Private-Sector Agricultural Research and Innovation in Bangladesh

Overview, Impact, and Policy Options

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Acronyms

ASTI	Agricultural Science and Technology Indicators
BADC	Bangladesh Agricultural Development Corporation
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
DAE	Department of Agricultural Extension
FTE	full-time equivalent
GDP	gross domestic product
HIES	Household Income and Expenditure Survey
HYV	high-yielding variety
IFPRI	International Food Policy Research Institute
IPM	integrated pest management
IRRI	International Rice Research Institute
NGO	nongovernmental organization
PPP	purchasing power parity
USAID	United States Agency for International Development

Abstract

Beginning from the late-1980s, liberalizing reforms established the framework for private companies and nongovernment organizations (NGOs) to introduce agricultural technology. Subsequently, privately introduced technology has supported the rapid expansion of poultry production, allowed off-season vegetable production, multiplied maize yields, extended hybrid rice to 6 percent of the area planted to rice, and accelerated the expansion of total irrigated area. Calculated farm-level benefits from selected private technologies totaled more than US$700 million in 2009/10. Fifty-one surveyed agribusinesses—comprising 47 locally owned companies, 2 subsidiaries of foreign companies, and 2 NGOs—reported that most of their technology came from foreign sources. Private agri-businesses also developed technology through in-country research. Extrapolating from the survey, private agricultural research in 2008 engaged more than 200 researchers with an aggregate budget of US$20 million. For example, competing companies not only assess imported cultivars, but also breed vegetables, maize, and hybrid rice in Bangladesh for local and, in some cases, regional markets. Government and donors not only support public-sector agricultural research, but also extend assistance to private research and technology introduction. Some policy obstacles remain, including regulatory obstacles to private introduction of rice, wheat, potato, and jute cultivars.

INTRODUCTION

"[E]radicating poverty in Bangladesh in the current generation is no longer a dream"
Asian Development Bank 2006, 16

Agricultural growth is crucial to reducing poverty in Bangladesh. Policies and programs that facilitate all public and private channels for the introduction of technology support agricultural growth and reduce poverty. The introduction of agricultural technology by private companies is increasingly important for agricultural development across Asia and Africa; however, most attention continues to focus on public in-country research. Consequently, little is known about private introduction of agricultural technology, including especially imported technology.

Bangladesh is an interesting case because of its specific history of pro-market policies and programs for agricultural innovation. During 1988–91, the Government of Bangladesh removed regulations blocking private imports of diesel engines for irrigation and limiting private introduction of new cultivars for all but five major crops. Subsequently, the United States Agency for International Development (USAID) supported private agricultural innovation through the Agro-based Industries and Technology Development Projects I and II during 1996–2005. Since 2008, the World Bank, through the National Agricultural Technology Project, has supported the Krishi Gobeshona Foundation to fund private and public agricultural research. If companies and farmers in Bangladesh can respond to policies and programs promoting private technology introduction in agriculture, similar policies may be considered for other poor countries.

The purpose of this report is to describe private agricultural innovation and research; to assess the impact of private technology on agricultural production, poverty, and the environment; and to identify government policies and programs that effect private technology introduction. The underlying study was based on a survey of private organizations, interviews, and other documents and studies.

Box 1. Overview of Methodology

The survey focused on private companies and several nongovernmental organizations (NGOs) involved in all aspects of agricultural production or processing, including input supply; large-scale crop, fish, and livestock production; and processing. The organizations surveyed were selected on the basis of the study team's prior knowledge, and advice from industry associations and experts (Table 1). Many larger organizations were purposively included in the knowledge or expectation that they were active in innovation and research and development (R&D). From June to October 2009, the team surveyed 51 organizations, including 49 companies and 2 NGOs. All were locally owned with the exception of 2 pesticide companies that were subsidiaries of multinationals headquartered in Sri Lanka and Switzerland. No company had foreign subsidiaries, but one NGO had offices and projects in multiple African and Asian countries. Organizations reported medians of 40 employees (ranging from 3 to 50,000) and US$390,000 in yearly sales (ranging from US$6,000 to US$435 million).

Table 1. Number of organizations surveyed by type of organization and activity

Activity	Private organizations for which the specified activity is their main activity						Total number of organizations with this as a major or minor activity
					Organization size[a]		
	Total	Locally owned companies	Foreign-owned companies	NGOs	Median sales US$1,000s (range)	Median employees (range)	
Total	51	47	2	2	390 (6–435,000)	40 (3–50,000)	–
Input supply, of which	29	26	2	1			–
Seed	13	12	0	1	950 (220–28,000)	50 (5–50,000)	18
Fertilizer	2	2	0	0	75 (6–144)	28 (15–40)	10
Pesticide	6	4	2	0	3,600 (3,600–20,000)	130 (7–200)	8
Machinery	4	4	0	0	100 (51–170)	19 (5–35)	7
Livestock, fisheries inputs	4	4	0	0	15,000 (42–68,000)	183 (14–1,200)	12
Large-scale production, of which	12	11	0	1			–
Crop-based	7	7	0	0	130 (7–440)	12 (3–40)	11
Livestock-based	3	3	0	0	94 (30–390)	77 (50–90)	6
Fishery-based	2	1	0	1	95 (29–160)	26 (16–35	3
Processing, of which	10	10	0	0			–
Crop-based	7	7	0	0	1,450 (43–435,000)	200 (13–10,000)	8
Livestock-based	2	2	0	0	1,500 (290–2,600)	170 (40–300)	3
Fishery-based	1	1	0	0	13,000	91	1

Source: Compiled by authors from survey data.
Note: NGOs indicates nongovernmental organizations.
[a]For large organizations, these data apply to one or more agricultural divisions only.

