Pakistan

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The public sector has provided most of the investment in agricultural research in Pakistan. The country's political and economic climate, coupled with unresolved intellectual property rights and problems with regulation enforcement, has dampened the considerable potential of private agricultural research. Despite these problems, private agricultural research has been increasing. Investment in private agricultural research more than doubled between 1988 and 1998, but remains at about one-fifth of public expenditure in agricultural research, which is at a very low level.

This chapter presents a study of private agricultural research in Pakistan. Its purpose is to: identify the magnitude and scope of private agricultural research, identify current policy and technical constraints that limit the potential of private agricultural research, and suggest policies and programs for increasing private investment to reach its full potential.

Information for the study is based on personal contact with secondary sources and a survey questionnaire. Relevant government agencies, key informants, and private companies were contacted and informally asked questions pertaining to private research. A formal survey was conducted of private companies that provided agricultural inputs and those that process agricultural commodities. The formal survey questionnaire was sent in May 1998 to firms in Pakistan that were conducting private agricultural research, had done this research, or had the potential to undertake private research.

This study follows two previous studies done in 1987 by Ahmad (1987) and by Pray (1987). Some results of this study are compared with the two earlier studies. This study is an update to the Ahmad (1987) study but also includes changes since 1987 in policy toward private research.

This chapter presents an overview of Pakistan's agriculture describing its role in the Pakistani economy, trends in agricultural production and productivity, and food supply and demand projections. It describes the public agricultural research system, the past and present private investment and research environment, and survey results, and identifies trends since the two 1987 surveys. It also discusses the structure and research investment of selected agricultural input industries in Pakistan.

Agriculture Sector

Agriculture is the largest sector of Pakistan's economy—ahead of manufacturing—and accounted for 24.6 percent of the total gross domestic product in 1997-98. The sector in 1998 employed 16.2 million workers, who represented 47.5 percent of Pakistan's total labor force (Government of Pakistan, 1996). Seventy percent of Pakistan's population of over 140 million lived in rural areas; however, there was an alarming upward trend in the growth of urbanization.

Three main sources of demand exist for Pakistan's future agricultural output. The first source is for food and fiber for the population of 140 million (in 1998), growing at a rate of around 3 percent per year. The population doubling time is approximately every 25 years. This means that Pakistan's population could reach over 250 million by 2020 and over 375 million by 2030. The second source of demand is the moderately rising per capita income, which increased at a real rate of 5 percent per year (Government of Pakistan, 1997a). Tastes and preferences change with rising incomes, often leading to a greater demand for edible oils and livestock products, in particular, milk and poultry. The third source is the demand for exports and resulting foreign exchange earnings.

The agriculture sector is an important source of foreign exchange earnings through exports of agricultural commodities and agricultural-based products. However, substantial foreign exchange is required for imports of agricultural commodities and products. The trade balance has been negative for most of Pakistan's history as a nation. Raw cotton has become the largest agricultural export commodity, except in years of depressed cotton production. Raw cotton exports accounted for 7.5 percent of the value of total exports in 1991-92, but exports of raw cotton fell to around 1 percent of the value of total exports in 1993-94 and 1994-95, when the crop was affected by the cotton leaf

curl virus and inclement weather conditions (Government of Pakistan, 1997a). Exports of rice, the second major agricultural export commodity, accounted for between 3.6 and 6.7 percent of the total value of all export earnings in 1988-89 to 1994-95. Fish, fruits, and spices follow as the next highest exported commodities in value terms. Total agricultural commodity exports as a percentage of the total value of all exports ranged from a high of 31 percent in 1988-89 to a low of 9 percent in 1993-94, when cotton production substantially declined, indicating the importance of a good cotton crop (Government of Pakistan, 1997a).

Raw agricultural items such as cotton, wool, and leather products provide the material for many value-added industries. Goods such as cotton yarn, cotton cloth, carpets, and leather manufactured from raw agricultural products accounted for between 33 and 38 percent of the value of total export earnings in 1988-89 to 1994-95 (Government of Pakistan, 1997a). Together, raw agricultural products plus semi-manufactured agricultural products (cotton yarn, leather, molasses, animal casings, and tobacco) provided between 45 and 55 percent of the value of Pakistan's foreign exchange earnings in the 1990s.

Agricultural commodity and product imports substantially contributed to total imports and the negative trade balance. The major agricultural import was edible oils, followed by grains, pulses, and flour. By value, edible oil imports were about 80 percent palm oil with the remainder mostly soybean oil. The category of wheat, pulses, and flour consists of over 85 percent wheat imports in any given year. Together, these two import categories represented 30-40 percent of the trade balance deficit in 1988-89 to 1994-95. In all, between 13 and 18 percent of the value of total imports were agricultural food commodities (Government of Pakistan, 1997a).

Agricultural Production, Productivity Growth, and Food Security

More intensive use of land and water resources, in combination with new interventions from research (in particular, new varieties) has yielded increased agricultural production and productivity. The significant potential to increase productivity through increasing the effectiveness of the extension, education, and training systems and investing in rural infrastructure has not been tapped. The agricultural input, product price, and trade policy environment, overall, has had a negative effect on productivity growth (World Bank, 1994).

Farm-level prices of several agricultural products have remained below free market prices. These included the price for wheat, which is the staple food, and the two main export crops of cotton and rice. Policies, however, were devised to allow duty-free imports of farm machinery and to subsidize fertilizer and credit. Both subsidies were later withdrawn.

The average annual growth in overall agricultural production since 1959-60 has been an impressive 3.2 percent, which favorably compares with growth rates of similar countries (World Bank, 1994). The overall growth rate in agricultural production for 1988-89 to 1993-94 was 3.6 percent, the same rate of growth as for 1979-80 to 1987-88. The growth rate fell to 2.3 percent during 1969-70 to 1979-80 due to several years of severe weather conditions and a virus that depressed cotton production. The growth rate in agricultural production in these three periods lags far behind the 4.9-percent growth rate experienced between 1959-60 and 1969-70. That period marked the beginning of the green revolution with the use of high-yielding varieties (HYV) and increased external inputs, such as water and fertilizer (World Bank, 1994). Thus, the growth rate in agricultural production slowed and, as indicated by the 1969-70 to 1979-80 data, can be cut in half by weather and disease factors.

Growth in agricultural productivity is also important in assessing the direction of future agricultural production. Partial productivity growth rates in terms of crop yields (kilograms per hectare) are presented in table C-1 for selected crops. The long-term growth rate for wheat yield was very modest at 0.8 percent. The yield growth rate trend of basmati rice, a large foreign exchange earner, was negative. The trend in sugarcane yield was also modest at 0.6 percent. Cotton yield grew steadily at 2.4 percent but suffered a 2.8-percent decline in 1993-94 due to adverse weather and disease. However, the crop rebounded with a record production of over 9 million bales in 1995-96.

Table C-1 suggests that the partial productivity measures of yield per hectare for some major crops have decreased, plateaued, or were increasing more slowly compared with previous periods, in particular, relative to the green revolution period. For example, a study of Punjab wheat yields by Byerlee and Siddiq (1990) indicates that wheat yields between 1966 and 1976 increased by 59 kilograms per hectare, but by only 21 kilograms per hectare in the following 10-year period, suggesting a sustainability problem. Similar compar-

Table C-1—Area, production, and yield growth rates of selected major crops, Pakistan, 1989-90 to 1993-94

Commodity	Area		Production		Yield	
	Weight[1]	Growth rate	Weight[1]	Growth rate	Weight[1]	Growth rate
	Thousand hectares	*Percent*	*Thousand tons*	*Percent*	*Kilograms/ hectare*	*Percent*
Wheat	7,993	0.4	15,187	1.2	1,899	0.8
Cotton	2,748	1.0	1,636	3.4	595	2.4
Basmati rice	1,086	1.2	1,184	.8	1,090	-.4
IRRI rice	863	-.1	1,980	.1	2,285	.2
Sugarcane	896	.1	37,002	.7	42,900	.6
Rapeseed	289	-1.2	215	-.5	748	.7

[1]These are 1989-90 to 1993-94 averages.

