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Plant Biotechnology in Asia

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Crop improvement facilitated by modern biotechnology is one the most significant developments in plant biotechnology research and development (R&D). Within Asia, plant biotechnology has largely been acknowledged as a key strategy for achieving food security and sustainable agriculture; many governments give high priority to agricultural biotechnology R&D. Current plant biotechnology research initiatives in selected Asian countries are presented in this paper. Many of these countries focus their biotechnology research on food crops and crops of high commercial value in the hope of meeting increasing food requirements and reducing poverty, particularly among resource-poor farming households. Harnessing biotechnology applications for the benefit of the poor, however, requires considerable attention in many areas, including appropriateness of and access to agri-biotechnology by resource-poor farmers, capability of the public sector in biotechnology R&D, regulatory framework that enhances the use of biotechnology applications, and public-private sector partnerships.

Key words: agriculture, Asia, biotechnology, biotechnology R&D, genetically modified crops, plant biotechnology

Developing nations of Asia have come a long way since the food crises of the 1960s. Over the last 30 years, higher productivity gains have been achieved, thanks to agricultural technologies such as high yielding varieties of rice and wheat, chemical inputs, irrigation, and improved cropping systems. Improvements in food security, poverty reduction, and per capita income initiated by the Green Revolution have been substantial and lasting (Rosegrant & Hazell, 2001). Between 1970 and 1995, per capita gross domestic product increased by 190%, cereal production doubled, and calorie availability per person increased by 24% (Asian Development Bank [ADB], 2001). In 1975, one out of every two Asians lived in poverty. By 1995, this ratio fell to one in four.

Government policies were at the heart of these economic and social gains. They reflected the belief that investments in increasing agricultural productivity were a prerequisite to economic development. These national policies were also supported by the public and private sectors and the international community.

Current Problems

Although life has improved for many Asians, about 900 million still live in poverty (ADB, 2001), and approximately 536 million of them remain undernourished. Growth rates of yields have slowed during the period between 1987 and 2001 (Huang, Pray & Rozelle, 2002). The intensification of agriculture and the reliance on irrigation and chemical inputs resulted in problems of soil salinity, pesticide misuse, and degradation of natural resources. The Green Revolution technologies were useful in the favorable and irrigated environments, but they had little impact on the millions of smallholders living in rainfed and marginal areas.

Further, there has been an alarming decline in public sector investments, which account for about 90% of the total investments in agricultural research and development. Asia's growth in agriculture research spending slowed to 4.4% in the 1990s from 7.5% in the 1980s (Pardey & Beintema, 2001). Even research investment by the Consultative Group on International Agricultural Research (CGIAR) is on the decline. The CGIAR has been instrumental in the spread of improved crop varieties of basic staples and new agricultural technologies; unfortunately, the budgets of many of its international agricultural research centers (not to mention many of their national program counterparts) have declined sharply in real terms over the past decade. For example, from 2001–2003, annual core funding for the International Rice Research Institute (IRRI), one of the CGIAR centers based in the Philippines, dropped by 26%; similar cuts are expected in the future ("Rice institute," 2003). This is most likely due to the fact that development agencies have tended to shift funding away from agricultural research and toward other priorities (Evenson & Gollin, 2003). This is real cause for concern, as these centers will have an important role to play in generating and sustaining future advances in agricultural technology for the developing world. These are the same centers that gave us those modern high-yielding varieties that were at the heart of the Green Revolution.

The above factors have been responsible for the decline in annual agricultural growth rates from an average of 3.3 % during 1977–1986 to about 1.5% during 1987–1996 (ADB, 2001).

Emerging Challenges

The future also presents a formidable challenge for Asia. In the next 20–25 years, Asia will have the highest absolute increase in population, from 3 billion to 4.5 billion. During the same period, the urban population will nearly double from 1.2 billion to 2 billion, as rural people move to the cities in search of employment. Urbanization and income growth frequently lead to shifts from a diet based on root crops (cassava, yam, and sweetpotato), sorghum, millets, and maize to rice and wheat, which require less preparation time, and to more meat, milk, fruits, vegetables, and processed foods. Meeting the food needs of Asia's growing and increasingly urbanized population requires increases in agricultural productivity and matching these increases to dietary changes and rising incomes. The demand for cereal production is predicted to increase by about 40% from the present level of 650 million tons. This increase will have to be achieved with less labor, water, and arable land, because there is no scope for increasing the cultivated areas.

