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Plant breeding and seed systems for rice, vegetables, maize and pulses in Bangladesh

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Plant breeding and seed systems for rice, vegetables, maize and pulses in Bangladesh

A report for the Global Partnership Initiative for Plant Breeding Capacity Building

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Abbreviations and acronyms

ARI	agricultural research institute
AVRDC	The World Vegetable Center (formerly Asian Vegetable Research and Development Center)
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BPH	brown plant hopper
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
BSMRAU	Bangabandhu Sheikh Mujibur Rahman Agricultural University
CGP	competitive grants programme
CIDA	Canadian International Development Agency
CIMMYT	International Wheat and Maize Research Centre
CRSP	Collaborative Research Support Program
DAE	Department of Agricultural Extension
DANIDA	Danish International Development Agency
EPDOA	East Pakistan Directorate of Agriculture
FAO	Food and Agriculture Organization
FSB	fruit and shoot borer
GDP	gross domestic product
GFP	genetic finger printing
GKF	Grameen Krishi Foundation
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (Germany)
HRC	Horticulture Research Centre
HYV	high-yielding variety
IARC	international agricultural research centre
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IRRI	International Rice Research Institute
ISTA	International Seed Testing Association
MNC	multinational company
MOA	Ministry of Agriculture
MOU	memorandum of understanding
MYMV	mung bean yellow mosaic virus
NARS	National Agricultural Research System
NATP	National Agricultural Technology Project
NGO	non-governmental organization
NIB	National Institute of Biotechnology
NPGRI	National Plant Genetic Resources Institute

NSB	National Seed Board
OPV	open-pollinated variety
ORC	Oilseed Research Centre
PETRRA	Poverty Elimination through Rice Research Assistance
PGRC	Plant Genetic Resources Centre
PRC	Pulses Research Centre
QPM	quality-protein maize
R&D	research and development
RDRS	Rangpur Dinajpur Rural Services
SAU	Sher-e-Bangla Agricultural University
SCA	Seed Certification Agency
SEDF	South Asia Enterprise Development Facility
SSCL	Supreme Seeds Company Limited
SPGR	sponsored public goods research
TAMNET	Tropical Asian Maize Network
TLS	truthfully labelled seed
USAID	United States Agency for International Development
YVMV	yellow vein mosaic virus

Executive summary

This study on plant breeding and seed systems for rice, vegetables, maize and pulses in Bangladesh is an input to a six-country study of plant breeding and seed systems. Studies on three countries in sub-Saharan Africa (Ghana, Malawi and Kenya), two in Asia (Bangladesh and Thailand) and one in Latin America (Uruguay) covered a range of experiences, income classes, sizes of system and dependence on global markets. Bangladesh has been included for the lessons learned and contrasts it presents with the other countries.

Bangladesh is a very densely populated country that has moved from chronic dependence on imports to meet basic food needs at the time of independence in 1971 towards becoming almost self-sufficient in rice production as a result of flood protection measures, irrigation, high-yielding varieties, efficient use of fertilizers and expansion of rural credit networks. Bangladesh is a success story that has worldwide significance for its efforts to reduce rural poverty through increasing use of the products of scientific research, including improved plant genetic resources.

The Bangladesh story also illustrates the importance of other key elements, most notably policies that foster the participation of private commercial and non-governmental organizations (NGOs) in the provision of agricultural inputs and marketing of products. Although the country has experienced political instability, Bangladesh's high degree of cultural and ethnic homogeneity, together with continuity of support for agriculture, have helped facilitate and sustain this progress.

International agricultural research centres have played significant roles in the progress that has been made, but Bangladesh also illustrates how these roles can evolve in response to changing conditions, capacities and scientific opportunities, such as biotechnology.

Bangladesh faces a set of choices associated with the challenges and opportunities brought about by this progress. Choices include how to most effectively deploy the existing public and private plant-breeding capacity, and how to strengthen it and maintain the momentum that has developed in the seed sector.

The complexities of plant breeding are discussed in detail in the introductory sections of this study. This is followed by overviews of the varied nature of cropping systems and their response to a changing economy; policy and regulatory frameworks; and the public and private sectors' roles in plant breeding, seed production and marketing.

The main section of the study examines plant breeding and seed systems for rice, vegetables, maize and pulses. These crops were selected because of their importance in cropping systems in Bangladesh and differences in varietal improvement approaches, and to facilitate comparisons with other countries and regions.

The section on rice briefly a background to research on the crop, with emphasis on its breeding, challenges, organization, current priorities, seed supply, issues of concern and future prospects. The Bangladesh Rice Research Institute spearheaded rice breeding activities in the 1970s with active support from the International Rice Research Institute and so far has released 52 modern varieties. Demand for quality seed and enabling government regulations have resulted in the growing involvement of private companies and NGOs, which have invested heavily in research and breeding, with a focus on hybrid varieties.

Vegetable research started in 1980 in the Bangladesh Agricultural Research Institute (BARI), with active support from the Asian Vegetable Research and Development Center (AVRDC, now the World Vegetable Center). Support from the Asian Development Bank and the United States Agency for International Development helped to establish the Horticulture Research Centre (HRC) at BARI, which by the year 2000 had released 34 varieties of different crops. The Bangladesh Institute of Nuclear Agriculture (BINA) is also engaged in vegetable breeding and has released seven varieties, while the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) has released one. Priority has focused on resistance to major viral and bacterial diseases. A variety of okra that is resistant to yellow vein mosaic virus has replaced most other varieties and now covers 85 percent of the area planted to this crop. Private companies, including Lat Teer, ACI, Supreme Seeds and Getco, have also invested significantly in vegetable research in response to increasing farmer demand for better varieties and quality seed.

Maize breeding at BARI initially concentrated solely on open-pollinated varieties; eight varieties were released between 1986 and 2002. The expansion of the poultry industry in the 1990s created demand for poultry feed, and private companies and the Bangladesh Rural Advancement Committee, the country's largest NGO, started to import hybrid seed. Maize cultivation expanded rapidly and BARI changed its breeding strategy to develop hybrid varieties. With support from the International Maize and Wheat Improvement Center, the International Institute of Tropical Agriculture and others, BARI has developed breeding strategies for short-, medium- and long-duration hybrids. At least 15 private companies are also engaged in breeding hybrids using both imported parent material and BARI lines.

BARI's Pulses Research Centre researches and breeds pulses, while BINA, the Bangladesh Agricultural University and BSMRAU are also involved in pulses research and breeding. More than 40 improved varieties of pulse crops with high yield potential were released between 1991 and 2009: BINA released one variety each of grass pea, lentil and black gram, four of chickpea and seven of mung bean; BSMRAU released three varieties of mung bean, and the rest were developed by BARI. Several of these varieties are now widely used in various parts of the country. Pulses research and breeding have had significant support from the International Center for Agricultural Research in the Dry Areas, the International Development Research Centre (Canada), the Canadian International Development Agency and AVRDC.

The study points to several promising areas for investment, including biotechnology, human resource development, strengthening regulatory systems and improvements in the mechanisms fostering collaborative research. The greatest challenges are in the area of the political and institutional will, necessary for the successful implementation of the reforms to which the Government and donor partners have committed themselves.

1 Introduction

Three years after its independence in 1971 Bangladesh experienced one of the worst famines of the twentieth century. At that time, several international agencies gave the country little prospect of ever being able to feed itself and designated it as being beyond recovery. Since then the Government's first priority has been to achieve food security through self-sufficiency in food production.

