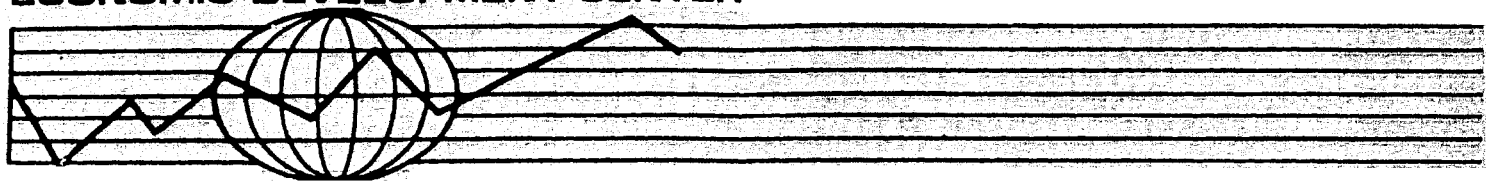
Report Number 1

October, 1986

ECONOMIC DEVELOPMENT CENTER



AGRICULTURAL RESEARCH AND TECHNOLOGY TRANSFER BY THE PRIVATE SECTOR IN INDIA

Carl E. Pray

ECONOMIC DEVELOPMENT CENTER
Department of Economics, Minneapolis
Department of Agricultural and Applied Economics, St. Paul

UNIVERSITY OF MINNESOTA

AGRICULTURAL RESEARCH AND TECHNOLOGY TRANSFER BY THE PRIVATE SECTOR IN INDIA

Carl E. Pray*

July, 1986

*Carl E. Pray is Associate Professor, Department of Agricultural Economics and Marketing, Rutgers University.

The research on which this report is based was in the Department of Agricultural and Applied Economics, University of Minnesota. The research on which this paper is based was supported by the U.S. Agency for International Development (Contract No. OTR-0091-G-SS-4195-00).

Table of Contents

List of Tables

PRIVATE SECTOR RESEARCH AND TECHNOLOGY TRANSFER IN INDIA: REPORT ON SEPTEMBER, 1985 SURVEY

Executive Summary

One of the goals of both the Indian government and USAID is to improve the income of small farmers, rural laborers and the urban poor. One of the ways in which the government has tried to improve their income is through promoting technical change in agriculture. The rate and direction of technological development in agriculture is directly related to the amount and direction of agricultural research and development and the importation of technology. Even imported technology usually needs some research to adapt the technology to local conditions. In developed market economies, private research plays a major role in developing new technology and adapting technology from other countries. The question is whether private research can make a larger contribution to the development and adaption of agricultural technology in India.

Most of the agricultural research and development in India is carried out by federal or state government research organizations. There is, however, some research in the private sector. This project had three working hypotheses:

1. The private sector was currently doing some important research in India and that it is growing in size.

2. Private research has already had some impact on agricultural productivity in India and has the potential to play a larger role in the future.

3. The direction and amount of private research could be influenced by government policies like government research investments, property rights, import policies and price policies.

These hypotheses were tested by interviewing about 25 agribusiness firms that do research; interviewing officials at the Indian Council of Agricultural Research, The National Seed Corporation, the Department of Science and Technology and ICRISAT; and reviewing available literature. The interviews were conducted from September 1 to 21, 1985, in New Delhi, Bombay, Poona, Bangalore and Hyderabad.

The survey confirms the hypothesis that there is private sector research in India and that it is growing. At least US$ 18 million were invested in agricultural research by the private sector in 1985. This is about 7 percent of the total agricultural research in India. While most of the private sector research is very applied some Indian companies are conducting more basic research in the areas of plant biotechnology, agricultural engineering and poultry breeding.

Private research has had an impact on agricultural productivity, but further studies will be required to accurately measure its impact. Private plant breeding has led to private pearl millet hybrids which may cover almost 2 million ha., sorghum hybrids on 200,000 ha., and maize hybrids on 300,000 ha. Companies are also selling private vegetable varieties, sorghum-sudan grass hybrids and sunflower hybrids. Virginia tobacco production technology is based on adaptive research by India Tobacco Company. New breeds of poultry are beginning to have an impact. Feeds research has improved commercial poultry productivity and cut the cost of feed. Pesticide research has increased the spread and productivity of the pesticides used in India.

There is evidence that both the amount and direction of private research have been influenced by government policy. Some companies interviewed suggested that government policy has discouraged local agricultural research by:

1. restricting the growth of firms which limits their ability to capture the returns to research;

2. requiring licenses for expansion of plants or production of new products which increases the uncertainty about being able to commercialize the results of research and the returns to research by adding years between invention and innovation;

3. restricting the areas in which large firms and foreign owned firms can invest or do research, i.e., farm implements and seeds;

4. the absence of product patents on agricultural chemicals, pharmaceuticals, agricultural equipment and plant varieties.;

5. import restrictions on prototypes, germplasm and scientific equipment.

Some firms said that the government had encouraged research through:

1. import restrictions on pesticides, poultry chicks and eggs and agricultural machinery and limited patents in chemicals;

2. government research - seeds research particularly seems to have benefited but also the tractor industry and poultry industry mentioned government research which was useful to them;

3. educating scientists which the private sector can then hire relatively inexpensively.

What is the net impact of government policy on the amount of private

research in India? There is less aggregate seed research but a higher ratio of local research to multinational seed resesarch due to government policies. Pesticide research has been encouraged and discouraged, but the low ratio of research expenditure to sales for the chemical industry as a whole suggests that policy may have lowered the total amount of private research. Tractor research, poultry research and feed research seem to have benefited from liberal importation of technology at the early stages of their development followed by protection at later stages. Research by the plantation and processing industries seems to have been crowded out by government research.

Policy has affected the direction of research. Indian chemical research concentrates on process innovation rather than product innovation. Private seed research is concentrated almost exclusively on hybrid crops because there are no property rights on other crops. There would probably be more private research on hybrid corn and sorghum if multinationals were allowed to play a more active role in the seed business.

There is more basic research in India than in any of the other countries surveyed. This appears to be mainly due to the scale effect - the Indian market for seeds, pesticides, poultry and tractors is far larger than any of the other economies surveyed. In several industries, however, policy may have supplied important extra incentive for research. The threatened ban on importing grandparent stock led directly to Venkateshwara Hatchery's decision to invest in poultry breeding.

Policies which might encourage more private research include: (1) strengthening property rights of inventors like patents and plant breeders' rights (although possibly restsricting foreign firms' rights). (2) allowing

companies with foreign owners to do research in the biotechnology area, (3) better cooperation between public and private researchers and more opportunity for collaborative research.

AID's most important contribution to private research was providing scholarships to train scientists abroad and helping the agricultural universities. Government and university research has assisted the development of the private sector, and government and university scientists have been hired by the private sector.

In the future, AID could assist the private sector by encouraging better understanding of the government policies that encourage or constrain private research. Conferences and research on this topic could promote policies and government agricultural research that takes advantage of the capacities of the private sector to develop new technology. AID might also be able to encourage private research through competitive research grants to the private research programs or cooperative public-private research projects. Programs like the AID-PACT program that encourage contact between private sector scientists in the U.S. and India may also be useful.

INTRODUCTION

One of the goals of both the Indian government and USAID is to improve the income of small farmers, rural laborers and the urban poor. One of the ways in which the government has tried to improve their income is through promoting technical change in agriculture. The rate and direction of technological development in agriculture is directly related to the amount and direction of agricultural research and development and the importation of technology. Even imported technology usually needs some research to adapt the technology to local conditions. In developed market economies, private research plays a major role in developing new technology and adapting technology from other countries. The question is whether private research can make a larger contribution to the development and adaptation of agricultural technology in India.

Most of the agricultural research and development in India is carried out by federal or state government research organizations. There is, however, some research in the private sector. This project had three working hypotheses:

1. The private sector was currently doing some important research in India and that it is growing in size.

2. Private research has already had some impact on agricultural productivity in India and has the potential to play a larger role in the future.

3. The direction and amount of private research could be influenced by government policies like government research investments, property rights, import policies and price policies.

These hypotheses were tested by interviewing about 25 agribusiness firms that do research; interviewing officials at ICAR, NSC, the Department of Science and Technology and ICRISAT; and reviewing available literature. The interviews were conducted from September 1 to 21, 1985, in New Delhi, Bombay, Poona, Bangalore and Hyderabad.

The results of these interviews and the literature review are presented in the following chapters. Chapter one presents the evidence on how much private research is being conducted and the objectives of this research. The second chapter reports the available information on the impact of private research. Chapter three attempts to identify the impact of government policy on the amount and direction of private research and chapter four examines the role of AID.

PRIVATE SECTOR RESEARCH AND TECHNOLOGY TRANSFER

Aggregate Investment

Indian government and private firms invest a very large amount of money and manpower in to research. In 1982-83, national expenditure on research and development in agriculture and nonagriculture was over a billion U.S. dollars and about 200,000 scientists, technicians and administrators were employed in R and D. The objective of about 20 percent of the expenditure was to develop agriculture, forestry and fishing. In 1982-83, 14 percent of all Indian R&D expenditure was by the private sector. Only 2 percent of Indian agriculture, forestry and fishing R&D was by the private sector (GOI, 1984). This 2 percent does not include pesticide research and agricultural machinery research and so total agricultural research by the private sector may be as much as 5 percent of the total agricultural research.

There is some controversy in India about how much private research there is. A number of observers suggested that there was almost no actual research by the private sector. They felt that the official expenditure figures were due to the tax incentives given for private sector research. Scholars that have actually surveyed industries found that there was a considerable amount of research by private companies (Sinha, 1983 and Shriram, 1979). Officials in the Department of Science and Technology suggested that the official figures may actually be an underestimate because as many as half of the companies who do research do not bother to register. The fact that two of the three seed companies interviewed were not on the 1983 list of registered companies supports this contention.

