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Technological Challenges in Asian Agriculture in the 1990s

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This chapter outlines the technological challenges for Asian agriculture in the 1990s. I first briefly recapitulate the major sources of growth in Asian agriculture in recent decades—that is, the spread of modern rice and wheat varieties accompanied by increased use of fertilizer and improved irrigation. I argue that the contribution of these factors to increased food production in the future will be much smaller compared to the past two decades and that, to sustain growth into the 1990s and beyond, we need to seek new sources of growth. The prognosis is that, without a renewed effort in food grain production, the 1990s will be a period of increasing foodgrain deficits in some of the major countries of Asia, which have been self-sufficient for much of the period since 1970. The critical ingredients of a strategy to reverse these trends are discussed with emphasis on the technical-scientific and the institutional issues in technology development and transfer.

TECHNOLOGICAL CHANGE IN CEREALS SINCE THE 1950s

Over the past three decades, there has been a major switch from area increases to yield increases as the major source of growth in world cereal production. This phenomenon is true for the developing world as a whole and is especially marked in Asia. As recently as the 1950s, expanding area was the major source of increased cereal production in much of Asia. For many countries, area increases now make a negligible contribution to raising cereal production; and in some cases, notably China, the area sown to cereals has actually declined in the past decade, with increasing competition for land from cash crops and urbanization.

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TECHNOLOGICAL CHANGE IN FAVORABLE AREAS

Three important changes in production technology have contributed to rapid yield increases in favorable (mostly irrigated) environments, but each is now showing definite signs of slowing.

Modern varieties. The story of the rapid spread of modern varieties of wheat and rice in Asia is well known (Dalrymple 1985). Less spectacular but significant gains have also been made in maize, sorghum, and millet over much of Asia. However, in the favorable environments where modern varieties have had their greatest impact, almost all the area is now sown to modern wheat and rice varieties and there is little scope to exploit the switch from traditional to modern varieties as a future source of growth. Moreover, since the mid-1960s there have been no additional *major* breakthroughs in raising the yield potential of cereals, and none are likely to occur in the 1990s, at least at the farm level. Yield potential in new wheat varieties has risen at a steady rate of 0.7–1 percent per year since the release of the first semidwarf materials in the 1960s (CIMMYT 1989). In rice, no increase in yield potential has been achieved since the 1960s, although important gains have been made in earliness and disease and insect resistance (Pingali 1988).

Irrigation water. Increased supplies of irrigation water made a major contribution to raising yields in the 1960s and 1970s in much of Asia. For example, over the past twenty years the percentage of wheat area under irrigation rose from 50 percent to 72 percent in India and from 66 percent to 83 percent in Pakistan. However, in recent years, expansion in irrigated area has slowed drastically as the easier and less expensive irrigation sites have been developed (Levine et al. 1988).

Fertilizer. Fertilizer use per hectare of cultivated land has expanded rapidly in the past two decades at over 10 percent per year to reach 78 kg/ha in Asia. In both wheat and rice production, fertilizer levels have reached modest to high levels of over 100 kg/ha of nutrients in irrigated areas of Asia, and there are diminishing returns to increased fertilizer doses *at current levels of fertilizer efficiency.* At the margin, grain-nutrient ratios in wheat (the amount of grain produced for each kilogram of fertilizer nutrient applied) appear to have fallen to less than 7:1 in India and less than 5:1 in Pakistan, compared to ratios of over 10 in the early years of the "Green Revolution."

Together, modern varieties, improved supplies of irrigation water, and increased fertilizer doses accounted for over 75 percent of the total yield increases in rice and wheat in Asia in the 1970s and 1980s (Herdt and Capule 1983; CIMMYT 1989). But, there is clear evidence that the contributions of each of these factors to yield increases in favorable environments have reached a stage of rapidly diminishing returns. There is already evidence that rates of cereal yield increase have slowed in some countries that were the early beneficiaries of the Green Revolution (e.g., Pakistan, India, and Turkey in the case of wheat).

The gap between farmers' yields and those on experiment stations has also tended to narrow in the original Green Revolution areas. In the area surrounding the International Rice Research Institute (IRRI) in the Philippines, the highest yields obtained by farmers now surpass yields recorded on the IRRI experiment station (Pingali 1988). A similar trend for wheat has been observed in the Indian Punjab, where farmers' yields in Ludhiana District now average over 4 t/ha. Furthermore, much of the remaining yield gap in these areas is not economically recoverable (Herdt 1988). Hence, in the most advanced areas, farmers have successfully adopted most of the newer technologies, and there is little technology waiting "on the shelf" to be transferred to farmers.

