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A CASE STUDY :

Agricultural research and development in the developing world : Too little, too late?

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SUMMARY : The developing world faces the tough task of producing adequate food to meet the demands of its burgeoning population, as yield levels of major crops have struck a plateau. Food and nutrition security being the major concerns, agricultural R and D in less-developed countries is at the crossroads. The most significant demographic characteristic is that 'virtually all population growth will occur in the poorer parts of the world'. The increasing population besides exerting pressure on food demand has also been striving to boost production and bring about balance in the demand–supply chain. Both rich and poor countries depend on the agricultural research conducted in the private and public laboratories of these countries. Those among the developing economies which strove to put their domestic agricultural R and D base into a state of preparedness for acclimatizing and absorbing the 'imported technology' on the one hand and to put the needed market and institutional arrangements in place on the other, emerged as the primary drivers of the adoption of new technologies. The need of the hour is to assess the ground reality is that whether agricultural R and D in the Third World countries is 'too little or too late'. The top five countries in terms of agricultural R and D spending are the United States, Japan, China, India, and Brazil. The government sector is still the main player in public agricultural R and D, in terms of execution as well as funding. Although government allocations still present the main source of funding, there are again considerable differences across countries. A number of developing countries depend on non-governmental sources of funding. The majority of international agricultural R and D is carried out by the 15 research centers of the Consultative Group on International Agricultural Research (CGIAR). India has one of the largest and most complex agricultural research systems in the world, with more than a century of organized application of science to agriculture. The loss of dynamism in the agriculture sector is the major cause of crisis in Indian agriculture. Research and development (R and D) has potential to offer long-term solutions to the problems of agriculture sector.In India, the public sector plays a major role in agricultural R and D. In the twelfth five year plan, the Indian Government addressed this deficiency by committing a significant percentage of AgGDP to agricultural R and D. ICAR and the SAU system are making a concentrated effort to better target research and to improve co-ordination of programmes across the various institutions. Food and nutrition security being the major concerns, agricultural R and D in less-developed countries is at the crossroads. Intensity of ARD in the developing nations is too little. But, it's never too late. Technology gap between developed and developing countries is increasing both, qualitatively and quantitatively.

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In the early 21st century, the science of agriculture has started to shift gears, just as it did 100 years ago. At the beginning of the 20th century, Charles Darwin's theory of evolution, the pure-line theory of Wilhelm Johannsen, and the rediscovery of Gregor Mendel's laws of heredity contributed to the rise of plant breeding, while Louis Pasteur's germ theory of disease and the development of vaccines opened up lines of research in the veterinary sciences. The next epoch in agricultural technology will also have fundamental biological science at its foundation. Today, scientists armed with new molecular biologies involving genomics, proteomics, recombinant DNA and supporting informatics technologies are delving deeper into the genetics of life, with potentially profound and pervasive implications for agriculture worldwide. The context in which that science will take place has evolved and shifted as well. The public purpose in agricultural R and D is less focused and more closely scrutinized than it was a century ago; the general public seems less trusting of some areas of science and perhaps of some scientists (National Science Board, 2002) and marked changes are taking place in the intellectual property regimes relating to the genetic resources used in agriculture and the technologies used to transform them (Boettiger *et al*., 2004 and Pardey *et al.*, 2004). Complacency has crept in too. Some question the need for continued public funding at recent levels, suggesting that the world's food problems are being solved or constrained by things other than R and D, or that the private sector will do the job (Runge *et al*., 2003). Others see a scientific apartheid taking shape, with large parts of the developing world being left behind or denied the prospects science has to offer for growth, development, and prosperity (Serageldin 2001).

The world's agricultural economy was transformed remarkably during the 20th century. The agricultural productivity growth that fueled this change was generated primarily by agricultural R and D financed and conducted by a small group of rich countries—especially the United States, but also Japan, Germany and France. In an increasingly interdependent world, both rich and poor countries have depended on agricultural research conducted in the private and public laboratories of these few countries, even if they have not contributed to financing the activity.