Source: Primary data from Agricultural Statistics of Pakistan (Government of Pakistan, 1997b); Growth rates: Log of 1980-81 to 1993-94 annual data for area, production, and yield, regressed on time (1,2,3…14). The growth rate is the first derivative of the estimated equation x 100.

isons indicate that rice yields have plateaued and that cotton yields increased at a decreasing rate in 1993-97, relative to the impressive increase in cotton yields in 1980 to 1990 (see Byerlee, 1994).

Although requiring further verification, this points to a potential problem. Pakistan's future agricultural production and productivity increases may not be able to be sustained at the same growth rates as in the past. Most food supply and demand projections for Pakistan forecast large agricultural commodity imports in the future if investment in the agricultural sector were to remain at its 1998 low levels. International Food Policy Research Institute projections for food supply and demand and net trade for selected agricultural commodities in 2020 are presented in table C-2. The supply projections consider the effect of future public and private agricultural research, agricultural extension and farmers schooling, marketing efficiency, infrastructure, and irrigation. The supply projections in table C-2 are based on a low-investment and slow-growth scenario in these components. The demand projections are based on population growth, per capita income growth, and projected consumer prices.

With the exception of rice, substantial quantities of all remaining commodities must be imported. Wheat imports would be about 8 times higher and edible oil imports 13 times higher than the 1993-94 levels. Wheat imports alone cost about $5 billion per year at 1998 prices. This puts enormous strain on Pakistan's foreign exchange requirements and impedes the future development of the country. Table C-2 also presents the production growth rates that various commodities would have to achieve to satisfy demand in 2020. These growth rates are substantial when compared with those in table C-1 and would require immediate action for a high-investment and high-growth strategy to achieve such rates.

Public Agricultural Research

At the time of the partition of British India in 1947, Pakistan inherited very little of the human and physical capital that made up what then was an internationally recognized research system in British India (Pray, 1978). There remained one agricultural college and one research station in three of the four provinces but with insufficient resources. In the 1950s, two more agricultural colleges were formed. In the late 1950s, research and teaching institutions in the North West Frontier Province and Punjab and Sindh provinces were established with American assistance from three land-grant universities. These institutions laid the groundwork for the current agricultural education and public research system.

In 1998, the publicly funded Pakistan agricultural research system was organized at the Federal and provincial levels. There were 74 research establishments at the Federal level and 106 research institutions at the provincial level in 1990 (Mellor, 1994). Three agricultural universities also conduct research. The Pakistan Agricultural Research Council (PARC) is the main body in agricultural research and conducts, promotes, and coordinates research in the country. The National Agricultural Research Center in Islamabad is PARC's main research facility. Long-term priority research is conducted at the Federal level, along with applied and adaptive research. Research is mostly adaptive at the provincial level.

Table C-2—Food supply and demand projections and net trade, to 2020, Pakistan

Commodity	Production	Demand	Net trade	Required growth rates[1] To meet 2020 production	Required growth rates[1] To meet 2020 demand
	Thousand tons			*Percent*	
Crops:					
Wheat	27,463	42,913	-15,451	2.3	3.8
Rice	6,207	5,309	898	2.2	1.5
Maize	1,895	2,748	-852	1.5	2.0
Other coarse grains	726	1,233	-507	1.0	2.6
Total cereals	36,291	52,203	-15,912	2.2	3.5
Edible oil	2	1,547	-1,545	NA	24.5
Roots & tubers	1,276	1,776	-499	1.9	2.9
Meat and eggs:					
Beef (buffalo)	764	1,109	-345	3.1	4.2
Sheep meat	1,254	1,507	-253	3.6	4.3
Poultry meat	381	679	-299	2.8	4.6
Total meat	2,399	3,295	-897	3.2	4.2
Eggs	669	775	-106	4.1	4.4

NA = Not available.
[1]Growth rates required to meet 2020 production and demand given 1990 production figures in Rosegrant, (1995, table 13).

Source: Rosegrant et al. (1995).

Pakistan's public agricultural research system has been successful. Several studies have documented the rate of return from past agricultural research in Pakistan (table C-3). Three studies, using slightly different methodologies, research, and extension expenditure calculations and time periods, documented that the overall internal rate of return from agricultural research ranged between 57 and 65 percent. The three major crops of wheat, rice, and cotton also have impressive returns to research. The returns compare favorably with what would be considered a good return from other public and private investments.

The high rates of return presented in table C-3 are largely from the green revolution period. There were substantial productivity gains from strong varietal improvement research programs and cooperation with international research centers. The high rates of return are an indication that Pakistan's public agricultural research system had done reasonably well in the past; however, the research system now faces several major difficulties. There has been a proliferation of research institutes at the Federal and Provincial levels without corresponding increases in trained scientific and management manpower and funding (Pakistan Agricultural Research Council, 1997). Management and control of research resources and information throughout the agricultural research system is weak (World Bank, 1990). Career advancement is largely based on seniority rather than merit.

The proportion of Ph.D's to total scientific staff in Pakistan, roughly 10 percent, would be considered very low relative to the proportion in developed countries. The latest figures show a ratio of agricultural scientists to population in Pakistan in 1988 at 44 per million, down from 60 per million in 1973. For comparison, the United States had 2,360 and the United Kingdom 1,400 agricultural scientists per million population (Mellor, 1994).

Pakistan spent only 0.02 percent of gross national product on public agricultural research in 1993, far below the level of most other countries (Mellor, 1994). The latest budget allocations for public agricultural research was around 1,100 million rupees (PRs) per year ($24 million). The funding environment for agricultural research indicates that it may be difficult to keep future funding levels, in real terms, from decreasing. A more serious problem related to research funding is the proportion of overall funding for actual expenditures on research by scientists (operational expenditures) and capital costs above that for salaries. Operational expenditures for research have declined to 10 to 15 percent, and sometimes lower, of overall research expenditures (Mellor, 1994, Vol. I, p. 202). Yearly expenditures on capital items are near zero unless purchased through a donor-funded project. Many scientists have indicated that soon they will be unable to conduct even maintenance research, and productivity and production will inevitably fall (Nagy and

Table C-3—Returns from agricultural research, Pakistan, selected years

Commodity/study	Period of study	Internal rate of return	Return eventually realized from one rupee invested
	Years	*Percent*	*Rupee*
All agricultural research:			
Azam et al. (1991)--			
All research	1956-85	57	10.9
Applied research	1956-85	82	20.9
General research	1956-85	56	10.2
Evenson & Bloom (1991)	1955-89	65	9.8
Nagy (1991)	1960-79	64	5.0
Wheat:			
Azam et al. (1991)	1956-85	76	16.5
Byerlee (1993) (Punjab)	1978-87	22	NA
Nagy (1991)	1964-81	58	NA
Rice:			
Azam et al. (1991)	1956-85	89	24.9
Iqbal (1991)--			
Punjab	1971-88	57	NA
Sindh	1971-88	50	NA
Cotton:			
Azam et al. (1991)	1956-85	102	43.5
Iqbal (1991)--			
Punjab	1971-88	90	NA
Sindh	1971-88	50	NA
Maize:			
Azam et al. (1991)	1956-85	46	3.8
Nagy (1991)	1967-81	19	NA

NA = Not available.