Annual rice production In Bangladesh increased from about 10 million tonnes in 1972 to approximately 29 million tonnes in 2008; this marked increase has made this country almost self-sufficient in rice even as the population continues to increase. This achievement was made possible by the implementation of flood protection measures, expansion of irrigation, use of high-yielding varieties, better use of fertilizers and the expansion of rural credit networks.

Bangladesh is now a transitional economy that is changing from a single focus on food security towards diversification in the agriculture sector to higher-value and, in many cases, more labour-intensive crops. Consequently, agriculture's share in the country's gross domestic product (GDP) has diminished over the years as the industrial and service sectors have grown (Figure 1). Industry grew slowly but steadily, with growth accelerating since 2000. As the political environment became more stable, foreign investment started to arrive and the clothing industry grew. The garment and knitwear industry has become the main export sector, replacing jute and tea, and has been a major source of foreign exchange since 1980, worth about US$5 billion per year and employing nearly 3 million workers, mostly women (Mahmood 2002). The service sector grew rapidly until 2001/02, mirroring the decline in the contribution of the agriculture sector, and is now the largest contributor to GDP. Per capita income increased from US$217 in 1991 to US$690 at the end of June 2009 (BBS 2004; 2009).

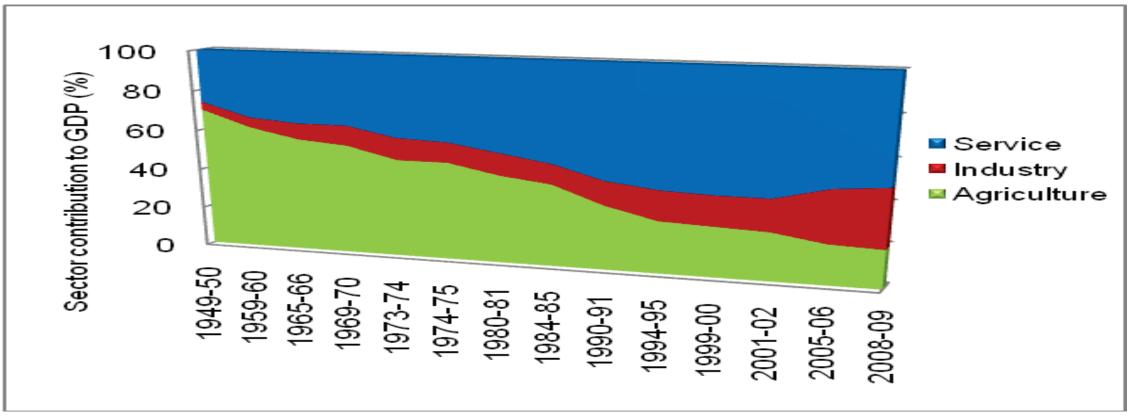

Figure 1. Changing role of agriculture in GDP and economy (1949–2009**).**
Source: BBS (1974; 1980; 2004; 2009).

The expansion of the garment industry, increasing landlessness and seasonality in labour demands in rural areas are contributing to rapid urbanization, which in turn is causing a loss of fertile agricultural land to other uses. Between 1984 and 1996, the total land area operated by rural households declined from 9.2 million ha to 8.2 million ha, a rate of nearly 82 000 ha per year (Halim and Rahman 2001). In 2005 it was 7.98 million ha (BBS n.d.), a loss of about 24 400 ha per year between 1996 and 2005. Future agricultural growth in Bangladesh must thus come from increases in productivity related to improvements in technology and practices.

The agricultural sector faces numerous challenges, including: (i) continuing to meet the food and nutrition requirements of the country's population, which is growing at about 1.6 percent per year; (ii) contributing to the growth for the economy as a whole through raising rural incomes, non-food production and exports and expanding agricultural service enterprises; and (iii) addressing the threats posed by a declining natural resource base and climate change.

Higher-yielding varieties, adapted to local conditions, suitable for prevailing cropping systems and/or tolerant of one or more biotic and abiotic stresses, offer one of the most promising opportunities. These improved varieties are the products of plant breeding activities carried out by an increasing number of organizations, whether public, private, commercial, non-governmental, local, national or external. The range of plant breeding processes is also expanding, most notably through client participation and biotechnology. Biotechnology is opening up varietal improvement possibilities that were at best remote with the use of conventional techniques. Value chains are multiplying and extending; in the process, participation in plant breeding is expanding.

Plant breeding for Bangladesh is becoming more complex, demanding and expensive. Breeding requires a combination of resources, capacities and enabling conditions to function effectively. Successful research involves collaboration within and across disciplines and organizations. Where a tradition of such collaboration is lacking, there is a need for leadership and facilitating processes that can foster it. Similarly the demands on the seed systems that link plant breeding with farmers are increasing dramatically, as farmers become more aware of the advantages of improved varieties and quality planting materials and turn to the market for seed.

This study examines plant breeding and seed systems for four food crops: rice, vegetables, maize and pulses. It focuses on past and prospective investments aimed at enhancing capacity and performance. These crops were selected because of their importance in cropping systems in Bangladesh and differences in varietal improvement approaches, and to facilitate comparisons with other countries and regions. The study is not a comprehensive review of plant breeding and seed systems in Bangladesh, but illustrates the major trends that are taking place in the country.

Section 2 presents a set of issues and questions relating to investments in plant breeding and seed systems. Section 3 includes overviews of (i) the varied and complex cropping systems of Bangladesh and how they are evolving in response to economic conditions and development activities; (ii) the policy and regulatory frameworks that govern plant breeding research and seed systems; and (iii) the organizations involved in plant breeding, seed production and marketing. Sections 4–7 look at breeding activities for the selected crops. The markets and value chains for these crops are quite different, as are the roles and activities of organizations involved in breeding them. These conditions collectively influence the level and character of breeding activities, as well as the extent of private-sector participation. The discussion also serves to identify lessons learned and possibilities for future investment in these crops. A final section presents major findings and conclusions.

2 Central questions

In the decades following independence, a range of public-sector institutions were established and charged with guiding the development of the country. Agricultural research institutes (ARIs) featured prominently in this effort and have made significant contributions to progress in the sector. The ongoing structural transformation of Bangladesh's economy has been facilitated in part by liberalization and growth of the private sector. The state has progressively reduced its role in several key sectors, but today it is still the dominant player in agricultural research. Investment costs, skill requirements and the public-goods nature of many of the products of research are among the factors explaining the limited interest of private commercial organizations in this sector. However, this is changing. The private sector, including non-governmental organizations (NGOs), commercial seed companies and private development organizations, are starting to see the advantages of investing in research and specifically in plant breeding capacity.

This study is an effort to answer the following questions:

1. How is the seed sector changing and how does that feed back into investment decisions about plant breeding by private and public organizations? Why are private organizations investing in plant breeding and what is the nature and extent of their involvement?
2. What are the dynamics among the public and private sectors and external organizations? How is the public sector responding and adjusting?

3. Looking towards the future, what is the potential for private-sector plant breeding? Will the country continue to rely primarily on the public sector?
4. Last but not least, what are the implications of this evolution in terms of the level and effectiveness of participation of clients, particularly farmers, in plant breeding?