But now the rich-country research agendas are shifting. In particular, they are no longer as interested in simple productivity enhancement. Dietary patterns and other priorities change as incomes increase. Food-security concerns are still pervasive among poor people, predominantly in poor countries. In rich countries we see a declining emphasis on enhancing the production of staple foods and an increasing emphasis on enhancing certain attributes of food (such as growing demand for processed and so-called functional foods) and on food production systems (such as organic farming, humane livestock production systems, localized food sources and "fair trade" coffee). In addition to growing differences between rich and poor countries in consumer demand for innovation, research agendas may diverge because of differences in producer and processor demands. Farmers in rich countries are demanding high-technology inputs that often are not as relevant for subsistence agriculture (such as precision farming technology or other capital-intensive methods). As well as differences in value-adding processes to serve consumer demands, differences in farm production technologies are emerging to serve the evolving agribusiness demands for farm products with specific attributes for particular food, feed, energy, medical, or industrial applications. As rich-country research responds to these changing patterns of demand, the emphasis of the science is shifting in ways that could undermine the international spillovers that contributed significant past gains in food production throughout poorer countries. These spillovers are not generally well understood, and their importanceis underappreciated (Alston and Pardey, 2006).

The developing world faces the tough task of producing adequate food to meet the demands of its burgeoning population, as yield levels of major crops have struck a plateau. Food and nutrition security being the major concerns, agricultural R and D in less-developed countries is at the crossroads.The most challenging task for planners is to match the demand and supply of food. While the demand depends largely on the rate of growth of population, the supply depends on the application of improved production technologies on a given land, especially in big and land-scarce countries. With population expansion, demand for food has been ever increasing. While it took 102 years (between 1825 and 1927) for the world population to increaseby one billion, the next billion took only 33 years (between 1927 and 1960), the subsequent billion has taken as little as 15 years (between 1960 and 1975) and the gap continues to further reduce (Pal and Byerlee, 2006). The average annualrate of growth of world population has remained fairly high even in the recent decades, e.g. 1.98 per cent during the sixties, 1.82 per cent during the seventies, 1.70 per cent during the eightiesand 1.41 per cent during the nineties1, 1.14 per cent during the lastdecade (2001–10) with a current population around 7.02 billion.

The most significant demographic characteristic for the next century is that 'virtually all population growth will occur in the poorer parts of the world'. The increasing population besides exerting pressure on food demand, has also been striving to boost production and bring about balance in the demand–supply chain. Aconsistently rising production largely realized through technology-driven productivity or yield break throughs, is the strategic answer on the supply side. Agricultural growth and expanding food supplies have been sustained in varying forms and content by agricultural R and D. Since the middle of the 20th century, a small group of rich countries (largely USA, followed by Japan, Germany and France) has been the cradle for agricultural R and D. Bothrich and poor countries depend on the agricultural research conducted in the private and public laboratories of these countries. The public purpose and global out reach in agricultural research of these countries were manifested in their persistent efforts to innovate and deliver component technologies, almost philanthropically, to facilitatean increase in farm-level productivity and food security among the developing economies.Those among the developing economies which stroveto put their domestic agricultural R and D base into a state of preparedness for acclimatizing and absorbing the 'imported technology' on the one hand and to put the needed market and institutional arrangements in place on the other, emerged as the primary drivers of the adoption of new technologies. On the positive side, the spread of Green Revolution Technology in certain regions of India, during the late sixties, is the strongest testimony of how R and D could transform a food-deficit and food-importing economy into a food self-sufficient economy.

Numerous challenges to agricultural technology that would have a huge bearing on agricultural growth and its sustainability over time are emerging at the local, national and international levels that cannot be tackled through conventional research alone. The new agriculture has inevitably become a more involved cob-web of bio-techand genetic complexities. Given the increasing trend to wards public–private partnership in extension education, farmers' own education, knowledge and comprehension would be inescapable inputs. In brief, formidable R and D challenges in and around agriculture, have alreadyset in. These are likely to assume more daunting technical complexities and going by the meager R and D effort by agreater majority of developing countries, they may soonland themselves into a technology gap.

