (for example, ASTA and similar organizations in other industrial countries) are ready to advise and assist in the establishment of national seed trade associations in each developing country; to train government and company staff on technical and regulatory matters; and to advise on national seed legislation and policies.

(ii) International Seed Health Initiative, a joint effort of the American, French, Dutch, Japanese, and Israeli Seed Trade Associations, promotes scientifically-based phytosanitary regulations that enhance seed quality and facilitate trade.

(d) Because of inordinate overhead costs in establishing joint ventures with existing public institutions, foreign private companies often prefer to work directly with smaller private seed companies. *Accordingly, donors and developing country governments should emphasize trade and investment liberalization to facilitate entry of private foreign companies into emerging seed markets.*

2. *Developing country governments should direct effort to establish company registration systems rather than variety registration and compulsory seed certification systems.* Such an approach would streamline new variety introductions and would facilitate private seed sector interactions with farmers to develop products that are appropriate for targeted farming systems, while maintaining accountability to host country governments. Companies that repeatedly distribute products that do not conform to government/international standards on labelling, seed quality, etc, would be subject to registration revocation. National seed trade associations could be consulted in the verification of a company or company's name.

(a) If a company registration system is not feasible for a particular country, then the next preferable scheme would be voluntary variety registration schemes. Information from variety performance/registration trials would be available for advisory purposes only. Governments could maintain a list of recommended varieties. However, the performance trials to determine varieties eligible to be placed on the recommended list must be conducted by an unbiased third party and not by government or public institutions.

(b) Regardless of the scheme that is adopted (for example, company or variety registration), registration fees should be kept at a minimum and registration procedures should be simplified to encourage small and medium-sized companies to enter the seed sector. Participation and involvement across a broad spectrum of small to large companies creates a desirable level of competition and an industry structure that is able to defend free market policies.

(c) If compulsory variety registration continues in force, seeds and crops produced for export should not be subject to these variety restrictions.

(d) Regional registration lists and programs (as in the EU) should be encouraged to the maximum extent possible.

(e) Governments should make private seed companies responsible for accurate labelling and dissemination of information about their products through simple but clear national laws.

3. *For variety development to meet specific country needs, donors and developing country governments should:*

(a) Promote cooperation among public and private research organizations — national agricultural research systems, domestic private seed industry, international private seed industry, and international agricultural research centers — to prioritize national research objectives and to identify comparative advantage in research.

(b) Consult with national seed trade associations in the identification of interested private companies.

(c) Devise arrangements for private companies to work with NARS and IARCs so as to maximize synergy from cooperative research activities.

4. *Governments of developing countries should strengthen intellectual property rights in seed technology, as follows:*

(a) Under no circumstances require companies to deposit samples of in-bred lines with public agencies as a precondition for seed sales. These requirements are sometimes enforced in conjunction with compulsory seed registration and certification systems.

(b) Adopt either the 1978 or 1991 UPOV Convention, which entails passage of national legislation establishing plant variety protection meeting international standards.

5. *Governments of developing countries should adopt liberal policies for seed import and export, as follows:*

(a) Formulate and communicate transparent import and export regulations, especially with regard to phytosanitary requirements; and

(b) As far as possible, abolish all import and export permit systems.

6. *Donors are encouraged to devise viable political risk insurance schemes specifically for seed trade and investment.*

Recommendations for National Private Seed Industry Development

Federico Poey

The development of a strong private seed system is crucial to improve the delivery of good quality seed to farmers. The level of agricultural development and existing seed industry components are unique to each developing country, so that interventions to improve seed systems must be tailor-made. The following issues merit special attention:

1. It is important that the existing or potential private seed sector be properly represented and given a leadership role during early discussions to plan laws, policies, and strategies to strengthen private seed systems.

2. A mechanism to strengthen dialogue with the private sector is through formation of a national seedsmen association with a balanced public-private sector participation. Existing or potential seed producers, distributors, importers, exporters, entrepreneurs, and investors should be included in the private sector participation. Government should recognize the association as representing private interests, and encourage association discussions with government agencies involved in research, production, quality control, marketing, regulation, etc.

3. Government should motivate and assist private R&D by providing ready access to breeding materials from IARCs and NARS. NARS should work hand in hand with local seed companies willing to do their own research to develop another source for hybrids and varieties in addition to multinationals and public sectors, thus contributing to more healthy competition.

4. Public sector institutions can offer seed processing and storage services at cost to emerging private seed companies, which would market seed under their own brand names.

5. Credit and financial assistance should be available for fixed and working capital for emerging seed enterprises, supporting investments in infrastructure and in production and distribution networks. Design of financial services should be adapted to needs of the emerging seed industry.

6. Multinational seed companies should have ready access to participate in national seed system development through convenient interactions with local firms such as joint ventures, licensing, etc.

7. Variety registration and seed certification should be properly designed or adjusted to help the private seed industry, not to hinder it.

   The principle task of official certification is to "audit" or confirm that companies maintain adequate quality control during seed

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production, processing, and storage. Government certification should by no means substitute for each company's own internal quality control measures.

However, official control should not include definition of what varieties are allowed to enter the market. This decision should be taken by individual firms according to their own and available variety performance information and marketing objectives.

In some countries, governments have tied production loans or crop insurance to the use of certified seeds. These arrangements encourage farmers to buy certified commercial seed and can support marketing efforts of private seed companies.

8. A "cottage seed sub-system" should be promoted for small farmers as a mechanism to introduce new varieties and to improve quality of seed for own-use or local sale. Care should be taken to avoid unfair competition with established commercial seed companies. The sub-system is effective in handling seeds of crops that may not be profitable for commercial seed companies, such as beans and vegetatively reproduced crops, and also in supplying seeds to remote areas lacking adequate marketing infrastructure.

Three Main Barriers: Weak Protection for Intellectual Property, Unreasonable Phytosanitary Rules, and Compulsory Variety Registration

Jon Geadelmann

Two types of protection for intellectual property in seed technology are: biological and legal.

Preserving intellectual property

Biological protection is achieved with hybrids; a company is able to maintain ownership of hybrids through physical control of inbred parent lines.

Companies can seek legal protection through various mechanisms:

- *Trade secrets.* In countries with trade secrets laws, companies are able to seek redress from anyone who steals their trade secrets. Companies have to demonstrate that what has been taken was kept as a secret, ie, that the company made an effort to prevent its dissemination.

- *Contracts and licenses.* A company may transfer seeds of a variety (for example, an inbred line for hybrid production) through a contract that restricts what the recipient of the seeds can do with them (eg, use only to produce hybrid seeds, not seeds of the inbred line).

- *Plant variety protection* (PVP). Industrial countries and many developing countries have laws establishing procedures for companies to register ownership of varieties.

- *Patents.* The US allows utility patents for normally bred varieties; the EU does not. Both US and EU allow patents for products of non-traditional plant breeding research, such as for genes from biotechnology research.

For non-hybrids, PVP laws are the primary mechanism to protect intellectual property. Seed companies are concerned to clarify two issues in PVP laws: farmer's privilege and close breeding.

Farmer's privilege

PVP laws vary from country-to-country in allowing farmers to save seed for own use and to sell seed to neighbors. The new US law and a recent Supreme Court decision give US farmers the right to plant saved seed but not to sell saved seed to neighbors; the old US law allowed farmers to sell seed. The EU goes even further, requiring farmers to pay royalty to the owner of the variety on seed saved and planted.

When farmers are allowed to sell seed to neighbors, the breeder of a variety loses return on research investment. This weakens incentive for private research, so that farmers lose in the long run.

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Close breeding

With PVP protection, a company that owns a variety may lose if another company is able to take that variety, breed to develop a very similar but new variety (for example, with different silk color, but otherwise the same), and register ownership of that new variety. Traditional criteria for a new variety require that seeds presented for testing produce plants that are *distinct* from other varieties, *uniform*, and *stable* over time (DUS criteria).

To protect variety owners from loss due to close breeding, the 1991 UPOV Convention introduced the concept of Essentially Derived Variety (EDV), enjoining member governments to adopt PVP laws that do not allow anyone to register ownership of a new variety that is essentially derived from a protected (owned) variety. The measurement of EDV is not yet exactly defined; test cases over time may establish threshold values for EDV.

Other intellectual property issues

The 1992 Convention on Biological Diversity gave attention to claims of some governments for payments from private companies for germplasm taken out of their territory that is used in breeding commercial varieties. Discussions on this issue have continued in FAO. Private companies fear loss of access to germplasm or charges that would interfere with development and marketing of new varieties.

Phytosanitary regulations on seed import

We need phytosanitary rules based on scientific risk assessment. Current rules may be unreasonable and nonscientific, creating unnecessary barriers to seed movement on the one hand, and ignoring some real phytosanitary threats on the other.

Unreasonable phytosanitary rules limiting seed trade may be motivated partly or primarily by protectionist sentiments. For example, the governments of New Zealand and United States limit maize seed imports based on concern about corn smuts, although evidence suggests that these are present in both countries. Japan sometimes refuses maize seed shipments after finding fusarium kernel rot, although the fungus is present in Japan.

But the lack of good phytosanitary barriers inflicts serious losses. For example, the United States has lost from import of Dutch elm disease and European corn borer from Europe. Currently, phytosanitary rules pay insufficient attention to maize streak virus, which is limited to Africa but could spread. Another pest which is limited but could spread is corn lethal necrosis, which is found in parts of Midwest United States.

Compulsory variety registration

Many governments allow seed companies to sell seeds of only those varieties that have passed some sort of government-controlled evaluation of the performance of the variety. Variety performance tests with compulsory variety registration are known as VCU (*value* in *cultivation* and *use*) trials, official trials, etc.

Systems requiring variety registration as a condition for seed sale are not the same as PVP. Variety registration based on variety performance tests do not establish ownership, but rather permission to sell a variety. PVP, on the other hand, can be voluntary and totally unrelated to performance; for PVP, seeds are tested against DUS and EDV criteria as already discussed.

In the basic system for compulsory variety registration, a government agency performs small-plot tests at relatively few locations, comparing new varieties against standard or check varieties. Only those new varieties that exceed standards by some threshold value are permitted to be sold to the farmers. Traits commonly considered include: yield, maturity, resistance to lodging, etc.

Proponents of variety registration argue that government tests protect farmers from poor varieties and also provide useful information to farmers to help them choose among varieties allowed for sale.

However, there are disadvantages and weaknesses in systems with compulsory variety registration:

- small plot official trials often produce a very limited database compared to private company small plot research tests and larger-scale tests;

- small plots do not fully represent the real world, that is, the farmer's field;

- seed source effects are often confounded with genetic performance;

- compulsory variety registration may eliminate lower-performing but much less expensive varieties from the market; and

- compulsory variety registration diverts government and seed company resources from more productive uses.

Summary suggestions

1. Pass laws establishing PVP consistent with the 1991 UPOV Convention, that is, that limit a farmer's right to sell seed to neighbors and that limit close breeding.

2. Develop and maintain reasonable and fair phytosanitary regulations and inspections.

3. Eliminate official trials, or at least eliminate performance thresholds (as a condition for seeds or a variety to be marketed), and use only as a source of information for advice to farmers on choice of variety.

World Phytosanitary System: Problems and Solutions

Denis McGee

Seeds can be efficient means of moving pathogens between geographical regions. There are many documented introductions of pathogens from one country to another by seeds that resulted in economic loss (Neergaard 1977). There is no question that regulations are necessary to protect against the international spread of plant pathogens. International movement of seeds is regulated by a standard phytosanitary certificate, as defined by the International Plant Protection Convention of 1951, which indicates that seeds are substantially free of injurious pests or diseases. It also has a section to deal with specific diseases or pests for which the importing country may require tests. In addition, each country has its own specific requirements regarding type of seeds and pathogens that may be admitted as follows:

- It may totally embargo particular seeds.
- It may require that some seeds be tested after import.
- It may ask that some seeds be treated, for example, with a fungicide.

Information for the phytosanitary certificate is generated and reported by the country exporting the seed. Seed health may be determined either by a field inspection of the growing crop or by a laboratory assay of the seeds harvested from the field.

The current world phytosanitary system has significant problems. This paper will discuss the reasons for and consequences of these problems, and suggest possible solutions.

Problems with the world phytosanitary system

Problems with the world phytosanitary system fall into five categories, as discussed below.

Poor understanding of potential economic losses from introducing pathogens

This can be attributed to lack of access to information on the pathogen and to insufficient research into the epidemiology of seed-borne diseases. A consequence of this problem is the proliferation of unjustified phytosanitary regulations that impair the movement of seeds worldwide. Resources that could be applied to protecting against the spread of economically important seed-borne pathogens are wasted on pathogens of minimal importance. An example is the requirement that all soybean seed lots exported from the United States to the European Union (EU) have to be tested for *Pseudomonas syringae pv glycinea*, the cause of soybean bacterial blight. This disease is widespread in the United States and has no detectable economic impact. It also has been present in Europe for many years. Since 1988, US seed companies have spent approximately

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$1,500,000 on testing for this pathogen on soybean seeds to meet phytosanitary requirements.

Lack of knowledge of relationships between tolerances in seed assays to risks of transmission of the pathogen to the planted crop

This also is a result of lack of access to information on the pathogen and of insufficient research into the epidemiology of seed-borne diseases. One consequence of this problem is that it leads to the use of non-scientifically-based tolerances by default. *Pseudomonas syringae pv glycinea* must be detected in each of five subsamples of 1 kg of soybean seeds to be denied a phytosanitary certificate. This tolerance was determined by negotiation between US and EU authorities and has no epidemiological foundation as a means of protecting against transmission of the pathogen by seeds.

A second consequence of this problem is that sample sizes may be inadequate or impractical. A grow-out test commonly used to detect *Erwinia stewartii* in corn seeds uses 400 seeds (McGee 1988). In the fifteen years the test has been used in the Iowa State University Seed Testing Laboratory, the pathogen has never been detected in a corn seed lot. Recent research indicates that 10,000 seeds would have to be tested to give any realistic chance of detection of *Erwinia stewartii* (Block 1995).

Lack of standardization in testing protocols

This problem results from the fact that, apart from sixty-five working sheets on seed-borne diseases published by the Plant Disease Committee of the International Seed Testing Association (PDC-ISTA), there has been no systematic effort to develop seed health test methods that are accepted internationally. One consequence of this is that different tests may be used by exporting and importing countries. In 1994, *Erwinia stewartii* was detected in Europe by a serological procedure in corn seeds that had been issued a phytosanitary certificate based on the grow-out test in the United States. A shipment of 20 metric tons of corn seed had to be returned to the US. Experiences such as this occur with considerable frequency in the seed industry.

A second consequence of this problem is that there are seed health tests in common use that have never been subjected to international standardization.

Different seed treatment regulations among countries

This results from variations in regulations and standards for efficacy and environmental risk of pesticides between countries. The main consequence of this problem is confusion regarding the legality of use by the exporting country of particular treatments and their rates of application.

Trade barriers

There is strong evidence that use of phytosanitary rules as trade barriers is becoming more prevalent with the development of free trade areas such as NAFTA and the EU, and by completion of the recent GATT agreement. Because these agreements remove tariffs as barriers to trade, other instruments such as phytosanitary certification can be used to achieve the same purpose.

A consequence of use of phytosanitary rules as trade barriers is widespread cynicism about the whole phytosanitary system that leads to ineffectual testing of seeds in the exporting countries and to mistrust during negotiations between countries on phytosanitary issues.

Solutions to phytosanitary problems

Five actions are suggested to improve the world phytosanitary system.

Better information sources for seed-borne pathogen

A good starting point to obtain information on seedborne diseases is An Annotated List of Seed-borne Diseases (Richardson 1990). This publication lists all seed-borne microorganisms that have been recorded in the scientific literature as being associated with seeds of all crops. Unfortunately the publication can be misused because it does not provide information necessary to justify phytosanitary regulations such as economic risks from introducing the pathogen or whether the pathogen can be transmitted by seeds. Seed-borne microorganisms may be placed on phytosanitary regulations merely because they are listed in this publication. There is an extensive world literature on seed-borne diseases that contains answers to many of these questions. It remains largely untapped, however, due to a lack of systematic organization of the information and difficulties in accessing hard copy reference sources, particularly in developing countries. Recent advances in the electronic media present opportunities to disseminate data efficiently and economically throughout the world. An international data base addressing key aspects of seed-borne pathogens could be of great value (table 2.2).

Such a database would provide the following:

- An information source of unprecedented comprehensiveness and power that will provide a unique resource for effective management of seed-borne diseases.
- Enhancement of the capacity of users to identify seed-borne pathogens, assess their economic impact, and devise control strategies.
- Provide ready access to scientific information needed to make rational and justifiable decisions on plant quarantine regulations.

Standardization of seed health test methods

The working sheets on seed-borne diseases published by the PDC-ISTA are the product of working groups assigned to develop protocols for each pathogen. This is a thorough process that is a good model for standardization of tests. Only sixty-five sheets have been developed over forty years, however. The PDC must become more productive in the supply of working sheets and in promoting them as methods that should be accepted internationally if it is to meet current demands for standardized tests.

Since 1994, European and US seed industries have formed an active international committee comprising scientists from the private and public sectors, who are now working on standardization of methods for twenty-five economically important seed-borne pathogens of vegetables (Wesselling 1996; Maddox 1996). It is expected that methods for field crop seeds will added later.

Access to worldwide seed treatment regulations

This is a difficult problem to resolve, because regulations are changing constantly. Making current information available in data-

Table 2.2 Proposed database on seed-borne diseases

Scope:

- All major crops

Structure:

- Potential economic impact of planting infected seeds
- Worldwide distribution
- Incidence of seed-borne infection
- Effect on seed quality
- Transmissibility of the pathogen by seeds
- Control by seed treatment
- Seed health assays

Output:

- Electronic and book format

bases that deal with regulations would greatly alleviate the problem. Regulatory databases such as the EXCERPT system of USDA-APHIS are already in existence or are being developed.

Improved communication and coöperation between phytosanitary authorities in different countries

One action that would greatly improve the environment for communication between countries on phytosanitary issues would be for each country to make a realistic appraisal of the diseases present in their country. Authorities should not rely solely on published records of pathogens, but accept the findings of "experts" who work in these countries and are knowledgeable about plant disease situations.

Revision of priorities in seed pathology research

A recent review of the literature on seed pathology over the period 1982-94 (McGee 1995), indicated that 23.5 percent of approximately 2,000 citations simply catalogued the presence of microorganisms on seeds. These types of publications are purely descriptive and do not address the potential for crop damage by planting diseased seeds or the management of seed-borne disease. Indiscriminate cataloguing of seed-borne microorganisms on seeds obscures seed-borne pathogens that might be of genuine economic importance. A case in point is maize chlorotic mottle which was first reported in 1973 (McGee 1988). No serious effort was made to determine that the pathogen was seed-borne until it caused an epidemic in winter nurseries in Hawaii. Because of the concerns of importing infected seeds into the US, seed transmission of the pathogen was investigated and shown to occur (Jensen et al 1991). Cataloguing of seed-borne pathogens is necessary, particularly for viruses and bacteria which traditionally have been neglected due to a lack of adequate seed health assays. Priority, however, should be given to pathogens that meet the criteria of maize chlorotic mottle in that the pathogen is limited in distribution and is of potential economic importance where found (McGee 1988).

Previous reviews of seed pathology have stressed the importance of establishing inoculum thresholds (tolerances) for seed-borne pathogens (Neergaard 1977; Kuan 1988.). Only a handful of the citations examined for this review addressed this topic, however. Research on inoculum thresholds is both complex and expensive. However, it is so fundamental to realistic and effective management of seed transmission of plant pathogens that little improvement in the worldwide seed health system will be possible unless priorities in seed pathology research are changed to meet this demand.

Conclusion

The overall goal of a world phytosanitary system is to protect against the spread of economically important pathogens without posing unnecessary barriers to worldwide movement of seeds. The present world phytosanitary system is not doing this effectively or efficiently. Resources are being squandered on unnecessary regulations, and many potentially important seedborne pathogens are being ignored. Implementation of the suggested improvements could lead to a system that is more effective in preventing spread of pathogens and less expensive to seed companies and governments throughout the world.

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Seed Regulatory Frameworks and the Availability of Crop Varieties

Robert Tripp

Strategies and visions of agricultural development vary widely among governments, donors, NGOs, and community groups, but one goal they are likely to share is the provision of better crop varieties. Despite significant differences regarding the most appropriate direction for agricultural development, there is little disagreement that farmers deserve access to a wider range of crop varieties than they currently enjoy. One of the impediments to achieving this goal is the regulatory frameworks that govern the conduct of plant breeding, seed production, and seed sale.

Introduction

This paper outlines the relationship between seed regulatory frameworks and farmers' access to seed of crop varieties. The first section introduces the subject of seed regulations and reviews how factors related to demand for seed and varieties affect public and private sector roles in national seed systems. The second section of the paper discusses how current seed regulatory frameworks limit the availability of crop varieties. The final section describes several strategies to address these problems.

Seed regulatory frameworks

Seed regulatory frameworks are the rules and regulations, and the norms, guidelines and standard practices, associated with crop variety development, seed production, and seed distribution. They may be divided into two broad categories: those regulations that determine the type of products (varieties and seeds) that are available to farmers; and those that are concerned with controlling the quality of the products once they reach the market. This paper addresses the first of these two categories, which includes: the procedures and practices that guide the conduct of plant breeding; the rules governing the official release of new varieties; and restrictions on the types of varieties that may be used or offered for sale. The implications of these regulations for seed imports and for the operation of private seed enterprises are also discussed.

An examination of seed systems must start with plant breeding. Although the procedures of plant breeding are usually not considered a part of formal seed regulations, they are strongly influenced by variety release requirements and perceptions of marketing regulations, and hence deserve attention here. Public sector plant breeders are guided by national and institutional policies in setting priorities for varietal characteristics and identifying target farming populations. They are also influenced by the requirements of variety release, and will naturally conduct their breeding programs to maximize possibilities for approval. Private sector plant breeders concentrate their efforts on crops and varieties where there is the best chance of commercial success, but are often limited by restrictions on access to markets. Variety release requirements, which are usually in the hands of public entities, may also affect private sector plant breeding initiatives.

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Variety release procedures are often managed by committees, which can have considerable power. As described by Douglas (1980, p 57), they can:

> establish guidelines for considering varieties from public and private plant breeding programs; determine whether varieties are to be recommended, considered "suitable," or listed as "unsuitable"; establish criteria for accepting varieties as eligible for seed certification; and assume responsibility for an allocation policy for seed of new varieties.

Variety release committees thus play a key role in the conduct of seed regulatory frameworks.

Variety release decisions help determine the range of varieties available to farmers. In some cases official release is only required for public sector varieties, while private sector varieties may be freely marketed. In other cases, private sector varieties must be submitted to the same release procedures. In addition, seed certification, which verifies that seed offered for sale conforms to the characteristics of the variety established in the release procedure, may be compulsory (in which case only seed of officially released varieties is available) or it may be voluntary.

The availability of crop varieties is also affected by import regulations. Imported varieties often have to go through the same variety release procedures as domestically produced varieties. In addition, some countries impose strict limitations on the importation of seed of particular crops, often related to policies that protect national seed industries.

Finally, seed regulatory frameworks may impose restrictions on the ability of the private seed sector to compete with public crop varieties. The regulations regarding variety release or seed certification may be managed in such a way that the private seed sector is effectively barred from participation. In other cases, there may be explicit limitations to private sector entry to seed production, particularly for certain crops.

Seeds and varieties

Before proceeding with a discussion of the effects of seed regulatory frameworks on the availability of crop varieties, it will be useful to define a few terms. Seed regulatory frameworks are meant to facilitate the operation of national seed systems. Seed systems can be divided into formal (public or private) and informal (on-farm or community level) sectors. In addition, any discussion of seed systems needs to clearly distinguish between demand for varieties and demand for seed quality. Seed is clearly the vehicle for any new crop variety, but in many cases farmers are able to maintain a variety once they have acquired an initial amount of seed. This is particularly true for self-pollinated crops such as rice or wheat. In these instances, demand for seed will be closely related to the development and introduction of new varieties. If variety turnover is infrequent, demand on the formal seed sector will be correspondingly low. In other cases, seed may be purchased every season, because hybrid varieties are used, or because of difficulties in seed storage or processing that make it more likely that farmers will look to the formal seed sector for better quality seed.

Thus seed demand is a function of farmers' interest in new varieties and farmers' requirements for an external source of seed of current varieties. Distinctions between these two potential sources of demand are important for understanding the overall demand for seed and identifying the most appropriate orientation for the seed sector.

Public and private roles in seed systems

The implications of these characteristics of seed demand for the relative responsibilities of the public and private sector in national seed systems are discussed in several recent studies (Pray and Ramaswami 1991; Jaffee and Srivastava 1994). In general, it is widely recognized that public sector seed production and distribution has often been inefficient, and that there is much scope for the expansion of the private seed sector in developing countries. Nevertheless, for crops or areas where seed demand is low or uncertain there is little to attract conventional private initiatives. These conditions obtain for less commercial farming areas and for self-pollinated crops, and they represent a larger proportion of total seed use than is sometimes acknowledged. There is thus a need for some type of public sector participation in seed supply, perhaps directly, or more probably by supporting or contracting private and community level seed production and distribution.

In contrast to seed production and distribution, plant breeding and variety development are areas that will continue to require a direct role for the public sector in many countries. It is often difficult for private enterprises to meet the costs of basic plant breeding research. Even in well developed seed systems, public sector involvement in plant breeding continues to be important (Knudson 1990). Thus our examination of the effect of seed regulations on variety availability needs to pay particular attention to public plant breeding, and to acknowledge that increasing privatization of the seed sector, however attractive, will not by itself resolve many of the problems presented by current seed regulatory frameworks.

Problems with current seed regulatory frameworks

Seed regulations are usually established and defended on the grounds of consumer protection. Farmers, and the general public, need to be protected from the consequences of widespread use of inappropriate varieties, and seed regulations help to address market failures in the processing and management of information. Although this view of seed regulations is accurate in many cases, there are also instances where the performance of seed regulatory frameworks is most usefully analyzed using other interpretations of regulatory regimes. Stigler (1971) proposed that many regulations are in fact the result of pressure by interest groups, and Bernstein's (1955) analysis of the life cycles of several US regulatory agencies shows how each comes to be captured by the interests it was established to regulate. Regulations and regulatory agencies can also assume a bureaucratic life of their own that may work at cross purposes to the original regulatory goals (Mitnick 1980).

The following discussion outlines problems with current seed regulatory frameworks that contribute to restrictions on the range of crop varieties available to farmers. The problems include inadequate assessment of demand for varieties, lack of transparency in the regulations, problems with the costs or logistics of implementing regulations, and lack of opportunity for wider institutional participation in the regulatory process.

Inappropriate breeding priorities

The results of the Green Revolution brought a number of critiques of plant breeding concerning the assignment of priorities between more and less favored environments (Lipton and Longhurst 1989). Although there has been considerable effort in the past two decades to address the needs of farmers in what Chambers (1991) calls "complex, diverse and risk-prone" environments, the generally lower utilization of modern varieties in these farming systems indicates that the challenge remains. On the one hand, it is undoubtedly more difficult to develop appropriate varieties for marginal environments, and some analyses show that the proportion of resources invested in breeding for these environments is reasonable (Byerlee and Morris 1993). On the other hand, farmers who are more isolated and command fewer resources are less likely than better organized, more commercial farmers to have their voices heard by public research institutions. Resource allocation in public sector agricultural research is far from transparent (Busch and Lacy 1983), and much can be done to improve responsiveness to farmers' concerns.

A more immediate indication of inefficiencies in public sector plant breeding are the instances where farmers select or improve upon discarded breeding lines or materials that are being tested to develop their own varieties. There are a number of examples where such farmer initiative has led to the development of widely used varieties (Green 1987; Maurya 1989; Salazar 1992). This is evidence that plant breeding procedures are often inadequately organized, or bureaucratically constrained, and illustrates the lack of congruence between official release standards and farmer priorities.

Delays in the variety testing process

Even when breeders are able to accurately assess farmer priorities, the process of variety testing can be very protracted. In Kenya (a typical example), a promising variety must be included in three years of national performance trials before being considered for release (Ruigu 1988, p 138). Because several cycles of multiplication from breeder seed are required to produce sufficient seed for sale or distribution, it is more than five years between the time that a variety is identified and when it is available to farmers. There are certainly dangers of rushing a variety to release without adequate assessment, but in many cases requirements for a fixed number of performance trials represent bureaucratic whims rather than technical optimums. In countries where private sector varieties must pass through the same testing process before official release, they may face the added disadvantage of having to compete on a playing field designed by their rivals in the public sector research institution.

Variety release procedures

In many countries, a variety cannot be sold unless it has been officially released. This is particularly true of public sector varieties, but at times the private sector must submit its varieties to the same procedures. In some cases there are two distinct steps; a variety is first approved for release, and then a second (separate, although normally straightforward) notification procedure advises the appropriate authorities of the variety's availability for seed production. Variety release or approval often requires several years of performance testing, as well as recording the morphological characteristics that distinguish the variety from others.

Variety release is usually the result of a committee decision. Due (1990) describes the process of releasing a bean variety in Tanzania, where the Grain Legume Coordinating Committee must send a recommendation to the Variety Release Committee, which in turn forwards instructions to the Seed Production Committee. Because funding for such committees is usually insufficient, and they may comprise representatives from geographically distant institutions, meetings are often cancelled or postponed. The rules and operating procedures of variety release committees may also be unclear, and their legal status is often not defined; five out of seven southern African countries recently surveyed had variety release committees with no legal backing (Commonwealth Secretariat, 1994).

This lack of transparency in variety release committees allows considerable scope for personal or professional politics. Ferguson (1994) points out that personal or prestige factors often play a role in committee decisions, and Douglas (1980, p 57) cautions against the practice of appointing committee members on a political basis. These committees meet infrequently, and because the deliberations do not represent exceptionally important concerns for many of the members, there are opportunities for the pursuit of particular personal interests, and less possibility for negotiation and compromise. Senior plant breeders may have considerable power in determining which junior staff are rewarded, or the viewpoints of particular disciplines, such as plant pathology, may be in or out of favor on a committee. Varieties from the private sector, international research organizations, or NGOs may not be given a fair hearing. Cromwell and Wiggins (1993, p 57), for instance, describe the delays in the release of a soyabean variety in Bangladesh that had been promoted by an NGO.

Even the formal standards used by a variety release committee may be problematic. Joshi (1995) reports the case of an early maturing rice variety in Nepal that, although lower yielding than other varieties, fit nicely into a rotation practiced by some farmers. The variety could not be submitted to the release committee because of its lower yield, despite evidence of demand by farmers. Standards for variety release may depend on other factors as well; Ulrich et al (1987) analyze the losses to Canadian wheat farmers caused by restrictions on the release of a variety judged inappropriate for Canada's export strategies.

Although variety release requirements may be defined for major crops, they are often not established for crops such as forage species (Ferguson 1994), and the uncertainty associated with this lack of definition often serves as a disincentive to plant breeders for developing new varieties.

The importance of adequate variety testing should not be underestimated, however. An accurate assessment of a variety's susceptibility to disease may require several cycles of observation, for instance. But the threat of major epidemics is also increased by the cumbersome variety release and distribution procedures currently in place in many national programs, leaving large areas planted to a few varieties (Heisey 1990). The problem is compounded when authorities ban older, susceptible varieties that farmers are accustomed to without offering adequate replacements. It can be argued that variety release can be made more agile without jeopardizing the legitimate concerns of plant protection.

National Variety Registers

A distinction can be made between variety release and the function of a national variety register that defines the varieties currently eligible for seed production. In some cases a variety may be included on a national register without having been submitted to testing for variety release; this is especially true for varieties that became established before the initiation of formal release prodcedures. Similarly, varieties that have been released in the past may be removed from a national register if demand drops or the variety is found to be susceptible to pests or diseases.

Kelly and Bowring (1990) and Bould (1992) describe the evolution of the variety registration system in the UK. Prior to 1964, there were no official systems for registering varieties or certifying seed, although voluntary schemes were in practice. The Plant Varieties and Seeds Act of 1964 established an index of variety names and introduced performance trials, as well as allowing variety protection under plant breeders rights. The index provided descriptions of each variety which could be used in seed quality control. A variety's inclusion in the index did not, however, depend on any predetermined results in performance trials, and the index was used instead to provide recommendations to farmers. Entry to the European Community in 1972 means that UK seed law now has to conform to EU directives. No variety can be marketed unless it appears in the EU Common Catalogue, which is composed of national lists of member states. A variety on a national list in an EU country must not only be distinct, uniform and stable (DUS) but also show value for cultivation and use (VCU).