3 Context

3.1 Overview of cropping systems in Bangladesh

Prior to the 1970s, most farms were either single- or double-cropped, depending on soil type and land topography. Irrigation was by traditional methods, using water from shallow rivers, *beels*[1] and ponds. Rice, jute, pulses, mustard, groundnut, potato, sweet potato and sugar cane were the major crops.

Starting from the 1970s, great efforts were made to increase rice production to meet the demands of the growing population. Flood protection measures were implemented and irrigation expanded from around 16 percent of the cropped area in 1981 to around 56 percent in 2007. This helped to increase both the area under cultivation and cropping intensity. Farmers started growing high-yielding varieties (HYVs) of rice and applying relatively high levels of fertilizers, made available and affordable through the expansion of fertilizer distribution and rural credit networks. Current cropping intensity averages about 176 percent although in some areas, such as Bogra and Comilla districts, it is almost 200 percent.

Rice continues to dominate the cropping system, occupying nearly 77 percent of the total cropped area (Figure 2). Three different rice crops are grown: *aus*, *aman* and *boro*.

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[1] Natural depressions or low-lying water bodies

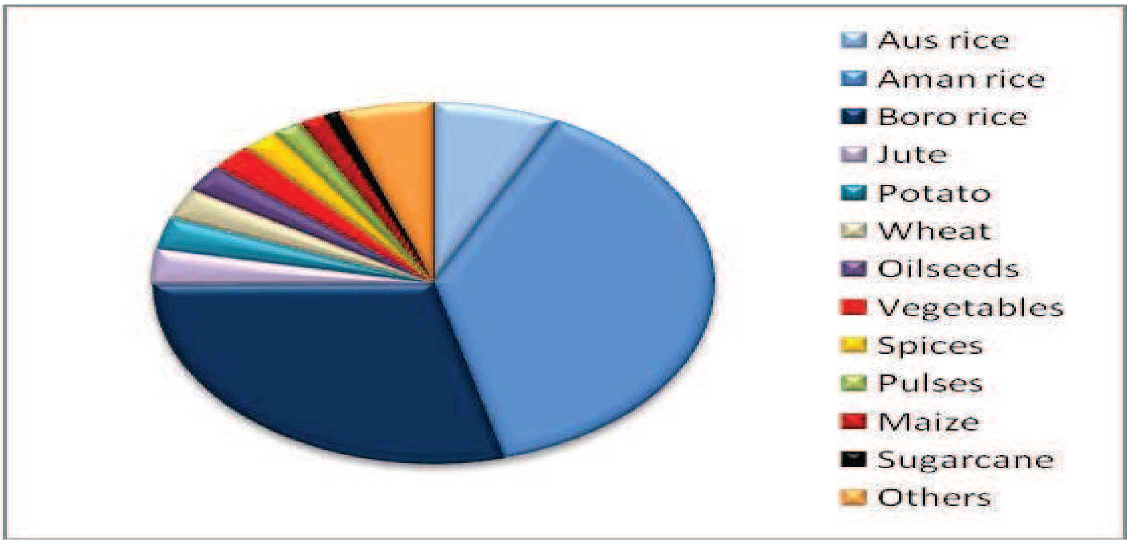

Figure 2. Proportion of area under various crops (2006/07).

Aus rice is generally direct seeded and grown during the pre-monsoon (or early *kharif*) season between March–April and May–June/July. *Aman* rice is usually transplanted during peak monsoon between July and September and harvested during October–December. *Boro* rice is usually transplanted during the mild winter (or *rabi*) season, around January–February and harvested in April–May/June. Broadcast *aman* or deepwater rice is usually grown between March–April and November–December and can withstand water depths of about 2 m.

The areas planted to early monsoon broadcast and transplanted (T) *aus* and deepwater rice have been declining; farmers have been switching to *boro* rice in areas where irrigation is available. *Boro* rice has contributed the largest share of total rice production since 1998/99 and currently accounts for more than 55 percent of rice produced in the country. This increase has resulted from increases in both area and yield per hectare.

The modern varieties of rice are photo-insensitive and can generally be grown in any season. Most cropping patterns include at least one rice crop, generally T-*aman.* Transplanted *aman–boro* continues to be the dominant rice–rice cropping pattern. Very little land is suitable for growing three rice crops in one year on the same land; however, farmers sometimes grow a third crop such as mustard, pulses, potato or vegetables. This requires adjustments in planting times to accommodate all three crops. For example, a cropping pattern recommended by the Bangladesh Agricultural Research Institute (BARI) for parts of Bogra and Tangail districts is T-*aman* (late July) – potato (late Nov) – *boro* (late Feb). These crops give yields of about 3.5, 25.0 and 5.0 tonnes/ha, respectively. The yield of each crop is lower than they would be if only two crops were grown, but the overall annual productivity and profits from three crops are higher than those from only two crops. Availability of irrigation and farmers' choice of the rice crop (*aus, aman* or *boro*) and variety (which may affect crop duration) often determines what other crops may be included in the cropping system. Wheat, winter maize, pulses, vegetables, root and tuber crops and spices are all grown during the winter (*rabi*) season and compete for land with *boro* rice. Sequences incorporating two cereal crops for food and a cash crop (e.g. T-*aman*–wheat–mung bean/legumes/oilseeds) are quite common in many parts of the country, as are several non-rice patterns, such as maize–maize in some parts of Bogra and vegetable–vegetable in many areas.

The average yield of rice in Bangladesh has increased from about 1.15 tonnes/ha in 1970 to about 2.73 tonnes/ha in 2008 (BBS 2010). According to FAO estimates (IRRI 2009), rough rice yield in Bangladesh was 3.88 tonnes/ha in 2007, relatively low compared with other Asian countries, such as China (6.35 tonnes/ha), Japan (6.54 tonnes/ha), Korea (6.27 tonnes/ha), Indonesia (4.69 tonnes/ha) and Viet Nam (4.87 tonnes/ha). Management factors that contribute to low yields include planting at the wrong time; use of poor-quality seed; inappropriate use of fertilizers and other inputs; failure to control weeds during the critical competition period; and ineffective control of pests and diseases. Soil-related factors associated with low yields include the very low organic matter content of many soils, particularly in the north and northwestern parts of the country, and widespread sulphur and zinc deficiencies. Other physical factors that often affect rice yield include unfavourable temperatures, floods and drought (Sattar, n.d.). Lack of modern varieties adapted to deepwater, saline and drought-prone areas also constrains rice yield improvement. The coastal areas of Bangladesh account for more than 30 percent of cultivable land, about half of which is affected by salinity. Overall nearly half a million hectares are affected by moderate to very high salinity. Most lands in the coastal region remain fallow in the *rabi* season because surface water is saline and unsuitable for irrigation, while groundwater is not intensively utilized for fear of salt-water intrusion into coastal aquifers (Mondal *et al*. n.d.).

Before 1971, maize cultivation was mainly limited to a few tribal areas of the southeastern Chittagong Hill Tracts. The rapid expansion of the poultry industry in the 1990s increased demand for maize grain as poultry feed and farmers, particularly in northern and western parts of the country, adopted maize as a cash crop. Currently, maize is grown on about 220 000 ha of land with average yields of around 5.7 tonnes/ha, producing well over a million tonnes of grains annually. However, local production meets only 55–60 percent of national demand for poultry and other feeds. The poultry industry is continuing to expand and demand for maize is likely to continue to rise, although outbreaks of avian flu in 2007 and 2008 may have dampened demand (Ali *et al*. 2008).