Role of Science and Technology

Science and technology have been the foundation of the social and economic gains made in agriculture over the past 30 years and will continue to underpin any necessary increases in agricultural productivity.

Plant biotechnology is one such technology that has been regarded as part of the "sustainable productivity equation" in agriculture (Cohen, 2001). Its present applications in agriculture include conventional breeding, tissue culture and micropropagation, molecular breeding or marker-assisted selection, plant disease diagnostics, genetic engineering and the production of GM crops, and the "omics" sciences (e.g., genomics, proteomics, metabolomics, etc.).

Unfortunately, harnessing biotechnology and its applications for the benefit of the poor will require considerable attention in many areas including: allocation of additional public resources to agricultural research; appropriateness of, and access to, biotechnology by resource-poor farmers; improvement in the seed distribution and extension systems; capacity-building of the public sector in biotech R&D; public education; policies and regulatory frameworks on biosafety, food safety, and intellectual property rights (IPRs); and stronger public-private sector links for both international and local collaborative undertakings.

Current Status of Plant Biotechnology in Asia

Many Asian governments—including China, India, Indonesia, Malaysia, Philippines, Thailand, and Vietnam—have given high priority to plant biotechnology research in the hope of addressing the pressing challenges related to improving productivity, farmers' livelihoods, driving rural development, and meeting food security demands.

China

China in particular has invested heavily in agricultural biotech research, ranking second only to the United States in terms of public sector investment (approximately US$112 million in 1999). This demonstrates the seriousness of China's commitment to plant biotechnology. In early 2001, China's officials announced that they planned to raise research budgets for plant biotechnology by 400% over the next five years. If this plan is carried out, China could account for nearly one third of the world's public spending on plant biotechnology. China's agricultural biotechnology research staff has become one of the largest in the developing world; work focuses on all applications including tissue culture, genetic engineering, marker-assisted selection, diagnostics, microbiology, genomics, and other related areas (Huang, Rozelle, Pray, & Wang, 2002). China's laboratories have identified more than 50 plant species and more than 120 functional genes that scientists are using in plant genetic engineering, making China a global leader in the field.

From 1996 to 2000, 141 GM crops were developed, 45 of which were approved for field trials, 65 for environmental release, and 31 for commercialization (of which around 20 were various Bt cotton varieties). Products already commercialized include Bt cotton, virus-resistant and altered-shelf-life tomato, color-altered petunia, and virus-resistant sweet pepper. Awaiting commercialization approval is GM rice resistant to three of China's main rice pests (stem borer, planthopper, and bacterial leaf blight). Field trials are ongoing for other major crops such as rice, potato, soybean, cucumber, papaya, maize, and tobacco.

China's experience with Bt cotton demonstrates the direct and indirect benefits of its investment in plant biotechnology research and product development. In 2002, Bt cotton was grown in 2.1 million hectares by around five million farmers (James, 2002). The average Bt cotton farmer has reduced pesticide sprayings for the Asian bollworm from 20 to 6 times per year and produces a kilogram of cotton for 28% less cost than the farmer using non-Bt varieties (Huang, Rozelle, Pray, & Wang, 2002).

Right now, China is struggling with issues of consumer safety and public acceptance, so much so that there have been no new approvals for commercialization. However, many competing factors are putting pressures on policy makers to decide whether to continue to commercialize transgenic crops. The demand for productivity-enhancing technologies by farmers and for cost savings by consumers, the rate of increase in research investments, and success with Bt cotton suggest that products from China's research program will one day become widespread inside China. According to Ernst and Young's Global Biotechnology report in 2002, it is anticipated that about half of China's fields will be planted with biotech crops within 10 years (Ernst & Young, 2002).