Source: Nagy and Ali, 1996.

Quddus, 1999; and Pakistan Agricultural Research Council, 1997).

A 1997 Pakistan National Master Agricultural Research Plan (NMARP) has spelled out priority areas of agricultural research and a blueprint and agenda of how the Pakistan agricultural research system can once again become a relevant contributor to increased agricultural productivity (Pakistan Agricultural Research Council, 1997; Nagy and Quddus, 1998). Included in the plan is the upgrading of management, a focus on priority research, and the upgrading of human and capital resources with a budget double the 1998 level. As part of the overall plan, the NMARP also encourages private agricultural research to contribute to increased agricultural productivity. Given the possible decline in long-term agricultural productivity, the projected food deficit problems, and the state of public agricultural research in 1998, private research must be encouraged to reach its full potential.

Private Investment and Research Environment

Agricultural research remained an almost exclusive domain of the public sector until the 1980s. The private sector was dealt a severe blow during 1972 to 1976. Along with large and medium private industries, many agribusiness firms were nationalized and merged under various state-owned corporations that controlled the processing and export of agricultural products. This continued until the early 1980s, when there was a slow beginning to the denationalization and deregulation of agriculture and agricultural industries and parastatals.

Privatization began in earnest in 1988, when the government initiated the privatization of many industries and took a more favorable stance toward private investment. The government, as of 1998, continued with privatization and disbanding of parastatals and introduced programs and policies to stimulate private investment. Steps were taken, for example, to phase

out the upper ceiling on landholdings by agricultural companies and facilitate easier access to credit. During 1988 to 1998, most subsidiaries of the Ghee Corporation of Pakistan, the Pakistan Industrial Development Corporation, and the National Fertilizer Corporation were privatized. Other parastatals—-such as the Trading Corporation of Pakistan, the Rice Export Corporation, and the Cotton Export Corporation—-were downsized and merged with the Trading Corporation. The Marketing and Storage Corporation disbanded. Other parastatals, including the Trading Corporation, have been exposed to competition with the private sector.

As previously indicated, Government policies toward agriculture have been unfavorable. Policies have kept farm-level prices of the three major crops—wheat, cotton, and rice—at lower than free-market prices, thereby decreasing farm-level profit margins. This can hurt private agribusiness investment since optimum input levels are lower than they would be under higher prices and wider farm-level profit margins from a free market. Farm-level profit margins were further squeezed with the removal of the subsidies on fertilizer and credit.

The government is still finalizing its regulations on intellectual property rights. Pakistan's Plant Breeders' Rights Act, drafted by the Federal Seed Certification Department in 1996 and vetted by the Geneva-based International Union of Plant Variety Protection has yet to become law. Pakistan, as a member of the World Trade organization and a signatory to the Trade-Related Intellectual Property Rights System, was committed to introduce legislation in the form of plant breeders' rights or a patent by January 1, 2000. In 1998, new open-pollinated varieties of crops developed by the public and private sectors were not patented and continued to be available for multiplication and sale by public and private agribusiness firms without restriction or paying royalties to breeders or public institutions. This has kept the multinationals from introducing many open-pollinated varieties with superior germplasm. Seed firms, however, can register all new varieties with the Federal Seed Certification Department, but many national firms do not use the registry. There is also a 10-year internationally sanctioned exemption of new varieties imported into Pakistan from other countries to 2005. Other agriculture-related innovations are being registered with the Patent Office, which now resides in the Ministry of Industries or the trademarks registry within the Ministry of Commerce.

What may be of more concern in the future for private investment in agricultural research is the enforcement of plant breeders' rights, patent regulations, seed certification, and truth-in-labeling laws. Once plant breeders' rights become law, enforcement becomes an issue. Enforcement of truth-in-labeling laws—labeling and identifying seed as being of a certain quality and pedigree—is a major problem (Alam and Saleemi, 1996). The Federal Seed Certification Department does not have the number of trained staff required to properly monitor seed certification and truth-in-labeling regulations. Seeds can be imported without being tested for their authenticity, and local seed can easily be mixed with good quality or an improved variety seed without much enforcement of the seed certification act. Past experience with enforcing the laws pertaining to weights and measures and the adulteration of agricultural chemicals—particularly fertilizers, pesticides, and herbicides—has been unreliable. This creates an environment of mistrust among farmers who are reluctant to pay high prices for agricultural inputs that may be adulterated or of poor quality.

In 1998, the cotton industry was the largest user of farm-level inputs. Fertilizer, pesticides, and cottonseed were in demand by cotton farmers and were targeted by private research. In particular, good quality and improved cottonseed was in high demand because of the cotton leaf curl virus problem. Seed companies obtain their highest returns from providing new cotton seed varieties but make little money with open-pollinated wheat or maize varieties. Competition is still very strong from the new wheat and maize varieties coming from the public research system and distributed by the Punjab and Sindh Seed Corporations.

The 1998 private investment and research environment was the best it had been since the nationalization policies in the 1970's. Official government policy is one of continued privatization, deregulation, and trade liberalization and the creation of an environment for the expansion of the private sector in agriculture, agribusiness, and research. However, the mood of most private investors in agribusiness is cautious, particularly for research that has a long-term payoff, partly because of the political and financial instability within the country. Despite the political change that brought in a fledgling democracy in late 1988, there were four interim governments consistent with each of the four regularly elected governments. The country's foreign exchange reserves are chronically low as are the government's financial resources to pay for internal and

external government debts. Further uncertainty is generated by developments with and in the countries on Pakistan's borders. These uncertainties led to cautious private investment and private research programs that can be characterized as short-term adaptive research taking advantage of technology transfer opportunities. Thus, while the 1998 government policy was amenable to private investment, other developments constrained the private sector and investors still remembered the nationalization period of the 1970's.

Private Research Investment

We conducted a formal survey of firms in the agriculture sector that provide inputs to farmers and to firms processing agricultural products. The survey questionnaire was sent in May 1998 to 362 firms in Pakistan that were identified as conducting private agricultural research, had conducted research in the past, or had the potential to undertake private research. Of the firms surveyed, 244 primarily produced or manufactured agricultural inputs to be used at the farm level and 118 were predominantly processing firms (tobacco companies do both but spend 80 percent of their research on agricultural inputs). The list of firms was based on the Ahmad (1987) survey list updated by information from all 31 Chambers of Commerce and Industries as well as from Agribusiness Trade Associations. Questions were asked about: (1) the area and type of research undertaken, (2) the number of scientists employed by qualification and number of technicians and field staff, (3) research expenditures, (4) support and collaboration with public research institutions, and (5) major constraints to doing research.

Of the 362 firms surveyed, 159 (44 percent) responded to the survey questionnaire. Table C-4 presents the number of questionnaires sent and the number of responses by agribusiness category. The categories are divided into firms that provide or do research on agricultural inputs, and firms that primarily process agricultural products. Each category is further divided by their identity as a multinational or national firm. Most firms that did not initially reply were contacted personally or by telephone. This elicited more responses but also indicated that in the final analysis, the majority of the firms that did not respond to the questionnaire did little or no research. Many firms are registered but not all firms are active. For example, there are over 100 national seed firms registered but only a few are active and fewer still actually do research (Alam and Saleemi, 1996). Thus, the 159 firms that did respond undertake some research and make up at least 95 percent of all firms that undertake private agricultural research.