Nevertheless, there are still large areas in favorable environments, such as Pakistan's irrigated Punjab, where yields remain low (2 t/ha) relative to potential yields, even though all farmers have adopted the improved wheat varieties and use modest to high levels of fertilizer. There is substantial potential to increase yields in these areas through a number of relatively small and incremental management changes that are specific to each area, such as better plant stand establishment, minimum and zero tillage, improved weed control, balanced fertilizer doses, and improved timing of irrigation water application. These factors could profitably increase wheat yields at the farm level by up to 50 percent in Pakistan's Punjab (Byerlee et al. 1986).

Finally, there are worrying indications that yields or productivity are falling in some of the best production areas. Flinn and De Datta (1984) have documented a decline in yields obtained on IRRI's experiment stations. In Pakistan's Punjab, farm yields of improved wheat varieties have remained unchanged since 1970 despite a steady increase in inputs supplied (especially fertilizer, which has risen from 40 kg/ha nutrients in 1970 to 114 kg/ha in 1986), indicating a possible decline in productivity. The reasons for this decline are not yet well understood but may relate to soil micronutrient problems, soil structure, soil health, poor stand establishment, low-quality irrigation water from tubewells, and worsening weed problems. Clearly, sustaining cereal yields and productivity in these favorable areas is a critical challenge in the 1990s.

Technological Change in Less Favorable Areas

The use of modern varieties and fertilizer has also expanded steadily into less favorable areas, especially in the past decade. For example, 50 percent of the sorghum and millet area in India is estimated to be sown to modern varieties, much of it in marginal areas. Semidwarf wheat varieties have spread to most of the rainfed areas receiving over 500 mm of rainfall annually, and they are diffusing slowly into the dry areas receiving less than a 500-mm annual rainfall (CIMMYT 1989). However, the yield impact of semidwarf varieties in marginal areas is much smaller, in part because of lower yield potential and in part because use of purchased inputs is less profitable and more risky. CIMMYT estimates that in irrigated areas of South Asia semidwarf wheat varieties grown with modest levels of fertilizer provided a 40–50 percent jump in yields over traditional varieties. In dry rainfed areas, the equivalent gain in yields of the semidwarfs is estimated to be less than 10 percent. Similarly, Barker and Duff (1986) estimated expected yield gains from rice research in favorable rainfed areas to be twice those in less favorable rainfed areas.

THE CHALLENGE OF FOODGRAIN SUPPLY IN THE 1990s

Almost all recent projections indicate a growing gap between supply and demand for food products in the 1990s in Asia, given current trends. The FAO (Food and Agricultural Organization of the United Nations) projects an increase in demand for all food of 3.1 percent per annum for the region and 2.5 percent for cereals. Food and feed demand will be increasingly driven by rapidly rising incomes in the region, projected to average 3 percent per year. Demand will increase fastest for income-elastic products such as livestock products and their derived demands for feed grains (FAO 1987). The FAO projections indicate a widening gap between supply and demand for cereals in the region and more in-depth projections for rice and wheat support this conclusion (Barker and Herdt 1985; CIMMYT 1989).

These projections do not suggest that famine will return to Asia. Rather they indicate that, if the food-feed demands of the growing populations and economies of Asia are to be satisfied in the 1990s, either substantial efforts will have to be made in agricultural research, extension, and irrigation, or food- and feedgrain imports will increase sharply.

TECHNICAL CHALLENGES IN THE 1990s

Plant Breeding and Biotechnology

Plant breeding has made a major contribution to increased food production over the past two decades. There are still substantial opportunities to achieve improved technology for specific problem environments and needs, such as wheat varieties for late planting in intensive cropping systems and rice varieties for nonirrigated environments. But, the rates of yield gains in these stressed environments will generally be much slower (CIMMYT 1989; Barker and Duff 1986). A large share of plant breeding research is now devoted to enhancing yield stability, especially the maintenance of disease and pest resistance in the face of evolving pest biotypes. Research managers and policy makers must recognize that substantial research resources will be required simply to maintain current yield levels in favorable environments.

Despite the excitement about the potential contributions of biotechnology to agriculture, the impact of this technology at the farm level will be small in Asia in the 1990s. Some commercial applications may be available, especially in rice (Anderson and Herdt 1988); however, they will consist largely of the incorporation of new sources of disease or pest resistance, based on a single or a few gene traits, to improve yield stability, rather than on changes that increase yield potential. Nonetheless, it will be important for countries in Asia to establish a capacity for biotechnological research on major crops to provide the technology for the even more challenging period beyond 2000.

Crop and Resource Management

Crop and resource management in the 1990s will need to play a much larger role in increasing productivity by exploiting the yield potential of available technology and in sustaining productivity gains while preserving the resource base. In addition, the trend toward reduced input subsidies and increasingly open economies will require greater production efficiency. In favorable environments, the emphasis will be on increasing the efficiency of water and fertilizer use, on minimum tillage and integrated pest control, and on sustaining cropping intensification over the long term.