India

Similarly, the Government of India also recognized early on the importance and potential of biotechnology when it set up the National Biotechnology Board in1982. This then became a full-fledged department in 1986 (Sharma, 2001). The Department of Biotechnology supported the establishment of seven Centres for Plant Molecular Biology throughout the country. Today, there are about 50 public research units in India using tools of modern biotechnology for agriculture, especially techniques for cell and tissue culture. The Indian government allocates an estimated US$15 million annually on plant biotechnology research, while the private sector contributes about US$10 million (Huang, Rozelle, Pray, & Wang, 2002).

The Indian plant biotechnology research agenda is dominated by tissue culture and micropropagation, exploitation of heterosis vigor, development of new hybrids and planting material with desirable traits, and the genetic enhancement of important crops (Sharma, 2001). India's success in tissue culture and micropropagation techniques led to the development of Micropropagation Technology Parks, which serve as a platform for the effective transfer of technology to entrepreneurs, including training and the demonstration of technology for mass multiplication of horticulture crops and tress. Considerable research progress has been made with cardamom and vanilla, both important crops. Cardamom yields have increased 40% using tissue culture plants.

A number of multi-institutional projects have also been launched, including the development of transgenics for resistance to geminiviruses in cotton, mungbean, and tomato, resistance to rice tungro disease, resistance to bollworms in cotton, development of a nutritionally enhanced potato with a balanced amino acid composition, and development of molecular methods for heterosis breeding.

The first GM crop to be released for commercial cultivation is Bt cotton, developed by the Maharashtra Seed Company (Mahyco) in partnership with Monsanto. The approval, which was given in March 2002, came after several years of field trials following the biosafety procedures laid down by the government. Three cotton hybrids were granted permission for field sowing in six states for three years. For the first season, farmer demand for Bt cotton seed was very high; it is estimated that 44,500 hectares of certified Bt cotton were planted by nearly 55,000 farmers.

Other transgenic crops that are awaiting approval for commercial cultivation include transgenic herbicide-tolerant mustard hybrids and nutritionally enhanced potato varieties.

Indonesia

In Indonesia's second long-term development plan (1994–2019), food security emerged as one of the most important issues in the national agricultural development framework. With an expected population growth rate of 1.4% per year between 2000 and 2010, rice consumption is expected to grow from 48.5–50 million tons in the year 2000 to 50–57.5 million tons in the year 2010 (Moeljopawiro, 1999). Indonesia is thus looking to new and improved agricultural technologies to increase farm productivity and recognizes the role biotechnology must play in research.

Since 1994, the government has been providing competitive grants for biotechnology research, resulting in significant increase in high-quality research activities. At present, several public institutions are engaged in biotechnology research of food crops (e.g., rice, corn, sweet potato, soybean) as well as other important commodities such as cacao and oil palm. Plant tissue culture and micropropagation techniques are well established at several laboratories, and large-scale commercial production of oil palm planting material has been developed. Diagnostics, in vitro technologies, and molecular marker technologies continue to be used in improving horticultural crops, including garlic, pepper, potato, citrus, banana, mango, and others. Research using more advanced recombinant DNA technologies is also starting to make headway. Limited field testing is being done for insect-resistant transgenic potato and rice.

Although no GM crops developed by the public sector have been commercialized yet, Indonesia earned the distinction of being the first Southeast Asian country that produced GM crops on a commercial scale. Monsanto's Bt cotton is now commercially grown in South Sulawesi province, covering over 4,000 ha. Multiple location field trials for both soybean and corn also developed by the private sector have been completed and are next in the pipeline for approval.

Philippines

The Philippine government recognized as early as the mid-1980s the potential role of biotechnology as a leading-edge technology for achieving sustained economic development. It remains a priority area to this day. The plant biotechnology research agenda is currently dominated by tissue culture and micropropagation, biocontrol, diagnostics, molecular marker technologies, and genetic engineering. Current GM research programs focus on: developing transgenic banana with resistance to bunchy top virus and papaya resistant to ringspot virus; delayed ripening of papaya and mango; Bt corn; rice resistant to bacterial blight and tungro virus and rice with improved nutritional characteristics; and coconut with high lauric acid content.