The trend in the official figures for agricultural and nonagricultural research by the private sector is very rapid growth(Table 1). The direction of this trend appears to be correct, but the rate of growth is probably exaggerated because the number of companies registered has increased very rapidly during this period which reflects growing awareness of the benefits to registration as well as growth in the number of research units.

In India, a number of Industry associations, cooperatives, some voluntary and philanthropic organizations also do agricultural research. Table 2 lists some of the cooperative research associations. Organizations 1, 2, 3, 6, 7 and 8 do some research on agricultural production or the utilization of agricultural goods.

The rest of this chapter reviews the growth of research in important agricultural industries. It is based on interviews conducted in India and the United States.

Research by the Seed Companies

In the early 1960's DeKalb started corn research in India. In the mid 1960's several local companies including Mahyco and Nimbkar in Maharashtra started research programs to develop hybrid corn, sorghum and pearl millet. A limited amount of vegetable research was started in the late 1960's. DeKalb closed their research and sales operation in 1968. In the 1970 Pioneer started a research program on corn, grain sorghum and sorghum Sudan grass. They closed briefly in the early 1970's and reopened in 1977. At present at least 10 private companies are doing some plant breeding research. Altogether the three biggest seed research programs spend about US$ 700,000 annually on

Table 1

TRENDS IN NATIONAL EXPENDITURE ON RESEARCH DEVELOPMENT AND RELATED SCIENTIFIC AND TECHNOLOGICAL ACTIVITIES 1948-49 TO 1983-84

(Rupees crores)

Year	1948-49	1950-51	1955-56	1958-59	1965-66	1970-71	1975-76	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84 Estimated
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(A) Expenditure on R&D													
Central Sector	1.10	4.68	12.14	21.78	62.45	112.47	287.63	412.49	500.36	580.49	721.94	908.67	1044.97
State Sector	n.a	n.a	n.a	1.00	3.51	12.58	26.73	40.24	46.04	59.34	71.79	88.62	99.25
Private Sector	n.a	n.a	n.a	0.15	2.43	14.59	42.35	75.87	92.14	120.69	147.00	161.38	193.65
Total (A)	1.10	4.68	12.14	22.93	68.39	139.64	356.69	528.60	638.54	760.52	940.73	1158.67	1337.87
(B) Expenditure on Related S&T Activities													
Central Sector	n.a	n.a	n.a	5.88	16.67	33.73	36.09	19.32	23.07	36.73	43.21	54.89	63.12
State Sector	n.a	n.a	n.a	n.a	n.a	na	5.21	10.77	12.72	16.39	19.51	24.00	26.88
Total (B)	n.a	n.a	n.a	5.88	16.67	33.73	41.30	30.09	35.79	53.12	62.72	78.89	90.00
Grand Total (A&B)	1.10	4.68	12.14	28.81	85.06	173.37	397.99	558.69	674.33	813.64	1003.45	1237.56	1427.87

Source: GOI 1984

Note:
1. Data for 1948-49 represents only expenditure of CSIR, ICAR, ICMR and DAE
2. A number of organisations are engaged in scientific and technological activities, such as weather forecasting, geophysical surveys, teaching consultancy etc. In addition they also undertake research for which in a number of cases no separate account is maintained. Wherever such details have not been provided, their expenditure on research has been estimated.
3. The number of units in the private sector varies from year to year. Data for 1965-66 related to 60 companies and that for 1970-71 to 109 companies. From 1975-76 data relates to the companies recognised by the DST under the Import Trade Control Policy, for 1975-76 the data relates to 300 companies, for 1978-79 and 1979-80 to 470 companies and for 1980-81 to 1982-83 to 600 companies.
4. Data for 1983-84 has been estimated by applying the following rates of growth: Central Sector 15%, State Sector-12%, Private Sector-20%

Table 2. R&D Expenditure by Cooperative Research Associations From 1980-81 to 1982-83.

(Rs. Lakhs)

Sl. No.	Name	R&D Expenditure		
		1980-81	1981-82	1982-83
1.	Ahmedabad Textile Industry's Research Association	99.85	109.23	113.35
2.	Silk & Art Silk Mills Research Association	70.94	66.02	90.50
3.	South India Textile Industry's Research Association	54.18	62.97	56.12
4.	Bombay Textile Research Association	55.70	72.32	81.00
5.	Indian Plywood Industry's Research Association	19.43	20.81	26.32
6.	Tea Research Association	164.27	160.87	194.57
7.	Indian Jute Industry's Research Association	121.00	145.20	174.24
8.	Wool Research Association	4.92	5.91	12.00
9.	Cement Research Institute	180.02	216.02	259.21
10.	Indian Rubber Manufacturers Research Association	2.65	3.42	10.52
11.	Automotive Research Association of India	24.19	34.41	72.28
12.	Electronics Research and Development Association	20.51	24.60	29.51
13.	Man Made Textile Research Association	10.34	16.31	20.44
	Total	828.00	938.09	1140.06

Source: Data compiled by Department of Science & Technology.

current expenditure for research. According to our interviews there are over 80 scientists employed by the private seed industry including 25 PhDs.

The private research programs in the 1960's concentrated on corn, sorghum and pearl millet. More recently research started on hybrid cotton and hybrid vegetables. Hybrid sunflower and hybrid safflower research started around 1980. Several companies are working on hybrid pigeon pea. One company is now sponsoring research on hybrid rice at an Indian agricultural university. Private research has resulted in sales or private hybrids of corn, sorghum, pearl millet, sorghum sudan grass, cotton, sunflower, tomatoes and other vegetables.

The India seed industry and research by the seed industry is growing. There are a number of new entrants into the industry and the companies that have been doing research are adding crops and scientists.

Plant Protection Research

There are a large number of companies doing research in India. They have at least 12 private experiment stations scattered around the country. Most of the companies that manufacture technical material run experiments in farmer's fields. The five companies that provided me with R&D budget information spend about $200,000 a piece on product development and registration research. These companies appear to be spending an equal amount on research to develop process innovations. All of these companies were owned in part by foreign companies. The wholly owned Indian producers of technical material have research programs which usually concentrate on chemicals other than pesticides. They spend a substantial amount of money on research to

develop new processes. Four companies which are representative of this category spent about $400,000 a piece on research, but most of that was spent on chemicals that were not agricultural pesticides.

Pesticide research and development appears to have grown rapidly until recently. Of the nine companies that I talked to three were clearly increasing, two were declining and the others were fairly stable.

The main emphasis of plant protection research and development activity has been testing the bioefficacy of products that are new to India and meeting the requirements for registration. While the main emphasis continues to be on insecticides there does appears to some movement towards herbicide development in India. Among insecticides the synthetic pyrethroids have received a lot of research attention recently. Now companies are working on a wide variety of pesticides including work on new developments such as chitin inhibitors. In contrast to Southeast Asia in India several companies are synthesizing and screening new compounds and many companies are doing process research to cut the cost of production or at least find new ways to produce chemicals developed initially by somebody else. There also is some work by the Indian private sector on biological means of pest control like pest, viruses and natural predictors. In Southeast Asia only plantations did this type of research.

Livestock Research

Research by the private sector on poultry in India is a recent phenomena. The exotic birds which became the basis for the commercial poultry industry were first introduced by the government and then popularized by the private sector - Shaver and Arbor Acres were the pioneers. Until the late 1970's foreign companies were the main source of grandparent stock and none of these companies did any breeding in India. The first company to start breeding in India was Venkateshwara Hatcheries (VH) in 1980. In the last few years two other companies have also started breeding in India.

The research in India by VH aims to adapt the best commercial breeds from Cobb and Babcock to India market conditions. In the US there is a price premium for large eggs. In India there is no price premium for egg size after a certain weight. Since the egg size and the number of eggs a layer produces are inversely correlated, US breeders have had to trade off numbers for size. In India VH has been able to trade size for numbers and this produced a more profitable layer. US broilers are bred for breast size with little concern about the number of eggs the parents lay. Most US operations are integrated from the commercial unit back to the hatcheries and only buy the grandparent stock from the breeding companies. In India and much of the rest of Asia there is little integration. The hatcheries are separate from the commercial operations and so the hatcheries will only buy birds that give enough eggs to make their parent stock operation profitable. VH has concentrated on keeping the beast size constant but increasing the number of eggs that the parents lay. This characteristic has made their broiler stock popular not only in India but also in Southeast Asia.

There also seem to be advantages in selecting birds under Indian conditions. Almost all barns there are open unlike the climate controlled barns of the US and Europe. The feeds may be somewhat different. Finally, poultry breeding is very labor intensive. Indian wages are low enough that the cost of research is far less than in the West.

In 1979 Venkateshwara set up their own company to produce vaccine because they were not satisfied with government supplies. They also established their own research and development program on vaccines.

VH, Hindustan Lever, Godrej and possibly other feed producers conduct a substantial amount of research on animal nutrition. A large number of pharmaceutical companies have introduced feed additives and pharmaceuticals that they develop in India or in other countries. However, due to lack of time we were not able to find out much about their activities or impact.

Agricultural Machinery

There are major research and development programs by private companies for the improvement of tractors and irrigation pumps. Some tractor manufacturers are now moving into agricultural implements. Until recently the development and manufacture of implements was reserved for the government research and the small scale industrial sector. The small scale sector has made many useful improvements but these companies do not usually have a formal research and development department.

The 1982 investments in tractor research are shown in Table 3. Two of the companies - Punjab Tractors and HMT Ltd. - are public sector companies. The rest are private companies. All of the private companies had technical

collaborations and/or were partially owned by foreign companies at some time in the past. However, at the moment the foreign equity in none of these firms exceeds 25 percent. The two companies that I interviewed have greatly increased their research expenditure since 1982. They reported that other companies are also expanding their research facilities and budgets.