In India, all public sector varieties must pass through release procedures and be notified for seed production, although the actual registration process is based on a few varietal characteristics, rather than the comprehensive DUS testing practiced in the EU (Turner 1994, p 11). In the United States, varietal registration is not required, and determination of performance is left to the market, although several voluntary variety testing schemes are in operation (Kelly 1989, p 42). A voluntary scheme operates in New Zealand as well, but before seed can be certified the variety must be accepted on a national list that requires proof of uniformity and stability (Hampton and Scott 1990).

Variety registers may function in different ways. Gisselquist (1994) distinguishes among:

those countries that require no prior approval for variety sale; those where seed sale is restricted to varieties on national lists; and those that utilize a common regional list, as practiced in the EU and under consideration by members of the Southern African Development Community (SADC) (Commonwealth Secretariat 1994).

To the extent that crop varieties must pass through a release procedure and be registered, it is legitimate to debate the type and level of standards to be used. With increasing technical sophistication, the standards and testing procedures can become quite costly. In general, the trend is to pass the costs of testing to the breeders and seed companies.

There is considerable debate over the extent to which exceptionally precise standards for variety registration or approval are always in farmers' interests. Berg et al (1991), for instance, question the emphasis on varietal uniformity for farmers in environments where the stability and adaptability of local landraces are due in part to their intrinsic variability. It is worth listening to the views of an eminent plant breeder who is concerned about two issues (Simmonds 1979, p 225):

> first, the possible stultifying effect of too rigid an application of DUS criteria (which are legal rather than agricultural in intent); and, second, the application of VCU principles (which are certainly unnecessary and expensive and can be regarded as potentially dangerous to farming)... The VCU criterion seems to have come to stay, however; if interpreted broadly it may work quite well but the risks and disadvantages of narrow interpretation are real; unrestricted lists, even if they were longer, would probably have served farming better.

Simmonds's remarks are made in the context of a discussion on plant breeders' rights, where very precise distinction among varieties is required. Plant breeders' rights were originally related to the International Union for the Protection of New Varieties of Plants (UPOV) convention that came into force in 1968. The recently concluded GATT negotiations require member countries to provide intellectual property protection for plant varieties, and many countries are moving toward establishing a varietal protection system. The issue has been the subject of considerable debate, particularly with respect to possible impacts on biodiversity (Crucible Group 1994). There is concern that increased protection may threaten farmers' customary practices of saving and exchanging seed, reorient plant breeding priorities towards the more affluent farmers, or even take control of local varieties away from farmers. The type of plant variety protection to be instituted in response to GATT is still being discussed, however, and it will be several years until the results are clear. In the meantime, however, there is much that can be done with respect to reforming conventional seed regulations in order to achieve wider availability of new crop varieties.

Seed certification

Seed certification takes place after varieties become available, but its conduct has considerable bearing on variety availability and hence it deserves some discussion here. Seed can be certified only if the variety has been officially registered. The term "seed certification" is subject to several definitions. In its strict sense (and the one used here) it is a measure of genetic purity, assessing the degree to which the seed conforms to the characteristics of the registered variety. But certification also often includes measures of seed physical quality, such as germination capacity or freedom from weed seed. Grobman (1992, p 141) is concerned that the two meanings "have been hopelessly confounded and unfortunately integrated into a single process" in many countries, and urges that the second usage be referred to as seed quality control. He emphasizes that all seed offered for sale needs to be subject to some type of quality control, preferably managed by seed enterprises themselves, with the government as the final arbiter.

Seed certification, on the other hand, is open to more debate.

Seed sold in the EU must be officially certified, while in the United States certification is voluntary (although widely practiced for certain crops) and is carried out by private associations. In India, seed of all public sector varieties is supposed to be certified, whether the seed is produced by public or private enterprises. Private sector varieties (mostly hybrids) are not certified because they have not been through official release procedures. In India, seed that is not certified may be sold as "truthfully labelled seed." A number of countries allow two classes of seed to be sold, one which meets certification standards and another which has not been subjected to official inspection (Bombin-Bombin 1980, p 7). Garay et al (1988) describes how a reorientation of seed regulation procedures in Bolivia allowed several certification options; as farmers and seed producers gained more experience, there was a gradual shift to higher standards.

Seed certification may not always be necessary, and may impose financial or logistic burdens on national seed systems. Private seed enterprises will tend to impose their own controls on the seed production process to ensure that the seed they sell is of adequate genetic purity. The costs of official seed inspection are normally charged to the seed producer (and passed on to the farmer). Agrawal and Tunwar (1990) estimate that seed certification costs in India are generally equivalent to 2 to 4 percent of the sale price of the seed. Certification in one Indian state may not be accepted in another, however, which complicates the movement of seed across state boundaries.

Kelly (1989, p 111) points out that the high costs of EU seed certification are ultimately borne by the farming community. In countries where all seed production and inspection is done by the public sector, lack of funds may restrict the coverage of the certification service and, where certification is obligatory, limit the supply of seed.

Standards used for certification may be unreasonably high, and seed enterprises may lose valuable stocks because of the rigid judgements of a seed inspector (Chopra 1986). In addition, official seed certification is subject to significant abuse; it presents opportunities both for bribes to pass unacceptable material and for additional payments to inspect legitimate seed. On the other hand, where certification is optional, lack of certification may be equated by farmers to lower quality and may deny the seed access to government extension or farm credit support programs.

The private seed sector and seed imports

A range of laws and regulations may be used by governments to limit the development of a domestic private seed sector or to control the import of foreign seed (Pray 1990; Pray and Ramaswami 1991, p 29). In addition, seed regulations themselves, presumably established for consumer protection regardless of the source of seed, can be manipulated or interpreted to support government objectives of discouraging competition from the domestic or foreign private sector.

In some countries the private seed sector may face considerable obstacles. Until recently, all public sector crop varieties in Zimbabwe have been produced by one company, the Seed Coop (Friis Hanssen, 1992). In some countries, variety release is managed by the public sector agricultural research institution, which finds itself controlling entry of varieties from its competitors in the private sector. There is currently considerable debate in India regarding variety registration and certification. Private seed companies prefer not to submit their varieties (particularly hybrid parents) to the government for registration, partly out of fear that their material will be appropriated by other breeding programs. Private companies in India are understandably concerned about proposals for compulsory seed certification (Turner 1994, p 15), and argue that the bureaucratic requirements of such a scheme would surely disrupt seed supply.

There is often inconsistency in the management of seed and varietal imports. In Nepal, the government is discussing the possibility of exempting Indian public sector grain crop varieties from passing through the Nepali variety testing and release procedures that are currently required of them. This would seem a justifiable procedure, given that these varieties have already been tested in similar environments. The private sector, however, can import vegetable seed from India without any testing requirements, and inappropriate varieties have at times entered the market (Rajbhandary 1994).

Plant quarantine is a key element of seed regulations, and is legitimately used to protect a country from the introduction of pests, diseases or weeds. It also can be used as a pretext for limiting seed imports, however. Douglas (1980, p 131) warns against the overzealous use of plant quarantine laws where there is often little justification.

Finally, it is worth noting that modifications in seed regulations to facilitate seed trade or to meet domestic industrial agricultural standards may have negative consequences for resource-poor farmers. If the strict certification standards necessary to promote a country's participation in seed export markets were applied to all national seed production they would serve as a disincentive to meeting the seed requirements of many less commercial farmers. In recognition of this fact, recent discussion of seed law modification to facilitate seed trade in southern Africa recommended the adoption of separate standards for small-scale seed production programs (Commonwealth Secretariat 1994, p 18).

Addressing deficiencies in seed regulatory frameworks

There are several common deficiencies evident in seed regulatory frameworks (Tripp 1995). Foremost among these is that the seed laws and plant breeding protocols of many developing countries are not consistent with the resources or purposes of national institutions. They have been modelled on European or North American examples, without reference to the social, economic and technological circumstances of the country (Grobman 1992). A second deficiency is that seed regulations are not well established, widely understood, or consistently interpreted. This causes uncertainties regarding possible options to improve the availability of new varieties or seed. Finally, the management of regulations that affect variety availability is often in the hands of small groups or committees who may not represent, or have access to, the interests of important sectors of the farming population.

An obvious solution would seem to be the introduction of more appropriate regulations, but our emphasis here is rather on strengthening institutions. Institutional change must accompany regulatory reform. Indeed it can be argued that regulations are products of institutions, and that the weaknesses of current regulatory frameworks reflect deficiencies in institutions. This interpretation has several implications for the design of development programs. First, strengthening national seed systems will be achieved not merely by changing seed regulations but by changing the institutions that manage those regulations. Second, a focus on institutional strengthening implies country-specific strategies; aid and advice must be tailored to particular circumstances. Third, there must be a commitment to the long-term development of national institutions, rather than a belief in quick policy fixes. The rest of this section discusses three broad areas of institutional change related to improving the performance of seed regulatory frameworks. The first area is concerned with possible changes in the management and orientation of public sector agricultural research. The second area addresses the importance of opening variety development and seed production to a wider range of players. The third area explores the possibilities of building regulatory capacity.

Improving the public variety delivery system

There is an undeniable need to make public plant breeding systems more responsive to the needs of representative farmers. Efforts in adaptive on-farm research (Byerlee et al 1987) or participatory research (Ashby et al 1987) can help reorient breeding priorities. Sperling et al (1993) describe a bean research program in Rwanda where farmers visited the research station and helped make selections. Maurya et al (1988) describe how lines from a rice breeding program in India were tested on farmers' fields, using farmer management and evaluation. Pain (1986) describes the success of location-specific breeding strategies for rice in Sri Lanka.

Innovations in variety development should be accompanied by more flexibility in variety release. Zambia has instituted a release policy that allows varieties that have been tested and found popular with farmers to be multiplied and distributed as non-certified seed while they undergo the testing scheme that is required for official release (DANAGRO 1988, cited in Cromwell et al 1992, p 60).

Perhaps most important, public agricultural research needs to better define its clients. Current donor policy towards greater private sector participation in seed markets is certainly appropriate, but an unfortunate consequence is that public sector research is sometimes encouraged to focus on its (legitimate) collaboration with the private sector, at the expense of addressing its equity responsibilities towards farming populations not likely to be served by private enterprise. The private seed sector can be an important conduit for public varieties, but the monetary (or at times merely policy-correct) attraction of earning royalties from privately marketed varieties can distract public research from its traditional clients (Lopez-Pereira and Filippello 1995, p 43). There is a difference between making public sector research more streamlined and efficient, on the one hand, and encouraging it to be a pale imitation of private enterprise, on the other.

Expanding the range of seed production options

There is no doubt that recent changes in policy towards private seed enterprises will result in the wider availability of crop varieties for many farmers. But as was pointed out in the introduction, there are many crops and farmers that will not immediately benefit from these changes. Private seed production requires relatively large and stable markets. Several examples of private sector success with small farmers involve the transfer of varieties already developed for commercial farmers in similar environments; this is the case of the widespread use of US sorghum hybrids in Mexico, as well as the successful entry of private maize hybrids originally developed for South Africa to drier regions of Zimbabwe (Rusike 1995, p 124).

The fragmented and uncertain markets that characterize much seed demand will have to be addressed by other means. Sperling et al (1994) discuss the distribution of seed of bean varieties developed by the national research program through merchants in local markets. Grisley (1993) describes the successful distribution of an initial supply of public sector bean seed in Zambia, and points to this as a "non-market solution" to the problem of variety dissemination. Several Latin American countries have had experience with the promotion of artisanal seed production (Lepiz et al 1994; Janssen et al 1992). The recent proliferation of smaller maize seed producers (Lopez-Pereira and Filippello 1995) is also encouraging in this regard.

In their discussion of developing forage seed production capacity, Ferguson and Sauma (1993) stress the importance of including seed production as one component of broader development projects. Cromwell and Wiggins (1993) survey a large number of NGO projects promoting local seed production capacity and draw conclusions for making such activities more economically viable.

In short, farmers' problems of inadequate access to appropriate crop varieties will be ameliorated, but not resolved, by more private sector participation. Reform of seed regulatory frameworks should be designed to encourage the search for innovative seed provision options that are not limited to conventional seed enterprises.

Building regulatory capacity

Pray and Ramaswami (1991) describe four stages in the development of national seed industries, beginning with farmer selection and supply, progressing through public sector responsibility and then increasing private sector participation, and culminating in a mature seed industry. This type of evolution will progress at different rates in different countries, and should be paralleled by a progression through various regulatory formats. Douglas (1980, p 122) cautions that the design of appropriate seed policy depends on a number of factors specific to the stage of development of national seed sectors, and emphasizes that,

> seed legislation is not just to protect farmers but to promote fair competition among seed enterprises and other seed sellers as well. Excessive legislation stifles the industry.

As private initiative assumes more responsibility for seed production and distribution, and at times for variety development as well, it is reasonable to consider how the market can also assume more responsibility for regulatory functions. But market capacity for regulating the type of product, and its quality, depends very much on location-specific factors. The US seed regulatory system, which emphasizes market control, is often held out as a model, but its success is related to the specific conditions under which it operates. Commenting on voluntary certification, for instance, Simmonds (1979, p 222) links its success to "a discriminating population of farmer-customers and efficient and competitive breeders." Kloppenburg (1988, p 107) shows that the US experience was not without its problems, describing the proliferation of companies in the late 1940s selling hybrid maize seed, often with multiple names for one variety.

The capacity of seed markets for self-regulation is related to the ability of seed enterprises (private firms or producer coops) to establish reputations (Klein and Leffler 1981), and this in turn is related to the development of relatively stable, secure demand. But in many cases, seed demand is still far from well defined, and many small firms are exploring the feasibility of providing seed to sectors of the farming population currently served only by informal seed systems. A market's regulatory capacity also depends on opportunities for consumers to exchange information and seek alternatives. But for many resource-poor farmers, isolation and poverty constrain their capacity to exert sufficient influence on the market.

Thus some type of public oversight of seed regulations will probably be required in many countries. FAO (1993) has developed general guidelines for a "Quality Declared Seed" system that offers the possibility of establishing a seed regulatory system consistent with national resources and markets. It includes the establishment of a list of eligible varieties for seed production, with potentially flexible entry requirements, and a monitoring system for seed quality that shares responsibility with seed producers and merchants.

Recent efforts by Sasakawa Global 2000 in Ghana to stimulate the development of a private seed industry after the collapse of the parastatal Ghana Seed Company place equal emphasis on strengthening the capacity of the government Seed Inspection Unit and developing small scale seed growers (Bockari-Kugbei 1994). Private sector involvement in regulation should be encouraged, however. Several countries in southern Africa have already begun to recognize private certification agencies, for instance (Commonwealth Secretariat 1994, p 13). Garay et al (1988) describe how several institutions were invited to participate in seed certification services in Bolivia.

National seed acts often provide general policy and an institutional framework for national seed systems, but vest authority for specific regulations in seed committees or seed boards. Bombin-Bombin (1980) emphasizes that one advantage of such a system is that subsidiary legislation can be managed by the most appropriate authority and can be amended or changed more flexibly than the basic seed act itself. These boards or committees deserve special attention when considering regulatory

Table 2.3 Seed regulatory deficiencies affecting the availability of crop varieties

Deficiency	*Possible Action*
1. Inappropriate priorities for public sector plant breeding	• More emphasis on location-specific plant breeding • More use of data on agroecological zones for targeting breeding • More adaptive research, farmer-participatory research • Clearer policy regarding public sector plant breeding mandate • Clearer division of labor, and collaboration, with private sector and community groups
2. Delays in variety testing	• Allow more farmer access to public varieties being tested; more pre-release seed multiplication • Confine extended testing or observation to priority plant protection issues • Utilize data from other countries when assessing imported varieties
3. Lack of consistency in variety release procedures	• Standardize and make more transparent the procedures of variety release committees • Establish adaquate frequency of committee meetings • Address possible bias in release of non-public varieties
4. Inappropriate standards for variety release or registration	• Emphasize performance in local farming systems; allow wider range of criteria • Utilize varietal distinctions [distinct, uniform, and stable (DUS)] consistent with national needs and capacities • Establish a plant breeders' rights system consistent with farmer seed saving and exchange • Utilize only very broad interpretation of value in cultivation and use (VCU)
5. Regulations biased against non-public varieties	• Encourage seed imports, consistent with legitimate plant quarantine considerations • Encourage private seed sector participation • Encourage local-level seed production initiatives • Do not require public sector variety release procedures for non-public varieties • In situations where the commercial seed sector is unable to address demand, consider public sector contracting or tendering of private firms or community groups
6. Seed certification requirements restrict seed supply	• Reconsider certification standards; make them more consistent with national needs and resources • Make seed certification voluntary • Encourage the licensing of independent certification authorities • Allow the sale of truthfully labelled seed
7. Seed regulation for export markets incompatible with local seed requirements	• Distinguish seed regulations needed for export and those appropriate for small-scale or local seed enterprises
8. Insufficient attention to national seed sector development	• Encourage and support national seed boards or seed committees; limit their ex-officio membership; emphasize their policy responsibilities

reform (Commonwealth Secretariat 1994; Bockari-Kugbei 1994, p 270). Garay et al (1988) describe the formation of regional seed boards in Bolivia, and as these became effective, the establishment of a national coordinating board was a logical outcome. National seed boards or committees must include adequate representation from the private seed sector (Chopra 1986, p 83); place more emphasis on committed and experienced membership, rather than ex-officio representation (Poey 1991); and operate with a clearly defined mandate.

Conclusions

Regulatory reform must begin not on paper but with the institutions that are active participants in the seed sector. National seed boards or committees need to assume more responsibility for policies that stimulate a dynamic national seed sector. They should assure that national variety release and registration procedures are flexible and transparent, and consistent with the needs of the nation's farmers. Less emphasis should be placed on the specification of seed regulations, and more attention devoted to establishing an institutional environment in which seed enterprises, farmers and consumers are able to negotiate their own regulatory frameworks in the context of an evolving national seed system.

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Streamlining for a Demand-Driven Seed Sector: A Framework for Policy Reform

Jitendra P. Srivastava

Improved seed — agriculture's oldest technology and most important input — has the power to ensure food supplies, create rural surpluses, and ultimately transform economies. The production gains from high-yielding wheat and rice since the mid-1960s in developing countries and the increased efficiency of agriculture (from a diminishing base in terms of number of farmers in industrialized economies) provide convincing evidence. For the past thirty-five to forty years, the public sector has played a dominant role in the seed drama, with international research centers transferring much-needed, higher-yielding seed for significant food crops to developing countries through national networks. This recipe yielded highly visible results. Provided local testing for crop adaptability was conducted, and seed production plants were in place, it was thought that the process would continue indefinitely.

But nature has built-in limitations. Some crops are not widely grown, nor widely adaptable. While international research has begun tackling problems of lesser crops, in more remote and specific environments, gains in new varieties are subsiding. Also, public sector entrenchment can feature inflexibility, inefficiency, and in some cases, irrelevancy with top-down decisions focusing research on seeds that farmers do not want. At the same time, nascent national research systems and seed producers often become protective of their turf, putting up barriers to the entry or acquisition of foreign seed products. This closed-end stance, associated with public-sector bias, further exacerbates defects and problems in the research-and-development base. The results include regulatory barriers that: impede the entry into the seed market of foreign seed researchers, traders, and private operators; and prevent, limit, or delay access to superior seed technology by a country's farmers (see Box 2.1).

Changing the status quo

In many developing countries, there is a pressing need for a framework of policies, related institutions and infrastructure that establishes a favorable climate for the entry and utilization of advances in seed technology to increase the yield and efficiency of crop production. Developing this framework will entail paring down and refining public sector participation, while strengthening and expanding the roles of all private sector participants from subsistence farmers and small farmer seed producers to domestic seed enterprises and multinational seed companies (see Box 2.3).

Trends, needs, and challenges

Current approaches to seed research, policies affecting seed flow, and supporting institutions and infrastructure are evolving as global trends impinge on the sector (see Box 2.2). The apparent new direction points toward demand-driven seed production, more private initiative, more competition — usually from the private sector, but in command-driven economies that persist, among parastatals — and market pricing in lieu

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Box 2.1 Most common regulatory barriers to seed movement

Impediments to entry of foreign seed traders and researchers and private operators in seed markets:

- Unreasonable phytosanitary or quarantine restrictions and procedures
- Compulsory variety registration
- Seed certification and control
- No private access to public-sector seed stocks
- Inadequate protection of intellectual property rights in seed
- Over-centralized administration of regulations

Deficiencies stifling farmers' access to superior seed technology:

- Inappropriate priorities for public sector plant breeding
- Delays in variety testing
- Lack of consistency in variety release process
- Inappropriate standards for variety release or registration
- Regulations biased against non-public varieties and structured for export markets
- Seed certification requirements
- Insufficient attention to national seed sector development

Sources:
The Agricultural Technology and Services Division (AGRTN) (September 1995): Reform of Seed Regulations - Easing Barriers to Better Seed Varieties, World Bank Agriculture Technology Notes, Number 12, Washington, D.C.
Tripp, Robert (1995): Seed Regulatory Frameworks and the Availability of Crop Varieties, Overseas Development Institute, London.

of subsidies. Needs and challenges emerge in response to these global trends.

Promoting a robust seed sector will entail addressing the specific needs of all private sector players (see Box 2.3). For example, subsistence farmers primarily require information and strong linkages to small farmer seed producers, while multinational companies require different institutional and policy responses to accommodate their need to relocate profits and establish joint ventures with domestic seed enterprises. At the same time, there are challenges common to all interested in improving seed research and production. These include:

- *Quality.* Is seed technology any good? Does it do what farmers need and want? Without demonstrable value-added, as defined by farmers themselves, new seed is not necessarily better and farmers won't use it. White-elephant seed production plants in numerous developing countries that churn out too much seed of varieties farmers don't value speak to this critical point.

- *Access.* If desirable seed is available on the research shelf, can farmers get hold of it, in sufficient supply and at an affordable price? Questions of access mainly imply control by government through policy and regulatory mechanisms, which can be conducive or stifling to seed flow. In specific countries, otherwise useful and beneficial technologies can be withheld or bypass farmers, leaving them less productive and less competitive.

- *Information.* The free flow of information is critical to an improved seed sector. What kind of information is available and how it is communicated impact the level and quality of participation by all seed producers. Information on improved harvesting prac-

Box 2.2 Global trends in the seed industry

- Globalization of agricultural research
- Investments in biotechnology R&D
- Shift in crop improvement and R&D from public to private sector
- Liberalization of trade
- Emergence of successful private seed companies
- Entry of multinational seed trading companies
- Greater attention to informal sector
- Debate regarding impact of legislation and trade agreements on intellectual property rights and biodiversity

tices, variety performance trials, external markets, seedborne pathogens, as examples, must reach a diverse audience through diverse media.

- *Enabling services.* The best seed available and the best-intentioned farmer are not enough. The farmer may need credit to buy such seed, advice from extension services on best practices for its use, and adaquate infrastructure, such as roads, communication facilities, and markets, to move his/her products. Such functions are generally, at least initially, provided by the public sector, and a critical mass of institutions that provide them need to be functioning in order to get seed and agriculture moving.

Critical issues

Having identified common challenges, public, private, national and international interests alike must contend with several critical issues that will define a country's path toward seed sector reform.

How can good varieties that outperform seed in farmers' fields be more efficiently developed? Open sourcing of seed is the ideal solution.This will dissolve the tension between foreign technology and internal innovativeness. International and domestic researchers, whether public or private need each other's talent and germplasm. Their research tracks need to converge more often than they currently do. Seeds have increasingly complex parentage. For rice, about two-thirds of varieties from the International Rice Research Institute have a borrowed parent, that is, an out-of-country genetic claim. Unless private firms also have access to such foundation seed, research efforts are stymied.

At the same time, public sector institutions should be divested from several activities — production, distribution, and marketing — for most types of seed over time. The critical path for public action regarding seeds entails trade liberalization of seed for research purposes and sale, a useful and workable legal environment for seed flow, and appropriate and transparent "rules of the game" for private sector involvement. The public sector may refocus its resources and personnel on research on less commercialized crops or adaptation of off-the-shelf germplasm for domestic conditions, quality and hazard control, training/promotion and credit. Nevertheless, in a given economy, the private sector may share in these functions.

If the motive of seed regulations is to protect national agriculture from biological hazards and consumers from unreliable seed, what are adequate and effective measures to ensure public confidence in seed? Numerous regulations — many well-intentioned, but several capricious and covert — are used in the name of consumer protection to keep competitors out of national seed markets. For example, phytosanitary standards to keep legitimate pests out are employed by virtually every country. Yet experts concur, many false issues are pursued, while real and

Box 2.3 Needs of seed producers

Category of Seed Producer	*Assistance Needs*
Subsistence farmers who save own seed	Information on: • most suitable variety • improved techniques for on-farm seed selection • improved harvest, cleaning and drying methods using local materials • access to small farmer/seed producer's seed and trained extension staff
Small farmer/seed producer	• access to most suitable varieties for locality • training in seed production of specific crops • access to credit • access to seed testing laboratory • assistance in conducting "on-farm" variety performance trials • close linkage to domestic seed enterprise and/or public research institution
Domestic seed enterprise	• access to improved varieties/hybrids • easy flow of improved germplasm • hard currency to purchase inputs • credit in local currency • market pricing and demand for improved seeds • access to information on external markets • government policies to promote seed export • plant variety protection • government policy incentives to undertake R&D
Multinational seed enterprise	• minimal restriction on international movement of germplasm/seed • government policies and legal framework for joint ventures with domestic companies • ability to relocate plants • plant variety protection • policies encouraging participation of national seed companies

Source:
Srivastava, Jitendra P. and Steven Jaffee. 1993. *Best Practices for Moving Seed Technology: New Approaches to Doing Business*, World Bank Technical Paper 213, Washington, D.C.

serious problems are ignored, in the name of phytosanitary control. Possible solutions include: upgrading knowledge of biological threats; using a global database on seedborne pathogens and seed treatment regulations; standardization of seed health testing methods; and gauging the economic dimensions of such threats as priorities in seed pathology research are revised.

Another possibility is self-regulation wherein the seed industry devises appropriate and enforceable local standards that are monitored and upgraded by seed producers' associations, among others. Cross-linkages to national and international associations can further serve to reinforce standards, professionalize conduct, and upgrade research and products throughout the industry, as it is commercialized. Seed systems do not have to be highly developed to benefit from such activity; self-regulation is at the heart of grass-roots endeavors, in addition to being the hallmark of the most reputable global seed producers.

How can the value-added that research yields be legally protected and economically captured by those who invest in it? Factors surrounding how seeds are replicated (whether easily in farmers' fields or only in the laboratory) and whether investment in research on crops can be captured for economic profit by the researcher are receiving increasing attention. Public researchers generally don't want to give away seed technology that private firms can make a profit on, nor would private firms want to invest huge sums in seed technology, only to have it pilfered by other agents, thus losing their investment.

A handy solution is offered by plants themselves. Seed of self-pollinated crops such as wheat and rice and of open-pollinated crops such as maize and sorghum can be readily sown for seed by farmers, while seeds of hybrids have to be bought new each planting season because seeds lose vigor in the next generation. Accordingly, public sector research focuses on self-pollinated food crops and private firms on hybrids where research profits are capturable. These divisions are not hard and fast. In large market economies, farmers often buy self-pollinated seed from commercial seed producers for assured quality and convenience. In large developing economies, without shared business ethics and enforceable legal controls, the prospect of having seed technology pirated may be too daunting for private firms to introduce self-pollinated seed for sale.

How will global trends affect small-holder farmers in less developed countries who most need improved seed? Only about one-third of seed used worldwide is sold commercially, and of that a paltry 10 percent is sold in developing countries. Another third is produced by public sector institutions, and the remaining third is saved by farmers for their own use next season. The great bulk (estimated at 80 percent) of crops cultivated in developing countries come from seed that escapes the monetized economy — the informal sector. With liberalization and privatization at the global level, the next big challenge is to move the great majority of developing country farmers, not just those in preferred areas, crops, and irrigated conditions, into the commercial mainstream.

Small-farmer seed producers are emerging as transitional go-betweens, connecting previously subsistence farming to diversified, commercial agriculture (see Box 2.3). Possible mechanisms for tapping into this vast reservoir of underutilization covers a broad range, including creation of cottage-seed subsystems and formation of national seed farmers' associations. As the cornerstone of strong, private seed systems they could contribute: their input for establishing research priorities; their fields as a source of new varieties and hybrids; and their energy as seed producers, distributors, importers, exporters, entrepreneurs and investors. In short, they are the missing link that will put private and public research on a common track, redesign policy regulation, seek common standards and approaches to phytosanitary control, and build reputations for reliability and innovation in the marketplace.

Final comment

The needs, challenges and issues inherent to the process of seed sector reform will be successfully addressed through collaboration and participation. Seed producers, from subsistence farmers to multinational companies, along with governments and donor agencies have critical roles to play in framing policies that promote a robust demand-driven seed sector.

3

Supply of New Varieties

Depending on factors such as crop and country size, foreign public and private research produces a flow of new varieties that farmers appreciate — or would, if governments allowed them to be introduced. When foreign-bred lines are not immediately suitable, crosses with local lines can add resistances and other features to create new varieties that farmers appreciate — or would, if governments allowed them to be introduced.

Four papers in this Section describe private supply of new varieties for maize and cotton and public supply of new varieties for wheat and rice.

Both public sector IARCs and private companies locate international breeding programs in a limited number of countries, then distribute new lines for testing in multiple countries. These breeding strategies rely on international movement of varieties to optimize returns to research investment. Other things equal, the faster a new variety spreads throughout its potential (multi-country) market, the greater the return.

With seed deregulation as recommended in the previous Section, private companies would be able to locate breeding to serve markets defined by ecological conditions and other technical criteria rather than political boundaries. Also, public varieties from IARCs and some of the stronger national systems could be expected to disseminate faster and further, boosting returns to public research.

Prospects and Constraints for Hybrid Maize in Developing Countries

Roberto W. Ansaldo and Ray Riley

Pioneer Hi-Bred has been developing, promoting, marketing and distributing hybrid seeds since the 1920s in the United States, and on a worldwide basis since the late 1960s. Over the years, we have seen many countries go through the process of improved seed technology development and adoption. These comments are based on our experience and commitment to hybrid seeds over the past seventy years.

Hybrid maize seed can be seen as one component in a larger system: in many countries maize is an important feed component (energy source) for expanding livestock and poultry industries. We seek to commercialize hybrid maize seed and other technology so as to move a majority of farmer-producers into mainstream commercial agriculture. In the Philippines, farmers have recently adopted silage technology, expanding the market for hybrid maize seed and lowering livestock production costs. Introduction of silage technology — along with hybrid maize — could have similar impacts in other developing countries.

The first part of this paper describes Pioneer's research and commercial strategies to develop and introduce maize hybrids, with particular attention to developing country markets. Parts two and three discuss hybrid maize markets in Asia. The final part describes constraints and solutions for spread of hybrid maize in developing countries.

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Product development, testing, and deployment for developing country markets

From a technical and organizational perspective, delivering improved varieties is a multi-faceted process involving: product development, testing, seed production, and marketing. In addition to the purely technical and organizational challenges to deliver products to markets, government policies often impact Pioneer's ability to serve markets. Policies that impede our ability to effectively serve markets include: unjustified phytosanitary obstacles, unnecessary variety registration requirements, lack of intellectual property protection, and lack of regional cooperation, particularly for small size of national markets.

Product development

Pioneer has an international network of forty-five maize research locations, more than 40 percent of which are in developing countries (three in Africa, five in Asian developing countries, and twelve in Latin America), with an annual research budget that has averaged about $100 million from the late 1980s. In research, the company collaborates with universities and other institutions to augment our in-house efforts.

Product development entails meeting market needs, which requires products that have "added value" according to farmers' criteria. When considering the feasibility of entering and effectively serving new markets, the company looks at market factors such as:

- maturity and ecological conditions,
- product attributes valued in the specific market (for example, insect and disease resistance, grain color and quality, management and stress consideration), and
- expected yield level, with attention to farmer access to fertilizer and other supporting inputs.

Based on assessment of what farmers value in existing or new markets, the company is able to focus information and genetic resources from its global research network to develop products for specific markets. Breeders in each of Pioneer's forty-five research locations develop new products from Pioneer lines, public materials, and licensed materials (that is, lines for which Pioneer pays royalties to other organizations). This process is facilitated by close interaction and sharing of information and germplasm among Pioneer researchers.