Private Research Areas

Table C-4 also briefly describes the type of research in each category. The agribusiness categories in table C-5 are similar to the Ahmad (1987) survey categories, except for the addition of herbal medicines and planting material/tissue culture, which are new areas of private research. Research varies from simple adaptive research, done by most national agricultural machinery firms, to technologically advanced research, as in the case of planting and tissue culture research. All respondents indicated that they did adaptive research (adjusting technology to local conditions). All multinational firms indicated that some of their research could also be classified as applied research (new technology creation), but only 5 percent of the national firms said they did applied research. The national firms included the planting material and tissue culture firm and several firms from the seed and sugar categories. Thus, most private research was adaptive and functioned as an adjunct activity to the main business of selling an input or processed product.

Scientists and Staff by Qualification

All 159 respondents answered the question about scientist and staff numbers (table C-5). Of the total 292 scientists reported, 4.5, 31.0, and 64.5 percent are qualified with a Ph.D., M.S., and B.S., respectively. In comparison, the breakdown for the same qualification categories in public agricultural research was 9.5, 63.5 and 27.0 percent, respectively (Pakistan Agricultural Research Council, 1997). The Ahmad (1987) survey reported 3.5, 45, and 51.5 percent for the same categories, respectively, indicating a slight shift toward the use of more B.S.-qualified scientists in place of scientists with an M.S. Multinational firms employ more scientists per firm (7.30 per firm) than do national firms (1.38 per firm). Multinational firms also hire more qualified scientists per firm. For example, multinationals hire more Ph.D.s per firm (0.50 per firm) than do national firms (0.05 per firm). However, comparisons with the Ahmad (1987) survey indicate that tobacco firms had two Ph.D.s in 1987, but none in 1998. Discussions with the tobacco and other firms indicate that they can do most of their adaptive research using well-qualified M.S. and B.S. trained scientists. Also, they say it is more difficult now to employ well-trained Ph.D. scientists, because Ph.D.s

Table C-4—Survey questionnaires sent and received and areas of research, Pakistan, 1998

Agribusiness category	Surveyed	Responses	Description of research
	-------Number-------		
Firms providing agricultural inputs:			
Multinational firms--			
Agricultural machinery	2	1	Manufacturing parts locally
Fertilizer	3	3	Agronomic field trials
Pesticide	5	3	Field trials/intellectual property rights
Seed	4	2	Variety and hybrid evaluation trials
Tobacco	2	2	Agronomic trials
Subtotal	16	11	
National firms--			
Agricultural machinery	98	34	Adapting imported machinery
Fertilizer	2	2	Agronomic field trials
Poultry/livestock feed	21	5	Feed ingredient substitutes
Poultry	8	6	Husbandry, new breeds
Pesticides	21	12	Agronomic trials
Planting material/tissue culture	8	1	Virus-free potatoes, dates, & bananas
Seed	70	26	New variety trials (hybrids)
Subtotal	228	86	
Agricultural product-processing firms:			
Multinational firms--			
Dairy & dairy products	1	1	Developing products to local taste
Tobacco[1]			Processing and curing trials
National firms--			
Dairy & dairy products	5	2	Product & processing development
Food processing	32	22	Product development
Herbal medicines	16	2	Product development
Maize products	2	2	Starch, edible oil, starch-based sugars
Sugarcane	35	17	Byproduct development (molasses, alcohol, biofertilizer), new varieties
Solvent oil extractor	9	5	Processing, new oilseed crops (canola)
Vegetable ghee	18	11	Alternative blending formulas
Subtotal	117	61	
Total	362	159	

[1]The same tobacco companies as above in "Firms providing agricultural inputs."

have more and better opportunities with pharmaceutical industries and Ph.D.s trained abroad usually try to stay abroad and work rather than return to Pakistan.

There are about two technicians and field staff to support each scientist. This 2:1 ratio holds true for multinational and national firm categories when taken separately. However, the category of firms providing agricultural inputs has about a 2.2:1 ratio, whereas the agricultural product-processing firms category had a 1.6:1 ratio. This compares with only a 0.4:1 support staff per research scientist ratio in the public agricultural research, indicating that the private sector has better support for its scientists (Pakistan Agricultural Research Council, 1997).

Private Investment in Agricultural Research

The survey questionnaire asked firms about their research expenditures. Although some firms responded, few gave complete information. We decided to estimate research expenditures based on the staff costs of technicians, field staff, and scientists, supplemented by the partial information from the survey results and information from personal contact with several the leading firms. Average staff costs were estimated at PRs 60,000 per month for a Ph.D., PRs. 30,000 per month for an M.S., PR. 15,000 per month for a B.S., and PRs. 7,500 per month for technical and field staff. The market for qualified scientists and staff is very competitive, and

Table C-5—Technicians, field staff, and scientists by qualification, Pakistan, 1998

Agribusiness category	Technicians and field staff	Number of Scientists			
		Ph.D.	M.S.	B.S.	Total
			Number		
Firms providing agricultural inputs:					
Multinational firms--					
Agricultural machinery	23	0	1	6	7
Fertilizer	21	2	5	13	20
Pesticide	81	1	8	14	23
Seed	16	3	3	4	10
Tobacco	14	0	6	8	14
Subtotal	155	6	23	45	74
National firms--					
Agricultural machinery	42	0	4	11	15
Fertilizer	21	0	9	4	13
Poultry/livestock feed	18	0	4	14	18
Poultry	86	1	6	12	19
Pesticides	26	1	3	17	21
Planting material/tissue culture	2	1	3	3	7
Seed	48	0	3	11	14
Subtotal	243	3	32	72	107
Agricultural product-processing firms:					
Multinational--					
Dairy & dairy products	18	0	3	7	10
Tobacco	4	0	2	2	4
Subtotal	22	0	5	9	14
National--					
Dairy & dairy products	18	1	5	7	13
Food processing	26	1	7	8	16
Herbal medicines	4	0	6	2	8
Maize products	9	0	2	6	8
Sugarcane	59	2	11	27	40
Solvent oil extractor	11	0	NA	3	3
Vegetable ghee	28	0	NA	9	9
Subtotal	155	4	31	62	97
Total	575	13	91	188	292

NA = Not available.

multinational companies paid the same rates as nationals. From the information provided by the firms, operating costs were estimated to be equal to the sum of total staff costs. Operating costs include management costs, materials and office supplies, laboratory supplies, travel and daily allowances, repair and maintenance, utilities, petrol, oil and lubricants, communications, rent, taxes, and daily paid labor. The firms did not estimate capital costs of research.

Table C-6 presents the estimate of staff and operating costs for private research in Pakistan for 1998. The cost per staff category, as presented earlier, was multiplied by the number of technicians, field staff, and scientists in each staff category from table C-5 and doubled to account for operating costs. Total estimated costs are in the order of PRs 255 million (US$5.7 million). As previously discussed, this estimate would include nearly 95 percent of all staff and operating expenditures in private agricultural research.