Maize can be grown in both *kharif* and *rabi* seasons although hybrid maize is promoted as a *rabi* (winter) crop sown after the harvest of T-*aman* rice. In this season maize competes with *boro* rice, wheat, pulses and vegetables. Growing maize in the *kharif* season involves higher risks because of possible flooding or drought. Maize is commonly grown in maize–fallow–T-*aman* rice, potato–maize–T-*aman* rice or maize/relay jute–T-*aman* rice cropping patterns.

A major constraint to increasing maize production is the high cost of inputs. Lack of cash or credit limits farmers' ability to buy hybrid seed and the fertilizers required to get the best out of them. Farmers sometimes plant seed from the previous F1 hybrid crop, resulting in poor yields. In addition, farmers often receive low prices for their harvest as part of repayment agreements linked to the supply of seed and inputs.

Indigenous varieties of vegetables have traditionally been grown, mainly by women, in and around the homesteads using low levels of inputs. Recently, many farmers have incorporated vegetables into their cropping systems in response to high demand, especially from urban populations, and profitability. The area under vegetable cultivation increased from 0.18 million ha in 1993/94 to 0.33 million ha in 2006/07 (BBS 2008). Production increased from 0.7 million tonnes in the 1970s to nearly 2.5 million tonnes in 2006/07 (BBS 2008). There is a trend, at least in parts of the country where climatic conditions are favourable, to move from subsistence farming to semi-commercialized vegetable cultivation. These farmers use improved varieties, high levels of fertilizers, improved cultural practices and pest control measures. Examples of such commercial production include pointed gourd in Bogra, onion in Faridpur, hyacinth bean in Chittagong, early cauliflower in Tangail and tomato in Jessore and Chapai Nawabganj districts. A marketing system is evolving to take advantage of the rising demand for fresh vegetables in urban markets. A very small portion of the vegetables produced are exported to the ethnic markets in Europe and North America.

More than 90 different vegetables are found in Bangladesh. Winter has the most favourable climate for growing vegetables, with low temperatures and low incidence of pests; winter accounts for about 60 percent of total vegetable production. Winter vegetables compete for land with *boro* rice, wheat, potato, pulses and oilseed crops. Major winter vegetables include cabbage, cauliflower, tomato, eggplant, radish, hyacinth bean and bottle gourd. Main summer vegetables include pumpkin, bitter gourd, teasel gourd, ribbed gourd, ash gourd, okra, yard-long bean and Indian spinach. Some crops, such as eggplant, pumpkin, okra, tomato and red amaranth, are grown in both seasons. Limited availability of quality seed, high costs of production and low farm-gate prices during the harvest season are among the main constraints to the expansion of vegetable cultivation.

Pulses, commonly known as poor man's meat because of their high protein and micronutrient content, have traditionally been a part of Bangladesh's predominantly rice-based cropping system. Most pulses are grown in the western region of the country, in the Gangetic floodplain, where soils have relatively high phosphorus and calcium content and pH ranges from 6.5 to 8.0. The most widely grown pulses are lentil, mung bean, black gram, chickpea and grass pea. Pulses occupy about 4 percent of cropped area, and about 70 percent of all pulses are produced in the relatively dry winter season. The country produces a total of about 0.55 million tonnes of pulses, of which lentil contributes about 38 percent, mung bean 12 percent and black gram 5 percent. Domestic production meets only about one-third of the country's needs, the rest is imported.

The main constraints on yields are genetic and cultural factors and are similar for all pulses. Sarker *et al*. (2004) identified the following constraints for lentil: low yield potential of local cultivars (low podding intensity and very small seed size); susceptibility of local cultivars to major diseases (such as rust, blight and collar rot); poor response to fertilizer and irrigation; yield instability owing to biotic and abiotic stresses; and low priority for resource allocation in the cropping system. With shrinkage in cultivable area and increasing demands for rice and high-value crops, pulses are often planted on marginal and less fertile areas, with delayed sowing, little or no fertilizer and often no weed control. As a result, yield is low. However, on-farm trials show the potential for high yields of chickpea and lentil with new varieties in parts of the Barind Tract.

Rice is facing increased competition from cereals, pulses, oilseeds, vegetables and root and tuber crops, particularly during the short, mainly dry, winter season when rice yields are highest. Farmers have also adopted other enterprises, such as livestock production and fish farming. Rice area has slightly decreased from highest peak of 10.80 million ha in 2001 to 10.57 million ha in 2008. However, growth in the areas of maize and vegetables seems to have been achieved so far at the expense of other crops. If demand for vegetables and maize continues to increase, will this affect the rice area? If this happens, will the loss in rice area be compensated by a breakthrough in rice yield? Should Bangladesh produce more rice in the *boro* season using underground water that carries heavy metals to the topsoil and depletes the water table, or substitute rice with cereals with lower water requirements? Answers to these questions are not clear and merit a discussion on policy trade-offs between food security and high-value crops.

3.2 Balance between public and private sectors

Government policies on agriculture and the private sector have evolved rather dramatically in the four decades since independence. At independence, Bangladesh faced large and growing food deficits and policy focused on achieving greater food security. As the scope for expanding the agricultural area was negligible, even at that time, emphasis was placed on increasing productivity of the many small farmers who were (and still are) the dominant feature of the agriculture sector. The Government of the time opted for a strong public-sector role in this process, in part from ideological preference but also because of limited alternatives. Conditions during the 1970s were not conducive to private-sector investment generally, but neither was there a capacity for major adjustments in the structure of agriculture[2].

Accordingly, the Government of the time moved towards creating a public agricultural infrastructure that would facilitate the required growth in farm productivity. In many instances the basic structures were those inherited from the previous administration. Names were changed, but the missions and *modus operandi* remained more or less the same. However, the agricultural research infrastructure underwent a significant transformation in the years following independence, with the establishment of a network of ARIs that focused on one or more commodities. In 1973, the Bangladesh Agricultural Research Council (BARC) was established to oversee and coordinate the ARIs' activities. Donors and the ARIs played major roles in this transformation, but government priority to agricultural development was critical to making it happen. A large research establishment, with extension services and public agencies to provide inputs and market outputs, was regarded as essential for achieving greater food security through improvements in productivity. Attitudes towards the roles that the private commercial sector could and should play in the process were at best ambivalent.

During the last 20 years, there have been significant adjustments in agricultural policy in response to changing circumstances, as well as a change of outlook on the private sector's participation in providing agricultural services, including research. First, farmers have achieved major improvements in productivity and Bangladesh is now self-sufficient in basic food grains (in a normal year). A reasonably consistent appreciation of the importance of agriculture by successive governments can take part of the credit for this significant accomplishment. Second, government policy became increasingly open to private-sector participation in the agriculture sector. NGOs played an important role in this process, as did pressure from donors. Third, the public-sector agricultural research and service sector had become very large and expensive and governments found it increasingly difficult to cover even the recurrent cost component of these organizations. Parastatals, such as the Bangladesh Agricultural Development Corporation (BADC), which was charged with the provision of inputs, required large and growing subsidies to be able to continue its operations. BARC and the ARIs in particular were very dependent on donor projects, most notably those funded by the World Bank, the United Kingdom and the United States. These projects covered significant portions of operational budgets as well as capital expenditures. The Government faced increasing difficulties in covering even staff salaries. Although these institutions made significant contributions to agricultural progress, they were by many accounts not very efficient.