Product testing

Once a new product has been developed (in any one of forty-five research stations), it goes in the second year (R2 in figure 3.1) to wide area research testing (for example, on five research stations x ten plots each). From there, the winners go in the next year, R3, to extended wide-area testing (for example, eight to ten stations x ten plots each). In the next year, R4, promising hybrids go into several hundred farm trials in "side-by-side" demonstrations with other varieties in farmers' field, typically in four-row sub-plots planted to each variety; in this first year of on-farm demonstrations, Pioneer provides free seed. In the next year, R5, tests expand to 1,000 or more farm plots; farmers buy seed for many of these demonstrations, while Pioneer contributes technical advice. Also in R5, Pioneer approves promising products for limited commercial release.

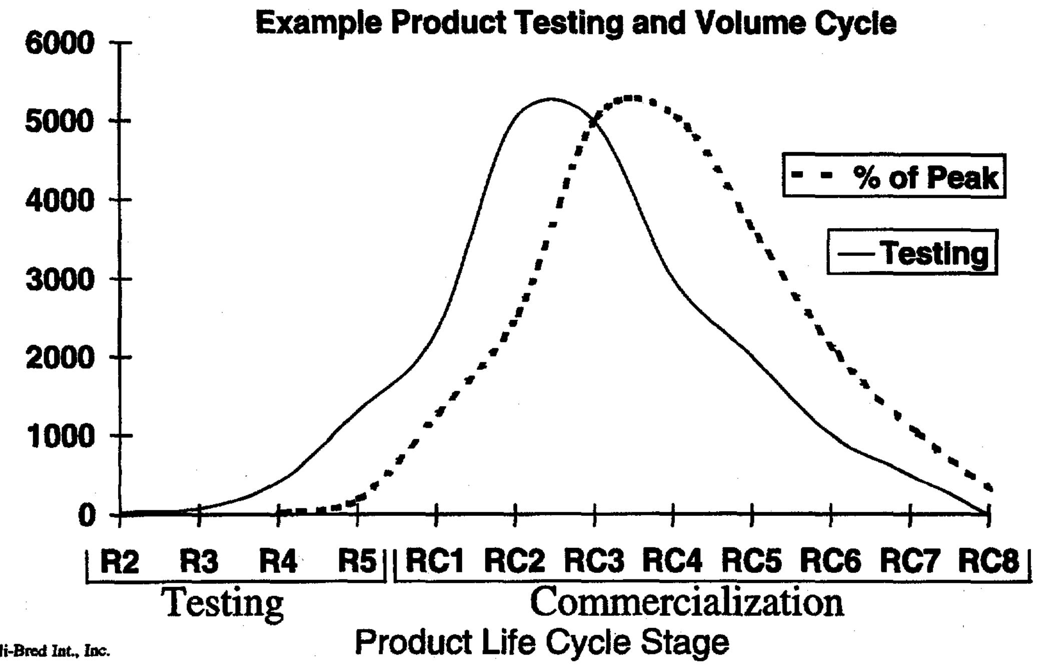
As this account shows, Pioneer typically carries out hundreds of on station trials and another 1,000 on-farm trials before bringing a new product into full commercial production. Initially, the purpose of these trials is to determine performance of the variety in representative environments with the expected range of stress and disease. A second objective of these trials, which is to measure and to develop the market, comes to the fore as testing moves onto farms in years R4 and R5.

The volume and quality of information coming out of Pioneer's own product tests far exceeds that from official government trials. In countries with mandatory variety registration — where governments do not allow sale of seeds until they have tested and approved the variety — superior varieties can fail due to poor information from government tests. For example, if a government bases its decisions on ten replications only, there is a 5 percent chance that the observed yield from those ten plots will be at least 7 percent higher or lower than the expected or "true" yield of the variety. (figure 3.2 shows the number of locations required to have 95 percent confidence that observed yield is within a given percent of expected yield.) Hence, with compulsory variety registration, not only do governments second-guess company decisions about whether or not a variety will sell, but they frequently do so with inadequate information, that is far less than companies have on hand when they make decisions about whether or not to promote a new variety and to make the necessary investments in seed production.

Production

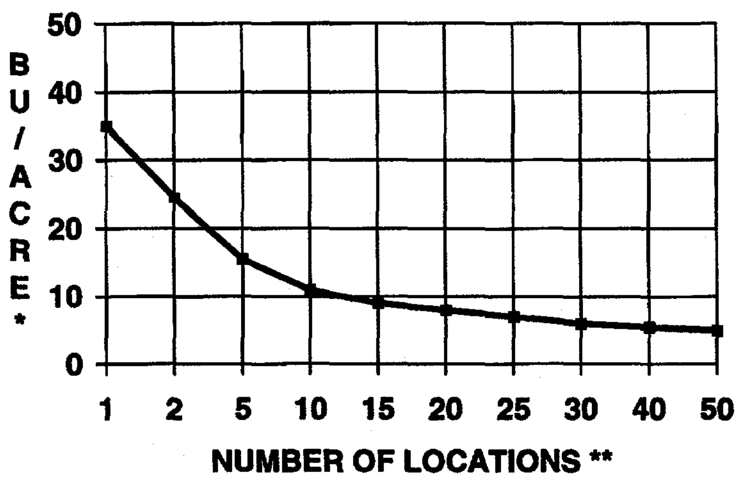
When entering a new market, Pioneer not only faces the challenge to develop and test new products, but also evaluates the sustainability of the business. Can seeds be sold at a profit that will allow for a sustained business operation? Is there a market for maize that allows the farmer to generate enough cash to pay for his investments and to recognize his rewards?. If conditions are favorable, Pioneer works out business arrangements for reliable seed supply.

Figure 3.1 Data driven decisions



Pioneer Hi-Bred Int., Inc.

Figure 3.2 Multi-location testing to evaluate performance



*Performance difference required for (20:1) confidence of a difference

**Number of locations comparing performance

(LSD = .05 @ 150 BU/AC)

Pioneer Hi-Bred Int., Inc.

Sales and marketing

Pioneer expands on-farm tests or demonstrations into the thousands during the first several years of commercialization (years RC1 and RC2 in Figure 3.1). For these tests or demonstrations, farmers buy seeds, while Pioneer provides technical advice. These tests provide farmers with information about variety performance, building market demand.

In markets with competitive private seed industries, the expected market life of a maize hybrid is about eight years from first commercial sale. The main cause of this turnover is genetic advance in breeding. Genetic advances support annual yield gains of 0.5 to 2 percent, depending on the market. Gains are toward the high end of that range in markets such as Thailand, where research is in early stages of development and where favorable markets exist for the increased grain that is produced. In more established markets, such as the United States, gains are lower. With steady genetic advance, even a very good hybrid can be overtaken and pushed off the market in ten years.

Policy-based barriers to serving new markets

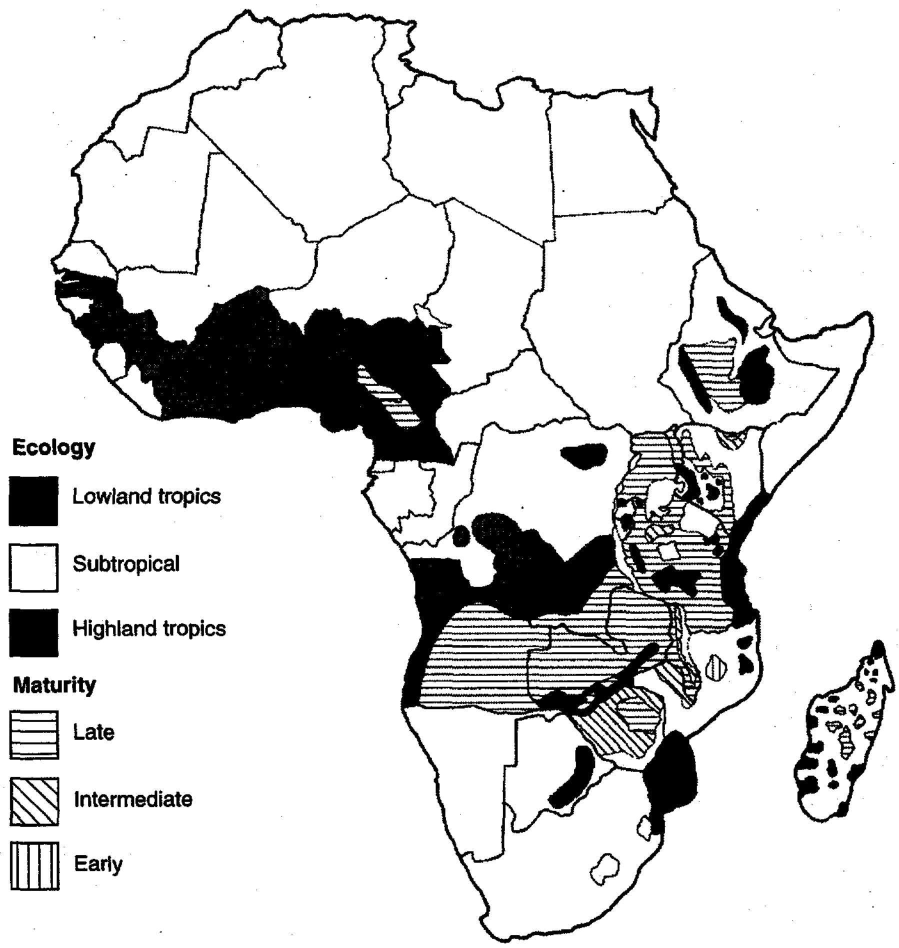
While previous paragraphs describe the technical and organizational challenges involved in developing new hybrids and getting seeds to farmers, the world is not so simple. Government policies often get in the way, blocking Pioneer's ability to serve markets. In many developing countries, policy-based obstacles have been so severe that Pioneer — and many other private seed companies — simply leave them alone. In some countries, obstacles are less severe, so that Pioneer is able to operate, but without full efficiency. Obstacles include:

- unrealistic phytosanitary regulations blocking seed import, such as quarantine requirements for diseases that are endemic to the seed importing country;
- excessive registration requirements, whereby governments block private company efforts to deliver seeds of new varieties to markets;
- loss of physical control of parents (that is, government demands that companies deliver samples of hybrid parent lines to certification or registration agencies, etc);
- local sourcing requirements for seeds or parent seeds, which obstructs company ability to introduce new hybrids or to move excess seed from country-to-country. This boosts seed costs to farmers; and
- inadequate protection for intellectual property rights, which discourages companies from bringing in their best materials.

The size of the market is a major consideration for Pioneer and other seed companies. Pioneer weighs costs to enter and serve a market — for example, research and development, overcoming policy obstacles — against market potential. Markets can and sometimes do extend across political boundaries; this is particularly true in Europe, where all countries accept varieties approved by any one government. Larger markets encourage more research and allow more efficient seed production and supply; Pioneer is able to deliver better products at lower cost. But when small countries allow political boundaries to divide markets by not allowing varieties or seeds from other countries to enter, each of the resulting markets may be too small to repay Pioneer for research and regulatory expenses required to deliver seeds to farmers. This is a problem in much of Africa, where political boundaries divide large potential markets into many small national markets, and where regulatory barriers add unnecessary costs to entering these small national markets.

The map in figure 3.3 shows CIMMYT maize mega-environments for sub-Saharan Africa. CIMMYT developed these mega-environments to guide research design; each mega-environment describes an area within which varieties developed with particular characteristics can be distributed. From a marketing point of view, mega-environments suggest size of market for new varieties. Clearly, mega-environments overlap political boundaries. Grain

Figure 3.3 African maize ecology map



Source: CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo) maize mega-environments for sub-Saharan Africa. (1989/90)

color is another important attribute. Table 3.1 shows hectares planted to maize according to grain color and ecology in Asia and Africa.

Maize hybrids in Asia: historical perspective

Maize hybrids were first introduced into Asia on a large scale in China in the 1960s. Many of the hybrids that were successful were temperate-zone varieties, and were not useful for sub-tropical and tropical areas of other Asian countries. By the early 1970s, the majority of the breeding programs in the other parts of Asia focused chiefly on the development of high-yielding open pollinated varieties (OPVs), led by the International Maize and Wheat Improvement Center (CIMMYT).

The 1980s saw the introduction of hybrid maize to many of the other Asian nations as average corn yields began to flatten, and private sector seed companies began to conduct operations in many countries. While the seed industries and markets in many Asian countries are still in the early stages of development, the 1990s should offer exceptional opportunities for increased hybrid use as maize consumption in the area increases, and the need for higher yielding maize increases. Table 3.2 shows the date of introduction for hybrid maize for the major maize producing countries of Asia as well as estimates of hybrid maize area for 1992.

Table 3.1 African and Asian maize area by grain color and ecology, ca 1990-91 (1,000 hectares)

Grain color and ecology	*Africa/Middle East*	*Asia (except China)*	*China*
white sub-tropical	8,000	840	620
white highland tropical	20	—	—
white lowland tropical	6,300	2,900	—
white transitional	1,500	—	1,200
white temperate	2,100	—	2,900
yellow lowland tropical	680	8,800	—
yellow sub-tropical	580	1,100	2,000
yellow transitional	—	860	1,900
yellow temperate	3,300	—	11,600

Table 3.2 Asia Hybrid Maize Area, 1992

Country	*hybrids introduced*	*hybrid area (1,000 ha)*	*OPV area (1,000 ha)*	*Percent hybrid*
China	early 1960s	15,300	5,700	73
India	mid-1970s	1,200	4,800	20
Philippines	1981	230	3,100	7
Indonesia	1985	60	2,900	2
Thailand	1980	320	950	25
other Asia	—	1,300	1,700	42
Asia total	—	18,400	19,100	49

China

China is far and away the largest maize producer in Asia. Almost three-quarters of its maize area is currently planted to hybrid varieties. Yellow dent hybrids from the United States were successfully introduced in the 1960s in the northern, temperate maize growing areas. These hybrids continue to be prevalent to this day. China's seed industry is currently dominated by the government. The basic mechanisms of a functioning seed market are in place, but inadequate seed processing and quality assurance procedures result in very poor quality seeds often being used by farmers. The genetic base for maize is also narrow, due to the government monopoly on the seed industry and lack of intellectual property protection.

India

Hybrid use in India is prevalent only in some of the southern and eastern parts of the country. Hybrid use is confined mainly at this time to the provinces of Andhra, Pradesh, Karnataka, and Bihar. Constraints on increased hybrid use in India have included the small size and low incomes of farms, and lack of hybrids suitable for some maize growing areas. Investment by private seed companies has been limited by a challenging business environment.

Philippines

Hybrid maize in the Philippines grew steadily to about 15 percent of total area in about 1987. Economic distress among farmers in the late 1980s caused hybrid use to decrease somewhat since that time. Volatile maize prices, a lack of infrastructure in some areas, and problems with access to credit for farmers have slowed hybrid adoption. Maize areas in Luzon and in some key areas of Mindanao use the highest proportion of hybrids.

Indonesia

Hybrid maize use in Indonesia has increased in some major maize growing areas such as West Java, Lampung, Sumatra, and Northern Sumatra. Maize growing areas on other outlying islands face greater difficulties in maize transportation and marketing, and have limited hybrid seed maize use. Maize also fits into a relatively complex multi-cropping system in many crop areas, where maize is not the crop of primary importance.

Thailand

Thai maize farmers use an increasing proportion of hybrid maize. The central and north central regions of the country currently use hybrids on almost 50 percent of maize area. Farmers in Thailand have historically purchased seeds of improved OPVs on an annual basis. However, hybrid varieties from the private sector are now beginning to dominate the seed maize market. Most maize is sold by farmers into a relatively efficient commercial marketing system, where maize moves into export channels or an ever growing poultry sector.

Projections of Asian maize consumption and implications for hybrid seed utilization

Consumption

Maize has historically ranked third in importance among grains behind rice and wheat in Asia. However, its importance has grown significantly in the last two decades as diets have become increasingly westernized. Rapid income growth in most countries in Asia has resulted in dietary upgrade favoring higher meat and dairy consumption.

For example consumption of both pork and poultry meat have doubled since 1983. To the extent that domestic livestock industries have grown to meet increased demand, maize consumption has increased dramatically along with other feedstuffs. Feed use of maize has grown in importance relative to food use. In 1973, food uses of maize accounted for 66 percent of total consumption and feed uses accounted for 34 percent. In 1993, these numbers reversed, as 36 percent is used for food purposes and 64 percent for feed.

At current rates of growth, consumption of maize in Asia will increase from a 1993 level of 153 million metric tons to almost 200 million metric tons by 2003. This represents an increase of 30 percent in the next decade. If income growth is sustained at levels of the past few years, consumption of meat and dairy products could increase an even greater amount, putting further pressure on maize producers in Asia to increase productivity.

An important question is how countries in Asia will supply maize to meet increased demand. Will maize be imported from international markets, or is there potential for increased production from within the region? As consumption of maize has increased, Asia's production has not kept pace. Net imports have been rising gradually in the last decade. Imports are likely continue to grow over the next decade. This will be particularly true if yield levels in many Asian countries remain at current low levels.

Hybrid technology to meet consumption needs

Rising maize consumption figures show the presence of economic motivation to boost maize production among the major maize producing countries in Asia. Increases in maize planted area along with steady yield gains fueled production growth in Asia from 1960-90. Maize area in Asia grew 52 percent from 1960-90, but further expansion is difficult due to land constraints and population growth. In many countries, maize is already being planted on highly marginal land. Increased maize production, if it is to come, will have to come from higher yields, increasing at a faster rate than in the past.

More widespread and extensive use of hybrid technology stands as a very effective means of achieving growth in yields on current maize area in Asia. Pioneer estimates that hybrids achieve yields 50 to 300 percent higher than open pollinated varieties in Asia, utilizing little more than a different seed at planting time.

Yield levels for maize producing countries in Asia are significantly lower than the world average (1986-91 average) of 3.6 tons/hectare (t/ha). China is the only country with yields over this level (4.0 t/ha), with Thailand (2.5 t/ha), Indonesia (1.79 t/ha), India (1.4 t/ha), and the Philippines (1.2 t/ha) falling below the average. Table 3.3 shows what maize consumption would reach in ten years at current rates of growth for the largest maize producing countries in Asia. Of these countries, China is currently a net exporter, and the rest are about self-sufficient.

Table 3.3 also shows the amount of total maize area that has to be planted to hybrids for countries to be self-sufficient in maize in 2003. Even under generous assumptions of yield growth with total maize area at 1992 levels, over eight million hectares of maize has to be converted to hybrids for the illustrated countries to remain self-sufficient. China and Thailand would have to convert virtually all maize areas to hybrid use, and significant gains would have to be made in India, the Philippines, and Indonesia for these countries to remain self-sufficient.

Constraints and solutions for extending hybrid maize in developing countries

What needs to happen to increase use of hybrid maize seed in developing countries where it is not currently prevalent, but where there is economic incentive for higher yields? What are the main constraints to increased hybrid utilization, and what changes are needed in economic and policy environments to allow seed markets to develop and farmers to use hybrid seeds?

First, in many developing countries, suspicion about hybrid seeds continues both out of ignorance and misinformation. These suspicions are often expressed as follows: that hybrid seeds are expensive; that hybrids are big consumers of agricultural inputs such-as chemicals and fertilizers; that hybrid seeds are tools of developed countries to control the agricultural economies of developing countries; etc.

Table 3.3 Hybrid adoption to meet Asian maize consumption in 2003

	Projected consumption in 2003 (1,000 ha)	*1992 hybrid area (1,000 ha)*	*hybrid area 1992 hybrid area as a % of total maize area*	*needed for self-sufficiency in 2003 (1,000 ha)*	*2003 hybrid area as a % of 1992 maize area*
China	117,000	15,300	73	21,000	100
India	11,800	1,200	20	1,900	32
Philippines	6,300	230	7	1,200	35
Indonesia	6,500	60	2	960	32
Thailand	6,300	320	25	1,300	100

Assumptions: (1) Authors' estimates of the difference between hybrid and OPV yields were used to determine how much production resulted from areas planted to hybrids and OPVs. (2) Hybrid yields are assumed to increase to 2003 at a 2 percent annual rate from current levels, and OPV yields at a 1 percent annual rate; these figures are consistent with long-term yield trends for countries where hybrids or OPVs predominant, respectively. (3) Using figures for current maize total area, the column on the right shows the percent of area that would have to planted to hybrids for countries to be self-sufficient in maize with projected consumption in 2003.

The situation calls for a hybrid seed education program to correct the misinformation of previous years promoted by well-meaning but misguided individuals. Governments and donors can and should play leading roles in this effort. An education program can avoid references to specific brands of hybrid seeds, focusing on informing farmers about issues such as:

- the economics of hybrid maize production, with attention to cost per ton of grain produced rather than cost per hectare;
- the positive impact of hybrid maize on farm profits; and
- suitability for varying levels of technology (low, medium, or high input) in developing countries.

Attitudes are already changing. Until just a couple of years ago, for example, the Philippines Department of Agriculture promoted OPVs rather than hybrids in government sponsored maize production programs. Today, however, the Philippine government pushes hybrids, and even CIMMYT promotes hybrid seed technology for developing countries.

Second, government agricultural and pricing policies can wreak havoc on farmers' decisions to use hybrid seed. Farmers use good seeds (and other inputs, such as fertilizers and chemicals) when they see chances to make money. Like good investment bankers, farmers exercise good "risk management." Governments complicate farmers' investment decisions by playing around with the question of whether or not to import maize. Once maize imports enter the picture, domestic prices drop, and farmers who invested for high yields may be left holding five metric tons per hectare with domestic prices half of what they were at time of planting and before maize imports.

Formulating and adopting consistent agricultural policies will lead farmers toward greater productivity and ultimately lower consumer prices.

Third, key maize production areas within countries have to be prioritized. Maize areas with the best agronomics, the best access to markets, and the most dynamic part of the farm population have to be targeted for conversion from OPV to hybrid use. Technology adoption typically occurs in stages over a period of time, so attempts to achieve widespread increases in hybrid use in all maize growing areas of a country will likely be futile. Rather, a step approach, targeting those areas most likely to use hybrids, should be used.

Fourth, many governments will have to improve environments to foster a competitive seed market and to achieve wider use of hybrids. In many cases, investments in infrastructure, post-harvest storage facilities, and extension services are called for to improve farm productivity and profit. Improved access to credit would in many cases dramatically increase farmer use of hybrid seed. Often a more attractive business and legal environment would motivate private seed companies to increase investment, and ultimately form a viable and competitive seed market.

Fifth, age-old obstacles to agricultural development (for example, small farm sizes, backward farmers, etc) should no longer be used as excuses for lack of emphasis on seed market development. Seed markets are well established in many developing countries despite extreme variations in farm size and sophistication, income levels, and the status of agriculture in the economy. Research is making available many viable hybrids for developing countries, and economic incentives to increase production are evident. Impediments to hybrid technology adoption can and have been eliminated in many developing countries despite past reservations about the likelihood of technology transfer.

Closing statement

Some governments "tilt the field" in favor of local maize breeders and against international companies. Governments do this by requiring lengthy variety registration procedures or simply by providing no protection for intellectual property.

However, maize plants wave no flags! The plant's germplasm is so varied and mixed that it crosses over many political boundaries. Ultimately the most important issue is to get the best possible genetics into farmers' hands in order to give them the plant characteristics they need to be successful. Countries can encourage foreign companies to bring in their best materials by establishing systems to protect plant breeder's rights.

An International Strategy for Cotton Breeding, Variety Introduction, and Seed Supply

Donald A. Pallin

Delta and Pine Land Company (D&PL) is the largest private cottonseed breeding, production and marketing company in the world. D&PL has commercial cottonseed products on the market in fourteen countries. In the United States, varieties owned or controlled by D&PL are planted on 70 percent of cotton area. The company is a leader in bringing new biotechnology cottonseed products to the market.

Cotton is a unique crop in the developing world. Cotton is a raw material for textile industries within developing countries and an important earner of foreign exchange. Because of cotton's commercial importance, performance of the crop from year to year often has social implications.

In developing countries where cotton is a major crop, governments characteristically have strong interest in and influence over cotton production. Whole bureaucracies exist to support and control production. Self-protective behavior by these bureaucracies sometimes inhibits introduction of new varieties or other technologies.

D&PL approach to foreign markets

The company's initial international efforts were based on license agreements with local seedsmen to produce and market D&PL varieties. However, increasing complexity in cottonseed technology is pushing D&PL toward joint ventures, where D&PL has more influence over day-to-day operations and can oversee technologies that are becoming more important; that is, delinting, conditioning, and treating. Also, the new transgenic varieties will require more experienced management.

On first entering into a new country market, D&PL screens large numbers of cultivars to evaluate competitiveness of its own germplasm against existing varieties. If needed, and depending on market opportunities, D&PL develops new varieties through conventional breeding protocols to overcome any shortcomings in its products that are identified in this screening process.

Once varieties are identified or developed, the company invests in extension-type marketing to demonstrate advantages of its new products.

When entering a new market, D&PL evaluates local farming and ginning practices in terms of their ability to produce high-quality planting seed. Where seed markets and production possibilities are satisfactory, D&PL finds a local partner, forms a joint venture, and constructs delinting and conditioning facilities.

The company introduces strict quality assurance controls and procedures in order to assure consistent production of high-quality seed. D&PL aims for country-by-country self-sufficiency in cottonseed production and processing to keep costs down. Once present in a country, the company introduces new technologies as market development warrants.

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Conclusions and recommendations

Developing nations can participate in and benefit from new technologies if they will create a level playing field on which all parties who have something to offer can compete on the basis of product performance. This level playing field comes with free markets. Testing and registration requirements can be obstacles to free markets. Market forces are very efficient in evaluation and accepting or rejecting new technologies.

D&PL urges governments to enact and enforce plant variety protection and patent laws, which are particularly important for cotton, a self-pollinated crop.

Corruption, bureaucratic stone-walling, and other impediments to market access must be avoided at all cost or new technologies will pass countries by. Government leaders are encouraged to recognize the potential advantages that modern technology can bring to their people, to encourage collaborative efforts by technology companies and local organizations, and to maintain a friendly and welcome environment for organizations with a proven track record in developing useful technologies.

Assessment of the International Transfer of Wheat Varieties

Mywish Maredia, Richard Ward, and Derek Byerlee

In this paper we present some empirical indicators of potential and actual transfers of wheat varietal technology across agroclimatic environments and countries in order to gain insight into some of the factors determining spillovers of varietal technology. The analyses presented in this paper also highlight the articulation and degree of complementarity of national and international crop improvement research efforts as reflected in potential and realized international transfers of wheat varieties.

We first use an econometric approach to estimate the coefficients of a global potential spillover matrix for wheat improvement research. We demonstrate the value of international yield trial data in estimating potential spillover effects of an international wheat improvement research system to address the following issue: To what degree is wheat varietal technology environment specific?[1] In other words, is there a yield advantage for varieties developed for a specific target environment compared to varieties developed for other environments and by the international research system? We then present estimates of actual transfers of wheat varieties from a global perspective and discuss the implications of the findings for the design of national and international wheat research systems. We open with a brief discussion of the concept of a spillover matrix and relate it to the basic model used in this study to estimate potential spillover coefficients.

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Due to space constraints the original paper has been edited for this publication. Elipses mark places where material has been deleted.

Spillover matrix: a conceptual framework

A critical feature of much agricultural technology is its environmental specificity. Transfer of agricultural technology, particularly biologically-based technology such as improved varieties, is limited by the spatial and temporal variation of environmental factors such as climate, biotic and abiotic stresses, photoperiod, and soil type. For instance, no one wheat variety will excel everywhere and at all times. The concept of a spillover matrix, C, makes the notion of environmental heterogeneity more tractable. The matrix C is usually an $m \times m$ matrix (where m is the number of agro-ecological environments) with spillover indexes or coefficients, c_{ij}. These technology spillover effects, c_{ij}, measure the performance of a technology developed for environment i, in environment 'j', in relation to the technology developed for environment j.

Potential sources of technology spill-ins are not only research programs in other environments, but also international and regional research programs that develop crop varieties not specific to a particular environment in a country. In such cases, technologies emerging from international programs are considered as an additional source of spill-ins but there is no corresponding target environment, implying that the spillover matrix need not be square.

As noted by Pardey and Wood (1994), two major issues need to be addressed in constructing such a matrix. The first relates to the estimation of spillover coefficients and the second is the environmental classification system employed. These two issues are discussed below within the context of varietal technology.

Spillover coefficients

In the case of varietal improvement research, the elements c_{ij} can be defined as the potential decline (or increment) in the yields of varieties developed for environment i when evaluated in environment j (Y_{ij}), relative to the yields of varieties developed for environment j (Y_{jj}):

$$c_{ij} = Y_{ij}/Y_{jj} \qquad (1)$$

Because of environment specificity, it is expected that $c_{ij} < c_{jj}$ — that is yields are less in environments for which the varieties are not specifically designed. Because of the differential response of genotypes to environmental variation (*G* x *E*, or genotype by environment interactions), the matrix C may not be symmetric. That is to say, c_{ij} is not equal to c_{ji}. *G* x *E* interactions result when test environments are heterogenous for properties which evoke different responses in the genetic lines evaluated. Those environmental properties are referred to as "selective" to distinguish them from other environmental properties (Antonovics et al 1988).

Most studies in the past have used subjective estimates of Y_{ij} in order to estimate potential spillover coefficients, c_{ij}. In this study, we use econometric procedures to quantify these estimates. . . .

Environmental classification system

The environmental classification system determines not only the dimensions of the spillover matrix but also the biological basis for estimating and interpreting the spillover coefficients. Unless disaggregated, it will be extremely difficult to delineate geographical areas that respond differentially to new technologies (that is, *G* x *E* interactions). However, it should not be so highly disaggregated that the dimensions of C become impractically large, leading to estimation problems. The environmental classification system should, therefore be crop specific and based on those delineating biological characteristics (that is, classification criteria) that allow for the expression of genotype by environment interactions.

Most studies in the past, including Englander (1991) and Davis et al (1987) have either used the Papadakis (1966) or the FAO climatic classification to characterize a location. In this study, however, we use the global megaenvironment classification system developed by the International Maize and Wheat Improvement Center (CIMMYT)(table 3.4). CIMMYT defines megaenvironments specifically for wheat improvement research, in terms of areas of similar biotic and abiotic stresses, cropping system requirements, and consumer preferences for types of wheat (Rajaram et al forthcoming). The CIMMYT megaenvironment classification system is used in this study instead of Papadakis or FAO, because the latter is inadequate for a specific commodity like wheat. Unlike the general Papadakis system, the CIMMYT system is based explicitly on selective environmental properties such as the moisture and temperature regimes in the winter season when wheat is grown. It delineates irrigated from non-irrigated areas within an agro-ecological environment, a distinction that is especially important for wheat.

Econometric procedure and data sources

CIMMYT's International Spring Wheat Yield Nursery (ISWYN) trial data for the years 1979-80 to 1987-88 were used to estimate a global potential spillover effects matrix for wheat improvement research.[2] This data set includes more than 24,000 yield observations, of which about 23,000 were used after excluding all observations pertaining to triticale and durum wheats. Also, local checks were excluded

Table 3.4 Classification of spring wheat megaenvironments (MEs) used by CIMMYT wheat program

ME	*Latitude degrees*	*Moisture regime* [a]	*Temperature regime* [b]	*Sown*	*Breeding objectives* [c]	*Representative locations/regions*
ME1 [d]	< 40	Low rainfall; irrigated	Temperate	Autumn	Resistance to lodging, SR, and LR	Yaqui valley, Mexico; Indus valley, Pakistan; Gangetic valley, India; Nile valley, Egypt
ME2	< 40	High rainfall	Temperate	Autumn	As ME1 + resistance to YR, *Septoria* spp., *Fusarium* spp. and sprouting	Mediterranean basin; Southern cone; Andean highlands; East African Highlands
ME3	< 40	High rainfall	Temperate	Autumn	As ME2 + acid soil tolerance	Brazil, Andean; Highlands, Central Africa; Himalayas
ME4A	< 40	Low rainfall; winter dominant	Temperate	Autumn	Resistance to drought, *Septoria* spp. and YR	Aleppo, Syria; Settat, Morroco
ME4B	< 40	Low rainfall; summer dominant	Temperate	Autumn	Resistance to drought, *Septoria* spp., *Fusarium* spp., LR and SR	Marcos Juarez, Argentina
ME4C	< 40	Mostly residual moisture	Hot	Autumn	Resistance to drought	Indore, India
ME5A	< 40	High rainfall; irrigated; humid	Hot	Autumn	Resistance to heat, *Helminthosparium* spp., *Fusarium* spp., and sprouting	Poza Rica, Mexico; Joydebpur, Bangladesh; Encarnation, Paraguay
ME5B	< 40	Irrigated; low humidity	Hot	Autumn	Resistance to heat and SR	Gezira, Sudan; Kano, Nigeria
ME6	> 40	Moderate rainfall; summer dominant	Temperate	Spring	Resistance to YR, LR, *Fusarium* spp., *Helminthosparium* spp., and sprouting	Harbin, China

a. Rainfall refers to just before and during the crop cycle. High = > 500mm, low = < 500mm.
b. Hot = mean temperature of the coolest month > 17.5oc; cold = < 5.0oc.
c. Factors additional to yield and industrial quality. SR = stem rust, LR = leaf rust, YR = yellow (stripe) rust.
d. Further subdivided into: (1) optimum growing conditions, (2) presence of Karnal bunt, (3) late planted, and (4) problems of salinity.
Source: Byerlee and Moya (1993).

because many were either not reported by the cooperators, not identifiable because of lack of information on cross and selection history, or were duplicated as one of the nonlocal check entries.[3] There were 209 unique wheat varieties in the 364 entries over the period of eight years. The number of different locations in 81 countries totaled 195. The trial locations were classified according to CIMMYT's megaenvironrnents discussed above (table 3.4). The wheat varieties were classified by their institutional origin as either:

- NARS (National Agricultural Research System) varieties (that is, crossed, selected and tested by national programs), or
- "CIMMYT varieties"[4] (developed through the international CIMMYT-NARS research collaborative system; that is, crossed and initial selections done by CIMMYT but with testing conducted by national programs).