In monetary terms, firms that produced or manufactured agricultural inputs accounted for two-thirds of private agricultural research and one-third of agricultural processing firms. Agricultural chemical research (fertilizers and pesticides) accounted for 41 percent of

Table C-6—Private agricultural research expenditure estimates, Pakistan, 1998

Agribusiness category	Research expenditures			Total[2]
	Scientists	Technicians field staff	Total[1]	
	Million rupees			*U.S. dollars*
Firms providing agricultural inputs:				
Multinational firms--				
Agricultural machinery	1.44	2.07	7.02	156,000
Fertilizer	5.58	1.89	14.94	332,000
Pesticide	6.12	7.29	26.82	596,000
Seed	3.96	1.44	10.80	240,000
Tobacco	3.60	1.26	9.72	216,000
Subtotal	20.70	13.95	69.30	1,540,000
National firms--				
Agricultural machinery	3.42	3.78	14.40	320,000
Fertilizer	3.96	1.89	11.70	260,000
Poultry/livestock feed	3.96	1.62	11.16	248,000
Poultry	5.04	7.74	25.56	568,000
Pesticides	4.86	2.34	14.40	320,000
Planting material/tissue culture	2.34	.18	5.04	112,000
Seed	3.06	4.32	14.76	328,000
Subtotal	26.64	21.87	97.02	2,156,000
Agricultural product-processing firms:				
Multinational--				
Dairy & dairy products	2.34	1.62	7.92	176,000
Tobacco	1.08	0.36	2.88	64,000
Subtotal	3.42	1.98	10.80	240,000
National firms--				
Dairy & dairy products	3.78	1.62	10.80	240,000
Food processing	4.60	2.34	13.88	308,444
Herbal medicines	2.52	.36	5.76	128,000
Maize products	1.80	.81	5.22	116,000
Sugarcane	10.26	5.31	31.14	692,000
Solvent oil extractor	.54	.99	3.06	68,000
Vegetable ghee	1.62	2.52	8.28	184,000
Subtotal	25.12	13.95	78.14	1,736,444
Total	75.88	51.75	255.26	5,672,444

[1]Estimated expenditure for scientific manpower plus the total estimated expenditure for technicians and field staff multiplied by two to account for operating costs.

[2]One U.S. dollar exchanged for 45 rupees at the time of the survey in May/June 1998.

agricultural input firm research expenditures. The sugar industry accounted for 35 percent of agricultural processing expenditures. Multinational firms accounted for one-third and national firms for two-thirds of research expenditures. Of the multinational firms, pesticide firms spent the most on research and almost twice that of fertilizer, the next highest category of firms in terms of expenditures. Poultry and sugar firms spent the most on research within the national firm category.

Pray (1987) estimated 1987 staff and operating costs to be a minimum of PRs 20 million. The Ahmad (1987) survey estimated 1987 research expenditures for staff and operating costs to be PRs 37 million when the same firm categories were included as in the 1998 survey. The Pray (1987) estimates were from direct personal contact with firms, and thus the expenditure data is very credible for the firms contacted. However, the Ahmad (1987) survey cast a wider net and included more firms in the food-processing and sugar industries.

Using the Pakistani general consumer price index (Government of Pakistan, 1997a) to inflate 1987 rupees to 1998 terms, PRs 37 million (in 1987) are equivalent to about PRs 100 million in 1998 rupees. Thus, the 1998 expenditure estimate of PRs 255 million from table C-6 is about 2.5 times the 1987 estimate. This indicates that the growth in private agricultural research over the last 10 years more than doubled.

A more than doubling of private research activity in 1988 to 1998 is encouraging. However, the amount spent on private agricultural research is small, given the relatively large agricultural sector and its importance to the economy. An expenditure of $5 million to $6 million is very small even if one considers that staff costs are one-half to one-fourth the costs of similar quality staff in developed countries. Private research expenditure is thus about one-fifth of Pakistan's total expenditure of about $25 million per year on public agricultural research.

Collaboration with Public Agricultural Research Institutions

The survey results indicated that there was no contact between 61 percent of all private sector agricultural research firms and Pakistan's public sector research system (table C-7). Only 18 percent of the firms indicated that they had active support and collaboration with public sector researchers, while 21 percent said they had some collaboration. The contact is highest among multinational firms, with over 90 percent of the firms indicating some or active support and collaboration, while the corresponding figure for national firms was only 35 percent. The agricultural machinery firm was the only multinational firm with no contact, and 88 percent of the national firms had no contact. Among the national processing firms, the majority of food-processing firms—sugar and vegetable ghee—had no contact.

Collaboration is in the form of general information flow and information on the latest research methodologies and techniques. Some firms hire public researchers as short-term consultants and collaborative researchers. One dairy firm and two fertilizer firms indicated that they sponsor research projects at public research institutions. Fauji Fertilizer Company and some national fertilizer companies sponsor M.S. degrees at Pakistan's three main agricultural universities in soil science and agronomy.

There was also some collaboration with the Agribusiness Directorate within the Pakistan Agricultural Research Council (PARC) (Nagy and Ali, 1996). PARC's mandate was to actively promote the commercialization of agricultural-related technologies developed in Pakistan at the national and international levels. The Directorate is comprised of two units: (1) the Transfer of Technology and Human Resources Development Unit, and (2) the Agro-Industrial Consultancy Unit. There is also an Agribusiness Cell within the Ministry of Food, Agriculture, and Livestock in Islamabad that promotes agribusiness. The Agribusiness Directorate within PARC and the Agribusiness Cell in the Ministry have a varied history of rising and falling in prominence, depending on the government's focus and the interest of the incumbent Secretary of Agriculture and PARC Chairman.

Incentives and Major Constraints to Research

A survey question asked if government policies and regulations provided incentives for private research. The unanimous answer was "No." No special government policies exist for tax relief to firms that do agricultural research. Most research equipment must be imported and is very expensive. High *ad valorem* duties are imposed on all imported laboratory and field equipment. And there is no differentiation between import duties on research equipment expenditures as opposed to production machinery expenditures.

Another survey question asked about major constraints to research. The questionnaire suggested three possible constraints: inability to find trained personnel, financial constraints, and official regulations and policies. No multinational firms answered this question, whereas 75 percent of all national firms answered (table C-8). Of the national firms, fertilizer, herbal medicines, and maize products did not respond. Followup contact suggested that multinational firms did not want to openly discuss these questions. Since multinational firm financing was linked to head offices abroad, there was a reluctance to discuss finances. Questions about official regulations and government policies are rarely voiced openly by multinational firms.

Of the 119 respondents, only the planting material and tissue culture firms indicated that they had problems finding trained personnel. Being a newer research area may account for this. In 1998, Pakistan produced a high number of good-quality M.S. and B.S. graduates to fill the market for the other areas of research. Ninety-two percent of those who responded indicated that financial constraints hampered their research effort. Most of these companies indicated that they cannot procure credit at reasonable rates for develop-

Table C-7—Public research institution collaboration and support, Pakistan, 1998

Agribusiness category	Private firms		
	No contact	Some collaboration	Active support and collaboration
		Number	
Firms providing agricultural inputs:			
Multinational firms--			
Agricultural machinery	1	NA	NA
Fertilizer	NA	NA	3
Pesticide	NA	1	2
Seed	NA	NA	2
Tobacco	NA	1	1
Subtotal	1	2	8
		Percent	
	9	18	73
		Number	
National firms--			
Agricultural machinery	30	3	1
Fertilizer	NA	1	1
Poultry/livestock feed	1	2	2
Poultry	2	2	2
Pesticides	2	6	4
Planting material/tissue culture	1	NA	NA
Seed	16	7	3
Subtotal	52	21	13
		Percent	
	60	24	15
		Number	
Agricultural product processing firms:			
Multinational firms--			
Dairy & dairy products	NA	NA	1
Tobacco[1]			
National firms--			
Dairy & dairy products	NA	2	NA
Food processing	16	2	4
Herbal medicines	NA	1	1
Maize products	NA	2	NA
Sugarcane	12	3	2
Solvent oil extractor	5	NA	NA
Vegetable ghee	11	NA	NA
Subtotal	44	10	7
		Percent	
	72	16	12
		Number	
Total	97	33	29
		Percent	
	61	21	18

NA = Not available.