Research by the tractor companies seems to be primarily aimed at improving the quality of their tractors although process research is also going on. In addition, companies are now developing improved equipment to be used with their tractors. The product improvement research can be divided into several types. First, Eicher and Escort are both trying to improve the fuel efficiency and the durability of their engines and tractors. Second, they have been working to improve the transmissions. Third, they are working to improve the hydraulics systems. Other than these common goals each company is trying to perfect specific features which Indian farmers will find attractive. One company is developing new sizes of tractors which they hope will better meet farmers' needs. Another is developing disc brakes and higher gears in recognition of the fact that tractors in India are more often used for transportation than for cultivation.

Research in the pump industry is primarily aimed at increasing the efficiency of the pump. They are doing this through improved design of the pumps and better materials. They are also developing more models so that they will have a pump which fits precisely to the needs of a particular farm. At least one company is experimenting with nonconventional sources of power for pumps such as solar power.

Table 3. Annual Turnover, R&D Expenditure and Manpower Employed By the Tractor Manufacturing Units in India (Year - 1982).

NO.	NAME OF THE COMPANY	TOTAL ANNUAL TURNOVER (IN LAKHS) Rs.	R&D EXPENDITURE (IN LAKHS) Rs.	% OF R&D EXPENDITURE OVER TOTAL TURNOVER	TOTAL NUMBER OF EMPLOYEES IN THE FIRM	TOTAL NUMBER OF EMPLOYEES IN R&D	% MAN POWER EMPLOYED IN R&D OVER TOTAL MANPOWER
1.	M/s Punjab Tractors	5700	68.45	1.2	2958 (1981)	129	4.3
2.	M/s Eicher Ltd.	5483	155.58	2.8	2448	216	8.4
3.	M/s Escorts Ltd. (Tractors & Engg. Div.)	22,883	133	0.58	5300	162	3.05
4.	M/s Escorts Tractors Ltd.	5,912	5.03	0.085	-	-	-
5.	M/s HMT Ltd. (Agricultural Machinery Division)	3,925 (year 1984-85)	45.72	1.1	2528	52	2.05
6.	M/s Mahindra & Mahindra Ltd.	26318	93.57	0.36	2974	67	2.2
7.	M/s Tractors & Farm Equipments Ltd.	6500	20.5	0.315	1246	21	1.685

* SOURCE : Information received from the Firms.

Source: GOI 1985

The Processing Industry and Plantation Sector

In much of Asia private firms in the processing and plantation sector have been a very important source of new agricultural technology. Historically, this was the case in South Asia also. The technology to grow Virginia tobacco was brought in by the British American Tobacco company before Independence. There were a number of cooperative research programs supported by private companies like the tea research institute at Tocklai in Assam.

At present the processing and plantation industries do not appear to do much research. Much of the cooperative research was taken over by the government. For example Tocklai is now a government research organization. Some industry groups still finance research. The Southern Planters Association has a research program on plantation crops. Textile mills associations located in Ahmedabad and Coimbatore support research on cotton and the silk industry supports research on silk and mulberry production.

This survey identified only a few individual companies that were doing research on production technology. The Indian Tobacco Company and Golden Tobacco Co. have registered research units. Hindustan Cocoa Products also has a research facility of some type. Nine sugarmills have recognized research groups. I was not able to visit any of these companies. I received mixed reports from outside observers about the activities of the sugarmills. The head of the India Sugarmills Association reported that none of the sugarmills did any breeding or selection of cane or any agronomic research. They did have agronomists on their staff and had small demonstration farms, but these were used for demonstrations not research. Two people that I talked to in the plant protection business said that a few of the biggest companies - like the

DCM Mills and Andhra Sugars Ltd. - did some applied plant protection and agronomic research.

The one processing company that has a major research program is Hindustan Lever Ltd. (HLL). HLL started its research and development activities in the 1950's in search of local substitutes for edible oils and for tallow for their soaps. Their leaders saw that population growth and the slow growth of oilseed production would turn the exports of oilseeds into imports. They also predicted that foreign exchange constraints would make it difficult or expensive to import tallow. Therefore, they started a research unit to investigate nonconventional sources of oil. They were quite successful. They developed oil from the Sal and Neem trees which had never been used commercially before. They also developed a way of making castor oil usable in making high quality soaps. With somewhat less scientific work themselves they worked with ICAR to introduce sunflower into India.

In the 1970's they branched out into other areas of agricultural research. Their feedmill operations grew out of their oilmills because the main use of the oilseed cake is for animal feed. They started work in animal nutrition in support of their feedmills. Then in the late 1970's they almost accidentally discovered a plant growth regulator that seemed to work very well. At about the same time they had been doing some long term planning exercises that concluded they should put more emphasis on agribusiness. However, they saw that the field of agricultural chemicals was already crowded and so they decided to concentrate in the area of biological technology. They substantially increased their research in a variety of fields: tissue culture research in cardamom, sugarcane, coconut, tea and pigeon pea; biological

fertilizers i.e. rhizobium; biological pest control; shrimp culture and now hybrid seeds. They are now doing gene splicing with single cell yeast to find out if they can produce vegetable oil commercially in the factory.

Summary

Table 4 shows the estimates of research expenditure by the private sector based on this survey and data collected by the Department of Science and Technology (S&T). A number of the firms surveyed would not provide information on the size of their research programs. The S&T data contains data on the fertilizer and processing industries. The S&T data is for 1982-83 and so it is probably an underestimate of the 1985 expenditure. The S&T data does not separate agricultural chemical research from other nonfertilizer chemical research. Chemical companies invested one percent of sales on research. The Rs. 420 lakhs in the fifth column is one percent of the 1985 pesticide sales. The last column contains the best estimates from the available data. It is still an underestimate because only 4 of the 10 plus seed companies which do research, none of the animal feed or veterinary pharmaceuticals companies and only part of the machinery companies are included.

The number of private sector scientists in the companies surveyed is presented in Table 5. It is clearly an underestimate, but it does at least indicate that there are a substantial number of well trained scientists now working in the private sector in India.

Agricultural research by the private sector in India has three distinctive characteristics. First, it is primarily adapting technology

Table 4. Private Research Expenditure.

	Survey		Department of Science & Technology			Survey
	No. Firms Reporting	R&D Expenditure (Million Rs.)	No. Firms Reporting 1982/83	R&D Expenditure (Million Rs.)	Other S&T	S&T (Million Rs.)
Seeds	4	8.5	na			8.5
Pesticides	5	15.2			420[a]	42.0
Fertilizer			4	15.0		15.0
Agricultural Machinery	4	108.7	5	30.1	408[b]	108.7
Livestock	2	21.0				21.0
Processing	0	na	24	25.6		25.6
TOTAL						220.8

Sources: Survey by Author, Department of S&T, 1983, and Department of S&T, 1985.

[a]Chemical industry spent 1% of sales on R&D in 1982/93. This ratio was applied to pesticide sales, 1985, to estimate pesticide research.

[b]This is just the tractor industry from Department S&T, 1985.

Table 5. Scientific Personnel in Surveyed Firms.

	Scientific Personnel in Surveyed Firms		
	No. Firms Reporting	No. of Scientists	
		PhDs	All
Seeds	7	25	81
Pesticides	9	19	40
Agricultural Machinery	3		150
Livestock	1	6	12
Processing	1	4	20
TOTAL	21	54	303

Source: Survey

produced by government or foreign research to Indian economic, social and agricultural conditions. Examples include adapting tractors to highway use, government and exotic hybrid crop varieties to local agroclimatic and taste conditions, and exotic poultry lines to the market structure of the Indian poultry industry. This is similar to private research in the rest of Asia. The second characteristic of Indian research is the importance of import substitution as a goal of research. Finding Indian raw materials to substitute for more expensive foreign materials is always a major part of research on process technology but the policies of high tariffs and import restrictions have greatly increased the incentive for research to develop substitutes in many areas. Research in the chemical industry to develop new processes for producing pesticides or agricultural machinery research that produces tractors that are less efficient or more costly than those available outside are negative examples of this type of research.

The third characteristic of a small but growing amount of research by the Indian private sector is that it is quite basic. Relative to other countries in South and Southeast Asia, Indian companies do more basic research. The Indian tractor industry does research on engines, transmissions and hydraulic systems. In Thailand and the Philippines there is little formal tractor research and the informal research deals at most with the design of body and in a few cases the transmission. A few chemical companies in India synthesize new chemical compounds including pesticides, plant growth regulators, new biological control methods, and animal health products. Several companies are doing genetic engineering and plant tissue culture is being used in several research programs. India is the only place in South and

Southeast Asia where effective poultry breeding and immunological research is being carried out by the private sector. It should be noted that this basic research is a recent phenomena - almost all of it started in the last ten years.

IMPACT OF RESEARCH AND TECHNOLOGY TRANSFER

So far, private sector research in India has had little effect on agricultural productivity. Some of the impacts have been listed below, but more research is required to actually measure the impacts of research. Technology developed by the private sector outside of India has had an important impact on the productivity of some commodities. In addition, the private sector has been an important means of transferring technology developed by the public sector to farmers. These impacts are impossible to quantify without further study, but the most important impacts have been noted.

Seeds

The major impact of private sector research in seeds is the increased yield due to corn, pearl millet and grain sorghum hybrids. Private cotton and sunflower hybrids have recently started to spread, and some private vegetable varieties may also have had some impact. Estimates of the impact of these varieties are shown in Table 6. The estimates of percentage under private varieties is based on company estimates and can not be verified without field research. Also, the assumption of 10 percent yield increase is far below what the companies claim for their crops. Their claims are based on experiment station yields, however, and there is no farm level data to verify what yield increases farmers are getting. One company is also selling private sorghum sudan grass hybrids for forage, and several companies have private vegetable seeds on the market, but we do not have any data on these crops.

Seed research has also led to some exports of private hybrids like the

Table 6. Impact of Private Varieties on Output.

	% Area Private Hybrids	% Area Total Hybrids	Total Area 83/84 (million ha)	Area Private	Increased Output* (000 mt)
Pearl Millet	10	25-30	10.9	1.9	50
Sorghum	1	20	16.1	.2	11
Corn	5	10	5.7	.3	32
Cotton	6	8-12	8.1	.5	46

*Assumes 10 percent yield increase due to hybrids.