The NARS varieties were further classified by their environmental origin based on the dominant megaenvironment in the country or region of development and information on the environmental niche (rainfed, irrigated, etc) for which the variety was released. CIMMYT varieties were classified into two classes: (1) those released in Mexico (CIM1); and (2) those released in countries other than Mexico or not released by any national program (CIM2).[5]

The question addressed in estimating a global spillover matrix is: how do varieties developed in a given megaenvironment (that is, the megaenvironment in which all the varieties are tested) perform relative to varieties developed in other megaenvironments (irrespective of their country of origin).[6] Also, we are interested in the issue of transferability of wheat varieties developed by the international wheat improvement research system spearheaded by CIMMYT. This international research system consists of the collaborative research and testing efforts by CIMMYT and the NARSs around the world. Its aim is development of high yielding, widely adapted wheat varieties that can be used by NARSs either as seed products or breeding parents in their wheat improvement programs.

The regression model used to estimate the spillover matrix is shown in Equation 2 (see below), where,

j is the test megaenvironment in which the yield data point is observed. The equations were estimated separately for the following seven megaenvironments — ME1, ME2, ME3, ME4A, ME4B, ME5A and ME6 described in table 3.4.[7]

Y^j_{hgt} is the observed yield (kg/ha) of the g'th entry at the h'th trial location in environment j and in t'th trial year.

$DLOC_h$ is a vector of dummy variables equal to one if the data point belongs to location h, zero otherwise.

$DYEAR_t$ is a vector of dummy variables equal to one if the data point belongs to trial year t, zero otherwise.

$$Y^j_{hgt} = a + \sum_{h=1}^{H} b_h DLOC_h + \sum_{t=1}^{T} c_t dYEAR_t + v \ VINT + \sum_{i=1}^{m} w_i DORIG_i + r \ MR + \epsilon_{hgt}$$

$$\text{for } j = 1, 2, \ldots, n \qquad (2)$$

VINT is a variable to reflect the age or vintage of a variety approximated by the trial year in which the g'th variety first appeared.

$DORIG_i$ is a vector of dummy variables equal to one if the g'th variety belongs to the origin group i (that is, developed for megaenvironment i), zero otherwise. There are nine such dummy variables; seven correspond to NARS varieties classified by their megaenvironment origin (DOME1, DOME2, DOME3, DOME4A, DOME4B, DOME5A, DOME6); and two correspond to CIMMYT varieties released in Mexico (DCIM1) and elsewhere or not at all (DCIM2).

MR is the inverse Mill's ratio (described further below).

$\in$ is the error term.

Thus, the performance of a variety is assumed to be a function of environmental variables (DLOC, DYEAR) and technology variables (VINT, DORIG). The variables VINT and DORIG represent characteristics of a varietal technology. Since we are using panel data, the location and year dummies (DLOC and DYEAR) are included to factor out the site and time effect on the observed yields.

The yield trial data are characterized by varietal attrition due to the replacement of older varieties by better yielding varieties in successive years of the trials. Since the probability of varietal attrition is correlated with experimental response (that is, yield), the traditional statistical techniques for panel data estimation will provide biased and inconsistent estimators (Hsiao 1986). The variable MR (inverse Mill's ratio) is included in the equation to correct for this selection bias of non-randomly missing varieties in the yield trials conducted over a number of years (Hsiao 1986).

Since the model is estimated separately for each megaenvironment, the coefficients for DORIG represent the performance of varieties of different environmental origins in a given megaenvironment relative to the "home varieties." The varietal group originating from the test megaenvironment were considered as the benchmark variable (that is, dummy variable $DORIG_j$ were dropped from the equation for each megaenvironment). Therefore, the coefficients of $DORIG_i$ are the differential yields defined as ($w^j_i = Y_{ij} - Y_{jj}$). These coefficients can be used to estimate Y_{ij}/Y_{jj} to give the elements of the potential spillover matrix, c_{ij}, based on the constant Y_{jj} (approximated by the arithmetic mean) for each megaenvironment.

Empirical results and the estimation of global potential spillover matrix

Model parameters in Equation 2 were estimated using the ordinary least squares method. The statistical results of the regression analyses are summarized in Table 3.5. The results indicate that the inclusion of dummy location variables had a significant positive effect on the R^2 of all the seven regression models. Except for ME1 and ME2, the dummy variables for trial years also significantly increased the R^2 of the estimated models.

The coefficient of VINT variable measures the gain in average yield/ha/year of new varieties in a given megaenvironment. Note that the coefficient is an average for all the varieties and is not specific to a particular origin group. Except in ME2 (high rainfall, temperate), ME3 (high rainfall, acid soils), and ME4B (low rainfall, winter drought), yield improvements are not significantly different from zero. The non-significant coefficients of VINT variable in many environments including ME1 (irrigated, temperate) confirm the difficulty that wheat breeders have faced in maintaining significant growth rate in yield potential since 1980s (Bell et al 1994). As indicated by coefficients of the MR variable (inverse Mill's ratio), there is a positive and highly significant (in most of the

Table 3.5 Regression results of potential spillovers at the megaenvironment level using ISWYN data, 1980s

Independent variables	*ME1* *Irrigated*	*ME2* *High rainfall*	*ME3* *Acid soils*	*ME4A* *Winter drought*	*ME4B* *Early drought*	*ME5A* *High temperatures*	*ME6* *High latitude*
1. Constant [a]	4880***	3390***	336**	2041***	1942***	2221***	3394***
2. Dummies for year R2 change [b]	0.02	0.02	0.23	0.17	0.17	0.05	0.08
F change [c]	35***	32***	184***	144***	46***	15***	124***
3. Dummies for location R2 change [b]	0.56	0.44	0.27	0.40	0.21	0.29	0.52
F change [c]	166***	131***	287***	159***	59***	113***	154***
4. VINT [a]	4.27	31.2	10.9*	2.5	28.1**	-2.2	4.7
5. Mill's ratio, MR [a]	155***	135***	111**	93	141**	97**	87.7**
6. Origin, DORIG [a,d]							
DOME1: Irrigated	0	-189**	-406***	-374**	-346**	34	-223***
DOME2: High rainfall	-232***	0	-509***	-307*	-275*	-177	-175**
DOME3: Acid soils	-507***	-141	0	-568***	-282*	-31	1
DOME4A: Winter drought	-66	-226*	-565***	0	-483**	-154	-259**
DOME4B: Early drought	-486***	-101	-290**	-334*	0	-161	-56
DOME5A: High temperature	-593***	-525***	-219	-672***	-328	0	-334**
DOME6: High latitude	-588***	-395***	-414***	-507***	-270*	-264**	0
DCIM1	527***	490***	-14	20	191	23	-91
DCIM2	227***	230***	-138	-105	16	7	-131**
Number of observations	4641	4248	719	1824	850	935	2913
R^2	0.61	0.53	0.78	0.65	0.40	0.53	0.68

*P < 0.05
**P < 0.01
***P < 0.001
a. Number given is the estimated coefficient (kg/ha).
b. Number given is the change in R2 when a given set of dummy variables is entered in the equation that includes all the other variables.
c. Number given is the change in F-ratio when a given set of dummy variables is entered in the equation that includes all the other variables.
d. Origin groups DOME1 to DOME6 represent cultivars developed by national programs for respective megaenvironments. DCIM1 indicates CIMMYT cultivars released in Mexico and DCIM2 indicates CIMMYT cultivars released in countries other than Mexico or not released anywhere.

megaenvironments) relationship between observed yields and the probability of retention in the trials.

The coefficients of origin variables (w_i) estimate the yield advantage (or disadvantage) of varieties originating in different environments relative to the test environment (kg/ha). The zeros on the diagonal indicate that the coefficient of variety group of the same environmental origin as the test environment is defined as the "benchmark" and all the other coefficients in that column represent deviations from that value.

The negative values of NARS technology in all the megaenvironments confirm the hypothesis that varieties developed in a test megaenvironment perform better than varieties developed in other megaenvironments. For example, the second number in the first column shows that NARSs varieties of ME2 (high rainfall) origin yield 232 kg/ha less on average in ME1 (irrigated) than the NARSs varieties developed for ME1 (after adjusting for other variables). The strength of this relationship is shown by the fact that nearly all the off-diagonal elements are negative and usually statistically significant. Significant negative values in a given column result from either: (a) both genetic differences among varieties and a difference in the selective environment at the test versus origin environments, or (b) only a difference in the genetic properties of the varieties tested. The latter circumstances could reflect different levels of breeding success and would result in symmetrical relationship such that $w^j_i = - w^i_j$. The abundance of negative values both above and below the diagonal show that CIMMYT's megaenvironment system reflects true differences in selective environmental properties.

The last two rows show that CIMMYT varieties perform well in most megaenvironments, especially in ME1 (irrigated) and ME2 (high rainfall). For example, CIMMYT varieties released in Mexico (DCIM1) enjoy a yield advantage of 527 kg/ha in ME1 (irrigated) compared to NARS varieties of ME1 origin. The positive yield advantage of CIM1 in many test megaenvironments indicates the potential of CIMMYT varieties to spill-over to these test megaenvironments.[8]

Akin to previous studies, the spillover coefficients are presented in table 3.6 in terms of percentage coefficients based on the average yields of the benchmark variable (that is, $c_{ij} = Y_{ij}/Y_{jj}$). Off-diagonal values less than one indicate that directly introduced wheat varieties from other megaenvironment yield less than those developed by local breeding programs in the test megaenvironment. Similarly, values greater than one (as in the case of CIMMYT varieties) indicate that directly introduced wheat varieties from these sources yield more than those developed by local breeding programs in the test megaenvironment.

The significant yield advantages expressed by varieties developed and evaluated in ME1, ME2, ME3 and ME6 (implying less direct spill-ins of NARS varieties from other megaenvironments) can be explained by the fact that these megaenvironments are comprised of countries with a strong experience in wheat research — for instance, India and Pakistan in ME1 (irrigated), Turkey and Spain in ME2 (high rainfall), Brazil in ME3 (acid soils) and the developed countries of Europe and North America in ME6 (high latitude). On the other hand, the "environmental distance" plays a role in explaining the significant yield advantage enjoyed by domestic varieties in ME4A and ME4B (drought environments). To a certain extent this also holds true for ME3 (acid soils) and ME6 (high latitude). For example, growing conditions in ME3, except for the acid soil, are very similar to those in ME2 in terms of water supply and temperatures (that is, environmental distance is less). Thus, ME3 varieties perform relatively well in ME2. However, in ME3 the soil toxicity adds to the distance between the two environments and constrains the transferability of technology from ME2. This is evident from the highly significant yield disadvantage of ME2 varieties (19 percent) when planted in ME3 compared to the small and less significant yield disadvantage of ME3

Table 3.6 Estimated spillover matrix for wheat improvement research at the global megaenvironment level

	Megaenvironments where varieties are tested[a]						
Origin of variety	*1 Irrigated*	*2 High rainfall*	*3 Acid soils*	*4A Winter drought*	*4B Early drought*	*5A High temperature*	*6 High latitude*
ME1 Irrigated	1.00	0.95	0.84	0.90	0.88	1.02	0.94
ME2 High rainfall	0.95	1.00	0.81	0.92	0.90	0.89	0.96
ME3 Acid soils	0.89	0.96	1.00	0.85	0.90	0.98	1.00
ME4A Winter drought	0.99	0.94	0.78	1.00	0.83	0.91	0.93
ME4B Early drought	0.90	0.97	0.89	0.91	1.00	0.90	0.99
ME5A High temperature	0.88	0.86	0.92	0.82	0.89	1.00	0.92
ME6 High latitude	0.88	0.89	0.84	0.87	0.91	0.84	1.00
CIM1 CIMMYT/Mexico	1.11	1.13	0.99	1.01	1.07	1.01	0.98
CIM2 CIMMYT/Other	1.05	1.06	0.95	0.97	1.01	1.00	0.97

a. Yield expressed relative to the yield of cultivars originating in that megaenvironment (= 1.00).

varieties (4 percent) planted in ME2. The asymmetry in the environmental distance between two environments explains the asymmetry in the spillover matrix (that is, C_{ij} is unequal to C_{jj}).

If we examine the performance of CIMMYT varieties (CIM1 and CIM2) across megaenvironments, the prominent result of the regression analyses is the wide adaptability and transferability of CIMMYT varieties to different environments. The environmental specificity and associated selective environmental heterogeneity evident in the comparison of NARS varieties is minimized when CIMMYT varieties are compared across different megaenvironments. This points to the success of the international research system in overcoming $G \times E$ interactions and developing widely adapted varieties, at least in the irrigated and high rainfall environments, which account for about 70 percent of the spring wheat production in developing countries.

Evidence of actual international transfer of wheat varieties

The major source of data for the empirical analysis of actual spillovers is a 1990 survey conducted by CIMMYT of wheat research programs in thirty-eight developing countries (Byerlee and Moya 1993). The inventory of all the wheat varieties released in developing countries during the 1966-90 period is classified according to the origin of cross as either CIMMYT variety or NARS variety. This information is used here to assess the direct and indirect international transfer of wheat varieties. Direct transfers are those varieties that are developed by research program A and directly released by research program B after local testing; an example is Pak 81, a CIMMYT bred variety released in Pakistan. By contrast, a variety used as a parent material in another country's breeding program is a case of indirect transfer.

Several important changes have occurred in the global system for producing varietal technologies since 1966, which reflect the increasing mobility of wheat varieties across international boundaries. The proportion of releases that are direct CIMMYT transfers has increased by 26 percent, and indirect transfers increased by 11 percent. In 1986-90, 85 percent of NARS releases were based on CIMMYT germplasm (that is, direct plus indirect transfers), compared to just 48 percent in 1966-70 (Byerlee and Traxler 1995).

By 1990, more than 650 (about 50 percent of total) wheat varieties released in developing

Table 3.7 Varieties released in developing countries, classified by the type of technology transfer embodied, 1966-90

Technology transfer group	*Number of varieties*	*Percentage of varieties*
1. Direct Transfer		
(a) from CIMMYT	575	44.3
(b) from other NARS	79	6.1
2. Indirect Transfer [a]		
(a) from CIMMYT	235	22.9
(b) from other NARS	38	2.9
3. Non-transferred varieties [b]	389	23.9
Total	1,317	100

a. Varieties based on NARS crosses using parent materials from other sources.
b. Varieties developed by NARS without direct or indirect transfers.
Source: Byerlee and Moya (1993).

Table 3.8 Percent of wheat varieties released in developing countries by type of technology transfer and region, 1965-90

	Region			
	Sub-Saharan	West Asia & North Africa	South Asia	Latin America
1. Direct Transfer				
(a) from CIMMYT	40.1	51.8	41.0	45.8
(b) from other NARS	20.4	26.3	4.8	2.1
2. Indirect Transfer from CIMMYT [a]	20.4	8.8	31.0	22.5
3. Non-transferred varieties [b]	19.1	13.2	23.2	29.6
Total	100	100	100	100

a. Varieties based on NARS crosses using CIMMYT parents.
b. Varieties developed by NARS without direct or indirect transfers.
Source: CIMMYT Wheat Impact Survey, 1990.

Table 3.9 Classification of NARSs by the extent of released varieties based on direct transfers, 1966-90

Less than 25 percent	*26 to 50 percent*	*51 to 75 percent*	*76 to 99 percent*	*100 percent*
Kenya	Argentina	Ecuador [a]	Guatemala	Algeria
Peru	Brazil	Egypt	Libya	Bangladesh [a]
	Chile	Ethiopia [a]	Mexico	Bolivia
	Colombia	Iran	Morocco	Burundi
	India	Jordan	Saudi Arabia	Lebanon
	China (South)	Pakistan	Sudan [a]	Myanmar [a]
	Zimbabwe	Paraguay	Yeman [a]	Nepal [a]
		Syria		Nigeria
		Tunisia		Tanzania [a]
		Turkey		Zambia
		Uruguay [a]		

a. Countries with a significant release based on direct transfers from other NARS.
Source: Adapted from Byerlee and Moya (1993).

countries were directly transferred from CIMMYT or other NARSs (table 3.7). Another 25 percent of the wheat varieties were based on indirect transfers from CIMMYT or other NARSs. The use of CIMMYT germplasm as direct transfers is consistently high across regions (table 3.8). The tendency toward using CIMMYT materials as indirect transfer is greater in Asia, where most advanced wheat breeding programs are located, compared with West Asia, North Africa, and Latin America, where a greater number of varieties are based on direct transfers.

The importance of direct CIMMYT transfers is also evident from table 3.9, which indicates that most of the smaller NARS have depended on direct transfers for more than half of their varieties; and a third of these have depended 100 percent on direct spillovers. Important exceptions to this rule are Mexico (where CIMMYT is located) and Pakistan (where the wheat-growing environments are very similar to those in Mexico). There are also significant country-to-country direct spillovers, as some of the countries with small wheat programs, such as Sudan, Bangladesh, and Nepal, import large numbers of varieties from neighboring countries. Most larger NARSs, on the other hand, have demonstrated a significant ability to develop varieties from their own crosses. Access to CIMMYT germplasm is, however, crucial to the wheat improvement programs in these large countries; even the Indian and Chinese spring wheat programs make use of CIMMYT germplasm in more than 50 percent of their releases through a CIMMYT parent used to produce an adaptive variety.

The increased coordination between CIMMYT and NARS in the global system of testing and sharing of germplasm has been an important component of the progress that has been achieved. Two factors have been crucial for the large direct and indirect transfer of wheat varieties that has occurred: (a) germplasm sharing through a network of international wheat nurseries coordinated by CIMMYT scientists since 1964; and (b) ongoing training and scientific exchanges between CIMMYT and NARS wheat breeders. In particular, it appears that the nursery system significantly reduces the transactions costs of transferring varieties developed anywhere in the world.

Conclusions and implications

Many important results pertaining to the issue of technology transferability emerge from the estimation of the potential spillover matrix and actual spillovers at the global and country levels. Research evaluation models have often used spillover matrices to account for the benefits of research conducted by other research programs in similar and different environments. These estimates have been based solely on subjective guesses and on the assumption of location specificity, which implies that the values of the off-diagonal elements in the spillover matrix are less than those of the diagonal elements.

The results for wheat presented in this paper, do not sustain this "location specificity" argument (at least in terms of yields) when the international research system is considered as a source of research spill-ins. Wheat varieties originating from collaborative CIMMYT-NARS international research system have proven to be highly transferable within megaenvironments and across different countries around the world. The yield advantage of varieties developed by the international research system, was as high as 13 and 11 percent in the high rainfall and irrigated environments, respectively. In other megaenvironments (such as low rainfall, acid soils, high temperatures, etc), the yields of CIMMYT varieties, although higher than imported NARS varieties, were not significantly different from yields of locally developed varieties. . . .

Thus, the overarching result of the global . . . . analyses is that varieties developed by the international research system perform better than or at par with the NARS cultivars in most of the major spring wheat environments indicating the success of the international research system in developing widely adapted wheat varieties. This success in combining high yield potential and wide adaptation can be attributed to: (a) large number of crosses (12,000 per year) made by CIMMYT breeders in Mexico; (b) the use of "shuttle breeding" that allows CIMMYT scientists to alternate selection cycles in different environments with high yield potential that differ in altitude, latitude, photoperiod, temperature, rainfall, soil-type and disease spectrum, and (c) the wide testing of advanced lines in collaboration with NARSs throughout the world (Romagosa and Fox 1993). The comparative advantage of this international research system lies in its ability to conduct such a large breeding operation.

However, it should be noted that wheat varieties are probably more "environmentally robust" than varieties of many other crops in terms of international transferability because the differences among production environments and local quality preferences are not as marked as in other crops such as rice, maize or beans. Evidence on the origin of varieties released in developing countries support these results of the potential spillover matrix. The analysis of actual spillovers indicate that more than 50 percent of total wheat varieties released in developing countries in the 1980s were directly transferred CIMMYT varieties. Also, 10 out of 36 countries surveyed by CIMMYT, report that 100 percent of all wheat varieties released in 1965-90 in these countries were based on direct transfers from the international research system. Even a large wheat producing country like Pakistan depends heavily on direct transfers from this international research system. For example, 80 percent of all varieties released in the Punjab for the normal planting date in the period 1980-90 were CIMMYT-origin.

These empirical findings, based on the origin of the released varieties in developing countries and the coefficients of the spillover matrix estimated in this paper, suggest that both the potential and actual spillovers of wheat breeding research are larger than have been reported to date. They also suggest the comparative advantage of the international research system in producing widely adapted wheat varieties. The possibilities of direct transfer of varieties developed by other programs that might be utilized effectively in a given area should therefore be taken into consideration in determining the appropriate type of wheat research in a given environment. Countries where wheat is not an important crop or where national agricultural research systems are not highly developed can consider the option of direct transfer of varieties developed by CIMMYT or other national wheat breeding programs as an alternative. This is especially so for countries where wheat is grown under irrigated or high rainfall conditions. These countries can benefit substantially from only a testing program without incurring large costs in adaptive breeding (crossing and selection) research. There are also implications for countries with large wheat growing areas or diverse environments and which have strong national wheat research programs. These countries need not devote resources for each and every environmental niche in the country. They can utilize their resources more efficiently by following a mixed strategy of direct importation of technology in some environments and local development of technologies in other environments which are unique to the country.

There are however, a few caveats to be noted about this study. First, given the fact that ISWYN trials are conducted by CIMMYT for the purpose of disseminating its germplasm, there is an overwhelmingly large representation of CIMMYT varieties (about 50 percent) in the data analyzed in this paper.

Second, the results are based on the megaenvironment classification system that may overlook important within megaenvironment variations such as late planting in intensively cropped irrigated areas. . . . The transferability of CIMMYT varieties may differ within a megaenvironment depending on the cropping system of a region and other country-specific factors.

Third, this analysis ignores other important factors like grain color, quality and stability which may be important in determining the local acceptability of varietal technology. If the technology available from other sources is high yielding in the local environment but not compatible with the socio-economic environment, then national programs can justify a local breeding program on the basis of other traits. But breeders agree that in field crop like wheat, yield is the most important trait used in making decisions about releasing wheat technology to farmers.

This paper has provided empirical estimates of potential spillover coefficients, which have hitherto been based on subjective guesses. In the age of shrinking budgets for agricultural research, national programs will have to seek advantage of research spill-ins from not only other NARSs in similar or other environments, but also from the regional and international research systems. This paper has demonstrated the usefulness of national and international yield trial data and the data on the origin of varieties in providing estimates of potential and actual spill-ins, from other research programs and international research system. Such information can be used to make strategic decisions about the design of crop breeding programs both at national and international levels that would lead to a more efficient global system of agricultural research.

Notes

1. This notion is usually referred to in the literature as "location specific."

2. With the exception of ISWYN year 1982-83, which was not included because data were incomplete.

3. Since local checks are likely to be the best cultivars grown by the farmers in a given location, their exclusion from the analysis may bias the results downward. However, local checks are not synonymous with locally developed varieties. In fact, about 70 percent of the local checks that were reported and identified were CIMMYT bred cultivars released by national programs.

4. CIMMYT is an international research center with the mandate to provide improved germplasm that can be used by a national program either as parent materials in their breeding program or released after local screening and testing. "CIMMYT variety" as used in this paper is a short for "advanced breeding line developed by CIMMYT in collaboration with NARSs" and should not be equated with the notion that these varieties are released by CIMMYT in any given country.

5. CIMMYT's headquarters is located in Mexico. However, cultivars developed by CIMMYT have to undergo the same procedure for release in Mexico as they would in any other country.

6. Since the potential transfer of varietal technology is constrained by differences among environments, the objective is to analyze technology transfer across megaenvironments and not across political boundaries (ie, countries) as done by Englander (1991). Relating the potential transferability of a technology to environmental zones is important because it allows us to determine the yield change as a function of variables which are based on G x E knowledge. Moreover, estimates of potential technology transferability based on political boundaries are often difficult to interpret (since it is very unlikely that a country or politically defined region will have a homogenous crop growing environment).

7. Because of insufficient number of observations the equations were not estimated for two spring wheat megaenvironments defined by CIMMYT (ME4C and ME5B in Table 3.4).

8. A note of caution is needed on the comparability of the coefficients across columns. The values of the coefficients reported in Table 3.5 are relative to the benchmark origin group (represented by zeros), and are therefore comparable across rows (technologies) but not across columns (environments). Thus we can say that in ME2, ME1 technology yields 189 kg/ha less than ME2 technology, but it is erroneous to say that ME1 technology yields 189 kg/ha less in ME2 than in ME1.

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Genetic Resources, International Organizations, and Rice Varietal Improvement

R. E. Evenson and D. Gollin

Rice varietal improvement is an important component of productivity gains in rice production. . . Until the development of the modern agricultural experiment stations in the middle of the 19th century, farmers themselves created improved rice cultivars in the form of distinct subspecies types or "landraces" of rice. Modern plant breeders in national agricultural research programs have been systematically developing improved rice cultivars in many countries for the past century. Since 1960, the International Rice Research Institute (IRRI) located in the Philippines has been providing international leadership and support to rice genetic improvement.

IRRI has a number of programs to facilitate rice genetic improvement. Its own plant breeding program (IRPB) produces improved cultivars, both in the form of "varieties" that are ready for use in farmers' fields and in the form of "advanced lines" suited for use as parent material in national plant breeding programs. IRRI maintains an International Rice Germplasm Collection (IRGC) designed to preserve germplasm and to provide it freely to the international scientific community — including national germplasm collections. In addition, IRRI maintains and coordinates a system of international nurseries, the International Network for the Genetic Evaluation of Rice (INGER), through which advanced genetic materials are exchanged and evaluated.

In this paper we . . . conduct a genealogical analysis of released rice varieties from national rice breeding programs and IRRI since 1965, when the first modern high-yielding rice varieties were released, and we trace the "routes" by which rice germplasm is incorporated into improved varieties. . .

The first part of the paper presents a brief discussion of rice breeding methods and the role of genetic resources. The second discusses databases and reports basic tabulations of genetic resource characteristics of released rice varieties. The third section reports an analysis of "routes" taken by varieties from origin to release. . . The final section summarizes economic implications.

Rice breeding and genetic resources

Rice is a self-pollinated crop. Because of this, genetically segregated lines remain genetically stable from generation to generation. Genetic changes occur mostly through deliberate "crossing" — or hybridizing of parental cultivars — and pureline selection of the resultant offspring (De Datta 1981). This technique of varietal improvement, known as "pedigree breeding" is not widely practiced with other cereal grains.[1]

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The original of this paper is scheduled for publication in "Economic Development and Cultural Change." *This abridged version is published with the permission of EDCC. Elipses mark places where material has been deleted due to space constraints. Since one table and several sub-sections have been cut, those which remain have been renumbered.*

Varietal improvement efforts in rice, as in all other domesticated crops, date back to the origins of domestication. The very processes of harvesting and planting tend to select for such traits as non-shattering, uniform maturation, high germination, and adaptation to local growing conditions. Harvesting for consumption will also tend to imply selection for high palatability and nutritional value. Farmer selection over many centuries has produced today's "landraces" of rice.

Cultivated rice falls into two species, *Oryza sativa* and *Oryza glaberrima*. The former is the common Asian cultigen, while the latter accounts for a small fraction of African rice production. In addition to these two cultigens, the genus *Oryza* includes about twenty wild species, although some scholarly disagreement remains on the exact number (Chang 1985). It has been estimated that about 140,000 cultivars of rice exist in the world today; more conservative estimates put the figure around 90,000. These include wild species, landraces, and modern varieties.

Organized breeding efforts probably date back to before 1000 AD in China, with the development of the Champa varieties of early ripening, drought-resistant rices. Modern efforts, however, can be traced to the late 19th century in several parts of Asia. In temperate East Asia, the first significant advances were made by Japanese farmers and scientists in developing relatively short-statured and fertilizer-responsive varieties called the *rono* varieties. These varieties, which included the popular Shinriki, belonged to the *japonica* class of rices, and were widely cultivated in Japan as early as the 1890s (Chang 1985, pp 441-443).

During the early part of the 20th century, Japanese scientists sought to create similar varieties that were adapted to Taiwan, which the Japanese then occupied. The main thrust of this research was to create japonica rices that were adapted to the more tropical conditions of Taiwan; the result was a group of varieties referred to as *ponlai* rices (Dalrymple 1986; Barker, Herdt, and Rose 1985). At the same time researchers in tropical Asia were busy seeking more productive varieties of rice from the other two main classes or races: the so-called *indica* and *javanica* rices.

Among the most important goals of rice breeding historically has been the development of fertilizer-responsive varieties that are widely adaptable to regions of different day length and sunlight intensity. More recently, breeders have also sought to incorporate multiple disease and pest resistance as well as tolerance of certain environmental stresses, such as soil salinity, iron toxicity, drought or flooding.[2]

This process has inherently involved the exchange of germplasm across countries and agroclimatic zones. As early as the 19th century, scientists were transporting rice varieties across national borders in an effort to bring in new and advantageous genetic materials. This effort attained new levels in the post-World War II period with the initiation of a program by the United Nations Food and Agriculture Organization (FAO) to cross *indica* rice with *japonicas*. Because the *japonica* rices tended to yield better than the *indicas*, this was seen as a possible means of increasing yield of rice in South Asia and hence as a means of averting hunger (Dalrymple 1986; Barker, Herdt, and Rose 1985, pp 54-55).

In 1950, a *japonica-indica* crossing program was started at India's Central Rice Research Institute in Cuttack. The FAO program developed several varieties that proved enormously successful including Mahsuri, which remains one of the most widely grown varieties in the world. Perhaps more important, the FAO program served as a model for a more intensive project initiated in 1960 by the Ford and Rockefeller Foundations along with other donor agencies. The new research center was the International Rice Research Institute (IRRI), located in Los Banos, the Philippines.

Many authors have recounted the development of the earliest high-yielding rice varieties at IRRI. Hargrove (1981) has pointed out that the first scientists at IRRI had a deliberate blueprint to create a semi-dwarf, fertilizer-responsive rice variety that would grow well under a wide range of conditions. The eighth cross made at IRRI turned out to be a near-immediate success; IR8, as it was designated, was a cross between the Indonesian *indica*, Peta, and the Chinese semi-dwarf variety, Dee-Geo-Woo-Gen (DGWG). An earlier Taiwanese cross of DGWG with the tall variety Tsai-Yuan-Chung had led to a similar plant, known as Taichung Native 1 (TN1). The two new varieties quickly achieved enormous popularity among farmers and scientists around Asia, and a large-scale internationalization of breeding efforts resulted (Barker, Herdt, and Rose 1985, pp 56-57).

Plant breeders typically rely on field or laboratory collections of genetic resources for "raw materials." Such collections are described as *ex situ*, as opposed to *in situ* collections which are preserved in their natural habitat. About 85,000 landraces and wild species are currently stored in a long-term *ex situ* facility at IRRI, under conditions of low temperature and humidity. (This collection is one of the primary responsibilities of the IRGC, mentioned above.) A subset of these cultivars are catalogued according to agronomic and genetic characteristics.