The world's agricultural economy underwent a remarkable transformation during the latter half of the 20th centuryled by the agricultural productivity growth generated primarily by agricultural R and D financed and conducted by a small group of rich countries. The need of the hour is to assess the ground reality is that whether agricultural R and D in theThird World countries is 'too little or too late'.

Agricultural R and D- Historical prespective:

Since the beginning of civilization, man has been persistently striving to develop different skills, knowledge and tools for his use. For instance, methods of irrigating and fertilizing crops were invented even before agriculture first appeared in the recorded history (Pal and Singh, 1997). Centuries of cumulative inventive efforts, however, were not enough to bring about

Table 1: Sector and institutional classifications for measuring resources invested in agricultural R and D

Sector categories	Institutional categories	Definitions
Public sector	Government	Research organizations directly administered by the national government
	Higher education	Academic agencies that combine university-level education with research in agriculture
	Non-profit	Agencies not directly controlled by the national government and without an explicit profit-making objective like commodity boards in agriculture
Private sector	Business	Entities with the primary aim of producing goods and services for profit; some of these companies have a R and D unit dedicated to agricultural research
	Public enterprises	Enterprises that are owned by government units; their primary activity the marketing and sale for profit of goods and services produced by private enterprise
International	CGIAR	Apex body to facilitate agricultural R and D at the global level

fundamentally new methods of production and augmenting food availability and the standard of living of people. Spectacular break through in the history of agricultural technology came only during the 20th century, out stripping all those achieved earlier in terms of composition, depth and power of the changes. These included farm power sources, introduction of new crops and better farming techniques like dry farming, use of genetics to develop new strains of plants and animals, animal husbandry, use of electricity in agriculture and chemical control of pest and disease in crops. Clearly, the 20th century concept of farm technology involved both science and engineering and depended on their free interaction.

The initial important developments in agricultural research during the first half of the 20th century did take place in the industrial countries particularly USA. But, the situation started changing since 1950s. The former colonies in Africa and Asia, post-liberation from the colonizers, have initiated large scale reforms to improve their agriculture, adopting the Western methods modified to their situations. In short, a sort of spill-over of production technology economies took place from the advanced countries to the developing countries.

Trends in agricultural R and D investments:

Public agricultural R and D spending:

Global public agricultural R and D investment (including government, non-profit and higher education sectors) totaled $23 billion in 2005 PPP dollars in 2000, the latest year for which comparable global data are available. Public agricultural R and D, however, has become increasingly concentrated in just a handful of countries (Pardey *et al*., 2006). The top five countries in terms of agricultural R and D spending, the United States, Japan, China, India and Brazil, spent 48 per cent of total global public agricultural R and D from 41 per cent in 1991. Mean while,only 6 per cent of the agricultural R and D investments world wide were conducted in 80 (mostly low-income) countries that combined had a total of more than 600 million people and accounted for 14 per cent of the world'sagricultural land area. In Latin America about three-quarters of the total public investments in agricultural R and D were spent by only three countries, Brazil, Mexico and Argentina. Since the mid-1990s the investment gap has widened between the region's low and middle income countries, which in part was the result of sharp cuts inresearch expenditures in some of the poorer, more agriculture-dependent countries such as Guatemala and El-Salvador. Similarly in Asia, although less pronounced, a knowledge divide between the region's rich and poor countries and the scientific "haves" and "have-nots" is becoming more and more visible. During the period1981–2002, especially in the latter decade of the period, both China and India intensified their agricultural research spending while other smaller countries, such as Malaysia and Vietnam, also realized impressive agricultural R and D spending growth. But other countries such as Pakistan, Indonesia and Laos, proved sluggishand at times negative, largely due to the Asian financial crisis, the completion of large donor-financed projects, or high rates of inflation. In Africa agricultural research has been historically better funded in some countries such as Kenya and South Africa compared to a large number of the very poorest countries in the region, specifically in Western Africa. But there is no evidence that this divide has increased over the past few decades this in part because of the donor dependency of many countries as well as the erratic nature of government anddonor support to agricultural research over the years.