Source: Survey

export of Mahyco pearl millet to Tanzania. The major impact of the seed industry as a whole has been to speed up the spread of hybrids and high yielding varieties of crops. They significantly increased the speed with which the diffusion of these varieties took place and, thus, increased the yield per acre of the major Indian crops.

Pesticides

The synthesis and screening research has not led to any commercial products so far. The main impact of local research has been to identify effective chemicals, to move them through the registration process and to cut the cost of production (although these costs are still above international levels). The economic effect of the availability of these chemicals is to increase yields or reduce the cost of inputs. Local research has also developed some pesticide manufacturing processes that have been exported to other third world countries. In addition, research has allowed some Indian companies to cut their costs low enough that they can sell some pesticides to countries in Africa which have not signed the Paris convention. The major impact of the transfer of pesticides to India has been on cotton yields which absorbs half of all the pesticides used in India. There has also been some impact on the yields of rice which is the other major crop in which pesticides are used.

Agricultural Machinery

The research in Eicher and Escort has leds to a wider product range - more high and low horse power models to meet the soil and crop requirements in different parts of the country and tractors that are more fuel efficient and last longer. Over the years, the average life of the Escort tractor has increased from 2,500 hours to about 4,000 hours due to a series of small changes. Recently, Escort introduced disc brakes and models with higher road speeds because so many tractors are used for hauling and transportation. Eicher developed new hydraulic system and new transmission for its tractors. These changes should cut the cost of crop production and the cost of transportation.

Kirloskar and Jyoti have improved the capacity and efficiency of their irrigation pumps over the years. The innovations that they and other firms develop are then copied after a few years by other manufacturers. The more efficient pumps cut the cost of cultivating or irrigated crops.

Poultry and Feed

The largest impact of technology transfer and local adaption in India may be in the poultry industry. Indigenous hens produce about 60 eggs per birds a year. Hybrid layers produce 220 eggs a year. Total egg production increased from five billion in 1971 to to 14 billion in 1985. Broiler production increased even more rapidly from 4 million birds in 1971 to 70 million in 1985. This increase has pushed down the real price of eggs and poultry meat over this period (see Indian Poultry Yearbook 1984).

Processing Industry

Although primarily a consumer goods and food processing company, Hindustan Lever has been moving into the input business. They started selling Mixtalol, a plant growth regulator, in 1984, and they have sold enough to cover 600,000 acres in 1985. They expect the market to be 5 to 10 million acres in 4 or 5 years. At a cost of Rs 50/acre, this will be a substantial market. They claim that it will increase yields of almost any plant by at least 20 percent and some plants like tomatoes by 50 to 100 percent. They have patented mixtalol in India, Europe and the US. Mixtalol is now being exported to Indonesia for test marketing. In several other countries - Bangladesh, Pakistan, Brazil and the Philippines - it is in the field testing stage. FMC is testing it in the US.

Indian Tobacco Company has one of the oldest private research programs and probably one of the most effective. It was not possible to visit their headquarters, and so, no numbers on their impact are presented here. It is know, however, that they helped to introduce Virginia tobacco into the Indian subcontinent. They have been able to reduce the cost of producing tobacco and increase the quality of tobacco leaf.

DETERMINANTS OF PRIVATE RESEARCH EXPENDITURE

There are three types of firms that do research on production agriculture: farms that are trying to reduce their cost of production or improve the quality of their output; input supply firms that are aiming to sell cost reducing technology to farmers; and the processors of agricultural products that want to reduce the price of the good they process.

Most of the private research in India is done by the input industries. The demand for the technology in the input industry is from farms and is determined by their production function and the final demand for their output. The decision to invest in research is made by the input producers on the basis of the expected returns to their investments. The expected returns will be a function of the aggregate demand for the input, the cost of producing new technology through research (a function of the cost of research inputs and the productivity of research), the cost of alternative sources of the technology (i.e., importing, contracting with government, lobbying the government for the research), cost of scaling up the technology, cost of marketing, cost of production, the expected market share and the expected prices of input.

Few farms in India are large enough to support research. Some of the plantations have cooperative research programs, but they are not considered in this study. Farms that do research use their new technology themselves, and sell it. It is mainly cost reducting technology and so it fits into the standard cost reduction model.

Food, beverage, fiber and tobacco processors are the next largest private research program. Some Hindustan Lever research, Indian Tobacco Company research and some research by sugarmills fit this category. In

addition, some of the textile mills have cooperative research programs which were not covered here. Processors that do agricultural research are trying to cut the costs of their inputs by helping their farmers reduce their costs of production. Something that sends prices up may either cause them to invest in research depending on the elasticity of substitution between this input and other inputs, the elasticity of demand for the input and the potential benefits from research which would increase the efficiency of their manufacturing processes or post harvest operations.

Most private research in India is carried out by the input supply industry so the economic trends and policies that affect that industry will have the most impact on aggregate research expenditure.

Government policies can influence the amount and direction of private research by affecting the expected profitability from these different investments. It is useful to distinguish two types of policies that influence the amount and direction of research: first, macro policies that affect the size and profitability of the industry in general and, thus, the demand for agricultural inputs or goods from the processing industry and second, policies that specifically affect the returns to research. Examples of the first type of policy are agricultural price policies and subsidies, exchange rates, barriers to the import of goods and government production. Examples of the second type include tax exemptions for research expenditures, patents, specific import restrictions on new technology, public sector research and extension.

This chapter will concentrate on the second type of policy. A brief look at the trends and structure of the input and processing industries, is

followed by a discussion of general technology policies and then an examination of how policy has influenced the amount and direction of research in specific industries.

Economic Trends and Macro Policies

Over the last three decades Indian agriculture has made a major shift from depending almost entirely on inputs produced on farm to purchasing a large share of these inputs. This commercialization of agriculture was due to technical change, land scarcity, the growth in foreign demand and other factors. The growth of input supply industries is summarized in Table 7. It shows a very rapid growth in the production of commercial inputs.

Food, fiber and tobacco processing have also grown rapidly in response to urbanization, population growth, income growth and technical change. Table 7 shows the index numbers of production in these industries since 1950.

Table 7. Processing and Input Industries Production.

		(Base 1970 = 100)				
		1951	1960	1971	1980	1983
Processing Industries						
Food Industries		42	63	98	128	166
Beverage		na	na	117	304	541
Tobacco		33	57	105	122	139
Textiles		72	90	100	115	115
Input Industries						
N - fertilizer	'000 tons	9	98	830	2164	3485
Tractors	nos.		1470	21139	67627	
Pesticides	tons tech. ingredients	200	7442	23713	49847	58798
Power Pumps	'000 nos.	35	109	259	431	492

Sources: World Bank except pesticides from Sarathy, 1985, tractors from GOI, 1985.

Notes: Tractors 1960 = 1962; Pesticides 1950 = 1952; 52; 1980 = 1978

Table 8

Availability of Patent/Variety Protection for "PARC" Inventions in Selected Developing Countries

	Mechanical/Electrical		Chemical				Biogenic						Other	
Country	Plough I Major	Plough II Minor	Fertilizer	Insecticide	Herbicide	Chemical Vaccine	Soybean	Corn Hybrid	Rice	Beef Cattle	Nitrogen-Fixing Bacteria	Live Virus Vaccine	Computer Program	Accounting System
U.S.A.	yes	no	yes	yes	yes	yes	yes	no	yes	no	yes	yes	no	no
Asia														
Bangladesh 1,2	no	no	no	no	no	no	no*	no*	no*	no*	?	?	no*	no*
India	no*	no	no**	no**	no**	no**	no*	no*	no*	no*	no*	no*	no	no
Indonesia 2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Korea (South)	yes	yes	no**	no**	no**	no*	no*	no*	yes	no*	yes	no*	no	no
Malaysia 1,2	yes	no	yes	yes	yes	yes	no*	no*	no*	no*	no	no	no*	no*
Nepal 4	yes	no	yes	yes	yes	yes	see footnote						no	no
Pakistan 3	yes	no	yes	yes	yes	yes	no*	no*	no*	no*	yes	yes	yes	no**
Philippines 5	yes	yes	yes?	yes?	yes?	no	no	no	no	no	yes	yes	no	no
Singapore 1,3	yes	no	yes	yes	yes	yes	no*	no*	no*	no*	no	no	no**	no**
Sri Lanka 3	yes	no	yes	yes	yes	yes	no*	no*	no*	no*	no	no	no	no**
Taiwan	yes	yes	no**	no**	no**	no**	no*	no*	no	no*	no	no*	no	no
Thailand	no*	no	yes	yes	yes	no**	no*	no*	no*	no*	no*	no*	no*	no

* This invention is specifically excluded from patent protection by national law.
** Although this substance is specifically excluded from patent protection by national law, the process used to produce the substance is not excluded.

Source: Evenson, Putnam, Evenson 1983

TABLE 8
FOOTNOTES

1. British patent law is assumed to hold in this country, owing to the provisions in its laws. British patent applications (whether or not by British citizens) have priority. In practice, a prior British patent is routinely granted approval in this country at the applicant's request. We refer the reader to chapter 37 of the Patents Act of 1977 of Great Britain. The U.K. prohibits the patenting of microbial processes or products for use on humans or animals. Ghana independently prohibits patents on pharmaceutical and medical substances.

2. This country has no patent act of its own.

3. "Microbiological processes and the products of such processes" are patentable. Whether this protection extends to microorganisms per se is not known and will depend on the interpretations of the domestic courts. In the absence of specific indications to the contrary, we have assumed that the nitrogen-fixing bacteria and the live virus vaccine are not patentable under these circumstances.

4. A patent is granted to a foreign inventor if he has obtained a patent in his own country and any three other countries. Presumably, patentability standards in those countries apply.

5. Other than meeting public standards of health and morality, no other criteria for patentability are cited. In general, we take mechanical, chemical and electrical inventions to be patentable, and others to be unpatentable. In the Philippines, U.S. law is assumed.