The germplasm bank serves two related functions. One is as a repository for genetic materials. By keeping little-used or uncommon varieties of rice in a long-term storage facility, the bank serves as a protective facility to prevent the loss of potentially valuable gene sources.

The second function of the germplasm bank is as a "lending library" of genetic resources for use by plant breeders. Breeders request materials from the bank — either by name or by some set of characteristics — and incorporate the materials into their programs of evaluation and breeding. Unimproved materials from the collection are used by breeders at IRRI and are also sent out freely to scientists around the globe. In addition, genetic materials are also incorporated in the genealogies of improved lines that are sent out from IRRI through the INGER.

Other germplasm collections are maintained by various national programs (as in India). Most local stations also have short-term storage facilities or keep stocks of some advanced lines. Breeding activities at the local, regional, and national levels recombine genetic materials. We can thus see a complex and involved interchange of germplasm throughout the international system of rice research establishments.

Rice varieties and characteristics

The role of IRRI is to improve rice productivity in the rice-producing countries of the world. IRRI's main program emphasis has been on the development of new rice varieties that have desirable characteristics.

The breeding sequence begins with the development of a strategy; this suggests a potentially desirable cross involving some combination of landraces, wild species, advanced lines, or released cultivars. The progeny from this cross are then evaluated over several self-pollinated generations. Selection of plants for uniformity is undertaken. . . Promising selections (cultivars or advanced lines) are field tested. Release as a variety is subject to careful evaluation. Only a small proportion of crosses are ultimately released as varieties (less than one percent for most programs). Most released varieties are planted by farmers although there is considerable variation in the degree of success in the field.

From 1965 to 1974, IRRI's breeding program released several important varieties directly as IRRI varieties (IR8 to IR36). National programs were responsible for most varietal release prior to 1974 and for all releases after 1974. Some IRRI crosses have been released as national varieties (sometimes with IR names), often after selection in the releasing countries. Similarly, crosses originating in a national program may ultimately be released as varieties in another national program.

The varietal database

For this study we have compiled a database for 1,709 modern rice varieties released since the early 1960s.[3] For each of these released varieties a complete genealogy was compiled. This included the date and origin of the cross on which the variety was based, as well as the data and origin of all parents, grandparents and other ancestors. Thus ancestry was traced back to original landraces or wild species. In addition we were able to determine whether the cross or any ancestors appeared in the INGER nurseries and whether they were selected from these nurseries for crossing.[4]

Of the 1,709 modern varieties and elite (advanced) lines, 33 were released prior to 1965 (and thus prior to the release of any IRRI materials).[5] Table 3.10 gives the frequency of release by country and by time period. For some varieties, release dates were not available; in such cases, approximate dates were estimated based on available information.

The data set includes materials from numerous countries. but it is relatively more complete for rice-producing countries of South and Southeast Asia than for those from other regions. India, in particular, is represented in the data set at a level that appears to be disproportionately large, with 643 varieties. Although India's breeding programs have a long and productive history, the data set probably reflects a bias towards India based on the extensive and available data.[6] Other countries represented by large numbers of varieties in the data set include Korea. with 106 varieties, and the combined countries of Latin America (239 varieties) and Africa (101 varieties). Japanese varieties were not included in this analysis.

The data indicate that numbers of released varieties rose steadily during the 1970s but have stabilized over the past fifteen years. In some countries and regions, however, such as Latin America, varietal release totals have climbed markedly in the most recent period.

International flows of genetic resources

Table 3.11 reports measures of international flows of genetic resources associated with the released varieties and the parents of the released varieties. Of the 1,709 released varieties, 390 (23 percent) were the result of a cross made outside the releasing country. IRRI was the source for 294 (17 percent) of these varieties. Other national programs were the source for 96 releases. (Table 3.12 provides country detail for varieties.)

After IRRI, India was the next largest exporter of varieties, with 28 Indian varieties released elsewhere. India was also a large importer of varieties; 70 of its 643 varieties originated elsewhere, with 53 from IRRI. Sri Lankan varieties were released 11 times in other countries. Twelve Thai varieties were released in Myanmar (Burma). Myanmar was one of the largest importers of rice varieties; 43 of its 76 releases were imported varieties. including varieties from Bangladesh, China, India, Indonesia, IRRI, the Philippines, Sri Lanka, Thailand, and Vietnam.

In addition to IRRI's direct role as a source of exported varieties, IRRI has served as a conduit through which elite lines have moved from country to country. Even before the establishment of INGER in 1975, IRRI scientists helped test and disseminate elite lines of rice around the world. This function was formalized with the inauguration of INGER. Through INGER's activities, elite lines and released varieties from national research programs have been made available for international testing and evaluation. Participating countries have gained access to promising varieties, and in some cases, they have been able to import them directly from the INGER nurseries.

INGER itself keeps a complete and accurate set of data on varietal importing that has occurred through its programs. INGER has documented more than 300 instances of varieties imported after appearing in INGER trials (Sehsu, personal communication, 1992). Our study lacks complete data on varietal releases in participant countries, especially in Africa and Latin America. Nonetheless, this study was able to identify nearly 200 instances in which varieties could have been imported through INGER.[7] In particular, INGER has played a significant role in disseminating IRRI lines. For

Table 3.10 Numbers of varieties included in the data set, by country of release and time period of release

Country/Region	*Pre-1965*	*1966-70*	*1971-75*	*1976-80*	*1981-85*	*1986-91*	*Total*
Africa	3	7	8	17	26	40	101
Bangladesh	1	7	8	11	4	3	34
Burma	0	4	6	21	37	8	76
China	0	1	8	30	31	12	82
India	10	67	136	139	125	166	643
Indonesia	1	2	5	21	10	9	48
Korea	0	5	11	35	40	15	106
Latin America	7	9	48	32	43	100	239
Nepal	0	0	1	10	4	2	17
Oceania	0	1	4	1	0	0	6
Pakistan	0	4	2	3	3	0	12
Philippines	3	4	13	23	8	2	53
Sri Lanka	3	14	4	8	21	3	53
Taiwan	0	3	0	3	0	0	6
Thailand	1	2	4	8	5	3	23
USA	2	5	18	17	3	6	51
Vietnam	0	16	6	16	16	5	59
Other S.E. Asia	2	1	8	7	6	5	29
Other	0	7	15	15	15	19	71
Total	33	159	305	417	397	400	1709

Table 3.11 International genetic resources flows by time period

Country/Region	*Pre-1965*	*1966-70*	*1971-75*	*1976-80*	*1981-85*	*1986-91*	*Total*
I. *Released varieties, percent based on:*							
IRRI cross	3	25	19	22	18	12	17
Other NAR cross	16	7	6	6	6	5	6
Own NAR cross	81	68	75	72	76	83	77
II. *Parents of released varieties, percent based on:*							
IRRI cross	0	24	29	33	23	19	24
Other NAR cross	27	25	21	15	18	20	18
Own NAR cross	73	51	50	52	59	61	58

Table 3.12 Matrix of varietal borrowing (numbers in parentheses represent borrowings through INGER)

	Other	*Latin America*	*Oceania*	*Bangladesh*	*Africa*	*Burma*	*USA*	*China*	*India*	*Indonesia*	*IRRI*	*Korea*	*S.E. Asia*	*Nepal*	*Pakistan*	*Philippines*	*Sri Lanka*	*Taiwan*	*Thailand*	*Vietnam*	*Total*
Other	9	7	0	0	0	1	0	5 (2)	16	3 (2)	18 (9)	6	5	0	0	0	0	1	0	0	71 (13)
Latin America	3 (1)	185 (2)	0	0	1 (1)	0	5	0	2 (2)	0	39 (15)	1	0	0	0	2	1 (1)	0	0	0	239 (22)
Oceania	0	0	1	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	6 (0)
Bangladesh	0	0	0	17	0	0	0	1	4 (1)	0	11 (3)	0	1	0	0	0	0	0	0	0	34 (4)
Africa	1	1 (1)	0	0	69 (1)	0	0	0	1 (1)	0	26 (12)	0	0	0	0	1	2 (2)	0	0	0	101 (17)
Burma	2	0	0	1 (1)	0	33	0	1 (1)	1	1 (1)	18 (5)	0	2 (1)	0	0	1	2 (2)	0	12 (6)	2 (2)	76 (19)
USA	0	1	0	0	0	0	48	0	0	0	2 (2)	0	0	0	0	0	0	0	0	0	51 (2)
China	0	0	0	0	0	0	0	66	1	0	13 (8)	1	0	0	0	0	1 (1)	0	0	0	82 (9)
India	5	0	0	0	1	0	0	0	573	0	53 (33)	0	1	0	1	1	4 (3)	2	1 (1)	1	643 (37)
Indonesia	0	0	0	0	0	0	0	0	0	29	18 (13)	0	0	0	0	1	0	0	0	0	48 (13)
SE Asia	0	0	0	0	0	0	0	0	1	0	7 (2)	0	21	0	0	0	0	0	0	0	29 (2)
Korea	0	0	0	0	0	0	0	0	0	0	1	105	0	0	0	0	0	0	0	0	106 (0)
Nepal	0	0	0	0	0	0	0	0	0	0	5 (2)	0	1 (1)	8	0	0	1	0	0	0	17 (3)
Pakistan	0	0	0	0	0	0	0	0	0	0	7	0	0	0	5	0	0	0	0	0	12 (0)
Philippines	0	0	0	0	0	0	0	0	0	0	25 (15)	0	0	0	0	26	0	0	0	1	53 (15)
Sri Lanka	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	51	0	0	0	53 (0)
Taiwan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	6 (0)
Thailand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	0	23 (0)
Vietnam	0	0	0	0	0	0	0	0	0	0	44 (27)	0	0	0	0	0	0	0	0	15	59 (27)
Total	20	194	1	18 (1)	71 (2)	34 (0)	53 (0)	73 (3)	601 (4)	34 (3)	294 (146)	113 (0)	31 (1)	8 (0)	6 (0)	32 (0)	62 (10)	9 (0)	36 (7)	19 (2)	1,709 (183)

varieties developed at IRRI and released by national programs, INGER was the apparent conduit in half of the cases, all of them in the period, 1976-91.

Since 1976, INGER has also become the primary channel through which nationally -developed varieties have been transferred from one country to another. Since 1976, 37 national program varieties have been imported through INGER. During the same period, the number of national program varieties imported through other avenues has diminished from 13 in 1976-80 to 6 in 1986-91. INGER has played an important role in facilitating the transfer of varieties across geographic zones; for instance, both of two Sri Lankan varieties released in Africa came through INGER, and both of two Indian varieties released in Latin America came through INGER.

Perhaps more remarkable than the direct international flows of varieties has been the international flows of parents of the varieties. Nearly three-quarters of the varieties in the data set (1,263) have at least one imported parent. Including imported varieties, 810 releases (47 percent) have at least one parent from IRRI, and 619 (36 percent) have at least one parent from another national program. Excluding imported varieties, more than 500 varieties have at least one parent from IRRI. Excluding both imported varieties and those with IRRI parents, more than 350 released varieties have at least one parent from another national program. This indicates that parental importing is taking place across national programs on a large scale. (Table 3.13 reports country details for parents.)[8]

The extent of international exchange — both of varieties and of parents — implies that a large majority of the varieties in the data set were developed using breeding lines from outside the country of release. In fact, only 145 varieties out of 1,709 (8.5 percent) were developed entirely from own-country parents, grandparents and other ancestors. Most of these were simple varieties with fewer than four landraces in their pedigree. The extent of this international flow of germplasm is extraordinary. No country in the data set has failed to take advantage of unimproved or improved germplasm from other countries.

Genealogical complexity

One outcome of the increased flows of varieties across national borders has been the increasing complexity of the genealogies of rice varieties. Whereas a released variety in the 1960s might have only three landraces in its genealogy, more recent releases have 25 or more landrace ancestors. In a sense, this increasing pedigree complexity is a measure of breeding inputs in the development of new varieties. Pedigree complexity can most easily be measured as the number of landraces, pureline selections, and mutants that are ultimate ancestors of a released variety. For released varieties containing more than one such ancestor, at least one cross must have been made by breeders corresponding to every two ultimate ancestors. Thus, varieties with large number of ancestors — and hence complex pedigrees — are the product of intensive breeding efforts...

Moreover, the share of ancestors delivered through IRRI lines has increased over time. For varieties released in 1965-74, IRRI provided 54 percent of ancestors, by number. For varieties released in 1981-90, IRRI delivered 72 percent of ancestors, by number. Thus, the usefulness of IRRI's breeding lines has not diminished following the early release of semi-dwarf rices. Instead, IRRI continues to offer national breeding programs highly useful packages of genetic material. These packages form the nucleus of contemporary breeding programs in most countries.

National rice improvement programs have depended to differing extents on IRRI lines as sources of genetic materials. Some countries have borrowed many of their released varieties or parent lines from IRRI, while others have used IRRI materials in conjunction with local varieties or other internationally available breeding lines. For example, Vietnam and Pakistan have based their modern varieties

Table 3.13 Matrix of parental borrowing (numbers in parentheses represent borrowings through INGER)

	Other	*Latin America*	*Oceania*	*Bangladesh*	*Africa*	*Burma*	*USA*	*China*	*India*	*Indonesia*	*IRRI*	*Korea*	*S.E. Asia*	*Nepal*	*Pakistan*	*Philippines*	*Sri Lanka*	*Taiwan*	*Thailand*	*Vietnam*	*Total*
Other	28 (2)	2	0	0	0	1	1	0	42 (23)	4	48 (13)	1	7	0	0	4 (3)	0	2 (1)	2	0	142 (42)
Latin America	116 (26)	73 (20)	0	0	4 (3)	0	22 (3)	0	62 (58)	3 (3)	161 (68)	4	0	0	0	8	6 (3)	5 (2)	10 (3)	4 (3)	478 (192)
Oceania	0	0	0	0	2	0	2	0	5	0	5	0	0	0	0	0	0	1	2	0	12 (0)
Bangladesh	4 (1)	0	0	1 (1)	0	0	2	1	18 (11)	2	34 (9)	0	2	0	0	2	0	1 (1)	0	1 (1)	68 (24)
Africa	33 (20)	3 (2)	0	0	34 (13)	0	0	2 (2)	57 (51)	6 (4)	42 (24)	0	6 (3)	0	0	3	3 (3)	5 (1)	5	3 (3)	202 (126)
Burma	26 (15)	0	0	0	0	1	0	1	68 (68)	5 (1)	38 (29)	0	1	0	0	7 (5)	0	2	0	3 (3)	152 (121)
USA	28	2	0	0	0	0	47 (1)	0	15 (15)	0	6 (4)	0	0	0	0	0	1	1	2 (2)	0	102 (22)
China	42 (13)	0	0	0	0	0	0	20 (7)	27 (27)	1 (2)	72 (52)	0	0	0	0	0	1	1	0	0	164 (101)
India	150 (32)	1	0	3 (2)	4 (4)	0	2 (1)	10 (3)	637 (101)	14 (7)	351 (174)	0	23 (13)	0	0	15 (6)	10 (4)	57 (14)	7 (4)	0	1,284 (365)
Indonesia	11 (3)	0	0	0	0	0	0	1	22 (12)	22 (1)	35 (14)	0	1	0	0	2	0	0	2	0	96 (30)
SE Asia	0	0	0	0	0	0	0	1	9 (5)	3	17 (7)	0	9 (1)	0	0	3 (2)	0	2	2	0	46 (15)
Korea	0	0	0	0	0	0	0	0	3 (3)	0	49 (15)	74 (8)	0	0	0	0	0	0	0	0	126 (26)
Nepal	9	0	0	1	1	0	0	0	7 (4)	1	10 (4)	0	2	0	0	1	2 (2)	0	0	0	34 (10)
Pakistan	1	0	0	0	0	0	0	2	6 (3)	0	12 (4)	0	0	0	0	1	0	0	2	0	24 (7)
Philippines	20	0	0	0	0	0	4	0	11 (2)	5 (1)	45 (13)	0	2	0	0	18 (2)	0	0	0	0	105 (18)
Sri Lanka	24 (3)	0	0	0	0	0	1 (1)	1 (1)	4 (3)	3 (1)	22 (4)	0	0	0	0	0	50 (5)	1	0	0	106 (18)
Taiwan	2	0	0	0	0	0	0	0	3 (2)	0	5	0	0	0	0	0	0	2	0	0	12 (2)
Thailand	12 (5)	0	0	0	0	0	0	0	12 (11)	2	7 (5)	0	0	0	0	1	0	1	11 (1)	0	46 (22)
Vietnam	11 (1)	0	0	0	0	0	0	3	34 (22)	3	63 (23)	0	1	0	0	1	0	0	0	2	118 (46)
Total	517 (121)	81 (22)	0	5 (3)	45 (20)	2	81 (6)	42 (13)	1,042 (421)	74 (20)	1,017 (462)	79 (8)	54 (17)	0	0	66 (18)	73 (17)	81 (19)	45 (10)	13 (10)	3,317 (1,187)

almost completely on IRRI lines, but Sri Lanka used a large pool of other breeding lines as sources of germplasm.

Landrace pools

Several concepts of germplasm "pools" are relevant for our purposes. We can identify all the landrace ancestors of a released variety. Alternatively, we can identify all the released varieties that are descendants of a particular landrace. To use the first approach, the 1,709 varieties in the data set trace to a total of 11,592 ancestors. Of these, 8,208 have come through IRRI lines and 3,384 have been acquired independently of IRRI lines.[9]

Following the second approach, however, we find 838 distinct landraces that are ancestors of the 1,709 released varieties. Many of these ancestors occur repeatedly in the genealogies of released varieties. Dee Geo Woo Gen, for example, is an ancestor for 1,105 varieties in the data set; Cina and Latisail each appear in more than 1,000 varieties. These three landrace selections are the parents and grandparents of IR-8, and thus have appeared jointly as ancestors to nearly 700 varieties in the data set.

In addition to DGWG, Cina, and Latisail, 14 other varieties have appeared as ancestors of more than 100 varieties. These 17 varieties together account for 8,439 of the 11,592 accumulated ancestors. The frequency with which these varieties appear as ultimate ancestors of releases indicates the enormous value of the genes they contain.

Although a relatively small number of landraces accounts for such a large amount of the genetic material embodied in the released varieties, it would be incorrect to assume that this figure implies genetic uniformity. In many cases, these ancestors appear far back in the genealogies of released varieties, so that they may be contributing only small amounts of genetic material, or even single genes.

For example, DGWG probably contributes little more to most varieties than the semi-dwarfing gene *sd l*. Similarly, *Oryza nivara*, which appears as an ancestor of 244 varieties, is represented only by the Gsv gene for resistance to grassy stunt virus, biotype 1 (Chang and Li 1991). The Indian varieties Ptb 21 and Ptb 18, each of which is an ancestor to more than 100 varieties, are both known to have resistance to brown planthoppers, tungro, and green leafhoppers (Swaminathan 1984, cited in Plucknett et al 1987).

By and large, national program breeders have sought to incorporate the useful genes from these varieties (and others like them) into local varieties, which are well adapted to environmental stresses and ecologies, and which satisfy local tastes and preferences. In some countries, breeders have worked directly with these landraces and pureline selections. More often, however, national programs have taken advantage of work performed by IRRI breeders in "packaging" these useful traits in improved lines. This continues to be true even in recent years, despite expanded international access to the original unimproved varieties.

Evidence for the role of IRRI in packaging advantageous germplasm can be found in the frequency with which IRRI has been the source of the most commonly used ancestors. The 17 most commonly used ancestors have appeared independent of IRRI lines in fewer than 15 percent of their accumulated occurrences. For example, *Oryza nivara* has appeared in the genealogies of released varieties exclusively via IRRI lines. Similarly, the Thai variety Gam Pai 15 appears as an ancestor for 139 varieties, but only two varieties (both Thai) have obtained Gam Pai 15 independent of IRRI. A variety from Andhra Pradesh, India, occurs in the genealogies of 379 released varieties, but only five releases have made direct use of the ancestor.

Thus, IRRI has played a major role in identifying sources of advantageous genes and in packaging these genes in forms that can be readily used by national programs. IRRI continues to function in the same role today, working extensively with unimproved materials. Curiously, however, relatively few additional materials have entered the ancestor pool through IRRI's efforts since the mid-1970s.

For each of the 838 ancestors of our released varieties, our study has identified all of its released progeny. and has noted the earliest release date for these progeny...

The data indicate that only 80 ancestors appeared for the first time through IRRI materials. An additional 47 appeared in released national varieties before 1965, and were thus part of the international varietal pool before IRRI was established. Since 1970, however, 687 ancestors have been added to the ancestral pool — but only 41 have been added through IRRI lines.

This suggests that national programs have continued to make use of IRRI lines that package material already used in released varieties. In some cases, these IRRI lines may be re-packaging IRRI's own old materials; in other cases, IRRI is re-packaging lines used in one country in a form suitable for another country. However, it must be noted that IRRI's focus on semi-dwarf plant types has limited its success in providing a broader landrace base for modern rice varieties.[10]

Many of the ancestors introduced by national programs are landraces that are locally adapted to certain micro-environments. Of the 606 landraces introduced by national programs since 1970, 414 have appeared in the pedigrees of just one released variety. In effect, then, national programs have been using IRRI packages of germplasm to upgrade the quality of local and traditional varieties.

The total pool of ancestors incorporated in released varieties appears to have grown by 25 to 50 landrace and pureline ancestors in almost every year since 1970. This suggests that as the available stock of improved varieties expands, farmers have more choices, and can choose locally adapted high-yielding varieties. The improvements of the original high-yielding varieties are no longer limited to favorable agro-ecological zones in major rice producing countries; instead, an increasing number of released varieties is available for widely varying production environments.

The data on landrace pools and on the importance of certain individual ancestors has implications for the management of global germplasm collections. Some have suggested that germplasm collection need not be exhaustive, since a relatively small sample of rice varieties will contain, statistically, almost all the alleles in the rice genome. It is clear that "core" collections offer a useful approach to the management and handling of germplasm collections (Hodgkin 1991). However, most experts appear to believe that comprehensive collection serves an important purpose (Chang 1989). Our research supports this principle. A landrace or wild species containing a single useful gene, such as *O. nivara*, can provide economically useful traits to hundreds of released varieties.

Although it is true that a relatively small sample of the total population of rice landraces would contain virtually all the genes in the species, it is equally true that genes for specific traits are often found only in minuscule numbers of landraces. This is true because cultivated rices are self-pollinated, with relatively low genetic variability within most localities. However, rice is grown across enough environments that significant genetic differentiation can be found across landrace populations of *O. sativa* (Oka 1991a). Upland rices are even more polymorphic genetically than are lowland rices, and wild species are far more polymorphic than either upland or lowland varieties of *Oryza sativa* (Oka 1991a) .

Empirical data suggest that wild species, isolated landraces, and other such "fringe" materials are important sources of resistance to diseases and pests of cultivated rice. For example, Oka notes that Chang (1989) reported finding resistance to white-backed planthoppers in only 0.8 percent of the 48,544 varieties of *Oryza sativa* screened at IRRI, whereas 45.4 percent of the 681 varieties of *Oryza glaberrima* displayed resistance, as well as 46.2 percent of the 437 wild Oryza species tested. Oka concludes that in rice, "wild relatives and primitive landraces are important objectives in germplasm collecting and conser-

Table 3.14 Routes of varietal release — descriptive statistics

	Number of varieties	Percent of varieties	Total area	Percent of area	Average number of landraces		Average number of landraces independent of IRRI		Average number of landraces with rare trait index [a] > 5.0
					Pre 1976	Post 1976	Pre 1976	Post 1976	
IRRI/inger	146	8.5	5177	13.3	n.a	13.2	n.a	0.0	12.55
IRRI/no inger	148	8.7	3959	10.2	5.4	12.4	0.0	0.0	7.66
Other/inger	37	2.2	411	1.1	n.a	4.2	n.a	2.1	3.35
Other/no inger	59	3.5	2954	7.6	4.4	5.2	2.5	1.6	4.14
IRRI parent/inger	214	12.5	6570	16.9	n.a	10.4	n.a.	1.2	9.55
IRRI parent/no inger	313	18.3	5589	14.4	5.6	9.5	1.7	1.4	6.53
Other parent/inger	208	12.2	4283	11.0	n.a	2.9	n.a	2.5	1.52
Other parent/no inger	151	8.8	3228	8.3	3.4	4.8	3.4	3.8	2.68
IRRI Gparent/inger	14	0.8	670	1.7	0.0	7.2	0.0	3.0	6.00
IRRI Gparent/no inger	94	5.5	1436	3.7	7.4	10.7	4.6	3.6	8.93
Other Gparent/inger	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.00
Other Gparent/no inger	180	10.5	1482	3.8	4.4	4.1	4.3	3.8	2.04
Pure national	145	8.5	3121	8.0	3.2	2.6	2.7	2.2	1.10

a. The rare trait index for a landrace is calculated as the ratio of the number of varieties in the data set for which the landrace appears somewhere in their geneologies to the number of varieties for which the landrace is a parent.

vation because they are expected to be treasure-houses of useful genes."

Vaughan (1991) reports that more than 40,000 accessions in the IRGC have been screened for resistance to blast, with comparable numbers for bacterial blight, green leafhopper, and brown planthopper. Vaughan notes that for blast and green leafhopper, resistance is evenly distributed across the germplasm collection. For brown planthopper and bacterial blight, however, resistance is concentrated in materials from given geographic regions and strata of the collection. Some sources of resistance have come from unlikely landraces; for example, Vaughan cites the discovery of cold tolerance genes in an Indonesian variety (Silewah) from 1,200 m elevation in Sumatra. Similarly, a variety from the dry zone of Sri Lanka has been used as a source of genes for flood tolerance.

Saxena (1991) notes that researchers first identified resistance to brown planthopper in the 1960s, with IR26 in 1973 the first semi-dwarf variety to show resistance. The single gene responsible for resistance, Bph-l, suppressed the original biotype of brown planthoppers. Evolution of new planthopper biotypes forced researchers to seek a succession of new resistance genes. however. To date, seven resistance genes have been identified, and resistance has been transferred from *O. officinalis* to *0. sativa.*

Similarly, Ikeda (1991) reports that resistance to six strains of bacterial blight has been found in varying levels in rice varieties from Asian countries. The frequency of resistance to different races of bacterial blight was different across countries; for example, varieties with the *Xa-3* resistance gene were found in almost all countries, but with a frequency of 17.2 percent in Indonesia and only 0.3 percent in India.

All of these examples suggest that large germplasm collections are important economically as sources of desirable genes. Evidence to support the importance of large germplasm collections can be found in the genealogy data analysis of released varieties. Some landrace and ancestor materials are used for very specific traits. They may have been identified through special searches of the germplasm collection, or they may be widely recognized for possessing particular characteristics. These varieties are desirable only for one attribute; they may possess other undesirable attributes. These landraces or wild species may occur in the pedigrees of numerous varieties, but they are used only infrequently as parents. *O. nivara*, for example, has been used solely as a source of resistance to grassy stunt. Its other characteristics make it an undesirable parent. Thus, *O. nivara* has appeared seven times as a parent in our data set, but it appears in the genealogies of 244 released varieties. The resulting ratio, 244:7, provides an index of its "rare trait" characteristics. . .

Routes (pathways) from origin to release

In order to analyze more formally the impacts of IRGC, IRPB, and INGER, it is useful to trace the routes by which varieties were released. . . These routes are defined to be mutually exclusive categories, so that each variety in the data set falls into exactly one of the following categories:

Borrowed varieties

1. IRRI line, borrowed through INGER (IRRI/INGER)
2. IRRI line, borrowed independent of INGER (IRRI/NO INGER)
3. Variety from another national program, borrowed through INGER (OTHER NATL/INGER)
4. Variety from another national program, borrowed independent of INGER (OTHER NATL/NO INGER)

Nationally developed varieties, borrowed parents

5. At least one parent from IRRI, borrowed through INGER (IRRI PARENT/INGER)
6. At least one parent from IRRI, borrowed independent of INGER (IRRI PARENT/NO INGER)

7. No IRRI parents, but at least one parent borrowed from another national program via INGER (OTHER NATL PARENT/INGER)
8. No IRRI parents, but a least one parent borrowed from another national program independent of INGER (OTHER NATL PARENT/NO INGER)

Nationally developed varieties and parents, borrowed grandparents

9. At least one grandparent from IRRI, borrowed through INGER (IRRI/GPARENT/INGER)
10. At least one grandparent from IRRI, borrowed independent of INGER (IRRI/GPARENT/NO INGER)
11. No IRRI grandparent, but at least one grandparent borrowed from another national program via INGER (OTHER GPARENT/INGER)
12. No IRRI grandparents, but at least one grandparent borrowed from another national program independent of INGER (OTHER GPARENT/NO INGER)

Nationally developed varieties, parents, grandparents

13. All parents and grandparents from country of release (PURE NATIONAL)

In practice, virtually no varieties fell into categories 9 or 11, since INGER has not been in existence long enough to provide many grandparent materials. Moreover, many varieties with borrowed grandparents also have borrowed parents — or even are borrowed varieties. . .

Since 1970, only 7.8 percent of new varieties have been of "pure" national development. The most significant channels of release have been the use of IRRI parents. Before 1975, IRRI parents were obviously not channeled through INGER, but in recent years, the largest single pathway for developing new varieties has been to use IRRI parents taken from INGER.

The importance of INGER can be seen by looking at the time trends on borrowing through INGER. Since 1981, more than half of released varieties (440 out of 797) have either been borrowed through INGER or were bred from parents borrowed through INGER.[11]

Table 3.14 reports numbers of landraces and proportions of rare traits by route and by region. This table shows that IRRI material has been the conveyor of high landrace content and high rare trait content. Data on area planted are also reported...

Economic implications

. . . Evenson and David (1993) report estimates of modern variety impacts for India, Pakistan, Bangladesh. Philippines, Thailand, Indonesia and Brazil. These range from a relatively high value for India to lower values for other countries. The approximate value of modern varieties in 1990 (in US dollars) in Indica rice regions was 3.5 billion dollars. If we consider this to be the cumulated contribution of the first 1,400 modern varieties, we obtain an average value of a released variety of 2.5 million dollars per year and this annual value continues into perpetuity because we are considering varietal improvements to be additive. . .

Notes

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1. The term pedigree breeding is used by De Datta (1981). With wheat and sorghum, for instance, methods of bulk breeding are generally preferred. For our purposes, these methods make it more difficult to trace flows of specific genetic material.

2. Recent technological advances require us to broaden our understanding of germplasm, however. Through tissue culture of various kinds, a number of types of plant tissue can be used to regenerate plants. In addition, some species have traditionally been regenerated from stems, shoots, tubers and cuttings, rather than for seed. Germplasm in its broadest sense is thus any genetic material that can be used to reproduce adult plants.

3. The study drew heavily on a number of data sets available through IRRI. The first of these was a list of elite lines and released varieties from more than forty countries. This data set, collected by V L Cabanilla and T R Hargrove for the International Rice Geneology Database provides information on the parentage and release dates of most indica rice varieties since 1968. An accompanying data set, containing more than 6,500 entries, contains breeding records that make it possible to trace complete or partial genealogies for all the elite lines and released varieties in the first data set. This data set is also based on work by Cabanilla and Hargrove, although much expansion and modification was carried out for this study. These alterations transformed the two data sets into a united, self-contained, self-referencing data set.

4. It was also possible to combine the varietal data with additional data sets from INGER. Two INGER data sets, from IRRI, were used. The first was a list of entries in INGER since its inception; the second was a list of the nurseries in which these entries were tested. By matching the names of varieties to the list of INGER entries, it was possible to infer the inclusion of varieties and ancestors in INGER.

5. These 32 varieties were generally regarded to be early "modern" varieties.

6. Most released varieties have been planted on significant acreage. In India, the Indian Council of Agricultural Research reports yields of two leading rice varieties in a number of districts. More than 150 varieties have been noted as important varieties in farmers' trials over the 1977 to 1989 period.

7. The criterion used was whether varieties developed in one country were released in another country two or more years following their appearance in INGER. (Given the omission in our data set of many countries in Africa and Latin America, which have imported actively from INGER, the figures appear to be consistent with the data maintained by INGER.) Since typography and nomenclature also make it difficult to match named varieties with INGER entries, it is likely that imports through INGER have been undercounted, rather than overcounted, in our study.

8. As many as 422 of the varieties based on internationally exchanged parents may have been developed from materials chosen out of INGER, in the sense that the parent first appeared in INGER trials four years or more prior to the release of the variety. About half of the INGER parents were IRRI materials, and half were varieties from national programs other than the one of eventual release. Parents chosen out of INGER have steadily grown to account for larger proportions of borrowing. By 1986-91, as many as 80 percent of parental selection may have taken place via INGER.