STUDY FINDINGS: PRIVATE TECHNOLOGY INTRODUCTION

Companies innovate to provide what customers want, to differentiate their products from other companies' products, and to improve their own production efficiency. Private organizations of all sizes reported the introduction of innovations. From the questionnaire and secondary sources, all but one of the organizations in the sample introduced new products or processes in the past five years (Table 2).

Table 2. Examples of new products or processes introduced during 2004–09

Product type	Examples of innovations
Inputs	
Seed	Cultivars for potatoes, hybrid rice, hybrid maize, vegetables, and other crops
Fertilizer	Biofertilizer from coconut dust, earthworm compost, and green manure
Pesticide	Pheromones, parasitoids, and phostoxin
Machinery	Corn shellers, rippers, threshers, straw-bundle cutting machines, and seeders
Livestock, fisheries inputs	Artificial insemination, fishmeal, and poultry feed
Large-scale production	
Crop-based	Cultivars for gladiolas, strawberries, longum, grapes, guava, jujube, and durian
Livestock-based	Shahiwal and Friesian cows and Sonali poultry
Fishery-based	Fish species and duckweed feeding protocols
Processing	
Crop-based	Rubber rollers, color sorters, and graders for rice processing; and solvent extraction for oil seeds and rice bran
Livestock-based	Beef products, flavored milk, and ultrahigh-temperature processed milk
Fishery-based	Individually quick frozen shrimp

Source: Compiled by authors from survey data.

For some regulated items, such as seed, pesticide, fertilizer, and veterinary pharmaceuticals, regulatory agencies maintain records of the technologies allowed. Such lists can show the pace of technology introduction. According to Bangladesh Seed Policy (GOB 1993), the government must recognize (that is, register) all cultivars before seed sale is allowed. For five (notified) crops—rice, wheat, potatoes, jute, and sugarcane—the government asks companies for fees, takes time to test cultivars for performance, and then decides whether or not to allow each cultivar. For other crops, registration is automatic and immediate, and is often avoided, so there is no complete list of available cultivars.During 2000–10, the government registered 76 rice hybrids submitted by a total of 23 private companies and NGOs, and 5 rice hybrids submitted by government agencies (the Bangladesh Rice Research Institute [BRRI] and the Bangladesh Agricultural Development Corporation [BADC]) (Table 3). On the other hand, government agencies submitted all 13 rice varieties (that is, nonhybrid high-yielding varieties [HYVs]) registered during 2000–10.

For potatoes, private companies submitted many imported varieties for review; the Bangladesh Agricultural Research Institute (BARI) tested these varieties at its own expense, then submitted those it liked for registration in BARI's name. For the other threenotified crops—wheat, jute, and sugarcane—public agencies submitted all varieties registered during 2000–10.

Table 3. Number of cultivars registered for notified crops, 2000–10

Species, type of seed	Cultivars submitted by private companies or NGOs	Cultivars submitted by public agencies	Total
Rice			
Hybrid	76[a]	5	81
Variety	0	13	13
Jute	0	3	3[b]
Potatoes	0	11	11[b]
Sugarcane	0	8	8[b]
Wheat	0	6	6

Sources: Seed Certification Agency 2007; Harun-Ar-Rashid, Julfiquar, and Ali 2011; DAE, BARI, and CIMMYT 2011; unpublished documents, BRRI; and personal communication, Wheat Research Center.
[a]74 from a total of 33 companies and 2 from an NGO.
[b]Data are for 2000–08 only.

For all nonnotified crops, such as maize and vegetables, private companies have introduced hundreds of cultivars, but there is no centralized record of what has been introduced. For example, the Seed Certification Agency registered 52 maize cultivars during 2000–08, of which private organizations submitted 44 (DAE, BARI, and CIMMYT 2011); however, a nonsystematic survey of seed stores throughout Bangladesh in 2008–09 found 70 maize hybrids (this was likely an undercount), of which 20 accounted for most sales. Most private maize hybrids come from companies in China, India, and Thailand, as well as other regional countries, with only 1–2 from local breeding. Most of the worlds' seed multinationals get cultivars into Bangladesh through locally owned collaborating companies; Syngenta is the only foreign seed company that sells seed through a subsidiary (Table 1 lists Syngenta's subsidiary in Bangladesh as a pesticide company).