Crop management will also increase in complexity because cropping intensity will be greater and because more emphasis will be given to input efficiency and sustainability (Pingali 1988; Byerlee 1987). Gains will be more incremental and less profitable than the gains from the Green Revolution technologies of the recent past. Hence, crop management will be more knowledge-intensive (a good example is integrated pest control) and will require more institutional support from extension, input suppliers, and irrigation systems (see below). Also, in marginal areas the key to increasing productivity will often be through crop management (in the form of improved tillage techniques, weed control, and rotations to conserve and efficiently exploit moisture) rather than through improved varieties.

Research on crop and resource management will need to be strengthened at the two extremes of adaptive and strategic research. Adaptive research is needed to tailor available technology to local conditions in relatively small and homogeneous areas. Few countries have developed the capacity to effectively undertake this type of location-specific and problem-oriented research. Second, strategic crop management research is needed for some major cropping systems to address widespread problems, such as the apparent decline in productivity in some systems, and to develop the knowledge and technology base for arresting this decline.

Intensification and Diversification

Three trends characterize many cropping systems in Asia—intensification, diversification, and specialization. Increases in cropped area now come largely from greater cropping intensity rather than expansion of the cultivated area. Diversification is driven by increased demand from a higher-income population for oilseeds, vegetables and fruits, and feedgrains. In some cases, these crops may displace basic foodgrains, but, given the necessity of maintaining foodgrain production, much of the area needed for "diversification crops" will come from fitting these crops into existing cropping systems to increase overall cropping intensity (Tetlay, Byerlee, and Ahmad 1989). Finally, with improved infrastructure and markets, there is a trend toward regional specialization that leads to the dominance of one or two major cropping patterns within a region and diversification across regions.

These trends in intensification, diversification, and specialization further increase management complexity and the importance of the sustainability issues discussed above. They also mean that varietal breeding of diversification crops, such as oilseeds and feed grains, will have to emphasize characteristics (especially earliness) that will allow those crops to fit into existing cropping systems.

SOME INSTITUTIONAL ISSUES FOR THE 1990s

Many institutional issues will have a bearing on whether the technical challenges of the 1990s are met successfully. Three issues are examined here: 1) national agricultural research programs, 2) private sector research and technology transfer, and 3) international agricultural research centers.

National Agricultural Research Systems (NARSs)

The success of the Green Revolution stimulated a rapid increase in agricultural research expenditures. In the 1970s in Asia, research expenditures rose by 10 percent per year in real terms. In the 1980s, this growth rate has slowed considerably, and in a number of important countries such as the Philippines and Indonesia research expenditures appear to have fallen in recent years. Most large countries in Asia now have well-established research programs for plant breeding in basic food crops, but even the stronger programs in the region experience cycles of maturity and decline (Ruttan 1986). National agricultural research systems (NARSs) are often unable to respond to changes in the environment, such as increasing cropping intensity or the outbreak of new diseases and pests. Research on crop and resource management is often still weak and fragmented among disciplinary groups. Above all, many NARSs lack a functional mechanism for diagnosing high-priority problems and setting the research agenda accordingly. Social science research capacity, which can help in diagnosing problems and evaluating technology, is still in its infancy in most NARSs. Continued investment in NARSs, both to sustain established programs and to broaden and improve the relevance of the research agenda, will be necessary in the 1990s.

Research management will need to develop appropriate incentive systems for promoting problem-solving research. Most NARSs still lack an effective mechanism by which the clients of the research system, the farmers, can effectively influence the selection of research priorities. Producer and commodity organizations, perhaps with a role in financing research, may be one way to more effectively link research and farmers (Ruttan 1986). Another recurring management issue is the low share of operating funds in the total research budget of many NARSs, which immobilizes researchers and restricts access to farmers and their fields. Investment in human resource development will also be a continuing need of many NARSs in Asia.

Agricultural research systems in the 1990s will require greater support from extension, input supply, irrigation management, and rural education to transfer and efficiently use available technology. Farmers' information and skills are much more important for the managerially complex, science-based agriculture now characteristic of much of Asia (Jain 1985). The Training and Visit extension system promoted by the World Bank has reformed many of the extension systems of the region, but in many cases the emphasis is still on a "recipe" approach to crop production, rather than the development of the broad understanding that farmers need to adapt and use the new technology efficiently. The level of rural education continues to be low in many areas of South Asia and West Asia and appears to be a growing constraint on improving productivity (Byerlee, 1987). The role of extension and education is likely to be particularly important in helping farmers to successfully utilize the results of crop and resource managment research with its greater complexity, emphasis on input efficiency, and relatively small incremental changes.