The present structure of Indian input industries is generally quite competitive with the federal and state government owned corporations playing an active role. In the seed industry, state and federal seed corporations provide about 50 percent of the commercial seed to farmers. The rest is supplied by between one and two thousand small companies that supply localized markets and six or more larger companies which produce seed for a broader market. Of these companies, one one - Pioneer - has a large foreign shareholder. In this case, Pioneer Overseas Corporation owns 40 percent while local investors own the rest. It is estimated by other firms that the largest private firm only has 5 percent of the commercial seed market.

Companies estimate the current market for pesticides to be about $350 million of which insecticides account for $225 million and cotton insecticides $150 million. Most of the technical material is produced in India - less than 10 percent of the technical material is imported. Over 20 private companies are producing the active ingredients for pesticides. Just over half of these firms have major foreign ownership. Only a small proportion of the production of Indian pesticide industry is government owned. Most of this is DDT which is produced by Hindustan Insecticides. Formulation of the finished product is carried out by multinationals and large scale companies which formulate about 30 percent of the finisheds product and over four thousand small scale formulators who produced the other 70 percent. In contrast, in the rest of South and Southeast Asia there is very little production of active ingredients, and most of the pesticide formulation is in the hands of the multinationals. There are a large number of firms producing technical material, including several government owned companies.

The tractor industry produces over 60,000 tractors a year. There are twelve firms in the tractor industry. Seven of these companies produce 93 percent of the tractors. Two of these - Punjab Tractors, Ltd. and HMT, Ltd. - are government owned. They produced about one quarter of the tractors in 1979 (Morehouse, 1980). The others are owned locally with minority holdings by foreign companies in several of them. There were large imports of tractors into India until 1973 when a ban on imports was imposed by the government.

The pump industry has three large companies - Kirloskar, Jyoti and Crompton Greaves, Ltd. Only the latter is foreign owned. About half of the market is supplied by the large companies. The other half is supplied by a large number of small companies that are concentrated around Ludhiana and Coimbatore.

The livestock industry has a wide variety of structures. The commercial poultry industry in India is not vertically integrated as it is in other countries. There are many commercial poultry producers and little concentration in the industry as a whole. There is much more concentration in inputs with one company holding a large share of the market for chicks throughout the country. This company faces competition from a large number of other producers plus the government which is a large producer of chicks providing about 10 percent of all chicks. There are a number of large firms in the poultry feed market (which makes up 80 to 90 percent of the total feed market), but the total number of suppliers of poultry feed listed in the Poultry Industry Yearbook runs into the hundreds. The commercial milk industry in the country is dominated by the National Dairy Development Board which is essentially producer owned cooperative.

Food processing is dominated by several large multinationals like Glaxo and Hindustan Lever. Textiles and sugar production have large numbers of firms and appear to be quite competitive. These are largely Indian owned. There is little government ownership in this area.

General Science and Technology Policy

India has had a policy of trying to develop its own technology and scientific and technical capacity. This is precisely the opposite policy of Thailand which has encouraged the import of technology and provided few incentives to local research. Aurora and Morehouse (1974) identify three major policies which the government of India has used in attempting to reach this goal: "(1) the provision of tax incentives for industrial expenditure; (2) the regulation of the importation of foreign technology; and (3) the creation of a large number of government supported industrial research laboratories." A fourth policy which provides some incentive for research is the patent.

The government has clearly been successful in building a large government research establishment in both agriculture and industry. Table 1 indicates the size of this establishment. These institutions have been important to the private sector as the major source of scientists for the private sector. They are also important as a source of consultants and for their facilities, some of which companies can use for a fee (Desai, 1980). In this survey, only the seed industry, however, said that they had received useful technology from government research organizations or that government research was an important input into their research programs.

There is some evidence that government research has helped India comapnies bargaining position when they are buying technology from abroad. Nayar (1983 II,34B) quotes a senior government scientist from the Regional Research Laboratory, Hyderabad, on the role of multinationals, as saying: "One [example] relates to NCL [National Chemical Laboratory] in Poona. The foreign firm wanted Rs.70 or 75 million for providing the technology. After they found that NCL had developed the technology, they came down to Rs.20 million, but the Government of India put its foot down and did not allow the import of technology. But we were not so lucky. In our case, the firm came down from Rs.40 million to nothing, and the government gave them a license for manufacture. (So that means they will not get the profits out of it?) You know what happens. They will say, 'Okay. We do not have this raw material in India to make it.' Therefore, they will import it and over-invoice."

The bottom line on the benefits of government research is whether the benefit of these cost savings reach the Indian farmer or consumer or not. If a product like a pesticide is protected by a very high tariff barrier, the only beneficiary will be the company that manufactures the pesticide - not the farmer. Thus, government research can play an important role in improving the bargaining position of companies and government organizations who want to buy technology, but the benefits will not necessarily go to farmers.

Import restrictions on technology appear to have led to increased private research in certain industries and influenced the direction of research. Before 1966, the government had a strong import substitution policy on goods but had a liberal policy on the importation of technology. "Hence, R&D was focused on import replacement in goods, and avoided import replacement

in technology" (Desai, 1980). After 1965, policies on technology importation tightened up, and it was difficult to get approval for technical agreements on major projects with foreign firms. According to Desai, firms increased their research expenditure and changed their research strategy to developing technology for "cost reduction, product improvement and diversification".

Some studies on R&D in the third world have suggested that the liberal policies on technology importation actually stimulates local research by making the payoffs to adaptive research higher. Mikkelsen (1984) finds a positive relationship between the availability of foreign technology and private industrial research expenditure in the Philippines.

Morehouse suggests that in India also there is a positive association between the availability of foreign technology and private industrial research or at least not a negative one. He reports: "One of the major lessons of the Indian tractor industry is that while initial dependence on foreign technology does not require indigenous effort to generate technology, it does not prevent it. Perversely, if the technology transferred is significantly inappropriate to Indian conditions and the terms of the transfer sufficiently disembodied (essentially the blue prints with little back-up technology consulting and training), external acquisition of technology may actually encourage indigenous effort."

Nayar (1983II:330) reports on a study that also tends to support the conclusion that foreign collaboration stimulates local research: "A study done by the Economic and Scientific Research Foundation of the top 300 companies in India shows that in 1969-70 ... companies with foreign collaboration (equity or technical) spent a far higher proportion of their sales income (0.59%) than companies without any collaboration (0.33%)".

Tax incentives have provided incentives for industries to report their research. It is not clear whether the incentives for the private sector have actually led to an increase in research, and there is considerable debate whether the research system as a whole is the engine of growth that Indians originally hoped it would be.

Patents are a policy tool which has stimulated private research in some countries but is not now used in the Indian agricultural sector. The patent law of 1970 explicitly forbids patenting of "a method of agriculture or horticulture"; "any process for the medicinal, surgical, curative, prophylactic, or other treatment of human beings or any process for a similar treatment of animals or plants to render them free of disease or to increase their economic value or that of their products"; or any substance "intended for use, or capable of being use, as food or medicine or drug". [Article 3(h), (i); Article 5(a)]. There is some protection for chemicals through process patents which last for up to 7 years.

A comparison of the Indian property rights with other Asian countries (Table 8) indicates that there is less coverage than in most other countries. Robert Evenson and his colleagues discuss two effects of this legislation: "The first effect deprives foreign inventors of economic rights to their invention in India; this may make the borrowing of foreign technology less costly. (It may also result in the inventions being withheld altogether, if the transfer thereof requires cooperation of other participation by the inventing firm.) The second effect deprives domestic inventors of incentives either to invent on their own or to modify foreign agricultural technology. Without offering protection to domestic inventors, the investment required to

adapt foreign inventions to local climate and soil conditions may not be forthcoming. This adaptation process is crucial to the diffusion of agricultural technology, especially mechanical and biogenetic technology ... Thus, by not providing domestic inventors with incentives to modify the inventions they borrow, the Indian legislation may actually increase dependence on foreign technology." (Evenson, Putnam and Evenson, 1983).

The government has a number of policies which appear to discourage local development of new technology. First, companies are uncertain whether they can commercialize the results of their R&D. The industrial licensing policy requires the government approve all plant expansions and the production of new products by firms that are above a certain size or more than 40 percent foreign ownership. There are policies which say if a company develops a new process or a new product,it should be allowed to commercialize it. However, the licensing requirement means, at least, that there is a substantial time lag between when a new technology is developed and when the government allows the company to start commercial production. In some cases, the government may decide that the company is not allowed to produce the product at all. This significantly reduces a company's incentive to invest in research and development. Two companies interviewed in this survey had examples of this type of problem. In one case, the firm had developed a new agricultural product based on its own research in India in the late 1970's, but it took five years to get the license to produce and sell the product. Another firm had developed a new type of industrial input through research in the 1970's and was never allowed to produce and market it.

Licensing requirements apply to large firms and foreign owned firms.

Some industries like farm implements were reserved for small companies only while foreign companies were forbidden in other industries like the seed industry. Government procurement practices on pesticides and irrigation pumps have helped the small local manufacturer since they mainly compete with prices while the bigger companies compete with the newest technology and quality and, thus, have to charge higher prices. In India, the evidence suggests that large firms not only do more research but also invest a higher percentage of their sales or earnings in research (Sinha, 1983). Foreign companies, which have ready access to foreign science and technology, frequently have more incentive to do adaptive research. By adding uncertainty that the largest firms and foreign firms will be able to commercialize their inventions, the government is reducing the incentives of the companies who should be doing the most research.

To quote T. Thomas: "there is no incentive for Indian companies to do basic R&D. Even when an Indian private sector company evolves a process or a product through its own R&D, there is no assurance that the company can get an industrial license or clearance under various other enactments such as the Monopolies and Restrictive Trade Practices Act, to take up a manufacturing venture based on R&D." (Thomas, 1981,203)

The other factor that some Indian scholars suggest is an important disincentive to research was that these licenses tended to establish monopolies. Their argument is that there may be little incentive to innovate because the profits just keep rolling in whether the company is innovative or not. Theoretically, whether a monopoly has any incentive to do process innovations or not depends on whether the government regulates prices and how

the government sets prices. If it set prices on the basis of the companies' cost of production, then process innovations which lowered the cost of production might not increase profits at all and there would be no incentive to innovate. If there is no price setting by the government, then there still should be some incentives for firms to do research although perhaps not at the optimal level for society.