As of 2008, the Plant Protection Wing of the Department of Agricultural Extension reported registrations for 123 active ingredients (such as glyphosate) or combinations of active ingredients, and 1,163 products—that is, specific brand name presentations of active ingredients (Plant Protection Wing 2008). Private companies hold all registrations; however, because the records don't show when each product was registered, they don't show the recent pace of private innovation.

The Source of PrivatelyIntroduced Technologies

Companies want innovation at the least possible cost. If a suitable technology is available, testing and adapting it as necessary is generally less costly and less risky than developing something from scratch. Among organizations that reported innovations, a large majority imported at least some of the technology (Table 4). Two subsidiaries imported technology from parent companies, while most imported from other foreign sources.

Companies have been able to introduce a lot of technology from foreign sources with little or no modification. For example, for broad spectrum poison pesticides, experts can make good guesses about what will work in Bangladesh so that adaptive research may be limited to official trials. To introduce rice processing technology, one prospective mill owner visited China, and eventually imported equipment from there. Private companies produce rice and wheat threshers based on models from BARI and BRRI, which in turn are based on imported models. In a recent survey of Bangladesh's seed companies for the International Finance Corporation, most companies reported collaboration with seed companies in one to nine countries, primarily Asian and European countries (Kabir and Huda 2009). Companies introduce new varieties from imported seed; for that matter, farmers do so as well, adopting varieties from India through smuggled seed.

Two seed companies reported innovations developed in-country by another organization (Table 4). Both innovations were rice varieties from BRRI, which were new to the companies, but not to Bangladeshi farmers.

Table 4. Numbers of private organizations by source of introduced technology

Organizations' main activity	Number of organizations reporting innovations	Source of innovations[a]			
		Developed in Bangladesh		Imported from	
		Own R&D	Other R&D	Parent company	Other source
Inputs					
Seed	13	5	2		9
Fertilizer	6	1			5
Pesticide	6			2	4
Machinery	5	3			2
Livestock, fishery inputs	4	3			1
Large-scale production					
Crop-based	9	3	1		6
Livestock-based	3				3
Fishery-based	2	1			1
Processing					
Crop-based	6	5			2
Livestock-based	3	1			2
Fishery-based	1				1

Source: Compiled by authors from survey data.

[a]Indicates the number of organizations reporting innovations from each source; organizations may report more than one source.

Private R&D

To determine private R&D efforts, organizations were asked about their research staff—in terms of numbers, education, and gender—and their R&D budgets. All 13 seed organizations and 11 of the other 38 organizations reported employing research staff. In 2008, the combined number of professional research staff (researchers, research technicians, and administrators) totaled 1,101 individuals, including 19 with PhDs, 74 with MScs, and 242 with BScs. These numbers include 9 women with MScs and 25 with BScs (Table 5).

In 2008, the seed industry accounted for 86 percent of all professional research staff and 89 percent of all research staff with PhDs, MScs, or BScs. The median proportion of time that seed research staff (researchers, technicians, and administrators) spent on research was 30 percent; other duties likely included seed production, which is technically demanding for hybrid rice, maize, and vegetables and also for tissue culture potatoes. Aside from the seed industry, five pesticide companies and one organization that processes livestock products accounted for most of the remaining research staff.

Some of the larger private seed research programs not only assessed imported cultivars, but also bred new hybrids and varieties from both imported and local genetic material. The Bangladesh Rural Advancement Committee (BRAC), Lal Teer, and Supreme Seeds have the largest programs (Kabir and Huda, 2009). BRAC has developed a popular maize hybrid from imported lines. BRAC, Lal Teer, and other companies breed vegetables including bottle, snake, sweet, and bitter gourds from both imported and local genetic materials; notably, Bangladesh and Assam are the centers of origin for bottle gourd. BRAC and at least one private company breed hybrid rice, using materials from the International Rice Research Institute (IRRI) and BRRI.

The reported R&D budgets across all 24 organizations totaled a combined US$10.8 million in 2008. Of this total, the seed industry accounted for US$9.7 million or 90 percent; the largest R&D budget among seed organizations was US$3.0 million. Pesticide companies reported a total of US$0.9 million for R&D; the largest reported budget was US$0.6 million.

Table 5. Researchers, research technicians, support staff, and R&D budgets, 2008

		Research and research support staff										
		Researchers by qualification (number of women)			Research technicians by qualification (number of women)			Support staff		Total professional staff[a] per organization		
Product type	Organizations reporting researchers	PhD	MSc	BSc	MSc	BSc	Diploma or other	Administrators	Other	Median (range)	Percentage of time spent on research, median (range)	Total R&D budget in US$1,000s (range)
Inputs												
Seed[b]	13	16	48 (6)	27 (2)	2	204 (17)	558	92	379	19 (5–689)	30 (19–95)	9,700 (16–3,000)
Pesticide	5	3	11	2	–	–	16	20	162	10 (6–19)	20 (19–85)	920 (7.2–590)
Machinery	1	–	–	1	–	–	7	1	3	9	NR	NR
Livestock, fishery inputs	1	–	1	–	–	–	2	2	5	12	NR	NR
Large-scale production												
Crop	2	–	–	2	1	1	6	2	2	6 (4–8)	49 (18–80)	40 (3.6–36)
Fishery	1	–	4 (1)	2 (1)	–	–	5	2	–	13	80	43
Processing												
Livestock[b]	1	–	2 (1)	–	5 (1)	3 (2)	11	42	3	62	NR	63
Total	23	19	66 (8)	34 (3)	8 (1)	208 (19)	605	161	554	–	–	10,800