[1]The same tobacco companies as above in “Firms providing agricultural inputs.”

Table C-8—Private research constraints of national firms, Pakistan, 1998

Agribusiness category	Firms responding to question	Trained manpower	Financial constraints	Official regulations & policies
		Number of firms		
National firms providing agricultural inputs:				
Agricultural machinery	34	NA	31	NA
Fertilizer	0	NA	NA	NA
Poultry/livestock feed	5	NA	5	NA
Poultry	6	NA	6	NA
Pesticides	10	NA	8	8
Planting material/tissue culture	1	1	NA	NA
Seed	23	NA	20	7
Subtotal	79	1	70	15
National agricultural processing firms:				
Dairy & dairy products	2	NA	2	NA
Food processing	22	NA	22	10
Herbal medicines	0	NA	NA	NA
Maize products	0	NA	NA	NA
Sugarcane	0	NA	NA	NA
Solvent oil extractor	5	NA	5	NA
Vegetable ghee	11	NA	11	NA
Subtotal	57	0	40	10
Total	119	1	110	25

NA = Not available.

ing their business or to undertake research. Twenty-one percent indicated that official regulations and policies were a constraint to their research effort. The respondents were pesticide, seed, and food-processing firms. It was not certain if the companies responded to direct constraints that hampered research or to a general complaint about rules and regulations that pertained to their business. Many seed firms did not like the strict regulations about testing and certifying seed, and many pesticide companies may have felt that the Agricultural Pesticide Ordinance Act regulating adulteration standards and generic products was too strict.

Structure and Research Investment in Selected Agricultural Input Industries

Seed Industry

From partition in 1947 into the 1960s, there was no organized effort to establish a formal seed industry. Provincial agricultural departments began producing wheat, rice, and cottonseed on private and public farms during the first part of the green revolution period. The 1998 public seed industry organization owes its origins to the 1976 Pakistan Seed Industry Project, initiated by the Food and Agricultural Outlook/International Bank for Reconstruction and Development (FAO/IBRD). The objectives were to release a new variety, to multiply seed, and to process, certify, store, and market agricultural products (Ahmad and Chaudhri, 1994; and Alam and Saleemi, 1996). Since the Seed Act of 1976, the regulatory, registration, and certification functions have been under the guidance of the Federal Ministry of Food and Agriculture. The new act initially ignored a role for the private sector and developed a public seed industry. The Punjab Seed Corporation (PSC) and Sindh Seed Corporation (SSC) were established for seed procurement and import, production, storage, and distribution in each of those two provinces. Similar corporations in the North West Frontier Province (NWFP) and Balochistan Province were considered economically unviable, and it was thought that the seed demand in these two provinces could be supplied by the PSC and SSC. The NWFP Agricultural Development Authority mandated two seed corporations in Punjab, and the Balochistan Department of Agriculture mandated two in Sindh to identify seed requirements and import the seed.

In the Punjab, for example, prebasic seed is produced at the public research institutes and multiplied at PSC farms to obtain basic seed (Ahmad and Chaudhri, 1994; and Alam and Saleemi, 1996). PSC then contracts the growing of basic seed with registered farmers to obtain

certified seed. Seed quality and control is administered by the Federal Seed Certification Department. Seed is then sold and distributed through both public and private organizations. The Punjab Agricultural Development and Supplies Corporation (PAD&SC), a sister parastatal that sells fertilizer and seed, marketed about 60 percent of the PSC seed. PAD&SC has its own sales depots but also sells through private dealers. The remaining 40 percent was sold by PSC through their own outlets and private outlets. At the beginning of each sale season, the agents are asked by PSC to indicate their anticipated demand. Seed pricing by PSC is based on the recovery of the cost to PSC plus a margin for overhead. The PSC and ADA no longer receive direct government subsidies, but SSC still does. However, indirect subsidies in all provinces take the form of government farms for seed replication.

The performance of the seed corporations has been less than was anticipated, although the PSC has had some success. The SSC was designed to operate like the PSC but had problems with organization and management and has not done as well as the PSC. Table C-9 presents the estimated seed requirements and actual seed distribution. Certified seed is made available for the major crops of wheat, cotton, rice, maize, and sometimes for gram (chick pea) and potato. Certified seed for vegetables, spice crops, oilseeds, and other pulses are not available through PSC or SSC. The 1991-92 figures in table C-9 are indicative of previous and more recent years. Although it was never the intent to cover 100 percent of seed distribution requirements for all crops, it was anticipated that high-yielding variety cereal crop requirements would be satisfied at the 75-percent level (Alam and Saleemi, 1996). Table C-9 indicates that they have fallen far short of their earlier intentions, despite the fact that, in the Punjab, PSC seed sales were tied to PAD&SC fertilizer sales. It has also been realized that PSC and SSC cannot fulfill the mandate to supply seed to NWFP and Balochistan. Supplying their own needs takes precedent, and because of different growing and agroecological conditions, the seed supplied by PSC and SSC was sometimes inappropriate.

PSC and SSC had the capacity to procure and distribute more seed. For example, together they could have doubled wheat seed distribution; however, several problems prevented them from doing this (Mellor, 1994, Vol I, p. 252; and Alam and Saleemi, 1996). Problems include a conservative parastatal management style, although it is understandable in light of a policy to take back all unsold seed from their dealers. Other problems include poor coordination, delay in shipments to dealers, wrong seed type shipped, limited storage capacity in certain areas, and poor packaging material. A PSC survey indicated that 51 percent of the farmers sampled in the survey did not use PSC seed because it was unavailable. A survey indicated that 83 percent of farmers sampled in the Punjab said they were satisfied with the quality of wheat seed and cottonseed that were reported to be of very high quality (Alam and Saleemi, 1996).

The Rafhan Maize Products company in the 1960s was one of the earliest private companies to enter the seed business. They developed hybrid maize varieties for contract growers for Rafhan's starch manufacturing business. Cargill Pakistan Seeds (private) Limited entered in 1984, and its activities involved variety trials of maize, wheat, soybean, and safflower hybrids. Among other early entrants were Jaffer Brothers (private) Seed Division, working on seed potato, and the Bukhari Corporation, working on cottonseed (see Alam and Saleemi, 1996; Ahmad, 1987; and Pray, 1987 for a history of the seed industry). The seed industry invested about PRs 25.6 million in 1998 in

Table C-9—Seed requirement and distribution by public seed corporations, Pakistan, 1991-92

Commodity	Estimated total requirement[1]	Annual requirement[2]	Actual quantity distributed	Annual requirement satisfied
	----------*Thousand tons*----------			*Percent*
Wheat	691.3	138.3	51.4	37.2
Cotton	76.8	76.8	15.3	19.9
Rice	36.7	7.3	1.9	26.0
Maize	32.2	10.7	.9	.08
Gram (chickpea)	35.3	7.1	0	0

[1]Estimated total seed requirement for all four provinces, if seed was replaced every year.
[2]Assumes wheat, rice, and gram seed was replaced every 5 years, cotton every year, and maize every 3 years.