Things have changed recently. More licenses have been granted in certain areas and more foreign technology and collaboration will be allowed to promote competition. The limit for investments that will not require licenses for expansion has been raised. Another policy called broad-banding has been adopted. Under it, a company that has permission to produce products in a particular field will have permission to produces any product in that field. For example, in the past if a company manufactured tractors, it could not get permission to produce the implements that went with these tractors. Now, tractor manufacturers can produce implements without special permission.

The attitudes at the highest political level have changed. However, the implementation remains to be seen. As an official from one large company said: "at present the top politicians are very enthusiastic about private sector research. The top bureaucrats are very skeptical about private sector research by Indian scientists. They do not feel that the Indian scientist can really develop anything new. Worse, government scientists are hostile to private sector research and private sector scientists."

Seeds

How much importance have these policies and other government policies had on the size and direction of private sector research?

Tax incentives do not appear to have had a major affect on the size or direction of seed research. Several seed firms who do research have not registered to get these tax incentives.

Restrictions on the importation of technology have been much more important. The government does not allow the importation of commercial seed except in emergency situations and then the government imports the seed. They also effectively restrict the importation of seed for breeding purposes. The government requires tests of all seeds that come into the country to prevent the introduction of seed borne diseases. It also requires that a sample of the seed be permanently deposited with the government. Most companies will not give their elite lines to the government because these lines may be used by government officials or other companies to compete against the original importer of seeds. Companies have offered to run the quarantine themselves under government supervision but so far the government has refused.

Since biotechnology in general and the seed industry in particular are not designated core industries, firms that have more than 40 percent foreign ownership are not allowed to invest. This has been a major deterrent to the main multinational seed companies which live or die by the proprietary lines they develop and do not like partnerships where they do not have control on how these lines are used.

The effect of these restrictions has been to force firms to ignore the government quarantine restrictions to bring in new seed or to reduce the

availability of foreign germplasm to Indian seed firms which makes their breeding programs less productive and, hence, they invest less in research. Another effect is to reduces the total amount of research because foreign firms are not allowed to sell seeds and do research. Foreign seeds almost never can be transferred directly to India and so foreign seed firms would have to set up research programs like they have done in Thailand, the Philippines and Pakistan. The government has succeeded in keeping all of them out except Pioneer and so they have reduced the total amount of research. In addition, these restrictions have reduced the amount of research in the commodities in which the multinationals are strongest - hybrid corn and hybrid sorghum.

The third major policy - building government research institutions - provideds the basis of the hybrid seed industry. The government research institutions could, however, have played an even more positive role. In the 1960s, the government developed the initial inbred lines and hybrids which became the basis of the private sector breeding programs. The availability of inbred lines of corn, sorghum and pearl millet from the government greatly reduced the cost of developing private hybrids through research because companies did not have to go through the 8 to 10 year process of developing the inbred lines. This provided the basis of the industry's early research programs. All of the earliest research by the Indian seed industry, with the exception of the DeKalb program, was established using inbred lines from the government breeding program. That breeding program was based on collections of Indian material and exotic material brought in by the Rockefeller Foundation and exchange programs with USDA and other national programs. The

private companies now also receive inbred lines of corn, sorghum and pigeon pea from ICRISAT.

Another important factor was the assistance of a few government and Rockefeller Foundation scientists. This was mentioned as a key factor in the early development of the two local companies that now have the largest research programs. In addition, the availability of well-trained scientists and technicians who had experience working in government research programs was also ann important source of technical skills and in many cases germplasm. Scientists have been attracted to the private sector by higher salaries and better facilities. A number of scientists who have retired from government service or international organizations like ICRISAT have also taken job in the private sector.

The absence of a plant variety protection act has meant that there is little incentive to do research on self pollinated crops. This is why almost all private sector research concentrates on hybrids like maize, sorghum, sorghum - sudan grass, pearl millet, sunflowers, cotton and pigeon pea.

There are several other government policies that reduce the incentive of private companies to do research. The first is competition from the government seed corporations. If these corporations do in fact push down the price of hybrid seeds as expected, profits of the private sector from their research to develop new hybrids will be reduced ad also their incentive to do research.

The second policy is the present seed certification process which reduces profits from developing new varieties or hybrids and, if amended as proposed, could greatly reduce incentives even further. To have a variety or

hybrid certified by the government is a lengthy process. It must have higher yields than the old standard variety in the All India trials or in one of nine regions. "Today the newly evolved varieties coming from the breeders after their own evaluation often have to undergo as much as six years of further testing before they can be considered for release" (Jain and Banerjee, 1982). At present, it is not necessary to have your seed certified in order to sell it. It is advantageous to do this because government extension services may then help to popularize the variety or hybrid. Also, some companies complained that officials in some areas of the country have used the current law to harass their salesmen who were selling uncertified seed. The disadvantage of certifying seeds is that companies lose income while waiting the six years to clear the testing program and then many of their varieties of hybrid are not certified. Most companies do not feel that the government breeders who run the certification system really give private varieties an equal chance against the public varieties which the government breeders developed.

The third government activity that has reduced research was bureaucratic reds tape which finally forced DeKalb and Escort to shut their seed operation in the late 1960's.

Overall, it appears that government research, which developed and released hybrids and inbred lines and provided technical assistance, has had a positive impact on research and encouraged research in maize, sorghum, pearl millet, cotton and pigeon pea. Most other technology policies appear to have had a negative impact on aggregate research and particularly reduced maize, sorghum and sunflower breeding.

The clear winners from these policies have been the Indian seed companies while the losers have been foreign seed companies. It appears that farmers may be the biggest losers from the restrictions on seeds because they would have gotten more improved seed. This is only speculation and will have to be tested in the next phase of this project.

Pesticides

The magnitude and direction of private R&D in pesticides in India is due to a combination of policies, the demands of the market and technology developed outside India. Direction of research refers to which crops, whether it is chemical control, biological control or IPM and whether the concentration is on insects, disease or weeds.

The aggregate growth in research was largely due to the demand for new technology due to the rapid growth in the pesticide market and the agroclimatic differences between the areas where the pesticides were developed and India. Consumption in the agricultural sector grew rapidly until 1975 when it slowed for a few years before reaching new peaks in 1979 when it slowed for a few years before reaching new peaks in 1979 and then 1984. This growth is primarily of insecticides and is largely due to the growth in cotton and rice production.

Demand for technology which is determined by the importance of the crop and the damage done by pests largely determines the choice of crops and which pests - insects, disease or weeds. According to estimates by the industry, the current market for pesticides is about US $350 million of which all insecticides account for $225 million and cotton insecticides $150 million. Private research reflects this breakdown with cotton insecticides

receiving the major share of research attention. The growth area which reflects expected needs rather than current sales is the increasing interest in herbicides. The shift in research toward herbicides reflects one supply side and one demand side factor. On the supply side, the West has developed many effective herbicides which can be transferred to India. On the demand side, herbicide demand is starting to pick up in Punjab and Haryana where the most modern agriculture is practices and many in the industry take this to be a sign of things to come.

Government policies have also affected the magnitude and direction of private research. The companies surveyed in this study did not see tax incentives as having a major impact on the amount or direction of research. Restrictions of the importation of technology, however, have played a major role in shaping the amount and direction of the industry. There are duties of 130 percent and 120 percent, respectively, on the importation of active ingredients and finished pesticides. In order to get permission to import pesticides at all, companies must agree to start manufacturing the active ingredient within about 6 years. In addition, there is compulsory licensing and a portion of the active ingredient has to be sold to small scale local formulators. In order to get permission to manufacture a product, the government has required that chemical firms invest a certain amount of their sales revenue in R&D. The absence of patents on agricultural chemicals and the presence of a well developed chemical industry means that many Indian companies can copy this product rapidly. The likelihood of copying, in addition to all of the conditions for importing or manufacturing, represent major barriers to the introduction of new products in India by foreign companies.

Most pesticide research on new products for the Indian market is dependent on more basic research conducted outside India. New pesticides that are discovered abroad lead to research in India on their bioefficacy, health and environmental impact under Indian conditions. If companies are not developing any new products or decide not to introduce new pesticides because of government regulations or other factors, the amount of private sector research on new products will decline. In this way, government regulations which restrict the introduction of new products may reduce the amount of new product research.

Government investments in chemical research appear to be most important as a source of private sector scientists rather than as a source of new technology. The agricultural universities and ICAR also play an important role in testing the bioefficacy of new products or new users of old products. The one area where there may have been some impact is in developing biological control methods which are starting to be commercialized and IPM methods which may affect pesticide use.

The other policies that have affecteds the direction and amount of research are regulations and patenting. Regulation has caused an increase in certain types of research. The requirements for registration made lit mandatory that a company introducing a new pesticide not only conduct bioefficacy and some environmental tests but also do more toxicology tests than required by the US EPA and repeat toxicology tests which were already accepted in the US and Europe. This has increased testing type R&D. Restrictions on the use of some of the chlorinated hydrocarbon group of chemicals led to rapid increases in the use of organophosphates and synthetic

pyrethroids. The introduction of these chemicals required research by the companies.

At the same time, regulation may be diverting research resources from new product or process development to research which duplicates work done elsewhere. The only people who benefit from the latter research are the scientists and technicians who do the testing.

There is a substantial amount of research to develop new processes for the production of pesticides. This is due to a combination of technical problems in a large industry (demand factors) and policies. The major demand side factor was differences between the costs and availability of the Indian pesticide industries' inputs and inputs in other countries.