Source: Compiled by authors from survey data.
Notes: Organizations reporting one or more researchers are considered to have R&D programs; this excludes organizations reporting research technicians but no researchers. NR indicates that data are not reported to protect firms' confidential information.
[a]Includes researchers, research technicians, and supporting administrators.
[b]One organization reported researchers in both seed and livestock processing.

Private agricultural R&D in Bangladesh has expanded rapidly in recent years. Much of this expansion occurred in the seed industry (Table 6), and featured existing large private companies diversifying into seeds. Among the 51

organizations in the sample, the number reporting that they employed one or more researchers (excluding research technicians) increased from 12 in 2001 to 23 in 2008 (including one organization with research in both seeds and livestock product processing). Over the same period, the numbers of researchers employed increased by 12 percent per year; in 13 seed organizations, the number of researchers employed increased by 15 percent per year.

Table 6. Researcher (and organization) numbers by subsector, 2001–08

Subsector	2001	2002	2003	2004	2005	2006	2007	2008
Inputs								
Seed[a]	33 (6)	36 (7)	37 (7)	38 (7)	43 (7)	50 (9)	66 (11)	91 (13)
Pesticide	7 (2)	7 (2)	7 (2)	7 (2)	9 (3)	10 (3)	10 (3)	16 (5)
Machinery	–	–	–	–	–	–	–	1 (1)
Livestock, fishery inputs	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
Farm products/plantations								
Crop	4 (2)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	2 (2)	2 (2)
Fishery	8 (1)	8 (1)	8 (1)	8 (1)	8 (1)	8 (1)	6 (1)	6 (1)
Processing								
Livestock[a]	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	2 (1)
Total	54 (12)	54 (13)	55 (13)	56 (13)	63 (14)	71 (16)	86 (19)	119 (23)

Source: Compiled by authors from survey data.
Note: Figures in parentheses indicate the number of organizations reporting one or more researchers.
[b] One organization reported researchers in both seeds and livestock processing.

Comparing information on innovations with information on R&D budgets and research staff provides some insights into innovation processes. Many organizations that reported innovations did not report any R&D expenditures or employing any researchers or any technical staff with advanced or even BSc degrees. This suggests that many companies rely heavily on staff with practical, hands-on knowledge to evaluate, master, and adapt new and imported technologies.

Although the study team tried to survey companies with innovations and R&D, the survey sample missed one major seed company as well as large companies with tea estates, jute processing, shrimp exporting, and food processing. The survey team estimated that, as of 2008, the total number of private agricultural researchers and the total private R&D budgets in Bangladesh were about double the combined totals reported by organizations surveyed—that is, about 230 researchers and US$20 million. With some caveats, survey-based estimates of the private research effort can be compared with the latest data on public agricultural research. In 2009, 31public organizations (21 research institutes and 10 universities) invested a total of 120 million 2005 purchasing power parity (PPP) dollars in agricultural research and employed 2,067 full-time equivalent(FTE) researchers (Rahia et al. 2011). The estimated US$20million that private organizations spent on research in 2008 is equivalent to 50 million 2005 PPP dollars. These data on public and private research staff and budgets are not strictly comparable. Public research staff and budgets are adjusted to exclude time and money spent on nonresearch activities; the detailed information that would be required to make similar adjustmentscould not be collected from private companies. From 2002 to 2009, public agricultural research expanded, but not nearly as fast as private research.

STUDY FINDINGS: THE IMPACT OF PRIVATE INNOVATION

From 1990 through 2009, real growth in gross domestic product (GDP) averaged more than 5 percent per year, with somewhat higher growth after 2000. Over this period, yearlypopulation growth slowed from 2 percent to 1.3 percent, so that real GDPgrowth per capita increased from roughly 3 percent to 5 percent per year (ADB 2009a; BBS 2009a). According

to Household Income and Expenditure Surveys (HIES), the percentage of the population that is poor fell 1 percent per year during the 1990s, and 1.8 percent per year from 2000 to 2005. During 2000–05, the percentage of the rural population in poverty, according to low (high) measures of poverty, fell from 37.9 percent (52.3 percent) in 2000 to 28.6 percent (43.8 percent) in 2005 (ADB 2004, 2006).

The overall impact of private agricultural technology on agricultural growth and poverty reduction is difficult to measure because of the ubiquity of private technology, as well as the many other factors affecting agricultural and economic growth. However, for some specific categories of agricultural technology, the impact of private technology introduction can be estimated from available data.