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[2] The sub-title of Bangladesh's First National Plan was "Planning for Socialist Development in Bangladesh", but many felt that the time was not right to use this model for the agriculture sector.

These developments have affected Government policy towards agriculture. Although agriculture remains a top priority of the Government, there has been something of a shift in focus from food security to include the importance of agriculture as a driver of overall economic growth. That shift has been accompanied by a growing acceptance of private-sector participation in a range of agricultural services. The Fifth Five Year Plan, 1997–2002 (Planning Commission 1998) states that “The public sector will provide infrastructure and support services including promotion of access to foreign markets, technology and capital. The Government’s major contribution to the development of infrastructure in the agriculture sector will be in the area of research and extension, provisions of quality seeds and creation of large scale irrigation works and barrages during the Plan period”, and that “The production of seeds and feed, streamlining marketing, increasing credit and strengthening disease control, etc. will also be given to the private sector so that the growth of agriculture can be raised significantly”.

Contract farming and agricultural exports are actively encouraged, with the private sector featuring prominently. Donor projects routinely featured efforts to involve the private sector, in the belief that private organizations were more efficient and effective than the public sector in selected areas, most notably in the provision of inputs. Public-sector agencies, including BADC and the Department of Agricultural Extension (DAE) were directed to assist private commercial firms and NGOs, in essence so that they could compete with the public sector. It was reasoned that over time these efforts would make it possible to reduce the size of the public sector.

However, the transition has been anything but smooth and is not regarded very seriously by many senior Government functionaries, who believe that their organizations, to varying degrees, are permanent and irreplaceable. A common view is that the profit orientation of the private sector seriously limits the latter’s interest in the provision of critical public goods, including the information and non-proprietary varieties that are vital to low-income farmers in particular. This observation does not negate the potential contributions of the private sector, but underlines the need to explore the private–public interface more systematically, to allow both to participate in ways that match their respective strengths and weaknesses (F. Bliss, personal communication).

For some time agricultural research remained largely in the public sector, and still is to a considerable extent. The public-goods nature of the products of agricultural research, as well as the time and expense associated with developing marketable products, made it difficult for companies to justify developing their own research capacities. However, large private companies and NGOs are increasingly seeing potential advantages of in-house research capacities. Recent Government and donor projects and policies have also required seed companies to develop research and development (R&D) capacities as a condition for loans.

Government support for public agricultural research remains a basic component of policy. However, the share of public expenditure allocated to agricultural research is low and declined from 0.29 percent of agricultural GDP in 1997/98 to 0.22 percent in 2004/05 (World Bank, 2008), compared with an average of about 0.62 percent of agricultural GDP in developing countries and 2.80 percent in developed countries. A level of 2 percent of agricultural GDP is generally considered a desirable target for developing countries.

During the past two decades reforms in public-sector agricultural services have featured prominently in both Government policies and donor-supported projects in an effort to make public-sector research more effective, efficient, responsive and sustainable. The current manifestation of this commitment is the National Agricultural Technology Project (NATP), supported by the World Bank and the International Fund for Agricultural Development (IFAD), which was launched in 2008 and could last for 15 years in three phases. NATP has four components: (i) agricultural research support; (ii) agricultural extension support; (iii) development of supply chains; and (iv) project management and coordination (World Bank 2008).

All components of the NATP, to varying degrees, envisage and include support for private-sector participation. The supply chain development component lies chiefly within the private sector. Support for agricultural extension is mixed, but consists mainly of a continuation of Government and World Bank efforts to strengthen public-sector extension via the DAE. Decentralization and stronger linkages among farmers, extension and research are also prominent themes in the project. It remains to be seen whether the latest efforts in these areas represent serious departures from existing practices. The effort to mobilize private- and village-level participation through common interest groups is essential, as government services can at best hope to reach between 5–10 percent of farm families directly.

NATP also reflects the growing emphasis that policy-makers place on the economic development dimension of the agriculture sector, in particular in its value-chain component. Food security and equity considerations have not been eclipsed, but the balance continues to change, and this has significant implications for the private sector's role in providing ongoing and future agricultural services.

The research component includes provision to "Finance activities related to: (i) competitive grants programme (CGP); (ii) sponsored public goods research (SPGR); and (iii) enhancing institutional efficiency of the national agricultural research system" (World Bank 2008). Private individuals and entities can apply for competitive grants. However, this component basically reaffirms a commitment by the Government (and at least one donor) to ensure that the public sector remains the dominant player in agricultural research for the foreseeable future. The SPGR subcomponent is an explicit recognition of the public-goods dimension of the research and the importance of public participation, as well as support for its implementation. SPGR goes a long way to ensuring adequate operational expenses for the national agricultural research system (NARS), including the universities. The private sector might participate, but essentially at the behest of BARC/ARIs.

NATP has a series of performance benchmarks that envisage expanding the Government's share of support for the operational budget as well as improvements in institutional efficiency. The struggle between the Government and the World Bank over adequate operational support for public-sector research and extension has been ongoing for well over a decade. Well-qualified and trained human resources are central to improvements in efficiency and performance. NATP includes support for advanced-degree training in agricultural sciences for staff from ARIs and there are a range of reforms, training and advisory services that are designed to strengthen the role and effectiveness of BARC.

3.3 The regulatory framework for seed

This section is based on the overview of seed systems in Bangladesh prepared by Danida for its Agriculture Sector Support Programme (Boedker *et al*. 2006).

The legal and regulatory framework for seed is currently provided by (i) the *National Seed Policy, 1993*; (ii) the *Seed Ordinance, 1977* (Amendments in 1997 and 2005); and (iii) the *Seed Rules, 1998*. The *Plant Quarantine Regulation* is considered part of the regulatory framework as it also affects the seed sector. The *Plant Variety and Farmers' Rights Protection Act, 2009*, which is awaiting final approval by Parliament, and the proposed National Plant Genetic Resources Institute (NPGRI) are also critical components of plant breeding and the seed system in Bangladesh.

The objectives of the National Seed Policy are to: (i) promote balanced development of public and private sector seed enterprises; (ii) simplify importation of seed and planting material; (iii) provide training and technical support for seed stakeholders in topics related to seed production, processing, storage and use of high-quality seed; and (iv) monitor, control and regulate the quality and quantity of seed produced in Bangladesh. The intention of the Policy was to rationalize and decentralize the national seed sector gradually and attract private investment. Over the years, the new policy framework has moved slowly towards an enabling environment (policy, institutions and infrastructure) for investments and initiatives by the private seed sector.

The Seed Ordinance stipulates the roles and functions of the National Seed Board (NSB) and the Seed Certification Agency (SCA). It also includes clauses covering import and export of seed, the representation of board members, regulation of standards for seed quality, approval and registration of new varieties, labelling of seed and the functions of SCA, and defines penalties for violating the ordinances or rules. The *Seed Amendment Act (1997)* provides the definition of seed dealers and changes in the structure of the NSB. The *Seed Amendment Act (2005)* incorporates clauses for non-notified crops and for increasing penalties for violation. The five notified crops are rice, wheat, potatoes, jute and sugar cane.

The Seed Rules elaborate on the role and function of the NSB and on the procedures for registration of seed dealers, registration of varieties and labelling of the seed offered for sale in sealed containers or packets. The functions of the SCA and its seed inspectors are highlighted. The Seed Rules also describe the regulatory framework for seed in more detail and stipulate the forms and procedures for variety registration, field inspection, seed certification and market control.