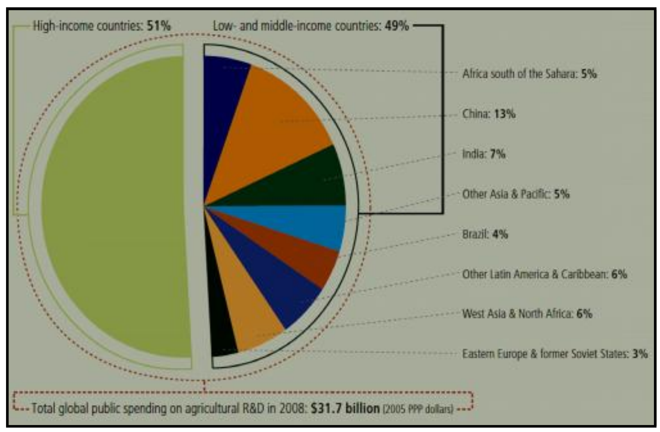


Fig. 1 : Average public sector spend in agriculture research

Table 2: Dollar invested in agriculture research for every $100 of agriculture output in 2012

Countries	Agriculture spend*
Pakistan	0.21
Nepal	0.23
India	0.40
China	0.50
Sub-Saharan Africa	0.61
Latin America	1.14
Brazil	1.80

Source: IFPRI

Private agricultural R and D spending:

Data on private sector investments in agricultural R and D remain very limited. In 2000, the only year for which global estimates are available, the private sector spent an estimated $16 billion 2005 PPP dollars 41 per cent of global total (public and private). Almost all of these private sector investments were made by private companies performing agricultural R and D in high income countries. Investments by the private sector in the developing world accounted for only 2 per cent of the total public and private agricultural R and D investments in 2000; of which most was done by Asian private companies (Beintema and Stads, 2010). The private sector plays a stronger role in terms of funding agricultural research given that many private companies contract research out to government and higher education agencies. But the role of the private sector in most developing countries is and will remain small given the limited funding opportunities and incentives for private research. Furthermore, most private sector research in developing countries focuses on the provision of input technologies or technical services for agricultural production. Most of these technologies are, however, produced in the high income countries (Pardey *et al*., 2006). Food and other postharvest accounted for 30-90 per cent in Australia, the Netherlands and New Zealand, chemical research between 40-50 per cent in the United Kingdom and United States. Pray and Fuglie (2001) found that share of private sector investments in the total agricultural R and D investments had grown during mid-1980s to mid-1990s in China, India and Indonesia (in a sample of seven Asian countries) and was higher than the growth in public sector investments. But the growth in private sector investments was uneven across subsectors. Investments in the agricultural chemical sector and, in lesser extent, the livestock sector increased substantially while growth was slower in other subsectors such as plantation crops and machinery.

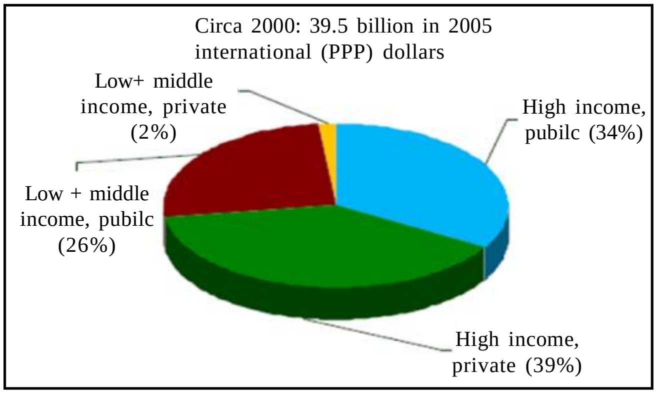


Fig. 2 : Composition of public and private agricultural research investments

International agricultural R and D investment:

The majority of international agricultural R and D is carried out by the 15 research centers of the Consultative Group on International Agricultural Research (CGIAR). The first four centers were established during the late1950s and the 1960s, with considerable financial support from the Rocke feller and Ford Foundations. During the1970s, the number of centers increased to 12 and the funding received per center increased over the decade. This led to a tenfold increase (in nominal terms) in the total CGIAR investments. Total funding continued to increase during the 1980s, but at a lower pace. During the 1990s, however, total funding grew less than the increase in the number of centers and spending levels per center could not be maintained. Since 2000, overall funding to the CGIAR has increased, but a larger proportion of this funding is support for specific project and programmes of research involving different centers and non-CGIAR research organizations (Beintema *et al.*, 2008 and Pardey *et al*., 2006).

There a number of other international research providers, mostly with a regional or sub-regional focus. For example, the two largest non-CGIAR agencies conducting research in Africa are the French-head quartered International Co-operation and Agricultural

Table 3: Agricultural R and D in these regions

Region	Non-CGIAR agencies conducting research
Africa	CIRAD -International Co-operation and Agricultural Research for Development
	IRD- Institute for Research and Development
Asia	JIRCAS- Japanese International Research Center for Agricultural Sciences
Latin	CATIE- Agronomic Center for Research and Education
America	CARDI-Caribbean Agricultural Research and Development Institute

Research for Development (CIRAD) and the Institute for Research and Development (IRD). In the Asia region, the Australian Centre for International Agricultural Research (ACIAR) does not conduct research in the region's developing countries itself but develops international agricultural research partnerships. The Japanese International Research Center for Agricultural Sciences(JIRCAS) mandate covers all developing countries; most of its agricultural research is done in Asia. Two important regional agencies that conduct agricultural research in Latin America and the Caribbean are the Agronomic Center for Research and Education (CATIE) and the Caribbean Agricultural Research and Development Institute (CARDI). A number of other international agencies are also active in agricultural R and D in these three regions.

Indian perspective:

India has one of the largest and most complex agricultural research systems in the world, with more than a century of organized application of science to agriculture. A proactive policy by the government toward agricultural research and education (R and E), coupled with support from a number of bilateral and multilateral donors, has produced an institutionally diverse research system that has achieved many successes, most notably the Green Revolution in the 1960s and 1970s. The country is not only self-sufficient in food but also commands a strong position in world markets for some commodities. Not with standing these achievements, the system must now ensure a more complex and expanding research investment on sustaining natural resources, enhancing product quality and ensuring food safety, in addition to increasing household food and nutritional security and reducing poverty. These new challenges require a rematching of needs with resources and a reorientation of R and D policy. Redirection of R and D policy and strategy must be in tune with national and international developments. Small holder farmers (those of less than 2 hectares) constitute about 80 per cent of total farm holdings and occupy 40 per cent of the agricultural land area. Despite a rapid increase in livestock production, the crop sector still contributes three-quarters of the total value of agricultural output.

Overall, India's agricultural achievements are impressive, with increased percapita food production and accumulating food stocks. Despite this success, India still faces many challenges in increasing agricultural productivity. First, to reduce poverty and malnutrition, which are most prevalent in rural areas, India needs notonly to improve the availability of food (through higher production and better distribution) but also to generate income and employment opportunities for the poorto provide them with access to food. Second, because accelerated economic growth and rapid urbanization are driving demand for high-value commodities, particularly livestock and horticultural products, future agricultural growth needs to bemuch more diversified. Third, sustainable management and use of natural resourcesis a growing challenge, with depletion of ground water, agro-chemical pollution and land degradation by water-logging, salinity, soil erosion and deterioration of soil fertility. Fourth, public investment in agriculture in real terms has shown a persistent decline, while subsidies for agriculture have increased over time despite the new economic policies. The decline in public investment has serious implications for agricultural growth and poverty reduction.