Private Sector Research and Technology Transfer

The private sector is playing an increasing role in plant breeding research in certain crops, especially in coarse grains and oilseeds, for which hybrid-seed industries are potentially profitable. Private sector research is also important for chemical and mechanical technologies, although most of such research still involves testing and adapting of technologies developed for the industrialized countries.

Private sector research usually places emphasis on areas with the largest market potential. This emphasis implies that research will initially focus on more favorable areas and on commercial farmers and may widen the differences between small farmers in marginal areas and their counterparts in favorable areas. Also, research on chemical technologies in the private sector will not necessarily promote input efficiency and sustainability by, for example, using such approaches as integrated pest management. Hence, public sector research systems will need to develop a strong complementary role to private sector research to ensure that social welfare objectives, such as equity and environmental issues, are adequately addressed.

Although the role of the private sector in research is limited to some crops, there is clearly an increasing role for the private sector in technology transfer. In many cases, input supplies, especially seed production and distribution, are still handled by the public sector and lack vigorous market promotion. The private sector can also play a larger role in supplying the information needs of farmers, especially in providing information on using purchased inputs more effectively (Byerlee 1987).

INTERNATIONAL AGRICULTURAL RESEARCH CENTERS (IARCs)

The role of international agricultural research centers (IARCs), such as CIMMYT (International Center for Maize and Wheat Improvement) and IRRI (International Rice Research Institute), has evolved considerably over the past decade. The IARCs play a vital role in germplasm and information exchange among NARSs, including strong NARSs in Asia, in India and China for instance. That role must be maintained into the 1990s. The IARCs are moving a larger share of resources from routine plant breeding research to strategic research, especially research related to stress tolerance and durable resistance to pests and diseases, and exploring new ways to increase yield potential. The international centers will also play a lead role in strategic research on crop and resource management that addresses major problems common to several countries.

An important part of the strategic research agenda of the IARCs for the 1990s will be investment in the new techniques of the so-called biotechnology. Given that much of this research will be conducted by the private sector for agriculture in industrialized countries, IARCs will at first have a potentially important role in adapting and applying the new techniques to problems of Third World agriculture, with the purpose of increasing the efficiency of conventional plant breeding programs. As discussed above, much of this work will emphasize pest and disease resistance, to enhance yield stability rather than to increase yield potential.

A major strength of IARCs in taking on these roles has been their relative isolation from political considerations and their sustained and assured budgetary support. It will be important to preserve these critical roles into the 1990s.

MARGINAL ENVIRONMENTS AND THE POOR

Development thought is notably "faddish," moving from an emphasis on community development in the 1950s to the "high-payoff input" model of technological change in the 1960s and 1970s to farming systems research, privatization, free markets, and policy reform in the 1980s. In the process of promoting growth-oriented approaches to development in the 1980s, we may have forgotten that the ultimate purpose of development is to reduce poverty, both relatively and absolutely. A critical instrument for achieving both growth and equity is the reduction in foodgrain prices through technological change. The 1990s should be a period of rededicating development efforts to alleviating poverty.

An important debate in the war on poverty in the 1990s will be the relative emphasis to be placed on favorable versus less favorable or marginal environments. Mellor (1988) estimates that about 500 million people live below the poverty line and that the absolute number of rural poor in Asia is evenly divided between favorable and less favorable environments. These statistics, plus the evidence presented earlier on expected lower payoffs to research investments in less favorable areas, suggest that caution is needed in abruptly shifting research attention from favorable to less favorable areas. Also there is evidence that technological progress in favorable areas will often benefit less favorable areas through "technological spillovers," labor migration, and lower food prices to the poor, including small farmers in less favorable areas, who are usually net food purchasers. Clearly, more research is needed to understand these complex relationships, but for the moment technological change in basic foodgrains in high-potential areas seems to be one of the most effective means to improve the incomes of the poor.

These conclusions also suggest that, although concern with sustainability of natural resources is often associated with marginal and fragile environments, the emphasis in the 1990s should be on sustainability in favorable areas, where increasing crop intensification and specialization appear to have important implications for sustaining productivity.

CONCLUSION

The rapid technological advances of the past two decades, especially in wheat and rice, should be seen as an extraordinary period of growth in world food production, especially in Asia. In the future we can expect much slower growth from the main sources of yield increases in recent years—spread of modern varieties, increased fertilizer use, and improved supplies of irrigation water. In the 1990s, ways must be found through improved crop and resource management to exploit this yield potential at the farm level, to promote input efficiency, and to sustain the resource base. Added to this challenge will be the need to increase the production of income-elastic food products, especially feedgrains, in the rapidly growing economies of the region, and the special challenge of increasing productivity and maintaining the resource base in less favorable areas. Rapid technological progress in foodgrain production *is* possible in the 1990s, but it will require a new research strategy, focusing on small incremental changes, and it will be more difficult to organize and manage.

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