A combination of government policies provided incentives for Indian firms to develop new processes for already established pesticides. First, there are no product patents on chemicals in India, but there is a patent protection for process innovations although the patents are very narrow and short lived - 5 to 7 years. Many companies do not bother to apply for these patents, and it is easy to get around them by just changing one step in the process by which the chemical is produced. Second, to get the registration to produce and sell a pesticide that is already registered just requires that your product is chemically identical to the commercial pesticide. Third, the one hundred percent plus duty on the import of pesticides allows a local producer with a less efficient new process to sell products for a lower price than an importer.

The investments in biological insecticides and biological control using natural predictors are a response to regulations chemical pesticides and

the likelihood of more regulator in the future. The accident in Bhopal strengthens a trend toward greater regulation that had already started some years back. This survey located only one firm that was doing any biological control research. Its technology is based on research carried out by the Commonwealth Institute for Biological Control in Bangalore.

Several multinational companies are doing basic research to develop new chemicals in India. They are synthesizing new compounds and screening them in India and elsewhere. In the case of one company, this is due to the combination of problems in repatriating profits and the low cost of doing research in India. Low cost is due to the low salaries of Indian engineers and scientists. These factors made it possible to synthesize new compound in India and then export them elsewhere for screening. The other company is interested in developing compounds that are related to natural pesticides. Their hope is to develop something like synthetic pyrethroids. This company chose to do its research in India because India has a number of natural compounds that do affect pests and also because it is inexpensive to do research in India.

How have policies influenced research? It is impossible to say what the aggregate effect of all of these policies has been on research by the agricultural chemicals industry. The ratio of investment to sales is about one percent compared with about 7 or 8 percent in the chemical industries of most developed countries. It does seem clear that there would be more private research if some of the constraints to its profitability could be removed. Privatization might also increase research since public sector chemical companies only spent .43 percent of their sales on research while the private sector spent about 1 percent (GOI, 1984: 43 and 44).

Policy seems to have affected the direction of research in several ways. First, there is more process research and some of that process research appears to be aimed at reinventing the wheel. Second, there is less applied research on new products because many of the major multinationals no longer introduce patented products into India or wait until they have introduced them many other places first. This may be particularly important with herbicides and fungicides in which India is a smaller market, and many of the new products are being developed in the West.

Poultry

The development of local breeding was the result of economic and policy factors. The economic fact was that the Indian market for hybrid chicks was growing very rapidly in the 1970's. This was due to the demand for poultry from growing urban areas with increasing income. It was also assisted by tax write offs for income earned from poultry. The technology policy which spurred local breeding was the 1978 government announcement that it would completely phase out imports of grandparent stock. It never completely did this, but it did substantially restrict the number that could be imported. Another factor led to expanded research once the decision to start research had been made was the low cost of research in India since both scientific and unskilled labor is very inexpensive.

After some long discussions between Venkateshwara, Cobb and Babcock, it was decided that the market was large enough to justify the expense of setting up a research facility. On the basis of these factors, Cobb and Venkateshwara set up the joint venture Vencob to breed broilers, and Babcock and Venkateshwara set up Venkateshwara Research and Breeding Farms to breed

layers. The foreign companies have provided their purelines and technical assistances in return for 40 percent ownership in these companies. Several other companies have started breeding operations since then. It seems likely that the success of Venkateshwara plus the continued rapid growth of the market, limited imports of grandparent stock and low cost of research were major factors in their decision.

In 1979, Venkateshwara set up their own company to produce vaccine because they were not satisfied with government supplies. They also established their own research and development program on vaccines. Government research on vaccines and foreign technology was the basis of their research program on vaccines, and the government has continued to do important research which is important to Venkateshwara's immunology program.

A number of government programs have assisted the growth of private research. Since their establishment, the Venkateshwara companies have been assisted with government loans for the expansion of their research facilities. Their research program is recognized by the government and, thus, can import research equipment without tariffs and licenses, and they get special tax privileges. Private industry officials suggested that government research had had limited impact on their research programs. Government genetic research has not been important except that it did find that cross breeding with local stock did not in any way improve the productivity of the commercial birds. Government did analysis of local feed ingredients which was important for animal nutrition work by the commercial feed industry.

The government competes directly against commercial hatcheries in the supply of chicks. In 1983, "government and other hatcheries" supplied 10

million hybrid layers and "organized hatcheries in the private sector" provided 35 million hybrid layers (Indian Poultry, 1984). It also supplies hybrid broiler chicks. This activity pushes down the price of chicks making poultry production more profitable but private research and private hatcheries less profitable.

It appears that there would be no private poultry breeding in India if the policy of restricting grandparent stock had not been announced and at least partially implemented.

Agricultural Machinery

The main factors inducing R&D seem to be increasing demand for tractors, increasing competition on the basis of technology and the inappropriateness of imported tractors. The government ban on tractor imports in 1973 protected the local industry and raised their profits. The tractors and designs that were originally imported were frequently not appropriate for Indian conditions. Indian tractors are used more for transportation than for cultivation. Western tractors were built primarily for cultivation and so there were problems with the gear ratios, the brakes and steering. Few tractors elsewhere face temperatures of the Indian hot season which also caused problems. Another economic factor that influenced the direction of research in both of the tractor and pump industry was the cost of fuel. Both industries were working to save fuel by increasing the efficiency of their machines, and one company was trying to develop solar power engines for pumps.

No one thought that the tax incentives had played an important role in inducing research. Restrictions on importing technology and technical assistance from abroad may have mad some effect. In the late 1960's, the

government was much stricter about technical assistance agreements. Indian firms had to strengthen their own R&D facilities to overcome the problems they encountered.

Some government research facilities have assisted private research. None of the tractor companies felt like they had gotten any useful technology from the government. Several companies had research contracts with government laboratories or universities for specific studies that the companies could not carry out themselves. The tractor manufacturers did find the government tractor trials at Budni useful. The tractor and pump manufacturers did not place much importance on patents. The large pump manufacturers felt patents offered them no protection against copies which would happen anyway.

This industry more than others gave the impression that investment in research and development was due to individual leaders of several companies who were technically trained and believed in research as a means of not only increasing their market share but also improving the country. Scientists within the companies and outside observers pointed to people like Vikram Lal at Eicher and Jyoti at Jyoti, Ltd. as important leaders. The success of the indigenous tractor produced by Punjab Tractors may also have spurred competition (Morehouse, 1980). When one company in an industry characterized by only a few firms starts to invest successfully in research and gains market share, others are almost forced to follow. It appears that something like this happened in the agricultural machinery area and, in particular, revitalized the tractor industry which had been stagnant during the 1970's.

Plantations and Processing

Only one firm in this category was interviewed in this survey and so generalizations are not possible. One observation from reviewing the literature is that the government research organizations may have had more of a "crowding out" effect on local research in this sector. This is a sector that has always had a mix of research by individual private companies, research fundeds by industry associations and government research. Since Independence, it appears that in the sugar, tea and cotton industries there has been a shift from research by private companies and associations to research by the government. For example, the Indian Central Cotton Committee research and the tea research station at Tocklai were both taken over by ICAR.

AID PROJECTS

AID's most important contribution to private research was in training scientists in the US and the development of the agricultural universities. Scientists in the seed industry were largely trained in the agricultural universities, and graduates from these universities were present in the other industries also. The universities also have been an important source of genetic material for private plant breeders, prototypes of some agricultural implements and recommendations on the effective application of pesticides. Poultry research by the universities provided management techniques and feed rations that assisted the early growth of that industry.

AID made a number of important contributions to the development of the poultry, seed and pesticide industries which indirectly increased private research. AID provided assistance in setting up a seed certification system and seed laws. AID staff assisted in developing early pesticide regulations through their work organizing and providing technical assistance to the Indian Pesticide Association.

AID/India has one project which is specifically aimed at encouraging research by the private sector. This project is called the PACT project. Its purpose is to provide capital required by firms that want to do research, to reduce the firms' losses if the research project is not successful and to increase the firm' likelihood of success by joining them with an American firm that has experience in developing technology. The project will put US companies in contact with Indian companies, provide loans to joint ventures between US and India firms and will write off the loan if the project is not successful. This project is just beginning.

The International Agricultural Research Centers have assisted research by private companies. The IRRI agricultural mechanization project which is financed by AID is designed to help private companies to improve small scale implements they produce. ICRISAT provides inbred lines and collections of genetic material of sorghum, pearl millet and pigeon peas to private research programs in India and elsewhere. Mahyco and ICRISAT breeders collaborated quite closely in the development of the most popular new pearl millet hybrid. Last year, ICRISAT provided a wide selection of breeding material and advice to a new seed company in the Hyderabad area.

There are several areas in which AID programs might be able to make a difference in the future. The first is the general area of technology policy. The current Indian government is reducing restrictions on the imports of technology. But the question of how much they should open up and what policies they pursue to encourage the development of local research and development is the subject of considerable debate. There is little knowledge among bureaucrats and policy makers about what agricultural research and technology transfer the private sector is doing or about how technology policies in other countries are working. There is little solid empirical evidence upon which policy decisions can be made. Thus, a conference on the topic of agricultural technology policy which includes policy makers, agricultural scientists, representatives of the private sector and social scientists might assist government to reformulate their technology policy.

It might be useful to have an initial conference which focuses on the accomplishments and potential of private research and, perhaps, reviews science and technology policies elsewhere. This first conference should be

held in New Delhi to ensure the attendance of policy makers. Then a second conference would have papers baseds on solid empirical work which quantifies the effects of certain technology policies in India and elsewhere. IIMl or ICRISAT might be a good venue for such a conference.

AID might also be able to influence technology policy by commissioning Indian economists and social scientists to do research in this area. Studies to identify public sector research that stimulates private sector research and identifying means of speeding the transformation of the results of public sector research into private technology should be part of the research agenda. These papers could be presented at the second conferences or in academic meetings.

AID support for agricultural universities and somewhat more basic research at ICAR and other government institutions like the new biotechnology institute may also be good investments.