The loss of dynamism in the agriculture sector is the major cause of crisis in Indian agriculture. This can be attributed to a wide range of problems including poor growth in the agriculture than non-agriculture sector. More specifically, the sector is facing problems of declining output and total factor productivity growth, emerging climate change and supply-side constraints, etc. Reverting declining factor productivity requires concerted efforts in refining the available technologies and developing new technologies. The emerging climate change points towards the proper management of resources like land and water to meet the food-security goals. Persisting problems of poverty, debt-trap, poor access credits, etc. are dragging the sector into distress condition. Other sets of issues like large post-harvest losses and weak linkages (both forward and backward) are also causing problems in agriculture.

Structure of agricultural R and D in India:

Indian Council of Agricultural Research (ICAR)

⇩

State Agricultural Universities (SAUs)

⇩

Private sector at both sector and commodity levels

There is "Under investment" In agricultural R and D:

The "under investment hypothesis" is a straight forward application of margin a list economic theory: if

Table 4: Agricultural R and D spending in India (million 2005 PPP $)

Year	Per researcher	Per agricultural labourer	Per capita
1996	0.07	4.05	0.95
1997	0.08	4.36	1.01
1998	0.09	5.23	1.2
1999	0.11	6.23	1.43
2000	0.11	6.2	1.41
2001	0.11	5.93	1.34
2002	0.11	5.86	1.32
2003	0.12	6.02	1.35
2004	0.12	5.91	1.32
2005	0.14	6.57	1.47
2006	0.15	6.78	1.51
2007	0.16	6.96	1.55
2008	0.19	8.04	1.78
2009	0.20	8.53	1.88

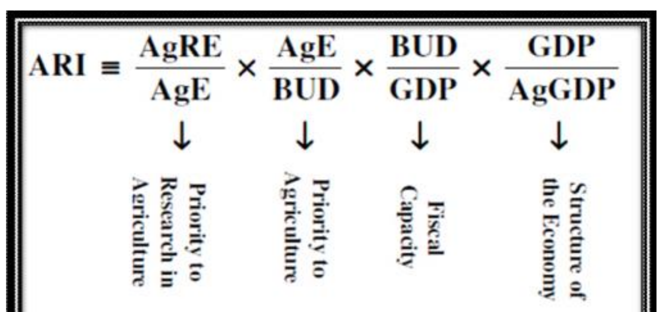
Source: Ministry of finance, Finance accounts, over the years

Table 5: Sector-wise total agricultural R and D spending in India (million 2005 PPP$)

Year	Public sector	Government sector	Higher education sector
1996	928.6	545.7	383
1997	1012.3	621.2	391.2
1998	1226.6	816.5	410.1
1999	1477.5	1011.2	466.3
2000	1486.6	942.6	544
2001	1440	930.5	509.6
2002	1441.3	902.4	538.9
2003	1496.5	955.2	541.3
2004	1487.9	966.7	521.2
2005	1676.2	1101.2	575
2006	1752.5	1140.6	611.9
2007	1815	1140.9	674.2
2008	2121.2	1385.9	735.3
2009	2276.1	1468.7	807.4

by policy decision or a budget constraint the social value of the last unit of product consumed (or input employed) is greater than the social cost, then there is under consumption or under use of the factor because it would pay to borrow until the social gain and social cost are equal. If projects are ranked in descending order by their expected rates of return (call it the marginal efficiency of investment) and the return of the last project under taken is higher than the social (opportunity cost of capital), this is prima facie evidence of under investment. Hundreds of individual studies of the social rate of return to research consistently show that the rate of return to public investment in agricultural research (40-50%) is higher than either the social rate of return on capitalor other opportunities for public investment. In general the return to public investment is higher than the privaterate of return even after allowing for the marginal excess tax burden of the tax collection system and the returns accrued to farmers. This because it is impossible to appropriate many of the benefits associated to the research done by private firms (Widmer *et al.*, 1988 and Evenson and Larry, 1995). There is no tendency for the rate ofreturn to decline over time. Furthermore, it appeared that the rates of return may be higher when the research isconducted in more-developed countries (Alston *et al.*, 2000). Roseboom (2002) defines the “underinvestment gap” as the difference between the economic rate of return of the marginal R and D project and the social rate of return.