The Philippines was the first ASEAN country to formulate a national policy on biosafety, and in 1990, the National Committee on Biosafety of the Philippines was created to review and monitor R&D activities involving genetically modified organisms and potentially harmful species. The first GM crop to go through the risk assessment process of the Biosafety Committee was Monsanto's Bt corn. After several years of successful greenhouse and multilocation field trials, Bt corn was finally approved for commercial cultivation in December 2002. During its first planting season, farmers planted around 100 hectares in the corn-growing regions of the country. In the second-season planting, more than 10,000 ha were planted to Bt corn. The performance of Bt corn is currently being assessed, although impact assessment results from nine field trials in 2001–2002 showed an average 40% yield advantage over non-Bt corn, producing 12,000 pesos/ha increased income (Gonzales, 2002). Field trials for bacterial blight-resistant rice are currently being carried out by the Philippine Rice Research Institute.

Malaysia

Biotechnology has been identified as one of the five strategic technologies expected to accelerate Malaysia's transformation into a highly industrialized nation by 2020. It has received strong government support and commitment with significant funding for R&D, infrastructure, and human resource development.

The Malaysian government strongly believes that biotechnology will propel the country into the new frontier of economic growth. It is set to invest US$3.7 billion to establish the Multi-Media Super Corridor (MSC) in which a Bio-valley will be located. Malaysian officials expect that the three biotechnology institutes will help to accelerate this new industry and attract foreign investment amounting to US$10 billion over the next 10 years.

Current research priority areas in plant biotechnology include tissue culture, molecular marker technologies, in vitro technology, and genetic engineering for plant improvement. Development of transgenic crops has been conducted primarily in public research institutes and universities. Significant progress is being made in developing GM crops such as rice, papaya, pomelo, orchid, pineapple, oil palm, chili, and rubber. Although there is still no commercial release of GM crops, confined field trials are being conducted for delayed-ripening papaya.

Thailand

Known as one of the world's largest net food exporters, Thailand is determined to maintain its position in world food production by continuing to invest in agriculture. As early as the 1980s, the government recognized the important role of biotechnology in increasing the competitive advantage of farmers and the country's agro-industry (Damrongchai, 2002). In 1983, the National Center for Genetic Engineering and Biotechnology (BIOTEC) was established to promote research and development in this strategic technology. Since then, Thailand has been very active in seeking and producing better varieties of plants using gene technology and other biotechnology applications.

Current research is focused on developing virus-resistant papaya, tomato, and chili, insect-resistant cotton, and salt- and drought-tolerant rice. Although none of these has reached market-scale production, virus-resistant papaya is considered the most promising GM product and the first to be introduced to farmers in the country. All transgenic papayas are being tested under greenhouse conditions and field tests in accordance with the Biosafety Guidelines and are also undergoing food safety tests following GM Food Safety Guidelines (Damrongchai, 2002).

In the meantime, GM crop seeds from foreign multinationals have already been introduced into Thailand. The first crop that was permitted for field trials and introduced in 1994 was Calgene's delayed-ripening Flavr Savr tomato. This was followed by Monsanto's Bt cotton and Novartis' Bt corn. The former had undergone the most extensive field trials in the country and have since been completed. However, due to strong opposition by several local NGOs, the product has been suspended at the political level for several years now.

Vietnam

The government of Vietnam has assigned the highest priority to biotechnology and views it as an essential and increasingly important prerequisite to achieve national goals and objectives for food, feed, and fiber production, healthcare, and environmental protection. Application of biotechnology is seen to be critical for increasing crop production to satisfy increasing domestic needs, to meet new export market demands, and to coincidentally conserve natural resources by developing improved and more sustainable agricultural systems.

Vietnamese plant biotechnology is largely at the stage of improving and adapting technology imported from advanced countries (Tuong-Van Nguyen, 2000). The use of conventional technologies such as in vitro micropropagation, virus elimination, somaclonal variation, anther culture, and haploid lines effectively improved crop productivity over the past decade. Gene transfer to breed disease- and pest-resistant varieties, as well as plants tolerant to adverse environment conditions, is also being pursued. Various interesting genes have been cloned or imported from other countries, and advanced techniques have been practiced extensively in research institutions.

As the second largest exporter of rice in the world, Vietnam is focusing much of its effort on improving its rice varieties. The Institute of Biotechnology, Hanoi, together with other institutions, is developing transgenic rice varieties tolerant to abiotic and biotic stresses and resistant to rice pests. It continues to build on its success in developing rice hybrids. Currently, hybrid rice occupies approximately 330,000 hectares giving the highest yields of 16 tons per hectare (Bhumiratana, 2002).