The Estimated Impact of Selected Private Technologies

Minor Irrigation

In December 1988, the Government of Bangladesh cut import duties on small diesel engines from 50to 0 percent, and removed a ban on non-aid-funded import of engines for irrigation (Ahmed 1995). Removing duties and allowing farmers to choose engines led to an immediate shift to low-cost engines from China and to more options in the market, including smaller engines. During 1976–88, irrigated area expanded an average of 108,000 hectares per year; after reforms allowed private traders to introduce engines according to farmers' demand, average annual expansion of irrigated area increased to 167,000 hectares during 1988–2007, or by an additional 58,000 hectares per year (Hossain 2009). Additional net income from private choice of irrigation equipment can be estimated as additional irrigated area multiplied by land rent for irrigated crops (roughly equivalent to the value of 1 ton per hectareof clean rice). In 2010, additional irrigated area reached 1.3 million hectares (58,000 hectares x 22 years from 1988 to 2010), yielding additional net income of US$534 million (Table 7).

Table 7. Estimated returns to selected technologies introduced through the private sector

Technology	1999–2000	2003–04	2006–07	2009–10
Private irrigation				
Additional hectares of irrigated area due to private choice of engine (calculated as 58,000 hectares per year from 1988 to 2007)	696,000 ha	928,000 ha	1,102,000 ha	1,276,000 ha
Additional net income per hectareof irrigated area	US$173/ha	US$225/ha	US$307/ha	US$442/ha
Additional net income from private choice of engines (estimated as the value of one ton of clean rice per hectare; see text)	US$120 million Tk 8.3 billion	US$209 million Tk 14 billion	US$338 million Tk 23 billion	US$534 million Tk 37 billion
Power tillers				No estimate
Hybrid rice				
Area planted (hectares)	27,000	50,000	394,000	670,000
Additional national rice production (estimating an additional yield of clean rice of 0.67 tons per hectare)	18,000 tons	33,000 tons	260,000 tons	450,000 tons
Reduced expenditure on rice imports	US$3 million	US$7 million	US$81 million	US$200 million
Maize				
Yield (tons per hectare)	3.6	5.8	5.7	6.8
Income advantage for maize vs. wheat in US$ per hectare (kilograms of maize per hectare x maize price) – (kilograms of wheat per hectare x wheat price)	US$102	US$362	US$504	US$621
Maize area (hectares)	33,000	81,000	220,000	202,000
Additional net income from private maize hybrids	US$3 million Tk 0.2 billion	US$29 million Tk 2.0 billion	US$111 million Tk 7.7 billion	US$125 million Tk 8.6 billion
Nonhybrid rice varieties				
Area planted to varieties informally introduced from India (hectares)				1,350,000
Additional net income from private varieties (estimated at US$44 per hectare; see text)				US$59 mill Tk 4.1 billion
Jute				No estimate
Vegetables and poultry				No estimate
Total additional net farm income from selected private technologies (excluding foreign exchange savings due to higher yields with hybrid rice)				US$718 million Tk51 billion
Yields and prices used in the above estimates				
Wheat yields, tons per hectare	2.2	2.0	1.8	2.8
Rice price, Thai 25 percent brokens, US$ per ton	173	225	307	442
Maize price, US$ per ton	89	112	164	186
Wheat price, US soft red winter, US$ per ton	99	144	239	230

Source: Rice and maize prices are from World Bank 2010; hybrid rice area and 0.67 tons per hectare yield advantage over varieties are from Harun-Ar-Rashid, Julfiquar, and Ali 2011; maize yields and area are from DAE, Krishi Diary for various years; wheat yields are from DAE (unpublished).
Note: Tk indicates Bangladesh taka.