Source: Ahmad and Chaudhri, 1994.

research-related activities (table C-6), which is about 1.8 times the PRs 14.4 million (in 1998 rupees) invested in 1987 (Ahmad, 1987). Investment by national seed firms on research is about a third higher than investment by multinational firms.

In 1987, there were 11 registered seed companies (Ahmad, 1987). Alam and Saleemi (1996) listed over 80 registered national seed companies in 1995, but the total rose to 159 in 1998; 150 in the Punjab, 6 in Sindh, 2 in NWFP, and 1 in Balochistan. The Federal Seed Department has 40 more candidate seed companies under scrutiny. The national seed companies organized themselves under two chambers: the Chamber of Private Seed Industry is the larger and is in Multan; the other is organized under the auspices of progressive farmer businessmen in Rahim Yar Khan in southern Punjab. Most companies, however, ceased or never began operation and not all companies certify their seed. Two of the more prominent national seed companies Jalundur Seed Corporation and Zaheerabad Seed Corporation, have established seed-processing facilities and carry out research on scientific lines (Alam and Saleemi, 1996). With the exception of one firm in NWFP, which produced an indigenous sunflower hybrid, all remaining national seed companies were engaged in marketing open-pollinated seed of public-bred varieties of field crops and imported seed vegetable crops. All companies must conform to truth-in-labeling regulations; however, many national companies import seeds and directly sell them to farmers without testing or registering them.

In 1995, there were five main multinational firms registered as seed companies: Cargill, Pioneer, Sandoz, ICI Pakistan, and Lever Brothers (Alam and Saleemi, 1996). Cargill has by far the major share of the market, followed by ICI and Pioneer. Cargill researched maize, sunflower, forage sorghum, wheat, rice and cotton; ICI researched maize and sunflower hybrids; and Pioneer researched maize, sunflower, and forage sorghum. Sandoz did a limited amount of research, and Lever Brothers has terminated its activities. A merger between Sandoz and Ciba Giegy formed a new firm, called "Novartis," but the seed division has yet to become fully operative. Another new company, AgrEvo, the result of a merger between Hoechst and Russul Uclof, was preparing to enter the business. Cargill Pakistan, along with its subsiduaries, was being taken over by Monsanto.

All multinational companies must, by law, register for seed certification. All imported plant material must be tested in Pakistan before large quantities are imported. No control exists over seed pricing, and adherence to the truth-in-labeling standards were left to the determination of the market.

Multinational seed companies mostly develop hybrids of sunflowers, maize, and fodder crops. Some firms market public-bred open-pollinated varieties but are limited by the absence of plant breeders' rights. Public activities dominate the wheat and rice seed market, making it difficult for national and multinational companies to compete. One of the most profitable areas in 1998 was in developing cottonseed varieties because of the leaf curl virus problems and recommendations that farmers change their seed each year.

The effect of the private seed industry on Pakistani agriculture is still relatively small. Many multinational firms have developed superior hybrid maize and sunflower varieties that double or even triple the yield of varieties being used by most Pakistani farmers in 1998. However, the amount of seed for use was still limited. Alam and Saleemi (1996) estimated that in 1995 private national seed companies provided 3 to 4 percent of wheat seed requirements and less than 1 percent of the rice seed requirement of the entire Punjab. Multinational seed companies provided from 1 to 2 percent of the wheat seed, 1 percent of the rice seed, and 3 to 4 percent of the maize seed requirement of the Punjab. No estimates exist for cotton and other seeds, but there is no reason to believe their shares are any higher than those of wheat, rice, and maize. However, the potential is great. Taking into consideration Pakistan's seed requirements and the amount of seed that the public (table C-9) and private sectors distributed, there is considerable scope for private seed companies in the future.

However, several constraints must be overcome before the full potential is realized. Apart from political and economic instability, other factors hamper an increase in private seed research and development. These include policies that favored the public sector over the private in terms of duty-free imports of seed-processing equipment, provision of state land and farms for seed multiplication, and donor agency funding of research and human resources, which to the private sector adds up to a subsidy that they do not get. Private seed companies paid 25-percent customs duty on the import value price of seed and in-bred lines (vegetable seed exempt). There is no tax holiday for the seed industry; they pay duty on the import of process-

ing plants and spare parts and pay local taxes on the movement of seed. There are indiscriminate imports of seed by unregistered seed companies, little enforcement of truth-in-labeling regulations, and a lack of awareness among farmers of the importance of good-quality seed (see Alam and Saleemi, 1996; and Mellor, 1994, Vol. I and II for a further litany of problems and constraints). Of the 23 national seed firms that responded to the survey question on major constraints to research (table C-8), 87 percent said they had financial constraints and 30 percent said that official regulations and policies were a constraint.

Fertilizer Industry

Commercial chemical fertilizer was first used in Pakistan in 1952-53, with a gift of 1,000 tons of nitrogenous fertilizer from the United States. But the existing varieties of wheat and rice were prone to lodging with high fertilizer use. It was not until the green revolution in the 1960s that high-yielding varieties arrived, triggering widespread use of fertilizer. A subsidy on fertilizer also helped to increase fertilizer use. Farmers used 6,600 nutrient tons in 1955-56, which steadily increased to a peak of 2,508,000 nutrient tons in 1995-96 before declining to 2,032,000 nutrient tons in 1997-98 (Government of Pakistan, 1997a). In 1997-98, 446,000 nutrient tons (22 percent) were imported. Pakistan produced most of its nitrogen fertilizer needs but imported phosphatic and potassic fertilizers.

Both public and private sectors were involved in fertilizer production and research. Public sector activities began with the Lyallpur Chemicals and Fertilizer (private) Ltd. plant in 1957 and the Pak-American fertilizer plant in 1958, followed by several joint ventures such as Pak-Arab, Pak-Saudi, and Pak-China fertilizer plants (see Ahmad, 1987, table IV-2). A Pak-Jordan DAP plant near Karachi was the latest and was expected to be completed by the end of 1998. The first private sector plant was built by Exxon in 1968. Two other private fertilizer plants followed: Dawood Hercules Chemicals, Ltd. (in 1971) and Fauji Fertilizers Co. Ltd. (in 1978). All private plants produce only urea.

In the 1970s privatization period, restrictions were put on private company fertilizer sales. In 1973, the government established the National Fertilizer Corporation of Pakistan, Ltd. (NFC) to take over the fertilizer-manufacturing facilities of the then state-owned fertilizer plants. In addition to fertilizer plants, the NFC operates the Fertilizer Research and Development Institute, a technical training institute, and a national fertilizer-marketing subsidiary. Restrictions were taken off private fertilizer sales, the fertilizer subsidy to farmers was abolished, and the NFC operated as an autonomous body that competes with the private sector. About 65 percent of the fertilizer production capacity is held by the private sector. Eight agencies marketed fertilizers in 1998: five public agencies and three private sector agencies represented by each private sector company, each having its own designated areas and dealers at the local level (Mellor, 1994). There is reported widespread adulteration and underweighing of fertilizer at the local dealer level, and black market prices were charged when some fertilizers were in short supply. Imports must be sanctioned by the government through the Directorate of Fertilizer Imports in MINFA, and sometimes the bureaucratic procedures result in delays of fertilizer imports, making them late for the sowing period.