Programs to assist private sector research directly like the PACT project seem to hold out some possibilities. Biological control of pests might be a area where the PACT program could held. There is at least one small firm that is trying to sell insect predators. There are other, larger firms that expressed some interest in this area. Capital from AID and technical expertise from US firms might be very useful. Several observers felt that capital to finance private research was very hard to get and that this was an area in which donors could assist the private sector.

A competitive grants program or a foundation to distribute competitive grants to public, private, industrial association research institutions may be another way of increasing research by the private sector and also stimulating

creative public sector research. It could also be used to encourage cooperative research between the public and private sector which might help to break down some of the communication barriers. USDA and BOSTID are providing grants to private companies to do research on sweet sorghum, safflower and mesquite among other things. AID may be able to draw on their experience and develop an expanded program of research grants to the private sector. A number of countries in the Latin American and Caribbean Bureau of AID are establishing foundations to provide competitive grants. It may be possible to learn something from their experience.

Appendix A

List of People Inverviewed

INDIA ADDRESSES

Peter Thormann
Program Economist
USAID
American Embassy
Chanakyapuri
New Delhi-110 021

Anil K. Chojar
Agricultural Specialist
Foreign Agricultural Service
U.S. Department of Agriculture
American Embassy
Chanakapuri
New Delhi

N. Patnaik
The World Bank
21 Jorbagh
New.Delhi-110003

Dr. S. R. Barooah
Director
Research and Development
Motilal Pesticides (India) Pvt.
305 Manjusha. 57, Nehru Place
New Delhi-110019

P. Kaushish
Marketing Executive
Agrochemicals
BASF India Ltd.
501, New Delhi House
27, Barakhamba Road
New Delhi-110 001

A. Basu
Manager
Agricultural Chemicals
India-South Asia
Du Pont Far East, Inc.
22, Basant Lok Community Centre
Vasant Vihar

A. R. Panicker
General Manager
Hindustan Insecticides, Ltd.
(A Government of India Enterprise)
Hans Bhawan (Wing-1)
1, Bahadur Shah Zafar Marg
New Delhi-110 002

Dr. Ing. S. Satyamurty
General Manager
Eicher Research Centr
Ballabgarh 121 0040

D. Ramesh
Deputy Manager Hydraulics
Eicher Goodearth, Ltd.
Eicher Research Centr
Plot No. 8, Sector 4,
Ballabgarh 121004

Homi D. Jijina
General Manager
Escorts Ltd.
Corporate Research and Development
Centre
25 KM. Mathura Road
Faridabad-121001

S. Chaudhuri
General Manager
Public Relations and Rural Development
IEL Ltd.
Ashok Hotel (Annex), 3rd Floor
50-B Chanakya Puri
New Delhi

H. C. Srivastava
Head, Agriculture Division
Hindustan Lever Research Centre
Andheri (East)
Bombay-400 099

P. Kapur
General Manager
Agri Products
Hindustan Lever, Ltd.
165/166 Backbay Reclamation
Bombay-400 020

Irfan Khan
General Manager
Corporate Communications
Hindustan Lever, Ltd.
165-166, Backbay Reclamation
Bombay-400 020

Subrata Roy
Deputy Director
Business India
The Editorial Office
Nirmal Bldg., 16th Floor
Nariman Point
Bombay-400 021

R. B. Barwale
Director
MAHYCO
Maharashtra Hybrid Seeds Co., Ltd.
19, Rajmahal, 84, Veer Nariman Road
Bombay-400 020

Dr. V. R. Gadwal
Manager Research
Maharashtra Hybrid Seeds Co., Ltd.
19, Rajmahal, 84, Veer Nariman Road
Bombay-400 020

G. M. Chopra
Director and General Manager
Alchemie Research Centre Pvt. Ltd.
Research Centre for Indian Explosives, Ltd.
CAFI Site
P.O. Box 155
Thane-Belapur Road
Thane 400 602

P. N. Pande
Product Manager (Pesticides)
Camphor and Allied Products, Ltd.
Universal Building, 1st Floor
Asafali Road
New Delhi-110002
Pesticides Division
Express Towers, Nariman Point
Bombay-400 021

Raj Kaul
Commercial Director
Bayer (India), Ltd.
Pesticides Division
Express Towers, Nariman Point
Bombay-400 021

Dr. G. L. Jain
Chief Geneticist
Venkateshwara Hatcheries Private, Ltd.
13/6 Milestone, Panshet Road
P.O. Girinagar
Pune-411 025

S. B. Thorat
Director
Venkateshwara Hatcheries Private, Ltd.
13/6 Milestone, Panshet Road
P.O. Girinagar
Pune-411 025

Simon J. Streatfield
President
Cynamid India, Ltd.
Nyloc House
254, D2, Dr. Annie Bessant Road
P.O. Box 9109
Bombay-400 025

C. D. Sipahimalani
Director
Agricultural Products
Cynamid India, Ltd.
Nyloc House
254, D2, Dr. Annie Bessant Road
P.O. Box 9109
Bombay-400 025

Dr. T. D. Pimpale
Product Manager
Pesticides
Cyanamid India, Ltd.
Agricultural Department
Nyloc House
254, D2, Dr. Annie Besant Road
P.O. Box 9109
Bombay-400 025

S. S. Date
General Manager
Kirloskar Brothers, Ltd.
Udyog Bhavan, Tilak Road
Pune 411 002

Prem Kishore
Associate Vice President
Kirloskar Brothers, Ltd.
Udyog Bhavan, Tilak Road
Pune 411 002
N. M. Eswaran
Madras Office
Sumitomo Corporation
Third Floor
Eldorado Building
112, Nungambakkam High Road
Madras-600 034

B. V. Rao
Managing Director
Venkateshwara Hatcheries
Private, Ltd.
Pune-411 025
Hyderabad-500 035

V. M. Hardikar
Vice President (Marketing)
Kirloskar Brothers, Ltd.
Udyog Bhavan, Tilak Road
Pune-411 002

Y. A. Pradhan
Manager
Rallis India, Ltd.
Fertilizers and Pesticides Division
Thane-Belapur Road
P. B. No. 91
Thane-400 601

Dr. C. B. Jagannatha Rao
Chief
Agro. Biology Division
Pest Control (India)
Private, Ltd.
Nishat Building
6-Lady Curzon Road
P.O. Box 5023
Bangalore-560 001
Karnataka

A. Abraham
Chairman
The Compound Livestock Feed
Manufacturer's Association of India
111, Mittal Chambers
Bombay-400 021
Dr. K. Srinivasan
Technical Managerers
Lipton India, Ltd.
10/1, Palace Road
Bangalore-560 052

V. Agnihothrudu
Rallis Agrochemical Research Station
Fertilizers and Pesticides Division
Rallis India, Ltd.
Plot Nos. 21 and 22
2nd Phase Peenya Industrial Avenue
Bangalore-560 058

M. S. Mithyantha
Analytical Chemist
Rallis Agrochemical Research Station
Plot Nos. 21 and 22
2nd Phase Peenya Industrial Avenue
Bangalore-560 058

T. B. Gour
Entomologist
Rallis Agrochemical Research Station
Plot Nos. 21 and 22
2nd Phase Peenya Industrial Avenue
Bangalore-560 058

T. P. Suresh
Toxicologist
Rallis Agrochemical Research Station
Plot Nos. 21 and 22
2nd Phase Peenya Industrial Avenue
Bangalore-560 058

T. R. Sawheny (Roger)
General Manager
Pioneer
8-1-39 Tolichowki
Hyderabad-500 008
Andhra Pradesh

Hans R. Bhardwaj
Research Manager
Pioneer
8-1-39, Tolichowki
Hyderabad-500 008
Andhra Pradesh

Lakshmi Nath Wahi
Secretary
Indian Sugar Mills Association
Sugar House, 39, Nehru Place
New Delhi-110019

N. K. Bhat
Indo American Hybrid Seeds
17th Cross, 2A Main K. R. Road
BSK II Stage
Bangalore-560 070

R. S. Deshpande
Assistant Professor
Institute for Social and Economic
Change, Hagarbhavi
Bangalore-560 072

Dr. K. C. Jain
Plant Breeder
ICRISAT (International Crops
Research Institute for the
Semi Arid Tropics)
ICRISAT Patancheru P.O.
Andhra Pradesh-502 324

REFERENCES

Desai, Ashok V., "The Origin and Direction of Industrial R&D in India", Research Policy 9(1980), 74-96.

Evenson, Robert, Putnam, Jonathan, and Evenson, Donald D., "Agricultural Invention and Legal Systems in Developing Countries", mimeo Economic Growth Center, Yale University, 1983.

Government of India, Department of Scientific and Industrial Research, "In-house Research and Development in Tractor Industry", New Delhi, May 1985.

GOI, Department of Science and Technology, Research and Development Statistics 1982-83, New Delhi, 1984.

Gupta, S. K. (ed.), Indian Poultry Industry 1984, New Delhi, 1984.

Jain, H. K. and Banerjee, S. K., "Problems of Seed Production and Procedures of Varietal Release in India",Seed Research Vol. 10(1), 1982.

Mikkelsen, Kent W., "Inventive Activity in Philippine Industry", PhD Thesis, Economics Department, Yale University, 1984.

Morehouse, Ward, "Technology and Enterprise Performance in the Indian Tractor Industry: Does Self-Reliance Measure Up?",Economic and Political Weekly, December 20, 1980.

Nayar, Baldev Raj, India's Quest for Technological Independence, Vols. I and II, New Delhi, Lancers Publishers, 1983.

Sarathy, A. P. (ed.), Indian Pesticides Directory Second Edition, Bombay: Scientia Publications Pvt. Ltd., 1985.

Sinha, Arun P., "Innovation in Indian Firms: Myths and Reality", Economic and Political Weekly, September 3 and 10, 1983.

Shriram, V. and Associates "Top 300 Companies", New Delhi: Economic and Scientific Research Foundation, 1979.

Thomas, T., Managing a Business in India, Bombay: Allied Publishers, 1981.