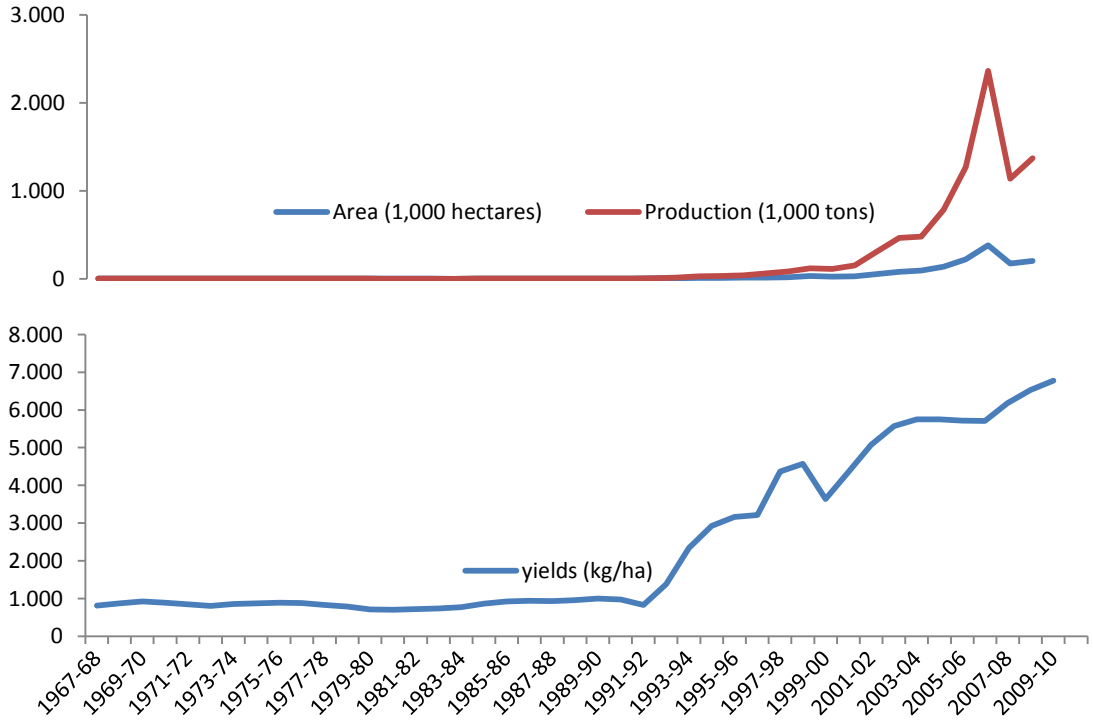
Power Tillers

During 1988 power tillers were so rare that one could spend weeks traveling around the country without seeing one. Cutting import duties on power tillers in late-1988 ledto power tillers almost completely replacing oxen for land preparation in the subsequent 15 years.

Maize

Shortly after the Government of Bangladesh removed controls on the introduction of new cultivars for all but five crops (GOB 1993), private companies and NGOs began to introduce maize hybrids from Thailand and other countries, later supplemented with some in-country breeding. With private hybrids, maize yields increased from an average of less than 1 ton per hectare for several decades through 1992 to more than 6 tons per hectare in 2010 (Figure 1). Maize yields in Bangladesh exceed yields in China and Japan (Bodker, Wulff, and Thorp 2006). The increase in net income from private hybrids can be estimated by assuming that farmers replace wheat with maize. With this assumption, farmers planting maize on 202,000 hectares in 2010 realized an estimated US$125 million in additional net income.

Figure 1. Maize area, production, and yield, 1967/8 to2009/10



Source: Data for 2003–10 are from DAE (2003 through 2011); data for 2001/02 and 2002/03 are estimated; all other data are from DAE, BARI, and CIMMYT 2003.

Hybrid Rice

Although rice is a notified crop, private companies and NGOs have been able to get rice hybrid seed into the market by going through the government's procedures to test and register each cultivar. In 2009/10, farmers planted private hybrids on 670,000 hectares (6 percent of rice area), while the area under public hybrids was minimal. Estimating a yield increase of 1 ton per hectare of paddy (equivalent to 667 kilograms per hectare of clean rice), private hybrids contributed an additional 450,000 tons to Bangladesh's annual rice production, saving the country an estimated US$200 million in rice imports in 2010. Because farm-gate prices for hybrid paddy are less than for nonhybrid paddy, farmers realized only a small portion of this national gain as increased net farm income.

Nonhybrid Rice Varieties

Bangladeshi farmers have adopted rice HYVs from India, even though the Government of Bangladesh has not approved them. To grow these varieties, farmers plant seed smuggled from India or grown and informally traded in Bangladesh. In

2010, Indian rice varieties covered 12 percent of planted rice area (Table 9). Farmers plant Indian varieties in all seasons, but especially in the late rainy season, when the short field duration of many Indian varieties gives farmers more options for the subsequent dry season crop. Estimating that the advantage farmers realize with Indian varieties is equivalent to one-tenth of the rental value of irrigated land in the dry season (circa 1 ton per hectare of clean rice, or US$442 per hectare in 2010), the additional net income from Indian rice varieties introduced through the informal private sector was US$59 million in 2010.

Jute

Farmers and informal traders introduced jute cultivars from India, which are now widely grown in Bangladesh. Because the government has not registered any jute cultivars from India, seed companies have not been able to incorporate production and trade in such seeds into their normal business. In recent years, the Ministry of Agriculture has issued yearly permissions allowing specific companies to import Indian jute seeds on a year-by-year basis.

Vegetables and Poultry

Increases in GDP per capita (see above) boost demand for high-value foods. The Bangladesh Bureau of Statistics (BBS) reports large increases in per capita consumption of animal protein, fruits, and vegetables from 1998/99 to 2004/05 (Table 8). According to the 2005 HIES (BBS 2007), middle-income people in rural areas spent 17 percentof their incomes on fish, meat, milk, fruits, and vegetables compared with 25 percent on rice. Private organizations introduce most technology—poultry breeds and feeds, vegetable cultivars—for high-value foods. As of 2001, poultry provided an estimated 78 percentof the meat produced in Bangladesh (Quasem 2003).