9. Note, however, that the total number of ancestors includes ancestors that have been replicated many times, not only in the total set of varieties, but even in a single variety.

10. In fact we regard IRRI's poor performance in contributing to the landrace pool to be a disappointing part of a program that otherwise has made great contributions. IRRI has introduced a new plant type in recent years and this may ultimately allow a broader base for landrace contributions by IRRI. It would appear, in retrospect, that IRRI was slow in moving to other plant types and less concerned than it should have been with broadening the landrace pool.

11. Note that grandparent varieties will have had a shorter period to have been influenced by INGER because of the time lag between appearance in INGER and their ultimate appearance as a grandparent. INGER, however, may have had a large impact on these flows, even if they were NO INGER flows because it stimulated more international searching for genetic resources. Similarly the IRRI landrace pool may also stimulate these flows by inducing national program efforts to complement IRRI materials. (See Gollin and Evenson 1991.)

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4

Country Experiences with Reform

Some developing countries have all along had more open seed regulatory systems than others, and some have reformed over time. Differences across countries and over time provide windows of opportunity to look at what happens when governments do not control variety introduction, require official seed certification, or otherwise interfere in private seed trade. This Section presents four country papers from the workshop.

In India, variety registration and seed certification have been voluntary all along. Recent policy changes give private companies access to germplasm from government research and ease barriers to entry for imported seed and foreign seed companies.

The government of Turkey moved dramatically from blocking to welcoming private seed trade through reforms in the early 1980s. With reforms allowing private companies to introduce new hybrids and varieties for many crops, farmers and consumers have realized large gains in income.

In Peru, policy reforms at the end of the 1980s shifted seed production from parastatals to multiple new private companies. Decentralization of responsibility for regulation and certification to regional seed committees has brought an influx of small seed producers into the formal seed industry.

In 1990, Bangladesh's Ministry of Agriculture, with authority from existing seed legislation, moved from compulsory to voluntary variety registration for all but five crops (rice, wheat, jute, sugarcane, and potatoes). Following deregulation, private seed companies and NGOs have tested and introduced new cultivars, including maize hybrids (field corn and sweet corn), sunflower hybrids, and vegetables.

Seed Industry Regulations in Relation to Seed Industry Development in India

Pramod K. Agrawal

India is predominantly an agricultural country. Agricultural policy is primarily aimed at self -sufficiency in major staple foods of cereals, pulses, and oilseeds. Self-sufficiency has been obtained in cereals and oilseeds, but India still depends on imports of pulses. In general, agricultural development focuses on food crops and is not export oriented except for tea, coffee, spices, and tobacco.

Plant breeding research and the development of new varieties

Public sector

In the last thirty years there has been a major reorganization of agricultural research in India. Research institutes in the central government have been transferred from the administrative control of the Ministry of Agriculture to the Indian Council of Agricultural Research (ICAR). Individual states have also transferred responsibility for agricultural research to the agricultural universities.

ICAR has organized "All India Coordinated Crop Improvement Projects" (first one in 1957) to speed up agricultural progress in the country. Today there are thirty-two coordinated crop improvement projects, fifteen research institutes, nine national research centres and five project directorates. India has emerged as a leader in the field of varietal development with one of the world's largest programs in variety improvement. More than 5,000 plant breeders are working at the agricultural universities and ICAR institutes. The ICAR annual budget for 1995-96 is Rs 5.6 billion (US$175 million).

The modest budget (by international standards) with a massive network of research infrastructure has yielded a rich dividend in the sense that India has developed from a food deficit country to an food exporting country. From the ICAR system more than 2,000 varieties of different crops have been developed; of course many of them are no longer in cultivation.

Private sector

In a survey conducted in 1988 by the author it was revealed that about ten seed companies started plant breeding research during 1948-1970 and about twenty companies during 1971-1985. Most of these companies had breeding programs for agricultural crops (Agrawal 1991). In recent years, some private companies have been paying increased attention to vegetables. The number of companies now engaged in breeding has increased to forty, out of which ten are working on vegetables. Five to ten percent of their revenues are spent on R&D (Arora 1994). Thus plant breeding research in the private sector is comparatively of new origin.

With the introduction of the new seed policy in 1988 and liberalization of investment policy in 1991 (maximum allowed equity participation for foreign companies and investors increased from 40 to 51 percent) private seed companies in India have established contact

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with transnational companies for accessing hybrid parent lines for seed production, marketing, and formation of joint ventures. A few transnational companies have opened subsidiaries in India.

Production and marketing of hybrid agricultural seeds (for example, sorghum, pearl millet, maize, sunflower, cotton, castor, paddy) and horticultural seeds (for example, tomato, egg plant, okra, watermelon, etc) have expanded considerably. Private seed companies have developed at least 122 varieties: 55 of vegetables, 39 of millets, 13 of cotton, nine of oilseeds, four of fodder, and two of pulses. About 70 percent of these varieties are hybrids (Agrawal 1991). The number of varieties developed by private sector companies is now estimated to be about 300.

In recent years hybrid paddy varieties have been developed and marketed by both public and private sectors. Private sector hybrid paddy varieties reportedly have performed well in farmers' fields. Private companies have been more successful in paddy seed production.

Cooperation between public and private seed companies and between private seed companies and governmental research stations has never been optimal because of conflicting interests in plant breeding research and seed testing procedures. With the changing environment, public sector breeding stations should pay more attention to create advanced breeding lines with value added (for example, disease resistance) or to basic research, results from which could be sold to the private sector to support private R&D.

New technologies to support plant breeding

The potential of biotechnology in agriculture has been recognized both by the public and private sectors. Department of Biotechnology (DBT) and ICAR have played key roles, creating awareness of the potential role for biotechnology to support plant breeding and to speed up varietal development programs. The DBT has funded the establishment of Departments of Biotechnology in many universities in India. Also, a few private sector companies have established biotechnology laboratories without government support. An exception is Tata Energy Research Centre (TERI), which got funds from DBT to establish a tissue culture laboratory for rapid multiplication of forestry species.

PROAGRO Seed Company, a leading research-driven company in India, has formed a joint venture with Plant Genetic Systems (PGS) of Gent, Belgium. The joint venture, Proagro-PGS India Ltd, has access to the proprietary technology of PGS, namely: Seed Link TM or Barnase (male sterility gene), Barstar (male fertility restorer gene), and Bt genes (for introducing insect resistance). Proagro-PGS is creating a 21st century state of the art biotechnology laboratory near New Delhi. The joint venture is expecting to commercialize the hybrid mustard (*Brassica juncea*) and insect tolerant tomatoes in India within two to three years.

Seed production

Public sector

Essentially the Indian seed industry consists of ICAR institutes, state agricultural universities, and public and private seed companies. Organized seed supply started with the establishment of the National Seeds Corporation in 1963. Subsequently thirteen state seed corporations and nineteen state seed certification agencies were established under the National Seeds Programme with a loan from the World Bank. These corporations virtually conduct no research and depend on flows of new cultivars from agricultural universities and ICAR Institutes.

Some agricultural universities and state departments of agriculture are also producing and selling seeds, though on a very limited scale. Their objective is primarily to popularize the varieties and hybrids developed by state universities and departments of agriculture.

Private sector

Private seed companies can be divided into the following categories:

1. Companies conducting research, organizing production, and marketing their proprietary products.

2. Companies organizing production and marketing cultivars developed by public sector organizations.

3. Companies that have no production base but are involved in marketing only. A large number of companies fall in this category.

An estimated 150 to 200 companies belong to groups 1 and 2. Group 3 is comprised of more than 10,000 distributors and dealers.

Seed supply

Over the years the quantity of commercial seed has increased (table 4.1). The annual turnover of seed business through the organized sector is Rs 13 billion (US$ 420 million; table 4.2). The bulk of this business is of agricultural seeds. Just over 3 percent by value is from hybrid horticultural seeds (table 4.3).

In volume terms, the Indian seed industry is dominated by wheat and paddy. In value terms, however, almost 50 percent of gross sales are hybrids of sunflower, cotton, and pearl millet (table 4.2). By rough estimate, public and private sectors each account for about 50 percent of turnover. Most public sector business is in open pollinated varieties, while the private sector emphasizes hybrids.

Table 4.1 Seed distribution of field crops of improved cultivars in India

Year	*Quantity (in 1,000 tons)*
1980-81	250.1
1984-85	484.6
1988-89	502.2
1992-93	764.7

Sources: Agrawal (1991); National Conference on Seeds, Agra., February 1993.

Seed Regulations

The Seeds Act of 1966

The main objective of the Act, which became effective in October 1968, is to regulate the quality of seeds offered for sale. Under this Act labelling of seeds sold for planting is compulsory, while seed certification is voluntary. Most of the horticultural and floricultural seeds sold are labelled, while agricultural seeds are certified. For seed certification, prior notification of the variety is essential, which entails formal release of the variety by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties. The process of release is quite elaborate and time-consuming.

Most private companies enter their hybrids and varieties in official trials and at the same time start marketing the same material as labelled seeds. Companies have their own networks for testing in different agro-climatic zones. Thus good planting material reaches farmers sooner than would be the case if companies waited for release and notification procedures.

There are nineteen state seed certification agencies. There has been lack of trained manpower for seed certification. Most of the personnel in seed certification agencies are drawn from departments of agriculture, do not possess adequate knowledge of seed certification, and do not appreciate its intricacies. Frequent transfers have also hurt the quality of work.

Most government officials recognize only certified seed as produced under the Act, although certification is voluntary.

The Seed Control Order, 1983

In 1983, government passed the Seed Control Order to regulate the seed sale. This order brought seeds within the purview of the Essential Commodity Act of 1955. As per the Act, all seed dealers and storage points are to be licensed.

Due to early legal challenge, the Seed Control Order became *sub judice* and was not

Table 4.2 Seed requirement and availability for field crops, 1992-93

Crop (sown area in millions of ha)	*Seed rate (kg/ha)*	*Total planted seed (1,000 t)*	*Commercial seed supply (1,000 t)*	*Commercial seed as % of planted*	*Seed price (rps/t)*	*Commercial seed sales (millions of rps)*
Wheat (24)	100	2,400	176	7.3	7,000	1,230
Rice (42)	30	1,300	172	13	9,000	1,550
Sorghum (15)	12	170	38.9 (18.9 hy)	22	28,000 hy	529
			(20.0 var)		14,000 var	280
Pearl millet (10)	4	42	18.4	44	50,000	920
Maize (6)	20	120	16.1 (6.1 hy)	14	20,000 hy	122
			(10.0 var)		10,000 var	100
Fodder sorghum			8.0		16,000	0.1
Pulses						
Chickpea (7.4)	75	560	16.5	3		
Pigeon pea (3.6)	20	72	5.30	7		
Lentil (1.2)	40	46	1.40	3		
Black gram (3.4)	20	68	9.00	13		
Green bean (3.4)	20	68	8.20	12		
Peas (0.55)	60	2.5	2.50	8		
Total			42.9		40,000	1,720
Groundnut (0.44)	150	1,200	82.5	7		3.3
Rape/must'd (5.7)	5	29	9.70	34	40,000	242
Soybean (2.4)	63	150	19.5	13	25,000	390
Sunflower (1.6)	10	16	9.70	59	20,000	1,360
Castor (0.81)	13	10	0.14	28	140,000	12.6
Linseed (1.2)	25	29	147	0.51	90,000 ha	4.4
					30,000	
Cotton (7.4)	120	150	22.4 (11.2 hy)	15	375,000 hy	4,200
			(11.2 var)		25,000 var	280
Total (141)		6,500		12		12,900

put into force for many years. In 1994, however, the Supreme Court upheld the legality of the order, so that it became operative from July 1, 1994.

The order establishes strict controls: dealers and storage points must display stocks and prices daily; government inspectors are free to enter and inspect premises where seed is stored and to draw samples; inspectors are empowered to stop the sale of seeds if they suspect any malpractice. Therefore, the Seed Control Order is contrary to the current liberalization of the Indian economy.

Breeder's Seed Supply, 1986

For many years, public sector institutions supplied breeder's seed to the National Seed Corporation (a parastatal) for production of foundation seed, which was sold to the private sector for production of certified seed. With these arrangements, spread of improved publically-bred varieties into farming communities was slow. Therefore, in a landmark decision, government decided to sell breeder's seed of publically-bred self-pollinated varieties to private seed companies having adequate facilities and manpower to produce foundation and certified seed. This decision helped to alleviate the shortage of certified seeds and stimulated seed production.

New Seed Policy, 1988

The Indian government severely restricted seed import and export until 1988. In September 1988, the government announced a New Seed Policy with the intention that "farmers should have access to the best material available," regardless of its origin. Import procedures were liberalized; most seeds and planting materials are now listed as "freely importable" items. Also, foreign companies were encouraged to participate in the development of the seed industry. Now, seeds of many foreign companies are available, particularly vegetable seeds.

New Industrial Policy, 1991

Prior to July 1991, foreign investors were allowed to have equity participation only up to 40 percent. From July 1991, the government decided to allow foreign investors to establish equity participation up to 51 percent in priority sectors, including the seed sector. Non-resident Indians are allowed 100 percent participation. Investors must apply for approval from the Reserve Bank of India, which will review their application without referring to other ministries and reply within a very reasonable period, that is, one to four weeks.

Export-Import of Seeds, 1989

Import and Export of seeds are regulated by the Plant, Fruits and Seeds Order, 1989, made under the Destructive Insects and Pests Act, 1914. Within the Ministry of Agriculture, Directorate of Plant Protection, Quarantine and Storage regulates import and export of seeds. For commercial consignments the following steps are required:

General

1. Registration with Joint Chief Controller for Import and Export.
2 Registration with Reserve Bank of India.

Export

1. Registration with Agricultural Processed Food Products Export Development Authority.
2. Export order (from importer) with complete terms and conditions.
3. Application to seed certification agency (for seed sample to be drawn from lots for laboratory test).
4. Application to Directorate of Plant Protection, Quarantine and Storage, Ministry of Agriculture, for Phytosanitary Certificate.
5. Preparation of Export Documents, which includes invoice, packing list, shipping bill, and exchange control declaration form (GR-Form) issued by Reserve Bank of India.

Table 4.3 Market analysis of hybrid vegetable seeds in India, 1993-94

Crop	*Total area (1,000s of hectares)*	*Area under hybrid (percent)*	*Hybrid seed marketed (kgs)*	*Seed price (rupees/kg)*	*Total value (Millions of rupees)*
brinjal	447	4.0	2,250	6,000	13.5
cabbage	223	21	15,000	8,000	120.0
cauliflower	421	0.59	1,300	4,000	5.2
chili	551	0.45	800	16,000	12.8
gourd	389	1.2	9,200	1,300	12.0
melon	157	2.1	6,600	2,500	16.5
okra	347	0.77	27,000	600	16.2
tomato	454	24	17,000	15,000	255.0
total			79,000		450

Source: Revised from Seed Association of India.

6. Attestation of documents, from PHD Chamber of Commerce, for certificate of origin.

   Note: At present there is no seed testing laboratory accredited by ISTA in India to issue ISTA seed analysis certificates for export.

Imports

1. Registration with the National Seeds Corporation.
2. Application to the Ministry of Agriculture for import permit (from the Directorate of Plant Protection, Quarantine and Storage).
3. Purchase contract (with supplier).
4. Inspection and sampling of consignment at the port of entry (Delhi, Bombay, Madras, Calcutta, or Amritsar). Consignments are released after 30 days, the period required for grow-out tests.

Lists of items freely importable, canalised, and restricted are as follows:

- *Freely importable*: seeds of cereals, pulses, oilseeds, vegetables, flowers, fruits and plants, tubers and bulbs of flowers, cuttings and saplings.
- *Canalised items* (import only through canalising agencies designated by the central Government, ie, the State Trading Corporation of India, Ltd, and Hindustan Vegetable Oils corporation, Ltd): seeds of groundnuts, safflower, soybean, cotton, sunflower, and rapeseed.

Many seed items are restricted for export, so that exports are permitted only under license. Important ones are as follows: seeds of castor, cotton (except grown under custom production), Egyption clover, fodder crops, green manure crops, jute, linseed, lucerne, mesta, onion, rubber, all oilseeds, and all pulses.

The Plant Varieties Act, 1993

Currently, no law provides for ownership of varieties. The Plant Varieties Act (PVP), 1993, is under consideration in Parliament.

The Act proposes to provides protection to: new varieties; extant varieties; and germplasm. Protection is provided for fifteen years from the date of registration. To qualify for protection, the variety must be evaluated through an appropriate evaluation system (hopefully through an independent agency having no interest in plant breeding research), and a prescribed quantity of seed must be deposited in the National Gene Bank.

Seeds deposited with the National Seed Bank will be freely available to researchers for developing new varieties. Also, if the government determines that domestic or international markets for the variety are not being met by the current owner, the government may grant license to any other person to produce and sell seed of the variety.

Seeds of protected varieties are not to be sold unless they are certified, which means that the owner of the variety must also provide parental material to certification agencies.

Farmers retain the right to save, use, exchange, share, and sell seed grown from seed of protected varieties.

Variety owners or seed dealers are to provide compensation to growers if a protected variety does not perform as advertised.

The National Gene Bank will manage international germplasm exchange. The Bank will arrange reciprocal exchange with countries or agencies that allow free access to germplasm. For others, the Bank will negotiate terms and conditions for germplasm exchange. The Bank will allow unrestricted access to germplasm from international agricultural research centers.

The Act provides for establishing a national authority for plant varieties protection, which will register varieties, maintain a list of registered varieties, evaluate materials for granting PVP, and to carry out related functions.

It is difficult to conceive that PVP legislation in the present form will stimulate plant breeding research in the private sector. Farmers would have the right to produce and sell protected material without any limit. Also, how can breeders protect their material if seeds of protected varieties or lines are to be deposited with the National Bureau for Plant Genetic Resources and Seed Certification Agencies? It will be difficult for a breeder to realize a return on investment if government decides to provide license to any person to multiply and market seed of a protected variety, as the law provides. The industry feels that this legislation reflects the compulsion of article 27, para (3)b, of the Trade Related Intellectual Property Rights (TRIPS) Agreement rather than conviction to provide protection and incentives to plant breeders. (The TRIPS segment of the World Trade Agreement requires all nations to enact suitable legislation to protect innovations.) Finally, regulation to protect transgenic plants is far from clear, as the issue is not mentioned in the draft Act.

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The Impact of Turkey's 1980s Seed Regulatory Reform

David Gisselquist and Carl Pray

Beginning in the early 1980s Turkey progressively eased regulations controlling private sector introduction of new agricultural technology through inputs production and trade. This study describes Turkey's 1980s seed regulatory reforms and estimates the impact of those reforms on variety movement, agricultural productivity, and incomes.

Turkey lies the same distance from the equator as Spain, northern China, Japan, Kansas in the United States, and southern Argentina. The country offers a wide range of climates that supports a varied agriculture—for example, along the Mediterranean coast, hot dry summers and mild winters support citrus and other fruit production, while on the Anatolian Plateau in the center and east of the country, cold winters and limited annual precipitation favor grain and pastures. With its relatively high latitude and wide range of climates, Turkey has been able over the years to adopt plant varieties, animal breeds, and other agricultural technologies from the United States and Central and Western Europe as well as from Mediterranean and sub-tropical countries.

Seed reforms

Pre-1980s government controls

Turkey's seed legislation dates from 1963, with Seed Law 308 giving Ministry of Agriculture (MARA)[1] authority over seed production, domestic trade, imports, and exports. While this law provides the framework for control, implementation depends on subsidiary regulations and practices.

Variety registration. With respect to variety registration (that is, listing of crop varieties for which seed may be sold), Article 4 of Law 308 gives the Minister of Agriculture authority to decide which crops are subject to compulsory registration. MARA has over the years insisted on compulsory registration for essentially all crops of interest to commercial seed firms.

For those crops for which varieties must be registered, Article 6 gives the Minister authority to decide whether or not to register each foreign variety after "adaptation tests in our country and after their economic and agricultural values have been determined..." Notably, the decision about whether or not to register a variety is not based on presence or absence of negative externalities, which are not even mentioned; rather, registration depends on economic performance.

Sometime before 1980, MARA began to issue "production permits" as a form of second-class registration. Production permits expire after a fixed term (often four years), and some production permits limit use of the seeds, such as to produce goods for export only.

Certification. Law 308 authorizes MARA to certify seed and to set quality standards. MARA exercised this authority by insisting on compulsory government certification and quality tests for all commercial seed.

Other Controls. With authority from Law 308, MARA annually fixed seed prices for most major crops. In addition, Article 11 gives

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MARA authority to control seed imports and exports, without limiting controls to phytosanitary issues. Before 1980s reforms, MARA used this authority to limit private seed trade primarily to vegetables.

1980s reforms welcome the private sector

Entering the 1980s, MARA limited variety approvals for most field crops to those sponsored by government research agencies. Private companies were more active in vegetables, importing and producing seeds. However, even here MARA controls held back new technology. For example, through 1980 MARA had registered (allowed) only one variety of hybrid cucumber and two of hybrid tomato, and trade in these varieties was monopolized by domestic companies licensed as sole distributors. Most traded vegetable seed was from local open-pollinated varieties. A number of sources report significant smuggling of vegetable seeds—for example, for many years all hybrid watermelon seeds were smuggled from Cyprus. Local firms, most prominently May Seed Company, produced seeds for open-pollinated vegetables.

Along with seed smuggling, other evidence of failed seed policies included government inability to popularize hybrid maize and large and expensive government seed agencies serving no more than about 10 percent of planted area. In the early 1980s, frustrated with these and other difficulties, officials redesigned policies to stimulate rapid expansion of Turkey's private seed industry and to invite multinational seed companies to participate.

In 1981, Turkey asked the International Finance Corporation (IFC) to help promote private seed production and trade. IFC in turn asked the Industry Council for Development (ICD)[2] to identify seed markets, to evaluate strategies for private participation in the seed industry, and to suggest policy changes (ICD 1982, vol 1, p 2). An ICD team visiting Turkey in early 1982 reported:

> The government variety testing program makes it extremely difficult to introduce genetic advances in seed technology available elsewhere in the world... The time span for new variety introduction, including hybrids, and their approval by the key Variety Registration Committee, is a minimum of three years... Seed companies operating outside Turkey have been very reluctant to undergo the lengthy time period required to obtain commercial introduction of hybrids in Turkey or to make available the local production of parent lines under the system of rigid price fixing and the minimum margin structure of the industry (ICD 1982, vol 1, p 35).

The ICD mission recommended that Turkey eliminate price controls on seeds and allow "free import ... by private organizations for testing and marketing purposes, subject only to phytosanitary import regulations" (ICD 1982, vol 1, p 75). Notably, allowing free import for marketing entails doing away with compulsory variety registration. And if seeds of unregistered varieties are to be multiplied in-country and then sold, compulsory seed certification would also have to go.

The government acted quickly on these issues, though reforms fell short of dismantling compulsory variety registration and seed certification. A 1983 ICD paper reports changes "in the body of regulations pertaining to the seed industry," including the following (Grobman 1983, pp 1-2):

- private companies from October 1982 are allowed to do their own performance tests for varieties they would like to introduce (companies report results to the government, which continues to decide whether or not to approve each variety);

- MARA's Registration Committee is prepared to issue production permits for new varieties "even without testing, provided that evidence is presented that such a variety has been successfully grown in a similar ecological region";

- testing requirements for variety registration are lowered from the previous minimum of three years to one to three years, depending on crop and type of seed (for example, one year for hybrids, two years for vegetables);
- from December 1983, each seed firm is allowed to set its own seed prices.

As part of efforts to stimulate private domestic and foreign investment, MARA and ICD organized a National Seed Enterprise Development Workshop in Istanbul in May 1984, inviting private Turkish and foreign seed companies and soliciting their views. Also, the government relaxed controls on private foreign investment and made credit available for seed companies.

Licensing Seed Companies. The government licenses seed companies in two categories, designating stronger ones (having some land and scientific staff) as research companies, which allows them to do their own variety trials. Other seed companies must ask research companies or government farms for help with variety trials.

Plant Variety Protection. In 1994, the government passed a law establishing a system for plant variety protection (PVP), which will allow companies to claim property rights in varieties. With implementation of this law, Turkey joins UPOV (International Convention for the Protection of New Varieties of Plants), a treaty organization in the United Nations system that sets standards for intellectual property rights in plant varieties.

Subsidies. The government from 1985 through 1994 has subsidized specific categories of seeds (for example, hybrid maize, soybeans, etc) in order to cut seed cost to farmers. The government annually announces subsidies per kilogram (kg) seed, and then pays that amount to companies against receipts demonstrating sale to farmers. Subsidies have fallen precipitously— for example, subsidies on hybrid maize seeds ranged from 12-38 percent during 1987-1990, fell to about 1 percent during 1992-1993, and were eliminated in 1994.

Impact on variety movement and seed industry

The chain of causality through which seed regulatory reform has an impact on agricultural productivity and incomes goes through variety introduction and seed supply. This section describes the impact of reforms on variety movement and on Turkey's seed industry. The next section looks at the consequent impact of new varieties and improved seed supply on productivity and incomes.

Variety movement

With seed reforms from the early 1980s, the number of improved varieties allowed for sale (with either registration or production permits) increased dramatically over the next several years, as shown in table 4.4. For sunflower, for example, the number of varieties allowed for sale increased from three in 1982 to about thirty in 1987. For soy beans, varieties increased over the same period from two to more than forty.

Many of these new varieties have been introduced and tested at the initiative of private seed companies. For private seed companies, identifying and introducing new varieties is a common strategy to expand sales. With a good new variety, a company can expand its market share in competition with other companies and can also expand the market, coaxing farmers to shift from saved seed or to change crops.

Even for crops that have had strong public sector involvement in seed trade, 1980s regulatory reforms brought significant increases in numbers of varieties available, through public as well as private agencies. In wheat, for example, the government allowed sale of seeds of only twenty-one improved varieties in 1982; on average, the government approved more than five new wheat varieties per year from 1984 to 1994. In 1980, Agricultural State Enterprises (TIGEM) produced seeds for fourteen wheat and four barley varieties; by 1994, TIGEM's offerings had increased to forty-two varieties of wheat and nine of barley.

In sugar beets, KWS (partner with the government in Pan Tohum) responded to competi-

Table 4.4 Varieties introduced by year and crop, 1982-94

Crop	Harvested area in 1990 (hectares)	Varieties available[a] as of 31/5/82	New Varieties 1/6/82-31/5/84[b]	1/6/84-31/5/85[b]	1/6/85-31/5/86[b]	1/6/86-31/5/87[b]	1/6/87-31/5/88[b]	1/6/88-31/5/90[b]	1/6/90-5/8/91[b]	6/8/91-20/7/92[c]	21/7/92-2/7/94[c]	cf: New varieties added to OECD list in 1993[d]
wheat	9,400,000	21	1	10	9	2	16	5	16	1	2	164
sunflower	715,000	3	5	8	10	6	7	20	11	7	0	127
cotton	641,000	9	2	0	5	1	1	5	1	4	0	18
maize												406[e]
hybrid	155,000	24	35	24	9	22	22	48	23	1	1	
other	360,000	20	1	0	0	4	5	0	0	0	0	
sugar beets	378,000	11	5	7	3	3	1	3	2	0	0	108
tobacco	320,000	31	0	0	6	1	0	2	0	0	0	
potatoes	192,000	8	3	6	3	1	0	14	13	8	3	
tomatoes	126,000	43	14	10	0	8	11	122	67	3	2	
soy beans	74,000	2	27	0	12	4	11	7	9	0	2	69
cucumbers	16,000	1	2	0	2	4	5	57	50	3	0	

Note: The major reform that allowed an increase in number of varieties available, as shown in the table, was agreement on the part of key MARA officials from about 1983 to grant production permits (ie, temporary registration) more expeditiously, and to sometimes waive in-country performance tests.

a. Cumulative number of varieties available on 31/5/82 includes varieties either registered or with unrestricted production permits on that date.

b. For all other dates, the table shows number of new varieties introduced from the previous date given in the table; number of new varieties is calculated as the sum of new varieties introduced with new registration or unrestricted production permits; lists have been scrutinized to avoid counting varieties that were, for example, newly registered but had previously been available with an unrestricted production permit.

c. From about mid-1991, MARA has stopped listing varieties with new unrestricted production permits in Resmi Gazete; hence, figures in the table presumably understate number of new varieties available from mid-1991.

d. The last column lists numbers of new varieties added to OECD's List of Cultivars Eligible for Certification in 1993. Since the US does not restrict varieties, US farmers legally have access to all of these new varieties. Farmers in EU countries, which share a Common Catalogue, have access to a large share of these varieties.

e. OECD gives no breakdown into hybrid and non-hybrid varieties.

Sources: Harvested areas for field crops are from: SIS, 1990 Agricultural Structure and Production, p 4. Total area for cucumbers and tomatoes are from: SIS, General Agricultural Census 1991, p 65. Available and new varieties for various years and periods are from: Resmi Gazete for 31 May 1982, 31 May 1984, 31 May 1985, 31 May 1986, 2 July 1987, 31 May 1988, 3 May 1990, 5 August 1991, 20 July 1992, and 20 July 1994. Numbers of cultivars added to OECD's list are from: OECD, List of Cultivars Eligible for Certification 1993 (Paris: OECD, 1993).

tion from several fully private competitors by selecting additional lines from their breeding program that are specially suited for Turkey.

Even without variety protection, companies have invested to identify, test, and introduce new varieties for non-hybrid crops, such as wheat and soy beans. During interviews in 1994, seed company managers reported only one case of a company multiplying seed of a variety introduced by another: TIGEM multiplied seed of a soy bean variety that May and its international partner Asgro had introduced. Seed company staff expect that 1994 passage of a law establishing PVP will stimulate more effort to identify and introduce non-hybrid varieties.

Expansion of private seed industry

Before the 1980s reforms, the few private seed companies importing and producing seed in Turkey focused on vegetables. In addition, there were two semi-private seed companies: Pan Tohum, a joint venture between the government's Turkish Sugar Factories Company and KWS, a German firm; and BETA, for which the dominant owners are sugar cooperatives, so that BETA is controlled by Pankobirlic, a government-run apex cooperative.

In 1980, the government directly managed or controlled most commercial seed production and trade through cooperatives and state owned enterprises, including Agricultural Supply Organization (TZDK) and TIGEM. For sugar beet seeds, Pan Tohum had a monopoly for production and import and distributed seeds through sugar cooperatives.

A 1985 World Bank paper reports nine new seed companies established from the time seed reforms began (Freiberg and Grobman 1985, p 280). That number increased rapidly as major US and European-based seed multinationals along with companies from Israel, Taiwan, Thailand, Japan, Korea, and other countries established a presence through joint ventures, licenses, or subsidiaries. In 1986, Turkish seed companies founded a Seed Industry Association (TEBD); TEBD in 1994 represents twenty-nine companies, most of which are private. The seed industry includes another fifty or so private companies that have not joined TEBD.

Along with increase in number of seed companies, private seed sales expanded to dominate commercial seed sales for several field crops and to take a share of sales for other crops, as shown in table 4.5. Most of the increase in private sales has been for varieties that private companies have introduced, so that private sales correlate strongly with technology transfer.

For wheat, despite subsidized competition from state-owned enterprises, private seed companies have introduced new varieties from CIMMYT and Europe, and more are in the pipeline, including a durum wheat from the United States. Recognizing that farmers multiply wheat seed for their own use and sale to neighbors, one seed company manager described his plan to continuously introduce new varieties, staying ahead of diseases and offering new varieties with attractive features (for example, durum wheat with low percent of yellow bellies). With farmers planting a million tons of wheat seed each year, a company gaining even a small share of the market could see big sales. In 1994, private companies sold wheat seed at about double TIGEM seed and grain prices. With higher prices, private wheat seed depends on other factors, such as quality and variety, to compete with public seed.