Early research by public and private sectors concentrated on response curve estimation of improved wheat, rice, and maize as well as sugarcane varieties on application methods and demonstration trials (Pray, 1987). NARC and the provinces undertook public research on fertilizers and soils. Private research includes agronomic fertilizer trials on most prominent crops to develop fertilizer application recommendations, fertilizer formulations, and blending recommendations, and soil and water analyses. The effect on increased production of fertilizer use in combination with irrigation and high-yielding varieties of wheat, rice, and maize is well documented and, in part, owes some of this success to fertilizer-related research. Salary and operating research expenditures on private sector fertilizer research in 1987 was about PRs 11.3 million (in 1998 rupees). This compares with an expenditure of PRs 26.64 million in 1998 (table C-6). The private sector continues to actively collaborate with public sector researchers (table C-7) and conduct and support trials with public research institutions and agricultural universities. Multinational and national fertilizer firms declined to answer the question on constraints to research (table C-8).

Plant Protection Industry

Plant protection relates to pesticide use. Herbicides are not widely used; most farmers use weeds as a source of fodder and family labor for weeding, which was inexpensive relative to herbicides. Integrated Pest Management (IPM) is used some for biological control on mango, apple, and sugarcane, but this technology is in the early stages of development and is not widespread.

The pesticide industry is almost exclusively in the private sector. The public sector provides facilities for pest scouting, advisory services, and aerial spraying for locusts. Private firms locally produce, import, and market pesticides. The multinational firms and many national firms have their own field and extension staff. Local production of pesticides was 19,757 tons in 1995-96, matched by imports of 17,447 tons (Government of Pakistan, 1997a). Close to 80 percent of pesticides are used on the cotton crop and the remainder on sugarcane, rice, and fruits and vegetables (Mellor, 1994).

The pesticide industry became active in 1980 when the government deregulated and privatized the industry. The government announced a new agricultural policy that included the withdrawal of the subsidy on pesticides, transferred importing and distribution of pesticides to the private sector, discontinued free aerial spraying, and encouraged the local formulation and manufacturing of pesticides (Ahmad, 1987). The most active multinationals to invest in Pakistan are Hoechst, Ciba-Giegy, Dow Chemicals, Pacific, Chemdyes (Bayers), Sandoz, ICI, FMC, and Burmah Shell.

The pesticide industry is regulated by the Agricultural Pesticide Ordinance and Act of 1973 and prescribes heavy fines and punishment of 1 to 3 years for adulterated pesticide products or generic pesticide products, and for unconformity to strict regulations. These regulations are enforced more aggressively than other government rules and regulations, because most pesticides are used on the cotton crop, the largest single commodity foreign exchange earner for Pakistan.

Research in plant protection is done by both the public and private sectors. Public research at NARC and the provinces include entomology, weed sciences, and IPM research. IPM biological control research was also done by PARC-IIBC, Rawalpindi, and was affiliated with CAB International in England. There were concerns that high and indiscriminate pesticide use had disturbed the natural balance of pests and parasites. In particular, the problem of the cotton leaf curl virus and its white fly vector may stem from this. Plant breeding, new agronomic practices, and IPM's use of biological control methods was a priority research area over 1993-97 to combat the leaf curl virus.

Private sector research on plant protection is mostly in pesticide use and is largely adaptive-type research. In the first instance, research was done to ascertain the suitability of the pesticide, application techniques, and the collection of economic data, which is the requirement under the law for the registering of a brand name and formulation. Many small local companies stop research at this point, but some local and most multinationals maintain a research program gathering additional agronomic and IPM data that feed into product development and demonstration.

The Ahmad (1987) survey estimated research expenditures on private pesticide research in 1987 to be about PRs 26.5 million (in 1998 rupees). This compares with an expenditure of PRs 41.2 million in 1998 (table C-6). Multinational firms spent almost twice as much as national firms. The private sector continued to collaborate actively with public researchers (table C-7). Eighty percent of the respondents to the question on constraints indicated that they had financial and official regulations and policy constraints for undertaking further research (table C-8).

The effect of pesticide use on Pakistan agricultural production is considerable. Production of the hybrid spring maize crop would be impossible without some form of plant protection use. A combination of the hybrid variety and appropriate pesticide use has enabled spring maize yields to increase sixfold over traditional maize varieties and farm practices. Chemical control of pyrilla in sugarcane is credited with having increased raw sugarcane yield by 10 percent and sugar recovery by at least 1 percent. Average per-hectare yield of horticultural crops increased by 72 percent in 1987-97; the cotton crop has doubled production since the 1980s; and the use of plant protection measures, mainly pesticides, is credited for a large portion of this increase. Similarly, the average yield of Virginia tobacco increased from 1,957 kilograms per hectare in 1987-88 to 2,300 kilograms per hectare in 1997-98, largely due to pesticide use (Pakistan Tobacco Board, 1998).

Concluding Comments

Pakistan made great strides in 1982-97 to encourage private investment in the country, in general, and in agricultural input and processing industries in particular. Private investment in agricultural research more than doubled between 1987 and 1997. Although the agribusiness research component is still relatively small, the potential for private investment in the agribusiness input and processing industries and accompanying research and development opportunities appears to be substantial. The seed, plant protection, and poultry sectors alone offer numerous opportunities

for investment expansion and research. Opportunities for the food-processing industries could also be substantial, given an effective demand from a growing and increasingly urban and younger population.

However, private investment firms seek political, economic, and financial stability within a country, transparent and appropriate rules and regulations, and the consistent and fair enforcement of those rules and regulations, along with the ability to profit from their investment. None of these conditions were much in evidence in Pakistan in 1982-97. This constrained private investment, which in turn kept private agricultural research at a low level. Private firms accept risk, but where risk is high, firms will do only the short-term adaptive research necessary to keep themselves in the market. Little long-term applied research will be done and basic research will never be undertaken.

Given the possible decline in long-term agricultural productivity, the projected food deficit problems that may occur in the 2000s, and the declining state of public agricultural research investment, encouraging private research to reach its full potential becomes an important option. This can be done only by decreasing the risk and uncertainty within the environment in which private firms operate. This paper has given an overview of private agricultural research and, through the review, has identified some constraints and problems that private research faces. Each agribusiness sector is unique, has its own constraints, and requires its own particular rules and regulations and solutions. Many solutions to the technical problems are documented elsewhere. While it will never be possible to eradicate risk, the government and private sector can work together in those areas where it is possible to make a difference.

The first area in which a difference can be made is by the passing of the intellectual property rights legislation. Such legislation is a prerequisite for any further development in the seed and new plant material research area. The second major area that can make a difference is the enforcement of all rules and regulations pertaining to intellectual property rights, patents, certification procedures, truth-in-labeling regulations, and other regulation areas that make a better agribusiness and research environment. Private investment and research would benefit from a transparent set of enforced rules within which to operate. A third area is ensuring that private sector agricultural research can operate efficiently and on a level playing field relative to public agricultural research and nonagricultural private research. Areas needing redress include local, provincial, and Federal tax policies, research equipment and spare parts import duty policies, custom duties on imported seed and in-bred lines, and regulations regarding research, in general.

As research techniques become more sophisticated and private firms attempt more applied research, developing closer ties with universities and technical schools would ensure that the appropriate number and type of qualified staff and scientists are being trained. Another area for consideration is fostering further and closer cooperation between private research and the public research system. Pakistan's agricultural research agenda benefits when private and public sectors operate efficiently and in collaboration.

While political and financial stability is always a concern, these areas can make a difference and reduce risk and uncertainty, encouraging the private sector to continue and expand its research agenda. Further research on private agricultural research could include more in-depth studies of individual industries. Further independent, in-depth research on research constraint identification and possible solutions to particular problems that can be brought to the attention of the government would be helpful. Agricultural research would also benefit by identifying mechanisms for more formal collaboration between the public and private sectors, and between the research community and government.

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