Table 8. Per capita yearly consumption of selected agricultural products, 1998–2005

Product	1998–99	1999–2000	2000–01	2001–02	2002–03	2003–04	2004–05	Yearly growth for the period (%)
Meat, kilograms	5.1	5.2	5.3	6.6	6.9	7.4	8.5	9
Eggs, number	31	32	34	34	52	59	59	11
Milk and milk products, liters	3.2	3.5	7.2	7.0	6.9	6.7	7.9	16
Fish, kilograms	12.3	13.3	14.4	14.5	14.3	15.5	16.3	5
Brinjal, kilograms	3.1	2.9	2.8	2.8	2.6	2.5	2.4	<0
Most other vegetables, kilograms	24.9	26.0	27.9	26.1	28.1	31.8	38.8	8
Bananas, kilograms	4.0	4.1	4.4	4.7	4.5	5.0	6.1	7
Most other fruits, kilograms	2.3	2.0	2.3	2.4	2.4	4.1	6.4	19

Sources: BBS 2006, 2009b.

Evidence of Forgone Gains from Limiting the Introduction of Technology

Bangladesh's lagging rice and wheat yields over the past 20 years contrast with maize yields over the same period. From 1990, yearly population growth averaged only 1.5 percent, while consecutive HIES (BBS 2007) report modest declines in rice consumption per capita. Even so, rice imports increased from 25,000 tons per year during 1991/92 to 1993/94 (when some was also smuggled out to India) to 810,000 tons per year for the 5.25 years from 2005/06 through September 30, 2010 (Directorate General of Food 2011). These data on rice consumption and imports suggest that rice production has grown less than 1.5 percent per year despite massive expansion in irrigated area.

Slow growth in rice production can be explained by slow turnover and incomplete farmer adoption of HYVs. Public nonhybrid rice varieties registered during 2000–10 covered only 3 percent of rice cropped area in 2009/10. Private

ricehybrids introduced during 2000–10 covered another 6 percent of rice planted area. Unregistered (illegal) varieties from India covered 12 percent of rice area. Lagging yield increases, as well as continuing farmer reliance on old, local, and illegal varieties, suggest large foregone gains due to the government's discouragement of privately introduced rice varieties.

Table 9. Planted rice area under government varieties, private hybrids, informal private varieties, and local varieties, 2009/10

	Percentage of paddy area in 2009/10			
Type of cultivar, source, name of cultivar, and year released	**Late rainy season (*aman*)**	**Dry season (*boro*)**	**Early rainy season (*aus*)**	**Three seasons**
Area planted to cultivars registered 2000-10	6	16	1	9
Bangladesh Rice Research Institute (nonhybrid) varieties, BR40-BR52	5	2	0	3
Private hybrids	1	14	1	6
Area planted to old registered cultivars	38	67	41	50
Bangladesh Rice Research Institute high-yielding varieties released 1985–99, BR17-BR39	13	60	26	34
Bangladesh Rice Research Institute high-yielding varieties released 1970–84, BR1-BR16	25	7	14	16
Area planted to unregistered cultivars	57	17	59	40
Indian varieties (new and old cultivars)	18	5	7	12
Other foreign varieties (old cultivars)	1	8	17	5
Local varieties, aromatic and non-aromatic	38	4	35	24
Total	100	100	100	100

Sources: Data on rice cropped area in 2009/10 are from BBS 2010. Data on shares of rice cropped area planted to various cultivars by season are from BRRI, Agricultural Economics Division.
Note: Aggregate shares are calculated for 5.7 million hectares for *aman,* 4.7 million hectares for *boro,* and 1.0 million hectares for *aus*.

Wheat presents another example of low yields with too few new cultivars. With public research providing all cultivars, wheat yields increased to an average of only 2.1 tons per hectare during 1995/96 to 1998/99. After 1999, wheat production fell due to falling yields, due in turn to susceptibility of available cultivars to rust. Yields bottomed out at 1.53 tons per hectare in 2005/06. The introduction of several resistant cultivars allowed wheat yields to rebound to a historic high of 2.8 tons per hectare in 2009/10. Even such yields are low considering that most wheat is irrigated. The number of available cultivars (only six registered during 2000–10; see Table 3) remains too low for the range in agroclimatic conditions where wheat is grown in Bangladesh, and too low to protect wheat production from future disease threats. Because India's wheat-growing areas are far from the border, farmers have not borrowed-in wheat cultivars from India.

No one can know what would have happened if the Government of Bangladesh had allowed private seed companies to introduce rice and wheat varieties as easily as maize hybrids. Companies cannot realize profit margins from varieties as high as from hybrids, but private companies do sell seeds of BRRI rice varieties; at least one company tried to sell seeds of Indian varieties but was stopped by the Seed Certification Agency. It is likelythat some companies would have tried to find Indian or other foreign-bred varieties to multiply for sale. In discouraging such initiatives by tests, fees, and uncertain approvals, regulators inflicted losses in the form of foregone gains on Bangladeshi farmers and consumers.