The Plant Quarantine Regulation was drawn up in 2005 and submitted to the Government; it is still awaiting approval. The aim of the Regulation is to ensure safe importation of plant products, including seed, into the country without creating obstacles to international agricultural trade and international transfer of germplasm.

To import seed into Bangladesh, an import permit and a phytosanitary certificate are required. The import permit is issued by the Plant Protection Wing of the DAE and the phytosanitary certificate is provided by the exporting country (Huda 2001). The International Seed Testing Association (ISTA) orange certificate is not yet mandatory for imports to Bangladesh but a quality certificate from the seed certification authority of the exporting country is required. In addition, imported varieties of the five notified crops must be listed on the Official National List of Varieties and comply with crop-specific standards.

Documentation required to export seed is issued by the Plant Protection Wing of DAE in the form of an export permit and a phytosanitary certificate. However, Bangladesh does not have an ISTA-accredited laboratory that can issue seed-quality certificates for export. This deficiency could become a more significant problem in the future as private and public agencies develop varieties that might serve wider markets in the region.

3.4 Institutional framework for public-sector plant breeding

3.4.1 National agricultural research system

The Agricultural Research Laboratory, established in Dhaka in 1908 under the Bengal Department of Agriculture by the British Colonial Government, underwent several transformations before becoming BARI in 1976. BARI is the country’s largest agricultural research facility. At present, the NARS consists of ten ARIs, with BARC as the apex body. BARC is responsible for coordinating research and fostering interinstitute collaboration, monitoring and reviewing the research programme, assisting the ARIs in strengthening research capacities, establishing system-wide operational policies and standard management procedures and assuring that each institute is optimally governed (BARC Act 1996). The responsibilities of BARC are being expanded under the NATP to include authority to allocate budget to the ARIs.

Three of the ARIs are involved in plant breeding for the crops included in this study: BARI, the Bangladesh Rice Research Institute (BRRI) and the Bangladesh Institute of Nuclear Agriculture (BINA). All three are autonomous bodies under the Ministry of Agriculture (MOA).

BARI: BARI has more than 600 researchers and conducts research on wheat, maize, vegetables, pulses, oilseeds, spices and most other food and fruit crops and trees. The institute is also responsible for technology testing and transfer and maintains an On-Farm Research Division. BARI has seven crop research centres, 14 research divisions, six regional research stations, 28 substations and a number of trial sites spread over various agro-ecological zones of the country. Among the seven research centres, the Horticulture Research Centre (HRC), Pulses Research Centre (PRC) and Oilseed Research Centre (ORC) are responsible for vegetables, pulses and oilseeds, respectively. ORC and PRC are currently under one management unit. HRC has a large facility with well-equipped laboratories and about 120 researchers. Commodity-based plant breeding research is carried out in these centres, in general independently from BARI's Plant Breeding Division, which focuses on maize, barley and other minor cereals. BARI also has a Plant Genetic Resources Centre (PGRC), which maintains germplasm collections for research and conservation purposes, and has recently established a Biotechnology Division.

BRRI: Established in 1970, BRRI conducts research on all aspects of rice and has nine regional stations with around 228 researchers. It employs 15 researchers in its Plant Breeding Division and maintains a Biotechnology Division with eight researchers and a Genetic Resources and Seed Division with ten researchers. It has enjoyed strong collaboration with the International Rice Research Institute (IRRI) in all areas, including plant breeding. BRRI is discussed in more detail in the rice section below.

BINA: BINA was established as a small radio-tracer laboratory in 1961, with a mandate to conduct research on rice, pulses, oilseeds, jute, cotton and tomato, applying nuclear/radiation techniques. It has five substations, employs about 80 researchers and maintains a Plant Breeding Division, including a tissue-culture laboratory. It started breeding crops in 1980, using local landraces and lines from other sources to develop early-maturing, disease- and salinity-resistant varieties with high yield and grain quality. BINA has used marker-assisted selection to identify genes for salt tolerance, fragrance and resistance to bacterial leaf blight in rice. Use of tissue culture techniques is at an early stage. Future priorities will focus on developing stress-tolerant (salinity, drought, submergence and heat) crop varieties using marker-assisted selection and induced mutation.

While breeders at ARIs make crosses and evaluate their own germplasm, most of their efforts are devoted to evaluating segregating populations and advanced lines from outside sources. The extent to which this is true varies, as discussed in the individual commodity sections. In the 1970s and 1980s use of advanced lines from external sources, particularly from international agricultural research centres (IARCs), was adopted as a strategy for quickly developing improved varieties suitable for local conditions. When BARI and BRRI were established this strategy made sense because they had too few breeders with the required experience to make local crosses and there was an immediate need for HYVs adapted to the local environment to increase food production quickly. However, the lack of trained breeders continues to be a major constraint, particularly in BARI.

Breeding efforts in ARIs are generally concentrated on open-pollinated varieties (OPVs), although in recent years there has been increasing focus on developing hybrid varieties, in response to demand from farmers for hybrid varieties of maize, rice and vegetables.

3.4.2 Plant genetic resources

Breeders will make more local crossings and use more biotechnological tools in the future, and the demand for local germplasm with desired characteristics is expected to increase. Apart from high yield, a modern variety is often expected to combine specific duration, nutritional attributes and adaptation to varying soil and water regimes, as well as resistance to pests and diseases and greater potential for added value. To meet these objectives, a wide range of germplasm must be available and breeders should have easy access to these resources.

All the ARIs and some universities have collected plant genetic resources for utilization in their breeding programmes and for characterization and short-term preservation. However, systematic evaluation and long-term preservation is incomplete and generally inadequate. BARC proposed the establishment of the NPGRI to act as a national repository for genetic resources of crops and other plant species. This proposal is being considered by the Government. The NPGRI would be responsible for the collection, morpho-molecular characterization, evaluation, documentation and preservation of germplasm, as well as the establishment of an electronic database to facilitate easy user access. It would encompass all public and private agencies, universities and NGOs and exchange materials with national and international organizations. In 1983 BARI established a PGRC in Gazipur; the Centre has the largest and most diverse collection of germplasm in Bangladesh and is the proposed site for the NPGRI.

3.4.3 Bangladesh Agricultural Development Corporation

BADC was established in 1961 (as the East Pakistan Agricultural Development Corporation) primarily to supply fertilizers, seed, minor irrigation equipment and limited mechanized services to farmers. It has played a major role in distributing chemical fertilizers and seed and installing irrigation equipment, which in turn facilitated the expansion of HYV rice cultivation during the 1970s and 1980s. BADC's role has diminished over the years with increasing private sector involvement during the 1990s, but it continues to play an important role in producing seed (Figure 3), particularly of OPV rice, and expansion of small-scale irrigation through public projects.