For selected crops, table 4.6 shows seed production plans by type of firm in 1994. Numbers do not show actual market share because some firms do not follow their plan (for example, TIGEM is unlikely to more than double wheat seed production from 1993), the seed may not all be sold, and some of what is sold may be exported. These are, however, the only numbers available to show market share. Subsidiaries of six foreign firms proposed to produce about half of the hybrid maize and sunflower seed. Most of the rest of the hybrid maize and sunflower seed as well 98 percent of the soy bean seed was to be produced by six Turkish firms that have joint ventures with for-

Table 4.5 Commercial[a] seed production, 1980-93
(metric tons)

Crop	*1980*	*1985*	*1990*	*1993*
Wheat				
private sector	0	< 1,000	7,000	10,000
public sector	49,000	188,000	124,000	103,000
Barley				
private sector	0	0	0	300
public sector	13,000	35,000	16,000	10,000
Hybrid sunflower				
private sector	0	80	2,600	3,500
public sector	0	10	30	40
OPV sunflower				
private sector	0	na	na	na
public sector	2,500	na	na	na
total		4,800	1,000	200
Hybrid maize				
private sector	na	1,800	4,500	7,200
public sector	na	300	200	200
total	900			
Sugar beets				
private sector	na	3,400	na	3,300
public sector	na	0	na	3,300
Cotton				
private sector	0	0	500	300
public sector	35,000	27,000	30,000	31,000
Potatoes				
private sector	na	800	4,200	2,200
public sector	na	6,300	900	200
total	2,000			
Chickpeas				
private sector	0	0	0	90
public sector	0	200	200	70
Soybeans				
private sector	0	800	3,200	3,600
public sector	0	1,100	600	200
Vegetables				
private sector	na	300	600	700
public sector	na	30	30	30
total	191			

Note: Data have been rounded off to two significant figures for hundreds and above; for hundreds and below, data have been rounded to one significant figure.

a. Seed produced by registered seed companies.

Source: Various publications of TEBD (Turkish Seed Industry Association).

eign firms. Unofficial estimates from the firms we interviewed suggest that market share for the largest firm in maize is about 30 percent and in sunflower about 25 to 30 percent. There appears to be strong competition in major seed markets; for example, the leading maize seed company reports that its market share is being eroded by smaller firms undercutting its price.

The large number of companies — local and multinational — involved in the seeds sec-

Table 4.6 Seed production plans by type of firm, 1994

Type of firm	*Maize*	*Sunflower*	*Soybean*	*Wheat*
Subsidiaries of foreign firms				
metric tons	6,200	1,500	0	2,500
percent share	50	48	0	1
Joint ventures				
metric tons	5,500	1,500	3,100	0
percent share	45	49	98	0
Other Turkish private firms				
metric tons	400	0	0	6,800
percent share	3	0	0	2
Turkish public firms				
metric tons	310	110	70	275,000
percent share	3	3	2	—
Total (metric tons)	12,400	3,100	3,200	284,000

Source: Calculated from MARA, Tohumluk Programi 1994 (Ankara: MARA, 1994).

tor in Turkey means that the industry has been competitive despite some tendency toward over-regulation (that is, continuing compulsory variety registration and seed certification).

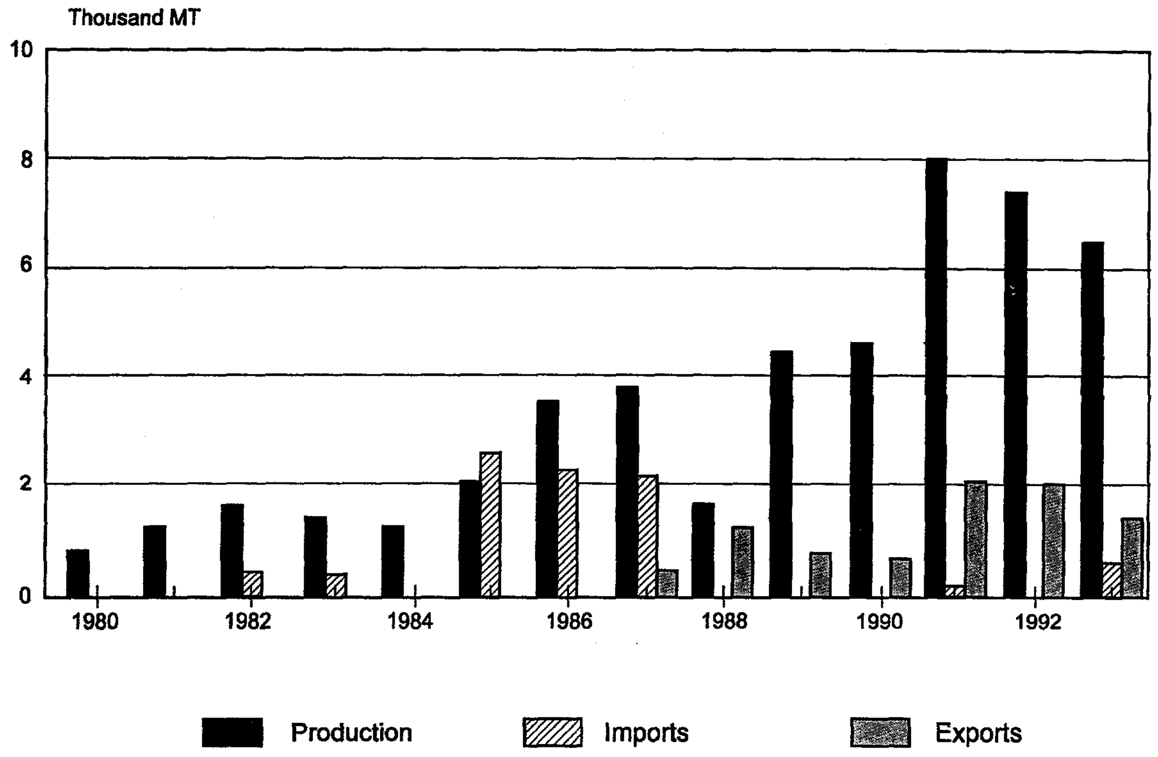
Seed imports and exports

Reforms lowering barriers to varietal introduction and to seed imports led to more imports for selected crops, such as maize and sunflower. Soon, however, local seed production expanded to take care of local demand and then pushed into export markets as well. Figures 4.1 and 4.2 show this progression for maize and sunflower: from 1988 maize seed exports have exceeded imports; for sunflowers, seed exports have exceeded imports from 1990. Once reforms allowed seed technology to enter, Turkey has been able to exploit its comparative advantage in seeds based on good climate, scientific skills, and low cost labor. Table 4.7 shows Turkey's exports and imports for all seeds. Chile, another early reformer, shows the same progression from maize seed imports, to local production, and then to exports.

Maize and sunflower seed imports in the early 1980s assisted introduction of new varieties, allowing farmers to adopt them before locally produced seed was available. During the 1960s, imports of Mexican wheat seed played a similar role, facilitating rapid expansion of area planted to new varieties. A recent study of maize yields for fifty countries over twenty-five years found strong correlation between yield increases and volume of seed imports (Pray and Echeverria 1992, pp 372-373).

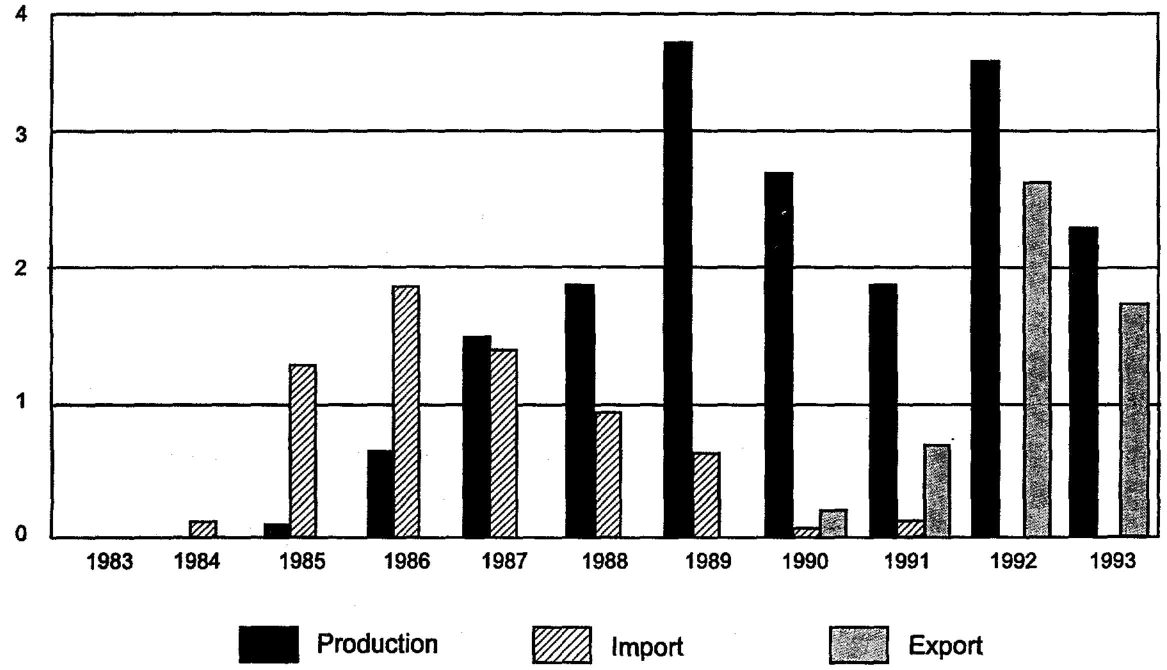
While continuing government efforts to discourage seed imports no doubt have some influence, their impact can be over-emphasized. Since the early 1990s, Turkey has been importing seeds for roughly 1 percent of planted area. This can be compared to seed imports into Thailand and Chile, which have more open seed policies, for roughly 1 to 3 percent of planted area in the mid-1980s (FAO 1987, p 307; Pray 1990, p 195). Seeds are bulky and costly to move, and even reasonable phytosanitary rules add to import costs. Aside from some high-value vegetable seeds and seeds that require special conditions for production, lower costs with in-country production sooner or later tend to dominate decisions about where to produce seeds, so that imports give way to local production.

Figure 4.1 Hybrid maize seed production, imports, and exports, 1980-92
(1,000 metric tons)



Source: Data from TEBD.

Figure 4.2 Hybrid sunflower seed production, imports, and exports, 1980-92
(1,000 metric tons)



Source: Data from TEBD.

Table 4.7 Seed exports and imports, 1980-93
(in tons, unless otherwise noted)

Crop	1980-82 average	1983-85 average	1986-88 average	1989-91 average	1992-93 average	Comments
Wheat & barley						virtually all in the public sector
export	0	0	600	2,000	700	
import	200	17,000	6,000	14,000	2,500	
Hybrid maize						mostly private, except for mid-80s imports
export	0	0	600	1,200	1,800	
import	200	1,000	1,500	50	200	
Hybrid sunflower						private sector
export	0	0	0	300	1,400	
import	0	500	1,400	300	0	
Vegetables						private sector
export	0	90	90	110	140	
import	20	90	140	200	210	
Potato						
import	10	3,500	6,700	7,100	2,100	
Soy bean						
import	1,300	3,400	5,000	2,500	0	
Cotton						
import	100	0	100	500	80	
Others						
export	0	50	40	300	40	
import	80	400	200	700	400	
Total export volume						
vegetables	0	90	90	110	140	
others	0	50	1,400	3,900	4,100	
Total export value [a] ($1,000)	0	5,000	5,000	8,000	12,000	
Total import volume						
vegetables	20	90	140	200	210	
potatoes	10	3,500	6,700	7,100	2,100	
others	1,900	22,000	14,000	18,000	3,200	

a. Value per ton of seeds exported has been estimated at $50,000 for vegetables, $1,500 for hybrid maize and sunflower, and $250 for wheat and barley, and $500 for all other crops.
Source: Volume of exports and imports from various TEBD publications. Values are estimated.

Shrinking public sector seed sales

Seed reformers in the 1980s concentrated on building up the private sector rather than tearing down the public sector. With even reformers afraid that private companies would not be interested in producing relatively low value seeds for open and self-pollinated crops such as wheat, barley, and fodder crops, government agencies, including state-owned enterprises, continued to produce seed for wheat and other major crops. In addition, the government continues to play a large role in seed trade through cooperatives.

As private companies expand, pressure mounts for government to limit state-owned enterprise seed production and unfair competition. During interviews in 1994, managers of some private seed companies vehemently objected to state-owned enterprise sales of hybrid maize seed. In the 1990s, the government has been debating plans to privatize TZDK, which produces potato and other seeds, and also TIGEM, which produces wheat and barley seeds. In addition, consistent losses on Agricultural Bank loans to cooperatives drain public funds, which pressures government to reduce interference in inputs trade.

However, seed industry sources expect the government through TIGEM to continue to produce wheat and barley seeds in the medium-term future. Also, KWS has just signed a ten-year contract with Pan Tohum, which suggests that the government plans to maintain a large share of the market for sugar beet seeds as well. Cotton seed production and trade continues to be dominated by state-managed cooperatives.

Reform impact on net incomes: benefits and costs

Since many factors (for example, macroeconomic policies, weather, and agricultural pricing policies) affect aggregate crop production, it is difficult to estimate the impact of seed reform from aggregate crop data. However, the impact of seed reforms has been uneven across crops, with productivity and incomes from selected crops showing dramatic movement. Hence, although total benefits are difficult to estimate from aggregate crop data, it is possible to estimate partial benefits for specific crops.

Partial benefits from seed regulatory reform

Maize. With a simple yield response function, we estimate the impact of post-reform hybrids on yields. Since Turkey is a small producer and regularly imports maize, we assume that changes in maize productivity and production have no impact on price. With some assumptions about input costs, we then calculate the impact of higher yields on farmer net incomes.

We model maize yields in tons per hectare as a function of hybrids, fertilizer, and rainfall.[3] Hybrid use is shown as percent of maize area sown to private hybrids (all of which came in after and because of reform; we do not include pre-reform [public] hybrids, which covered only 1 percent of maize area in 1992 [CIMMYT 1994]). We also include a trend variable to capture impact of transport improvements, extension, etc. Annual fertilizer use on maize is calculated from 1980 share of fertilizer applied to maize times annual total fertilizer use (FAO reports that share of fertilizer going to maize drops slightly from 1980 to 1988; we use 1980s share throughout; see Ange 1994, p 10). For rainfall, we use national annual rainfall.

Table 4.8 reports results of this regression. The coefficient for percent of maize area planted to hybrids is positive and significant in all specifications. The trend variable is positive and significant and lowers the coefficient for hybrids. Fertilizer is not significant in the regressions except when the trend variable is not included; over the period, national average fertilizer use and hence calculated use on maize grew slowly.

Figure 4.3 shows actual yield of maize and projected yield using estimated coefficients from specification two and actual values for fertilizer use, rainfall, and trend, but with zeros for post-reform hybrids. The gap between actual and projected yields was greatest in 1990 at almost 2 tons per hectare (**t/ha**). Impact of post-reform private hybrids on maize yields in Turkey parallels a similar impact of imported hybrids on maize yields in Greece during the 1970s (see figure 4.4). Virtually all maize in Greece is irrigated, which largely explains why national average yields for Greece exceed those for Turkey. Figure 4.4 also shows lower maize yields in Syria, a country which limits variety introduction, and higher yields in EU countries, which allow free intra-EU movement of varieties.

During 1990-92, annual gross value of additional production due to post-reform hybrids was about $130 million ($255/ha over 515,000 hectares (has)). We did not find cost of production surveys showing cost differences between local and hybrid maize. We estimate change in net farm income per hectare due to hybrids as the value of increased production due to hybrids less higher cost for hybrid seed and cost to harvest and dry increased production (see Table 4.9). With these costs, we estimate that post-reform hybrids boost annual net farm incomes in 1990-92 by $ 97 million (see table 4.9).

Table 4.8 Maize yield response function, 1961-91

Specification	*% hybrid*	*ln % hybrid*	*fert/ha (kgs)*	*ln fert/ha (kgs)*	*Rainfall*	*Trend*	*Adjusted R2*
1.	3.40	—	0.011	—	2.44E-04	—	0.916
	(0.474)		(0.0019)		(7.37E-04)		
2.	2.888	—	1.38E-03	—	4.58E-04	5.34E-02	0.924
	(0.522)		(5.30E-03)		(7.14E-04)	(2.73E-02)	
3.	—	0.056	—	0.161	—	—	0.868
		(0.009)		(0.031)			

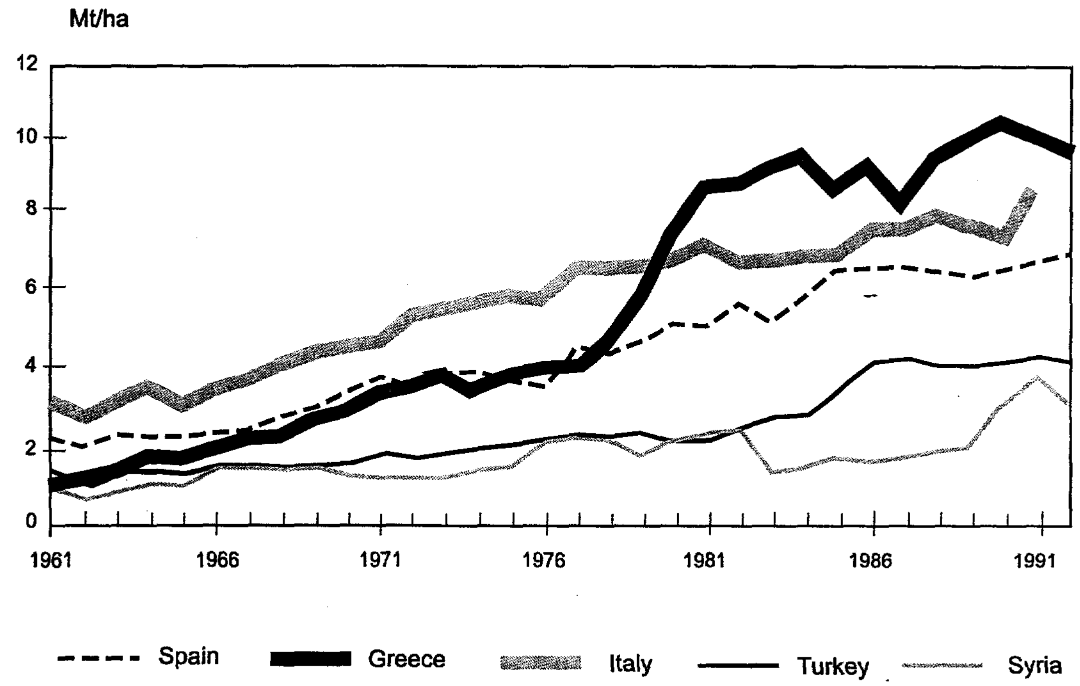
Note: Numbers in parentheses are standard deviations for the variables.
Sources: Percent of maize are planted to private or post-reform hybrids was calculated from TEBD data. Fertilizer use if from FAO data on 1980 percent of fertilizer use on maize (Ange 1994, p10) multiplied by FAO annual data on national fertilizer use. Rainfall is from national annual data.

Table 4.9 Calculating net benefit from hybrid maize, 1990-92

Item	*Before reform, 1980-82*	*After reform, 1990-92*	*Total change*	*Change due to hybrids*
Average yield				
volume (metric ton/hectare)	2.18	4.13	1.95	1.43 [a]
value at $178/ton ($/ha)	388	735	347	255
Average fertilizer use on maize				
volume (kg/ha)	87	120.8	33.8	0
value at 178/ton ($/ha)	15.5	21.5	6.0	0
Seed for representative hectare				
OPV seed volume at 37 kg/ha (kg/ha)	37	26	(11)	(11)
OPV seed value at $178/ton ($/ha)	6.6	4.6	(2)	(2)
hybrid seed volume at 28 kg/ha (kg/ha)	0	8.4	8.4	8.4
hybrid seed value at 2,970/ton ($/ha)	0	25.0	25	25
total seed value for representative hectare ($/ha)	6.6	29.6	23.0	23.0
Harvesting and drying costs, calculated as 1/6th value of production ($/ha)	65	123	58	43
Net gains ($/ha)	—	—	260	189
Total area planted to maize (hectares)	581,000	515,000	—	—
Total benefits for 1990-92 maize planted area ($1,000)			$134,000,000	$97,000,000

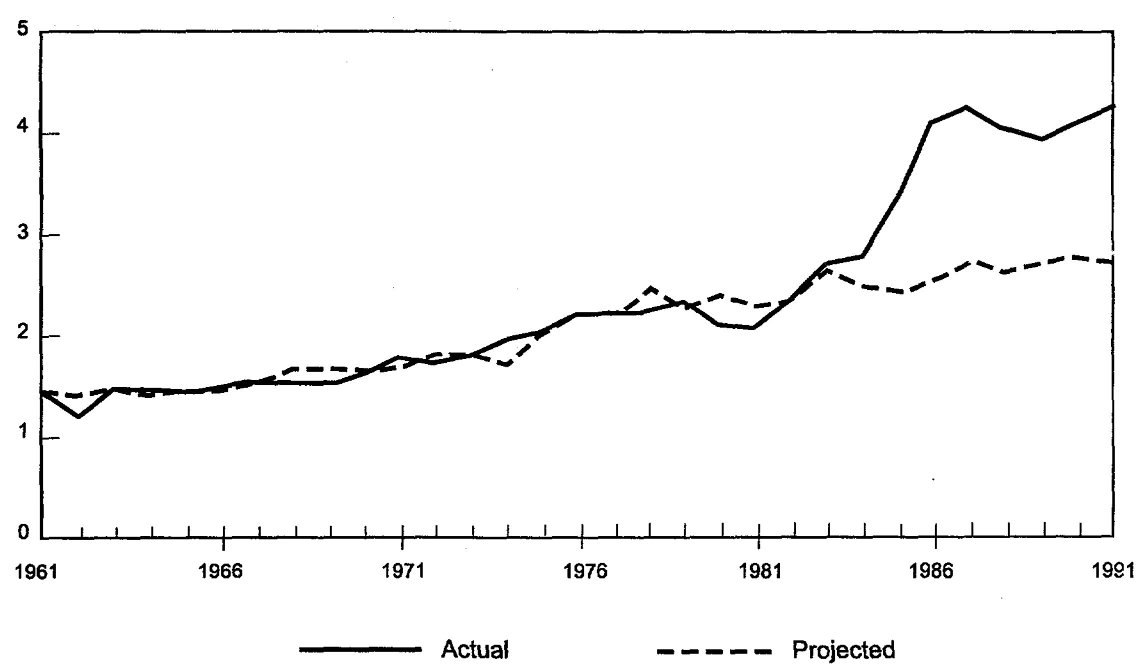
a. Actual yield less projected yield, using estimated coefficients for national average fertilizer and weather.
Source: Maize prices, fertilizer prices, and seed rates from: CIMMYT, 1993/94 World Maize Facts and Trend (Mexico: CIMMYT, 1994).

Figure 4.3 Maize yields in the Mediterranean region, 1961-91



Source: Data from USDA.

Figure 4.4 Maize yield: actual and projected, 1961-91 (tons/hectare)



Source: Actual from SIS, *The Summary of Agricultural Statistics* (Ankara: SIS, various years). Projected using coefficients from Table 4.2.

Vegetables for export. Vegetable exports is an area where one would expect an impact from reforms allowing in new varieties as well as new specialty chemicals, particularly plant growth regulators, which are important for high value horticulture production. The limited data which are available confirm an impact, but the picture is incomplete (see Table 4.10). This section is based on information from a 1994 FAO and MARA study, *Turkey: Horticulture Subsector Review: Approaches to Market-Led Development.*

Value of vegetable exports (including tomato concentrate and other canned vegetables) increased from roughly $100 million in 1979-81 to near $400 million in the early 1990s. For tomato concentrate, exports increased from nothing in the early 1970s to $89 million in 1991. Exports of other canned vegetables doubled to nearly $100 million in two years from 1989 to 1991. Other vegetable exports increased from $60 million in 1981 to $192 million in 1991 before falling back somewhat in 1992.

Growth was not even across all vegetables, but was rather concentrated in a few. Among canned vegetables, "pickled cucumbers and artichoke hearts packed in glass have become major export items in the last two years" (FAO and MARA 1994, annex 4, p 9). Among fresh and frozen vegetables: fresh potato exports went from $5 million in 1987 to $37 million in 1991; fresh cucumber exports increased from $1 million to $13 million over the same period; and frozen vegetable exports increased from $7 million to $26 million in the same four years.

The pattern of export growth suggests that regulatory reform was a factor. For one thing, fresh and frozen vegetable exports grew most rapidly at the end of the period. Also, we can correlate export growth for particular products with introduction of new varieties. For example, the increase in fresh and pickled cucumber exports can be linked to reform, since only one cucumber variety was allowed for sale in 1982 compared to more than 100 in 1992. Similarly, the number of potato varieties allowed increased very rapidly from 1988, while potato exports jumped in 1991.

With total vegetable exports increasing much more than $200 million from the early 1980s (see table 4.10), and with evidence that new varieties contributed to exports for particular vegetables, we estimate that new technology coming in with 1980s regulatory reforms added at least $100 million to annual vegetable exports (about half for fresh and frozen and half for canned vegetables) by the early 1990s. All of this increase does not represent higher incomes, since exports are pulling resources away from other activities. Without trying to work through a general equilibrium model, we estimate that net incomes increase by one-third of the value of additional exports (from a rule of thumb taken from the *Economist*). Hence, by the early 1990s, $33 million is a lower bound estimate of the impact of regulatory reforms on annual incomes from vegetable exports; farmers, traders, and processors share the increase in income.

Seeds for export. Seed exports depend on seed imports almost in the same way garment exports depend on imports of zippers and cloth. Before reforms, when companies could not freely send seeds and other technology to Turkey, they did not arrange seed production in Turkey for international markets. In other respects — climate, low-cost labor, skills — Turkey is an attractive country for seed production. With 1980s regulatory reforms, Turkey's seed exports have grown dramatically, but from a low base; volume and value are still low.

We have data on volume but not value of seed exports. Table 4.7 reports volume and estimates value of seed exports with some assumptions about seed prices. Annual total value of seed exports grows from zero in the early 1980s to an estimated $12 million in 1992-1993. Compared to other agricultural products and exports, seed exports are a small matter. Assuming, as above, that net income gains are one-third increases in trade, the increase in net incomes due to seed exports may be about $ 4 million.

Table 4.10 Vegetable production and export, 1979-1992

Crop and category	*1979-81*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
Tomato												
production (1,000 tons)	3,550								5,750	6,000	6,200	
fresh export (1,000 tons)	42								78	34	107	
fresh export ($US millions)							30	24	13	13	29	
Tomato concentrate												
production (1,000 tons)				155	150	105	164	198	290	250		
export (1,000 tons)										124	149	
export (see "vegetable exports" below)												
Potato												
fresh export (1,000 tons)							44	48	40	22	219	
fresh export ($US millions)							5	5	6	5	43	
Onions												
production (1,000 tons)	1,071								1,360	1,550	1,700	
fresh export (1,000 tons)							133	164	148	85	202	
fresh export ($US millions)							12	15	17	13	33	
Cucumbers												
production (1,000 tons)	503											
fresh export (1,000 tons)							3	7	12	23		
fresh export ($US millions)							1	4	7		13	
Vegetable exports ($US millions)	ca 100 [a]										379	
of which:												
tomato concentrate										74	89	
canned vegetables									< 50		98	
other vegetable exports [b]	60 [c]	72	65	81	96	126	96	98	89	109	192	163
of which:												
fresh vegetables							65	69	65	55	149	
frozen vegetables							7	15	15	25	26	
dehydrated vegetables							12	12	6	8	13	

a. Estimated.
b. Data from SIS, reported in GATT, 1994.
c. Data for 1981 only.
Sources: FAO and MARA, Turkey Horticulture Subsector Review: Approaches to Market-led Development (Rome: FAO, 1994), tables 7 and 9, and annex 4, p 9 and table 1; and GATT, Trade Policy Review: Republic of Turkey (Geneva: GATT, 1994), vol 1, pp 59-60.

Total costs of seed regulatory reform

An estimate of the costs of seed regulatory reform depends on what changes are considered to be regulatory reforms and what are not. For example, someone might think that regulatory reform entails doing away with phytosanitary restrictions, and then consider losses from diseases introduced through imported seeds to be one of the costs of reform. To avoid confusions, we clarify the definition of regulatory reform.

Defining regulatory reform. Seed regulatory reform focuses government regulatory activities on efforts to control negative externalities, reducing or eliminating other government interferences in seed production or trade. Hence, seed regulatory reform:

- Emphasizes trade and investment liberalization rather than privatization. Ending a public or private monopoly or oligopoly by revising regulations to allow free entry and competition is regulatory reform. On the other hand, privatizing a government seed parastatal is not regulatory reform, though it may be worth doing for other reasons.

- Promotes new channels for introducing new varieties, and does not attack existing government research. Regulatory reforms ask government scientists to pay more attention to their own research, and to spend less time and effort interfering with private company decisions to introduce new varieties.

- Does not address the issue of subsidies. Whether or not to subsidize can be an important question because of impact on government spending. However, in most cases, seed subsidies do not seriously interfere with private company ability to introduce superior varieties.

From this definition of seed regulatory reforms, we consider costs of 1980s regulatory reforms in Turkey.

Externalities from imported pests and diseases. We found no evidence for any increase in losses from imported pests and diseases. As of 1994, many experts argue than Turkey's phytosanitary rules are in some respects unnecessarily strict and suppress seed trade. The manager of a Turkish seed company reported that, notwithstanding phytosanitary controls, customs officials pay more attention to commercial import controls than to seed condition. Arguably, government could improve phytosanitary protection by getting rid of extraneous seed import restrictions (for example, that only seed firms can import) and focusing on realistic phytosanitary concerns.

Farmer losses due to inappropriate varieties. Evidence suggests that 1980s regulatory reforms reducing the government's role in selecting and promoting new varieties have reduced farmer losses from planting inappropriate varieties.

During government crash programs to introduce Mexican wheat in the 1960s and hybrid maize in the 1980s, government agencies decided which varieties of seeds to buy and where to distribute them around the country. The government offered incentives in the form of credit or subsidies to farmers buying government-selected seeds. In both these programs, farmer choice of varieties after several years showed major differences from initial government allocations, which suggests assignment of some inappropriate varieties and possibly some farmer losses (Frizzell 1968; also personal communications from maize seed experts during interviews in 1994).

Currently, with private companies having a larger role in seed trade, markets participate in the selection and expansion of new varieties over several years; the government no longer makes large commitments to new and unproven varieties, and we did not see private companies taking big risks promoting unknown varieties. This makes sense: private companies want to build public confidence in their brand name; any big failure promoting an inappropriate variety would weaken that trust.

Before reforms farmers lost by planting inferior varieties available in Turkey when superior (but illegal) varieties were available in world markets. In some cases, particularly for high value vegetables, farmers smuggled seeds to avoid planting inappropriate (inferior) legal varieties. In this respect also, regulatory reforms have reduced planting of inappropriate varieties, and have also reduced smuggling.

Farmer losses due to poor quality seed. Evidence suggests that seed quality has improved. With regulatory reforms bringing rapid expansion of private seed production and trade, farmers have shifted a significant share of planted area for some crops — notably maize, sunflower, many vegetables — from own-seed to private commercial seed. This shift improves seed quality. Furthermore, reforms have broken crop-by-crop public and private monopolies and oligopolies in commercial seeds; more competitive commercial seed markets favor improvements in quality. Also, Turkey now produces seed for export; improving quality to compete in export markets presumably has a positive impact on quality for domestic seed as well.

Although TIGEM's seed production has fallen by more than 100,000 tons, that is due to other policy decisions, not regulatory reforms. What happens to TIGEM, and what impact that has on wheat seed quality is tangential to costs and benefits of regulatory reform. Indeed, regulatory reforms have brought in 10,000 tons of private wheat seed production, which by itself improves wheat seed quality.

The government continues compulsory seed certification and official tests. However, one anecdote suggests that private companies take care of quality even without government involvement. In 1994, employees in one seed company stole expensive vegetable seed before packaging and replaced it with cheaper seed. Sale of mixed seed threatened the company's reputation. Apprised of its error, the company paid damages to affected farmers. Turkish seed companies maintain quality to protect their brand names.

Impact on domestic seed industries. In some countries, a common argument against regulatory reforms is that seed imports will damage domestic inputs industries. In Turkey, the domestic seed industry not only expanded after reforms but also boosted export sales.

Weakening of Public Sector Research. During the 1980s, MARA cut the budget for General Directorate of Agricultural Research (GDAR), and new private seed companies hired away thirty to forty senior GDAR scientists, including leaders of plant breeding programs. Whether or not 1980s changes in GDAR have been a major loss to the country (experts in Turkey disagree on the issue), changes have arguably been due more to coincidental budget cuts than to regulatory reforms.