Placing a country’s agricultural R and D efforts in an internationally comparable context requires measures other than absolute levels of expenditures. The most common research intensity indicator is the Agricultural Research Intensity Ratio (ARI). It the ratio formed by the sum of agricultural R and D investments (AgRE) over the agricultural gross domestic product (AgGDP). For two decades the ARI was held up as an instrument of coercive comparison: if a country’s neighbor with similar characteristics had a higher ARI, the presumption was that the country was not trying hard enough to support agricultural research. The ARI first appeared in a World Bank sector paper on Agricultural Research in 1981.



Adapted from Elliott (1995).

The four meaningful elements in this identity are:

– *Priority to agricultural research*: The share of agricultural research in total agricultural expenditure (AgRE/AgE)

– *Priority to public agricultural expenditure* : The share of public expenditure on agriculture in total public expenditure (AgE/BUD)

– *Fiscal effort (or Fiscal capacity*): The share of public revenue and expenditure in the Gross Domestic Product (BUD/GDP)

– *Structure of the economy*: The inverse of agriculture's share in the Gross Domestic Product (GDP/AgGDP).

The need for collaboration between the public and private sectors:

There is no greater incentive for collaboration between the public and private sectors in agricultural research than the enormous challenge posed by global food security, which will require that limited global resources be used in the most effective way to develop sustainable systems that also conserve natural resources. In the last decade there has been a strong trend for governments of donor countries to encourage and in some cases require, increased participation by the private sector in agricultural research.The significant investment of the private sector in biotechnology, perhaps more than any other single factor, has clearly demonstrated the need for and significant advantages associated with collaboration between the public and private sectors in agricultural research and development. Indeed, the requirement for a minimum critical mass in R and D, particularly in biotechnology, has been the major stimulus for most of the mergers and acquisitions in the private sector. The development of biotechnology applications is capital intensive, requiring substantial long-term investments, which often can be mobilized only by the private sector. Thus, most investments in biotechnology are made by the private sector. Amajor challenge for both the private sector and the public sector is to find ways to collaborate in sharing and transferring appropriate new and superior technologies, which often are proprietary, from the private sector to the public sector.

Collaboration between the public and private sectors is essentialin planning future research strategies that are global in coverage and requires co-operation by all the major entities in agricultural research in industrial and developing countries. This co-operation should ensure that limited global resources in agricultural research are used in the most effective way to strategically address the issue of food security in the developing world by optimizing the comparative advantages of the public and private sectors.

Conclusion:

There has been "under investment" in agricultural R and D both in terms of foregone benefits and in terms of preparedness to meet established political comments to reduce poverty and hunger. Countries at all levels of development have the fiscal capacity to develop a sufficient system to participate in and benefit from what will, it is hoped, be a coherent and effective global system. By treating the establishment of legal frameworks, institutional arrangements and governance processes as "investments" we will have to keep in mind that the processes must have positive results in terms of established goals. India has substantially increased its public funding of agricultural research since the late 1990s and this trend will likely continue in coming years. Nonetheless, India's research intensity ratio, measured as public agricultural R and D spending as a share of agricultural output, continues to be relatively low. In the twelfth fiveyear plan, the Indian Government addressed this deficiency by committing a significant percentage of AgGDP to agricultural R and D.No uniquely best system for all situations; goal is to find the most appropriate system. Investment in innovation is needed to support all components. Role of "institutions" is vital, partnerships and network are the cornerstones.

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