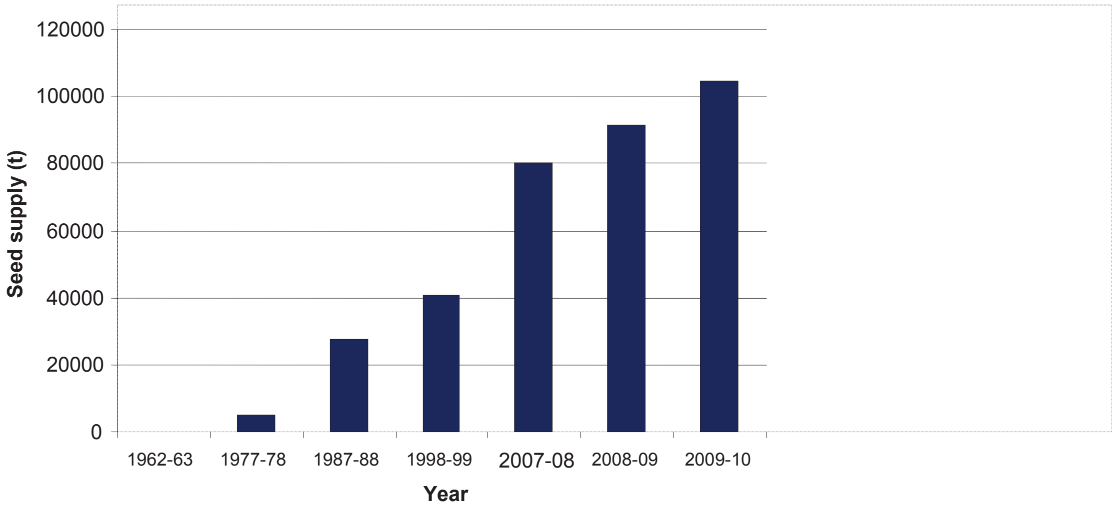

Figure 3. Growth in volume of seed supply by BADC since its establishment
Source: M. Nuruzzaman, unpublished data.

BADC produces foundation seed using breeder seed received from the ARIs. It maintains 21 seed multiplication farms and 12 seed processing centres and uses almost 60 000 smallholders as contract growers for production of certified seed. It produces seed of cereals (rice, wheat and maize), potato, jute, pulses and oilseeds, vegetables and spices. It supplies about 20 percent of the country's cereal seed requirements and about 2–5 percent of seed of other crops. It has about 1 300 licensed dealers for marketing certified seed, including registered private seed dealers and NGOs. In addition, it has two agro-service centres (at Kashimpur near Dhaka and in Comilla) to help growers with inputs and technology and conducts promotional activities for vegetables and fruits for export.

Fertilizer distribution was first put into the hands of private wholesalers in 1975–1977. Controls on farm-level sale prices were removed in 1982–1983. The Government's monopoly on fertilizer import was lifted in 1991. In the first 5 years after fertilizer price controls were removed, farmers gained significantly as the marketing margin between wholesale and farm-level prices decreased by 29 percent (Samad 1999). Imports and use of fertilizer increased substantially in the 1990s compared with the early 1980s.

In the irrigation sector, between 1986 and 1988 the Government liberalized private importation of diesel engines and in 1989 dropped key clauses in groundwater ordinance to lift restrictions on tube-well siting distances. This led to a dramatic expansion of *boro* rice production, and in 1999, *boro* production surpassed that of *aman* for the first time.. Recently however, there has been growing concern about possible negative consequences of groundwater extraction for *boro* rice cultivation; aquifers are not being fully replenished by precipitation and the water table is falling every year, reducing the availability of water for both drinking and irrigation. It has been argued that more wheat or other crops could be grown with the same amount of water.

3.4.4 Department of Agricultural Extension

DAE is the largest Government agency under the MOA. It is the primary agricultural extension agency responsible for technology transfer on crops. Its Plant Protection Wing is charged with enforcing plant quarantine rules and regulations, and issues import and export permits for seed and plant products.

DAE has a network of 75 horticultural nurseries throughout the country that produce seed, vegetable seedlings and ornamental plants for sale to the public. The quantity of seed produced is negligible in the context of the national seed market.

DAE's current role in seed production is through a 5-year project, "Production, Storage and Distribution of Quality Rice, Wheat and Jute Seeds at Farmers' Level", which started in 2007. Through this project DAE provides training to farmers and supports the production of improved seed of the three crops. The project works through block demonstrations. Each block consists of one to three farmers, who are given training in seed production, and the blocks are used as practical demonstration sites. Farmers have acquired better knowledge and skills in quality seed production through the training programme of this project, and the project has supplied almost 20 percent of cereal seed in recent years. Some of these farmers produce excellent quality seed, and also sometimes act as contract growers for private companies. However, the farmers do not have access to processing or proper storage facilities and therefore often have to sell seed in the open market at low prices (Rahman 2010). For a detailed discussion of this effort and other local participatory initiatives in the seed sector, see Van Mele *et al.* (2005), most notably Part V, "Pro-Poor Seed Systems".

3.4.5 National Seed Board

The NSB is a statutory body comprising 21 representatives from various official institutions and the private seed sector. The Secretary of MOA chairs the NSB, while the Director-General of MOA's Seed Wing acts as Member-Secretary. NSB is the apex body which finally approves any variety release. It also advises the Government on issues relating to seed, policies and standards, etc.

3.4.6 Seed Certification Agency

The SCA, established in 1974, is the statutory body under the MOA's Seed Wing which authorizes seed certification and variety release. It coordinates technical committee meetings, and field evaluation and the variety release system through its field inspection wing. It maintains a National Seed Testing Laboratory in Gazipur, with a regional laboratory in Ishurdi, Pabna. It also has 25 other seed-testing laboratories around the country with basic facilities. The private seed sector is pushing hard for an ISTA-accredited laboratory to be set up in the country, either as a private initiative or as a part of SCA.

SCA has a staff strength of 223, including 30 field officers to carry out field inspections. An additional 112 positions have been approved recently. All its positions are filled by DAE staff, who are often transferred back to DAE, resulting in a loss of trained and experienced manpower. SCA has too few staff and too little budget to make field evaluations of the large volume of seed produced by BADC, private companies and contract growers scattered around the country.

BADC and private companies sell truthfully labelled seed (TLS) produced by contract growers. TLS are exempted from quality certification by SCA. These seed lots are certified by the producers themselves, and in many cases this has resulted in the sale of poor-quality seed under the name of TLS. This reduces farmers' trust in this so-called 'quality seed'. Seed companies are progressively taking into account the need for self-regulation and setting their own quality standards. The Bangladesh Seed Association compels dealers who sell corrupted or counterfeit seed to pay a fine, close their shops for a few days and hang a banner in front apologizing for their transgressions.

3.5 Agricultural universities

There are four agricultural universities under the Ministry of Education – Bangladesh Agricultural University (BAU), Sylhet Agricultural University, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) and Sher-e-Bangla Agricultural University (SAU) – as well as five science and technology universities. Plant breeding research is conducted in the universities through their graduate research programmes.

The Department of Genetics and Plant Breeding and the Department of Agronomy at BAU have been working on several crops since the 1970s, including rice, wheat, tobacco, soybean, vegetables, pulses and oilseeds. They have implemented soybean breeding projects with external assistance and released several varieties of soybean, two varieties of mustard/rapeseed and one rice variety. SAU, which was established recently, has limited facilities and plant breeding programmes. It recently signed a memorandum of understanding (MOU) with the Supreme Seed Company to initiate a collaborative breeding programme. BSMRAU was established in 1983; it has eight academic staff in plant breeding and has secured approval for an additional eight staff members. Since 1993 BSMRAU has made major efforts in evaluating segregating populations of its own crosses of rice, pulses and vegetable crops. It also evaluates fixed lines and potential cultivars from other sources. It has recently signed an MOU with a private company (ACI Ltd) for collaboration in seed production.