Seed cost. Hybrid seeds are much more expensive than non-hybrid seeds; furthermore, farmers must replace hybrid seed every year, whereas they can often keep their own non-hybrid seed. However, returns far exceed seed cost. Also, all-or-nothing adoption patterns suggest that all farmers, poor as well as rich, take advantage of new seed technology. Sugar beet area has shifted almost entirely to hybrids, as has sunflower area. Depending on region of the country, maize area has either shifted or not shifted to hybrids.

Information on seed costs can be misleading. Switching to hybrids, farmers are able to reduce seed rate; for example, the seed rate for hybrid sunflower in Turkey is only 3 kg/ha compared to 20 kg/ha for OPV seeds; even though hybrid sunflower seeds are 5-10 times more expensive, the lower seed rate largely compensates for the price differential. For sugar beet, seed rate has fallen from 30 kg/ha with multigerm (non-hybrid) seed to 3 kg/ha with new monogerm (hybrid) seed.

Net impact of regulatory reforms

Following the train of evidence from seed regulatory reforms through seed trade to crop yield and production, we have estimated annual benefits from reform for selected crops only — maize, vegetables for export, and seeds for export — at about $130 million. Furthermore, the costs of regulatory reform, as discussed above, have been non-existent to insignificant in Turkey. Seed quality has most likely improved, and farmers have more information and choice, so there is less risk they will plant an inappropriate variety. With low to non-existent costs, the estimate of partial benefits (benefits for several crops) can be taken as a lower bound estimate for net benefits.

Aggregate net benefits might be much larger than the above estimate of partial benefits. We have not tried to estimate benefits for all crops; for example, we have ignored the impact of reforms on vegetable production for local markets. Also, benefits increase over time as farmers and seed companies gain experience with new technology and as seed companies increase international contacts and financial capacity. In Turkey, seed regulatory reform has had a positive and significant impact on net income.

Concluding observations and recommendations

Both before and after 1980s reforms, most new technology in Turkey has come from foreign countries. This observation echoes a similar finding by Eduardo Venezian for Chile: "the overall most important innovations in Chilean agriculture post-1960 ... originate mainly abroad" (Venezian 1987, pp 107-108). Hence, reforms did not change the source of new technology, but did change channels and facilitate flow.

Multiplying channels for technology transfer

McMahon encourages developing countries to move from the "national institute model" for agricultural research toward a system with "many research players" and with "upstream, downstream, and horizontal links among institutes, universities, firms, policy-makers, and social groups" (McMahon 1992, p 6). Antholt advocates making room for "institutional pluralism" featuring an enhanced role for the private sector in generating and spreading technology in agriculture (Antholt 1994, p 16).

In Turkey, reforms from the 1980s have favored establishment of multiple channels for agricultural research and technology transfer in the private sector. Before reforms, private individuals broke the law to test foreign varieties with smuggled seeds. Reforms de-criminalized these research activities, encouraging private individuals to scout varieties in other countries, bring seeds back and test them in Turkey, and then introduce new varieties to the market. After reforms, Turkish seed companies have multiplied channels to world technology. For example, one company in 1994 reported formal connections with at least seven international companies and Cornell University as well as $ 50,000 annual expenditures to test new varieties of maize, wheat, and other crops in Turkey.

Turkey not only takes existing technology but also influences and contributes to international research. Most multinational seed companies do their breeding research in one to several countries, limiting research in other countries where they operate to adaptation trials. KWS, for example, breeds sugar beets in Germany but selects lines for Turkey and many other countries. Several Turkish seed companies report sending materials for crossing to the breeding programs of international partners. After reforms, one multinational has established a breeding program in Turkey to develop sunflower varieties resistant to the orobanche parasite, taking advantage of the presence of the parasite. The varieties to be developed are intended not only for Turkey but also for other countries to which the orobanche parasite is expected to spread.

Unfinished Business

Although the seed industry has modernized and established strong international linkages, some current policies continue to limit competition and also limit farmer access to new technology.

Seed import controls block competition. The government limits imports to established seed companies, limits the amount that a company can import based on its record of seed production, and (arguably) enforces some excessive phytosanitary restrictions that do not address realistic pest or disease threat.

While Turkey from the 1980s has allowed multiple new varieties, compulsory variety registration and seed certification have remained in place. Also, Turkey may be back-sliding toward tighter variety controls. Private seed industry sources assert that major companies have no trouble getting their varieties approved, either for production permits or registration. In 1994, company representatives report that the Registration Committee approves about 80 percent of applications for production permits and 95 percent for registration. However, compulsory variety registration may be a more serious barrier to entry for varieties sponsored by newer and smaller seed companies.

Recommendations

Conclusions support the following two recommendations for donors and developing countries:

- Whenever increasing the flow of new varieties and other seed technology to farmers is an objective of a project or program, donors and governments are encouraged *to study regulations to assess the extent to which they discourage or block private sector introduction of new varieties and other seed technology.* These assessments can be attached to agricultural research projects, trade reform studies, inputs projects, etc.

- Depending on the outcome of assessments, donors and governments are encouraged *to promote seed regulatory reforms as opportunities arise.*

Many programs and projects propose to introduce new technology to farmers in developing countries. Often, these programs depend on government research and extension services to breed and disseminate new varieties. While these agencies have a role, they are not the only possible institutions that could have an impact. If governments or donors explicitly want the public sector to monopolize variety introductions, then it makes sense to continue controls that block private channels while trying to strengthen public research. However, when there is no commitment to a public sector monopoly, then it makes little sense to design projects or programs to support government breeding and extension without at the same time considering relatively inexpensive or even costless seed regulatory reforms to un-block private sector channels.

Taking this approach, programs and projects for agricultural research and extension can be re-cast as agricultural technology projects, with components to reform seed regulations that block channels for variety transfer through the private sector. A recent World Bank Agricultural Technology Project for Mexico illustrates this pattern (World Bank 1992).

Notes

1. The Ministry of Agriculture and Rural Affairs (MARA) dates from a reorganization in 1994, which split the Ministry of Agriculture, Forestry and Rural Affairs. For all time periods, this paper uses the acronym MARA to designate the ministry responsible for agriculture, though the name and other duties of that ministry have shifted over time.

2. ICD is a US-based non-profit organization, supported by large multinationals, with a mandate to promote trade and investment to support development.

3. We also looked at impact of irrigation on maize production. Since maize irrigated area is not available, we used percent of total area under irrigation. The coefficient for irrigation was not statistically significant.

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Reforms, Regulations, and Recent Developments in the Seed System in Peru

Joseph E. Cortes

In the late 1980s, the government of Peru, with the support of the United States Agency for International Development, initiated a development project with a seed component in an effort to increase private sector production and distribution of seeds and to establish a non-government quality-control system.

The first two years of the project were dedicated to bringing the public and private sectors together and (a) delineating the basis for a national seed system, (b) training personnel, (c) establishing regional seed associations, and (d) creating "seed awareness" among farmers to promote seed use and to increase demand. A new government in 1991 further emphasized the advantages of private sector participation.

Reforms and results

In terms of policy reforms, there were three key policies in the form of decrees that were instrumental in the development of the private seed industry: (a) the de-activation of two seed production parastatals; (b) the transfer of the parastatal seed infrastructure to farmer associations; and (c) the creation of regional seed committees responsible for assisting the development of private seed enterprises as well as seed certification.

The results in the Peruvian seed system were as follows:

- Growth of the private seed industry from seven to sixty-one enterprises by 1994.
- Grouping of the private sector into associations of private seed enterprises.
- An increase in seed production from 12,000 tons in 1990/91 to 17,500 tons in 1991/92; all seed in the project was produced by private enterprises.
- Inspection and laboratory testing of all seed by regional seed committees (performed at the request of seed companies, even though certification is non-mandatory)
- Financial autonomy was achieved by six of the eight regional seed committees by 1994.
- Regional training courses on seed production and quality control.
- Installation of seed drying and processing facilities in two key areas, managed by regional seed associations and open to any farmer wishing to establish a seed enterprise.
- Provision of on-site technical assistance to new seed entrepreneurs.
- Annual seed meetings among representatives of the government, private seed companies, and regional seed committees to identify constraints and propose solutions.

Recent developments

As of May, 1995, Peru has increased its number of seed enterprises to 178 (see table 4.11). This is primarily due to the incorpora-

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Table 4.11 Number of private seed enterprises in Peru, 1988-95

State/department	*1988*	*1991*	*1995*
Arequipa	—	5	18
Ica	3	5	7
La Libertad	—	6	20
Lima	4	6	8
Lambayeque	2	10	11
Piura	1	6	22
Cusco	1	3	38
San Martin	—	3	9
Andahuaylas	—	—	45
Total	11	44	178

tion of eighty-eight potato seed enterprises in the highlands. Table 4.12 provides information on number of seed enterprises by size as well as total area and crops under certification for the Departments of Apurimac, Arequipa, Cusco, Ica, La Libertad, Lambayeque, Lima, Piura and San Martin in 1995.

Of the 178 existing seed enterprises, 12 percent have production areas ranging from 50 to 1,700 hectares, 33 percent are producing 10 to 50 hectares of seed, and the remaining 56 percent are smallholders with 1-10 has in seed production (table 4.12). As mentioned earlier, small seed producers are mainly located in the highlands and are involved in potato seed production, though some are in the coastal areas producing seed of rice, grain legumes, wheat and maize. The 43 percent of medium and large seed enterprises (by Peruvian standards) are located in the coastal and jungle areas of Peru, which has the larger commercial production areas, and in some cases in the highlands where potato seed producers are grouped into associations.

Of importance is to note that all 9,300 hectares currently under seed production are being inspected, tested and certified by the regional seed committees on a fee basis, although seed certification is not mandatory in Peru.

Sources of improved germplasm and seed

Table 4.13 presents the origin of improved germplasm by cultivar. Cotton, which is a major commodity in Peru, is mainly dependent on local and US germplasm. Rice, another major crop, is originally derived from materials spanning the globe. However, these cultivars are bred by IRRI, regionally tested by Centro Internacional de Agricultura Tropical (CIAT), and introduced by the national research institute.

Corn seed germplasm has different avenues. Transnationals such as Pioneer have a contract agreement with a Peruvian seed company in which Pioneer provides the parental materials and seed is produced and marketed by the Peruvian enterprise. Cargill, in a similar mode, provides their parental material from Brazil and a local company produces and markets their own seed.

The University of La Molina has an active corn breeding program and their materials are provided to a select group of seed producers who produce and market under the auspices of an association. There is also a local seed company with its own breeding program. The corn breeding program of the national research institute is the other source of improved cultivars, which is sold in the form of foundation seed to local seed enterprises. Most of their improved materials emanate from Centro Internacional

Table 4.12 Characteristics of seed enterprises by department, 1995

State/Department	Total number of seed enterprises	Number of seed enterprises with: less than 10 hectares	between 10 and 50 hectares	more than 50 hectares	Kinds of seeds	Total seed area (hectares)
Arequipa	18	11	7	—	mostly rice, some wheat and potato	220
Ica	6	3	1	2	mostly cotton, some beans and maize	2,000
La Libertad	20	5	14	1	rice and potato, with some maize, beans, and wheat	380
Lima	12	6	3	3	mostly cotton, some maize, beans, barley, and wheat	1,600
Lambayeque	11	1	6	4	mostly rice and cotton, some cowpea and maize	660
Piura	22	10	8	4	mostly cotton, some rice, soybean, sunflower, cotton, maize, potato, wheat, grain legumes, and fruit trees	1,900
Cusco	38	30	7	1	mostly potato, some wheat, maize, bean, barley, oat, quinua, peas, and kiwicha	340
San Martin	8	1	5	2	rice and cotton, some maize	240
Andah'ylas	45	33	9	4		1,100
Total	178	98	59	21		

Table 4.13 Source of cultivars in use in Peru

Crop	*Cultivar*	*Origin*	*Area (percent)*
Cotton	Tanguis	Peru	60
	Pima	United States	30
	Del Cerro	United States	5
	Asperos	Peru	5
	Others	Peru	
Rice	Vinflor	Philippines-Vietnam	43
	Inti	China	16
	Linea 14	Philippines	14
	BG 90-2	Philippines	6
	Sican	Peru-Africa	5
	Amazonas	Peru-Philippines	4
	Others		
Maize (hybrid)	Marginal 28	CIMMYT-Mexico	30
	Cargill	Brazil	29
	PM	CIMMYT-Peru	20
	Penta	Cuba	15
	Poey T-66	United States	6
Maize (OPV)	Blanco Uru'ba	Peru	10
	Pardo	Peru	5
	Chancayano	Peru	5
	Puente	Peru	5
	Others	Peru	75
Beans	Canario 2000	CIAT	50
	Centinela	CIAT	30
	Others	CIAT	20
Lima beans	Sol De Ica	Carolina Del Norte	20
	Iqueno Precoz	Carolina Del Norte	20
	G De ICA	Carolina Del Norte	20
	Promesa De Ica	Carolina Del Norte	20
	Senor De Luren	Carolina Del Norte	20
Wheat	La Molina 82	CIMMYT	50
	Bavilan	CIMMYT	40
	Others	?	10
Potato	Tomasa Tito	United States/Peru	10
	Condemayta	Holland-US/Peru	8
	Yungay	Ecuador/US-Peru	2
	Revolucion	Holland/Peru	2
	Mariva	Peru/Holland	1
	Andina	India/Peru-Bolivia	8
	Cica	UK/Colombia	0.5
	Canchan-Inia	Peru	25
	Many others	Peru	

Table 4.14 Volume and value of US seed exports to Peru, 1991-92 to 1993-94

Kind	*1991/92 (volume in kgs)*	*1992/93 (volume in kgs)*	*1993/94 (volume in kgs)*	*1993/94 (value in $1,000)*
Grasses	10,100	—	50,100	51,900
bermudagrass	5,100	—	17,500	12,400
orchardgrass	—	—	12,300	17,700
ryegrass, perennial	5,000	—	4,000	8,100
sorghum-sudan cross	—	—	16,300	13,700
Forages	14,700	60,100	153,300	455,100
alfalfa, certified	4,000	45,800	107,500	330,200
alfalfa, uncertified	10,700	14,300	42,400	118,500
clover, red	—	—	2,300	3,700
other	—	—	1,100	2,700
Leguminous vegetables	613,000	718,900	1,989,300	791,100
bean, gram	—	—	2,000	4,700
bean, kidney	26,500	10,000	—	—
bean, other	—	—	1,800	3,000
chickpea	—	—	16,400	9,900
lentil	—	—	63,300	29,200
pea	566,800	708,900	1,855,100	727,000
other legumes	19,700	—	20,600	17,3000
Vegetables	110,800	123,300	125,000	928,400
beet	5,100	580	—	—
cantaloupe	—	340	1,900	7,200
carrot	6,700	20,800	9,300	77,200
cucumber	32	1,300	540	4,200
lettuce	—	580	120	3,800
onion	1,000	490	2,000	37,500
radish	4,700	—	130	5,500
spinach	24,000	4,600	9,800	49,600
tomato	2,100	2,600	2,400	180,500
watermelon	2,300	6,700	2,900	35,000
other	64,900	85,200	95,900	527,900
Field crop seeds	35,000	54,000	16,100	22,000
corn (except sweet)	25,200	—	—	—
grain sorghum	9,800	54,000	16,100	22,000
Flower seeds	—	110	210	8,700
Sugar beet	7,200	—	1,500	11,900
Other seeds	23,800	5,200	15	7,600
Total	814,000	962,000	2,337,000	2,277,000

Source: Foreign Agricultural Service, USDA (United States Department of Agriculture).

de Mejoramiento de Maiz y Trigo (CIMMYT).

Almost 100 percent of the improved bean seed varieties in Peru have been developed at CIAT, tested by the bean program of the NRI, and released after two years. Parental material of lima beans, however, originate in North Carolina and are made available through the the national research institute to seed producers.

Wheat varieties are also very much dependent on CIMMYT research covering 100 percent of the varieties offered. As for potatoes, their center of origin is Peru, which explains the large number of local varieties. Most of the improved varieties are generated through the International Potato Center (CIP), which works closely with the potato research program of the national reserach institute.

The seed of other crops such as vegetables, grain legumes, grasses and forages is obtained by direct import of bagged seed mostly from the United States. Table 4.14 shows the annual quantities of Peru's seed exports from the United States during 1991/92-1993/94 as well as their dollar value in 1993/94. Although a few of the seed enterprises import some of this seed, most of it is brought in by importers with distributorships in various areas of Peru. It is interesting to note from table 4.14 that in the three years from 1991/92 through 1993/94, Peru's seed imports from the United States have almost tripled.

1990 Seed Policy Reform in Bangladesh: Moving Away from Variety Lists

David Gisselquist

This paper describes 1990 seed policy reforms in Bangladesh. While these reforms are not ideal, features may be recommended for other developing countries where farmers currently have poor access to modern seed technology. Key features of 1990 seed reforms in Bangladesh include:

- government abandoned positive variety lists for most crops, allowing anyone — private companies, NGOs, and public institutions — to sell seeds of new varieties without prior government variety testing and approval; and

- government implemented these reforms through executive decision, acting with authority from existing seed legislation.

Bangladeshi seed policies and trade prior to reform

During the 1970s and early 1980s, Bangladesh's economy had strong socialist features with limited scope for private seed company activity. Government agencies allocated foreign exchange and controlled private investment, whether foreign or domestic. With these controls, the only commercial private seed trade allowed was for vegetable seeds.

By the end of the 1980s, socialist patterns and controls on investment and international trade had given way to markets. However, by the time general economic liberalization had gone far enough to allow private seed companies to operate, the government had already introduced restrictive seed policies that specifically blocked private seed production and trade.

The Seeds Ordinance 1977 gives the executive branch authority to regulate seed import and trade, and provides for a National Seed Board (NSB), chaired by the Secretary of Agriculture, to advise government. The general intent of the act seems to be to allow government to set some seed quality standards, in terms of germination and purity, for seeds of specified crops or varieties (sections 5 and 6, The Seeds Ordinance 1977, *Bangladesh Gazette*, 19 July 1977, p 4):

> If the Government after consultation with the [National Seed] Board is of opinion that is is necessary or expedient to regulate the quality of seed of any kind or variety to be sold and used for the purposes of agriculture, it may, by notification in the official Gazette, specify such kind or variety to be a notified kind or variety for the purposes of this Ordinance...
>
> ... the Government may, by notification in the official Gazette, specify ... the minimum limits of germination and purity with respect to any seed of any notified kind or variety...

Although the Seeds Ordinance seemed to deal with quality issues more than varieties,

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NSB used the authority of the Seeds Ordinance to create lists of allowed varieties for virtually all crops grown in Bangladesh. During a 1985 seed workshop in Bangladesh, the Director of the Seed Certification Agency stated that "It is not legal to import any variety without approval of NSB" (Bangladesh Agricultural Research Council 1985, p 18).

In a pattern that has been common in developing countries, Bangladesh's list of allowed varieties at the end of the 1980s was short and — except for vegetables — limited almost entirely to varieties that had been identified and promoted by government scientists in the Bangladesh Rice Research Institute, the Bangladesh Agricultural Research Institute, and other public institutions in the national agricultural research system (NARS). Many of the approved varieties had been bred and released as lines by international agricultural research centers (IARCs), then subsequently tested for years by NARS scientists before NSB approval allowed their introduction to Bangladeshi farmers.

For rice, the list at the end of the 1980s allowed about twenty improved varieties. However, many of these have been of no interest to farmers, leaving relatively few useful varieties for three rice seasons (early and late monsoon and winter). Government scientists through the years generally ignored farmer interest in short duration varieties; seeds of some short duration varieties have come in illegally from India. Similarly, government scientists did not approve *pajam*, which was for more than a decade the most widely grown improved rice variety in Bangladesh.

For other field crops, the list of varieties allowed was much slimmer than for rice. For example, toward the end of the 1980s, the official list offered only two varieties of soybeans, one of sunflower, and two of maize.

For fruits and vegetables, the government also limited varieties allowed for import. Government controls protected lucrative markets for seeds of some popular varieties (for example, for seedless watermelon). For fruits, government obstructed introduction of new varieties of papayas and bananas, but high farm profits stimulated illegal trade in planting materials; toward the end of the 1980s seed dealers smuggled papaya seed, and banana cuttings of an improved variety from India moved farmer-to-farmer.

Stimulus for seed policy reform: intention to diversify

At the end of the 1980s, Bangladeshi farmers took advantage of liberalized market access to irrigation equipment (primarily low-cost diesel engines from China) to expand irrigated area at record rates. Rapid growth in rice production promised to bring national rice self-sufficiency. Seeing success with rice, planners in the Ministry of Agriculture feared that farmers would suffer weak rice prices and loss of income unless they could be encouraged to diversify into crops other than rice.

The Ministry intended to improve farmer access to inputs for a variety of crops, leaving farmers to choose the particular crops into which they might want to diversify. In other words, the Ministry did not want to choose winners, but rather wanted to offer farmers a menu of options.

One episode in the Ministry's effort to expand farmer crop options illustrates difficulties with in-country breeding and restricted varieties lists. The Secretary of Agriculture chaired a 1989 meeting on a particular minor field crop as one option. At the meeting, an expert from Bangladesh Agricultural Research Institute proposed that his institute could breed improved varieties. At the time, the government of Bangladesh had approved and listed only two varieties for the crop in question. Following a breeding strategy, Bangladesh could look for introduction of new varieties in ten years. However, the crop in question was one of the crops covered by the Asian Vegetable Research and Development Center (AVRDC), which is located in Taiwan, a country with the same latitude as Bangladesh and with comparable climate. Suitable varieties were available from

AVRDC as well as other regional and international sources.

Through these and other exchanges, Ministry officials recognized that relying exclusively on in-country breeding and requiring prior government approval for new varieties obstructed farmer access to suitable varieties already available elsewhere in the world. If Bangladeshi farmers were to gain access to a menu of crop options in the foreseeable future, then variety lists had to go.

Reform: doing away with variety lists for most crops

Anticipating opposition, leading officials in the Ministry of Agriculture did not want to act on an important technical matter without gaining some support from specialists in the Ministry. In 1989, the Ministry established a committee to review and recommend new seed policies. As expected, the main opposition to liberalizing introduction of new varieties came from government scientists in the national agricultural research system, including leaders of the Bangladesh Agricultural Research Council.

In 1990 the committee reported, recommending new seed policies, including relaxing introduction of new varieties to improve farmer access to technology available in world markets. Acting expeditiously to implement the committee's recommendations, the government used authority from existing seed legislation to do away with variety lists for all but five crops. One of the key steps was an intra-Ministerial order to the Plant Protection Wing to write seed import permits according to species, not varieties, for all but five crops.

The government exempted five major crops — rice, wheat, potatoes, sugar cane, and jute — from this reform. The real reason for continuing variety controls for these crops seems to have been that most government scientists dealt with these crops; allowing continuation of variety controls for these crops was designed to buy their agreement to do away with variety controls for other crops. At the time that the new policy was being designed, there were some strained arguments to justify variety controls for major crops such as rice and wheat. Some argued, for example, that for a major crop there was risk that farmer choice of a "wrong" variety could lead to significant regional or national losses; wide adoption of a disease-susceptible variety could lead to collapse of production in some future year. However, these arguments generally do not bear close scrutiny. Experience in Bangladesh with spread of new varieties suggests that farmers and scientists have time to gain experience with a variety before it is widely grown. Also, if scientists want to discourage a particular variety because it is susceptible to disease, the variety can be put on a negative list (which is inherently less restrictive than a positive list). Furthermore, doing away with or relaxing a variety list is likely to lead to more varieties being available and grown, which would cut risk of production collapse.

Subsequent to 1990 seed reforms, many organizations have gotten involved in identifying and introducing new varieties. For example:

- Local seed companies have been testing hybrids of maize, sorghum, and sunflower in collaboration with foreign seed companies.

- The Bangladesh Tobacco Company, subsidiary of a multinational, has been introducing hybrid sunflower in an out-growers program.

- International Development Enterprises, an international NGO, has been assisting local input dealers to introduce new imported hybrids for popular vegetables.

- Grameen Krishi Foundation and Bangladesh Rural Advancement Committee (BRAC), two large local NGOs, have organized farmers to grow hybrid maize on several hundred hectares.

Most important, local seed traders have expanded domestic sales, increased contacts with foreign companies, and strengthened their ability to influence future policies. In recent years, private seed dealers have pressed for relaxing variety controls on potatoes, one of the five crops exempted from 1990 reforms.

Despite liberalizing introduction of new varieties, the government has maintained existing programs for breeding in public research institutes. This makes sense, insofar as it takes time to see how private organizations will respond to new policies. Some adjustment in government research focus may be considered in the future.

Rules governing certification have not been a major element of reform. The government did not require certification before reform, so compulsory certification has not been a problem. Certification is available as a service from the Seed Certification Agency.

BADC, a parastatal, has organized some seed production, mostly through contract growers, but there are also some large BADC seed farms. BADC subsidizes its seed, which upsets private traders dealing with potato seed but so far has not been a major obstacle for other private seed trade. BADC seed has often been of poor quality. More importantly, after 1990 reforms, private seed dealers are able to compete by offering seed of new varieties that farmers would prefer to varieties available from BADC.

Donor involvement in 1990 seed policy reform

The issue of seed policy reform emerged during 1989 discussions between the Asian Development Bank (ADB) and Ministry of Agriculture while ADB was designing a program loan to support the Ministry's ongoing reforms with fertilizer and irrigation. Shortly thereafter, the Ministry of Agriculture asked USAID to provide some technical advice on seeds; USAID arranged for consultants from the Mississippi State Seed Technology Laboratory. While donors contributed some ideas and information, officials in the Ministry of Agriculture drove the reform process through to success in 1990.

In 1990, ADB included key features of seed reforms as conditions in its Foodcrops Development Program Loan (FDPL). ADB asked the government to "Allow the private sector to: (i) import seeds and genetic material (subject to health requirements)..." with a note exempting rice and wheat seeds from this condition (ADB 1990, p 72). In late 1990, ADB reported this condition as accomplished (though variety controls also remained for jute, sugar cane, and potatoes).

The World Bank assisted in negotiating conditions for ADB's FDPL and repeated the key condition concerning seed imports, but with a weakening amendment, in Agricultural Support Services Project (WB 1991, pp 26, 33):

> under the normal quarantine controls, both public and private sectors seed companies would be allowed to freely import all types of crop seeds *for testing* [emphasis added] by June 30, 1992 ...

While the government independently liberalized seed trade in 1990, and ADB confirmed that policy through conditions in a 1990 loan, World Bank conditions dealing with seeds did not oppose government control over varieties allowed for commercial trade. On the other hand, the World Bank asked that companies be allowed improved access to seeds for all crops (for testing), including the five crops for which the government continued to control varieties allowed for commercial seed sale. Another World Bank condition in the same project asked for unspecified changes in seed regulations and laws.

Subsequent to 1990s reforms, several donor-supported projects have had seed policy components that have encouraged private seed companies. Also, from 1993 the World Bank has repeatedly criticized variety-based restrictions for five crops; for example, a 1995 report urges that "to encourage private sector seed development, the Government should eliminate the 'notified' crops distinction for potatoes and jute" (World Bank 1995, p.61).

Bangladesh seed policy reform in international context

With 1990 reforms doing away with variety lists for all but five crops, Bangladesh moves toward patterns common in the United States, India, Chile, and other countries, where private companies are allowed to sell seeds of new varieties without prior government approval based on performance (or VCU [value in cultivation and use]) tests. These governments leave variety performance evaluation to companies and farmers, who communicate their assessments through the market.

Bangladesh's decision to maintain its single-country positive lists for five crops — rice, wheat, potatoes, sugar cane, and jute — continues patterns that have obstructed variety transfer into many developing countries. This pattern of single-country positive lists is superficially similar to patterns in Europe, but there is an important difference. Most European countries maintain positive lists of allowed varieties for many crops, but they are multi-country lists rather than single-country lists. Governments in the European Union accept varieties tested by other governments without any further tests. These varieties are listed in two Common Catalogues, one for field crops and another for vegetables.

The government of Bangladesh did away with single-country positive lists for most crops with simple government orders, acting with authority from existing seed legislation. This same pattern of reform is accessible to most developing countries with single-country positive lists. Also, countries could, by executive order and without any formal international agreements, move to multi-country lists. Bangladesh could, for example, announce that it would automatically accept rice and wheat varieties registered by a list of other governments. Moving toward automatic registration for varieties tested in other countries is more limiting than doing away with positive lists, but it can be far less limiting than a single-country positive list.

Conclusion

If reform options are to be considered in terms of what is best for the farmer, standard economic theory supports policies that give farmers the chance to test and choose varieties, except where externalities are a factor. In other words, governments can leave decisions about variety performance to farmers. Where this is not possible because of opposition from interested quarters, partial reform may be possible, limiting variety lists to a few crops or moving towards multi-country variety lists. When a political compromise is possible, expeditious reform is often legally possible through executive orders by the minister of agriculture, with authority from existing seed legislation.

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Annex 1: Workshop Program

Monday, June 12

9:00 to 9:30 am	*Introduction*: Carl Pray, David Gisselquist, Jitendra Srivastava, and Will Candler
9:30 to 12:00 pm	**Session 1**: Technology Transfer: Conceptual Framework and Special Non-Policy Issues for Agriculture Chair: Jitendra Srivastava Discussant: Brian Fikkert Speakers: Larry Westphal, Phil Pardey, and Don Plucknett
1:00 to 2:45 pm	**Session 2**: International Variety Supply: Public Research Institutions Chair: Derek Byerlee Discussant: Dana Dalrymple Speakers: Mywish Maredia and Doug Gollin
2:45 to 5:30 pm	**Session 3**: International Variety Supply: Private Companies Chair: Mark Condon, ASTA Discussant: Carl Pray Speakers: Bobby Ansaldo, Ray Riley, and Jon Geadelmann

Tuesday, June 13

9:00 to 11:00 am	**Session 4**: Policy Obstacles and Incentives to Variety Transfer: Seed Regulations, etc Chair: David Gisselquist Discussant: Robert Tripp Speakers: Jitendra Srivastava, Jim Elgin, Dennis McGee, and Edward Eggers

11:15 am to 12:30 pm and 1:30 to 3:15 pm	**Session 5**: Country Focus: Seed Policies, Projects, and Experiences Introducing Foreign Varieties through Public Research and Private Companies Chair: Matthew McMahon Discussants: Shiv Singh and Will Candler Speakers: Joe Cortes (Peru), Carl Pray (Turkey), Pramod Agrawal (India), and Venkatachalam Venkatesan (Nigeria and other African countries)
3:30 to 5:30 pm	**Session 6**: Policy Reforms to Increase the Flow of New Varieties to Farmers in Developing Countries Moderator: Douglas Forno Panelists: Frederico Poey, Carl Pray, Robert Tripp, Mark Condon, and Derek Byerlee

Annex 2: List of Participants

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Annex 3: List of Other Papers Presented and Distributed at the Workshop

Basant, Rakesh and Brian Fikkert, "The Effects of R and D, Foreign Technology Purchase, and Domestic and International Spillovers on Productivity in Indian Firms," forthcoming in *The Review of Economics and Statistics.*

Byerlee, Derek, "On the Comparative Advantage of International Agricultural Research: Exploiting Economics of Size to Generate Global Spillovers," paper prepared for workshop on "Integration of Research Efforts of ICRISAT with NARSs and with other International Institutions," ICRISAT, Hyderabad, 14-16 Dec, 1994.

Dalrymple, Dana and Jitendra Srivastava, "Transfer of Plant Cultivars: Seeds, Sectors, and Society."

Evenson, Robert and Larry Westphal. "Technological Change and Technology Strategy," forthcoming chapter in T N Srinivasan and Jere Behrman, eds, *Handbook of Development Economics*, North-Holland Publishing Co.

Fikkert, Brian, "An Open or Closed Technology Policy: The Effects of Technology Licenses, Foreign Direct Investments, and Domestic and International Spillovers on R and D in Indian Firms," unpublished paper.

Fikkert, Brian. "Reforming India's Technology Policies: The Impacts of Liberalization on Self-Reliance and Welfare," unpublished draft.

Jaffee, Steven and Jitendra Srivastava, "Seed System Development: The Appropriate Roles of the Private and Public Sectors," World Bank Discussion Paper 167.

Wood, Stanley and Phillip Pardey, "Agroecological Dimensions of Evaluating and Prioritizing from a Regional Perspective: Latin America and the Caribbean," discussion paper, ISNAR.

Wood and Pardey, "Methods for and Limitations of Ecoregional Analysis," paper prepared for "IFPRI Ecoregional/2020 Vision Workshop," 7-9 November 1994, Airlie House Conference Center, Virginia.

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