Other target crops for improvement include maize, the second most important food crop in Vietnam; fruits such as citrus, mango, papaya; leafy vegetables; root and tuber crops including sweet potato and cassava; sugar cane; and soybean.

Papaya Biotechnology Network of Southeast Asia

Indonesia, Malaysia, Philippines, Thailand, and Vietnam are members of a regional biotechnology initiative called the Papaya Biotechnology Network of Southeast Asia. The network, which was established by ISAAA in 1998, strategically chose to concentrate on the development and commercialization of transgenic papayas with either of two traits: resistance to papaya ringspot virus or delayed ripening to enhance shelf life. This commodity and trait-specific focus has enhanced the ability of member countries to deal with issues pertaining to regional regulatory harmonization and has allowed capacity building that is focused on technical training for product developers and regulatory training for risk assessors. Further, the network has proven to be a successful model of North-South and South-South cooperation that brings together both public and private sector institutions and organizations to promote the donation, transfer, and sharing of proprietary biotechnologies (McLean, 2003).

Conclusion

The importance of the agricultural sector to economies in Asia cannot be overstated. Agriculture as a percentage of total GDP in Asia is approximately 20%. This percentage compares with less than 5% for the world, 2% for the United States, and 7% for Europe (World Bank, 2001). It is also the largest sector in some economies, despite the fact that economic statistics tend to understate agriculture's importance, because they only represent on-farm production and ignore post-harvest and value-added processing as well as agricultural input industries. The agricultural sector also employs more workers in Asia than any other region, 58% (United States Agency for International Development [USAID], 2002), and a large percentage of the population depends directly or indirectly on agriculture (e.g., India, 67%; Indonesia, 55%; Philippines, 70%; China, 75%).

Considering the above, any increase in agriculture production will have a tremendous impact on the lives and economies of Asian countries. For example, a US$1 increase in agricultural production generates US$2.32 of growth in the overall economy (USAID, 2002). Countries who benefited from the Green Revolution can attest to this. Between 1970 and 1995, per capita gross domestic product increased by 190%, cereal production doubled, and calorie availability per person increased by 24% (ADB, 2001).

In spite of past success, however, 900 million people in Asia still live in poverty. Growth rates of yields have slowed during the period between 1987 and 2001 (Huang, Pray, and Rozelle, 2002). The pressure on the environment and resource base will be unprecedented in the 21st century. Population and consequent urbanization will increase, resulting in more demand for food, feed, and fiber production. These are the reasons why governments in Asia are looking for new ways to improve and boost their agriculture sectors in a sustainable manner. The application of plant biotechnology in agricultural research is just one component in this equation. Plant biotechnology is judged to be critical for increasing crop production to satisfy increasing domestic needs, to meet new export market demands, and to coincidentally conserve natural resources by developing improved and more sustainable agricultural systems.

Harnessing biotechnology and its applications for the benefit of the poor, however, will depend on a number of critical elements. Because new agricultural technologies are increasingly complex, knowledge intensive, expensive, and location specific, clear priorities need to be established. The right mix of funding and research effort needs to be apportioned between tried and tested applications (such as conventional plant breeding, tissue culture and micropropagation, and diagnostics) and the more modern genetic technologies (such as genetic engineering and the development of GM crops). Strategies must be directed at clearly defined target crops and traits that affect poverty reduction, food security, environmental conservation, and competitiveness.

The public sector should coordinate its efforts to take advantage of the willingness of the private sector to contribute to the search for new technologies and focus on those areas where companies are unwilling or unable to invest in. The problem with this approach, however, is the public's growing distrust of the private sector. Until now (with the exception of China), all GM crops that have been released commercially in Asia are products of foreign multinationals, adding subtlety to the issue. It is for this reason that these new technologies must be implemented under the auspices of regulatory frameworks that have the public's trust and confidence. Communication and education will play a key role in helping to achieve this.

Finally, strong political will and commitment by governments, manifested by appropriate public policies and investments, will be crucial in the struggle to improve the livelihoods of millions of Asians.

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