The Environment

Private technology contributed to agricultural growth, which brings with it a variety of concerns about environmental and public health. For example, the cultivation of saltwater shrimp in coastal regions conflicts with crop production. The tradeoff between gains and costs for specific technologies and ecologies is subject to continuing debate. A comprehensive review of these issues is beyond the scope of this report, and would in any case be controversial. However, something more

can be said about pesticides. From 1989, the government removed limits on allowed volumes of registered pesticides that each company could import. This led to more competition among companies and better service to farmers, but it also led to more pesticide use. Pesticide consumption increased at an average yearly rate of 11 percent, from 4,800 tons in 1989 to 25,500 tons in 2005—about 3 kilograms per hectare of net cultivated area. Farmers sometime use pesticides improperly, such as spraying vegetables too close to harvest. But even with proper use, pesticide poisons threaten environmental and public health. On the other hand, some pest control technologies reduce those threats. This study encountered public and private programs promoting integrated pest management as well as the use of pheromones, parasitic wasps, and other nonpoisonous pest control inputs.

STUDY FINDINGS: PROGRAMS AND POLICIES AFFECTING PRIVATE INNOVATION

Government agencies and donors have multiple points of contact with private organizations through which they can influence private innovation and R&D. Government and donors channel financial assistance for private R&D. Twelve of 51 surveyed organizations reported current grant support from the government and/or donors for R&D. Private organizations asked for more research grants, as well as tax relief, including a tax holiday for R&D. Seed companies asked that the government declare the seed business to be an industry, which would improve companies' access to credit and government facilities.

Private organizations look to public agencies not only for money, but also for technical assistance. BRRI reports dozens of pending requests from private organizations wanting to sign Memoranda of Understanding for access to BRRI technologies and/or facilities. BARI works with several private organizations to research biological control agents (parasitic wasps), pheromones, and microbial pesticides (fungi). USAID supports private engineering shops to design and produce small machines to compress urea into super granules (1.8–2.7 grams), and private fertilizer dealers to buy and operate the machines, and to sell super granule urea to farmers.Three companies reported undertaking collaborative research, for example, to develop eggplant cultivars with an introduced gene to reduce pest damage.

Science-based companies look to the government to provide scientists. Companies not only recruit entry-level technical staff from public universities, but also engage public-sector scientists as consultants, and often hire them away midcareer, or recruit them after retirement.

Organizations had many suggestions for regulations (too many to detail here). Because technology and other factors change over time, the Government of Bangladesh revises regulations from time to time to meet the current situation. For example, the Agricultural Pesticides Ordinance of 1971, which authorizes the government to list allowed pest control products, did not cover biopesticides; in 2009 Parliament passed legislation to allow the registration and introduction of biopesticides.

Among all agribusinesses, seed companies were most interested in regulations. Three repeated requests were (a) to relax barriers to the introduction of new cultivars for three of five notified crops (that is, rice, potatoes, and jute; sugarcane and wheat are of less interest to private seed companies); (b) to stop fake seed (that is, seed sold in packages copied or stolen from seed companies); and (c) to establish plant breeders' rights.

All governments regulate agricultural technology that threatens environmental or public health. Many governments regulate the introduction of some technologies based on performance; in the case of the Government of Bangladesh, such regulations apply, inter alia, to cattle breeds, fertilizers, and cultivars for five crops. Support for these regulations comes from various quarters, including some private companies that see regulations as barriers to competitors' entry. As noted above for rice and wheat, regulations can inflict high but unseen costs in the form of foregone gains.

CONCLUSIONS

For more than two decades, the Government of Bangladesh has encouraged private companies and NGOs to introduce agricultural technology. Privately introduced technology has supported the rapid expansion of poultry production, allowed off-season vegetable production, multiplied maize yields, extended hybrid rice to 6 percent of the area planted to rice, and accelerated the expansion of total irrigated area. Calculated farm-level benefits from selected private technologies totaled more than US$700 million in 2009/10. Most of these gains have been achieved with imported technology.

Technology transfer appears to have motivated in-country R&D. For example, in 1990, when Kushtia Seed Store imported and introduced the first maize hybrids from Thailand, the company had no trouble finding hybrids that would yield much more than available open pollinated varieties. Twenty years later, with scores of hybrids already in the market, companies systematically review available hybrids from foreign breeding; some also breed for desired characteristics. In this case, technology spill-ins led to technology-based competition, motivating companies to invest in R&D. Companies and NGOs have been expanding their R&D efforts. Some vegetable cultivars from private breeding in Bangladesh have been introduced into other regional countries.

The government and donors have established programs to assist private R&D, but there is room for improvement. Private organizations ask for financial assistance, collaboration, and educational support. Some regulations delay or block private innovations. Both private and public organizations are learning new ways to collaborate. For example, the Bangladesh Fertilizer Association publishes a soil science journal, providing a venue for government scientists to report research findings.

Insofar as farmers and consumers benefit from private agricultural innovation, these innovations have a public benefit. Because private organizations do not capture all of the benefits, they are not motivated to do the socially optimal amount of innovation and R&D. Thus, there are good reasons for government and donors to extend grants and other financial assistance for private agricultural innovation and R&D, and especially for innovations considered to have more social returns.

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