Plant breeding at BAU has declined in recent years. However, BSMRAU is expanding the number of staff positions in plant breeding with a view to making it a central feature of its curriculum. BSMRAU's proximity to BRRI and BARI provides opportunities for collaboration in research that both BSMRAU and the research institutes seem interested in expanding.

3.6 The private sector

Most plant breeding in Bangladesh continues to be in the public domain. However, NGOs and private companies are becoming increasingly involved in plant breeding, in response to the growing demand from farmers for good-quality and better-performing varieties.

The Seed Policy of 1993 and Seed Rules of 1998 paved the way for active participation of the private sector and NGOs in seed production. The increased participation of private-sector actors in seed production is also a result of several donor-driven Government projects. The Food and Agriculture Organization of the United Nations (FAO) supported the Strengthening of the National Vegetable Seed Program (1986–93), working with BADC, BARI and DAE. the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) supported the Bangladesh German Seed Development Project with BADC (1989–2000). Danida supported seed industry development through their sector-wide support activities in agriculture and worked with all the players in the seed industry (2002–2006). All these projects contributed to stimulating the private sector to produce and market good-quality seed as well as strengthening the capacity of the public-sector actors, thereby improving the interface between the sectors.

The project on Poverty Elimination through Rice Research Assistance (PETRRA), supported by IRRI, stimulated participatory research and action among farmers and other institutions, including BRRI, the Rural Development Academy in Bogra, and some NGOs (Van Mele *et al*. 2005). This created a number of good examples of farmer participatory research and, on a limited scale, promoted good-quality seed production at farmer level. The activities of the South Asia Enterprise Development Facility (SEDF) and KATALYST (a Ministry of Commerce project) to promote entrepreneurship and business development also enhanced private-sector involvement in seed production and marketing. Their sectoral and subsectoral studies were very important tools guiding investors' decisions on seed-crop choice, area selection, marketing strategies, etc. SEDF also provided a matching grant of up to US$50 000 to some of the private investors to assist in research and development of processing and production facilities. At least four private companies have established facilities for plant breeding and seed processing (Table 1).

Table 1. Private companies involved in plant breeding

Company	Year established	Number of breeders	Choice of crops
Lal Teer Seed Ltd	1995	16	Rice, vegetables
ACI Ltd	1997	6	Rice, potato, vegetables
Supreme Seed Ltd	2005	10	Rice, maize, tomato
Getco Agro Vision Ltd	2006	3+	Rice and vegetables

Some private companies are involved in multiplying seed from foundation seed received from BADC and breeder seed from the ARIs, and have established a network of seed growers; however, most companies import seed and sell through dealers (Rahman 2010). There are about 60 private seed companies in Bangladesh, and they have formed a number of associations, such as the Seedmen's Society of Bangladesh, Bangladesh Seed Merchants' Association and the Bangladesh Seed Growers' Welfare Association. In 2003, the seed associations formed the Seed Federation of Bangladesh to represent the business interests of the private companies and influence the Government in seed-related policy issues.

While this expansion in private-sector seed activities has been impressive, the growth in the number and scale of companies outstripped the capacity of SCA to monitor activities and certify seed. Self-regulation by at least some of these bodies is beginning to take place but as yet it is inadequate.

3.7 Non-governmental organizations

Bangladesh has several thousand NGOs, about 20 of which are involved in seed production and marketing. The most important include the Bangladesh Rural Advancement Committee (BRAC), Grameen Krishi Foundation (GKF), Proshika, Rangpur Dinajpur Rural Services (RDRS), Gono Kollan Trust, Agricultural Advisory Society, ActionAid, Padakhep, Shushilon and Helen Keller International. These and other NGOs are involved in multiplication and marketing of seed, including seed of hybrid rice, maize and vegetables. They have also formed a seed NGO forum to promote their interests. The extent and quality of NGO involvement in seed production varies substantially, and there are debates about how well the NGOs balance their philanthropic, microcredit and commercial objectives.

BRAC, established in 1970, is one of the largest and most reputable NGOs in the world. It provides various social development services. It employs nearly 120 000 people in Bangladesh and is working in eight other countries. BRAC's microfinance operation disburses about US$1 billion a year. It has a diverse portfolio. It established *Aarong*, its fashion and home décor brand in 1978, which earns about US$25 million in annual sales. It is an internet service provider and runs a bank, a university and informal primary schools. It runs feed mills, chicken farms, tea plantations and packaging factories. In 1997 it started exporting vegetables, in collaboration with the Horticultural Export Development Foundation (Hortex). Income from BRAC's operations provides about 80 percent of the money it disburses to the poor; the remainder is aid from donors. BRAC entered vegetable breeding and seed production in 1996.

3.8 International collaboration

ARIs have enjoyed strong collaboration with IARCs since the 1970s. Notable collaborations include BRRI and IRRI for rice, BARI and the International Maize and Wheat Improvement Center (CIMMYT) for wheat and maize, BARI, the International Center for Agricultural Research in the Dry Areas (ICARDA) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) for pulses, BARI and the World Vegetable Center (AVRDC) for vegetables, BINA, BSMRAU and AVRDC for mung bean and other pulses. ARIs also have connections with other external public and private organizations and universities that are sources of germplasm and knowledge. Recently BRRI initiated a breeding programme on super rice with the Chinese Academy of Science. While international collaboration has benefited the ARIs by providing training, germplasm and advanced lines for testing, it may also have helped to develop a sense of dependence. This might be a reason why ARIs have not been involved in extensive local crossing. There are also growing contacts between ARIs in Bangladesh and national and international seed companies in other countries, mainly in Thailand, India and China.

Further discussion of public and private international collaboration is included in the crop sections.

3.9 Biotechnology

Some observers feel that biotechnology could enable breeders to break the current yield ceilings for HYVs (M.M. Rahman, personal communication). Although a growing number of public and private institutions have biotechnology laboratories, they lack trained professional staff, maintenance and supplies. In April 2010, Parliament approved the *National Institute of Biotechnology (NIB) Bill 2010* creating the NIB as an autonomous agency under the Ministry of Science and Information & Communication Technology.

Biotechnology research at BARI started with the establishment in 1985 of a tissue-culture laboratory for production of disease-free potato seed. A second tissue-culture laboratory for micropropagation of horticultural crops was established with FAO assistance in 1993. This became the Biotechnology Division in 1998. Recently, a state-of-the-art research laboratory with a modern, automated, Class II research greenhouse was established under HRC with Government funding. HRC's priority is to develop a precise diagnostic protocol for tomato leaf curl viruses for use in developing virus-resistant varieties of tomato and other crops using recombinant-DNA technologies (Akhond n.d.).

BRRI has conducted research on DNA finger printing and marker-assisted selection for salt- and drought-tolerant rice varieties. BINA has excellent research facilities with a molecular technology and biotechnology laboratory in addition to radiation technologies to undertake advanced breeding techniques.

Use of biotechnology in the universities is very limited, except at the BAU, where a Department of Biotechnology was established in 2001. The Department of Genetics and Plant Breeding at BAU also has a tissue culture laboratory and established facilities for molecular breeding and genetic finger printing (GFP) with support from the United States Department of Agriculture and Danida. The GFP laboratory finger printed 157 crop varieties of 20 crop species in 2005–06, 204 rice varieties in 2007–08 and is completing work on 150 traditional and stress-tolerant varieties of rice, eggplant and rapeseed in 2010 (L. Rahman, personal communication). Dhaka University is conducting research on applying biotechnology to development of improved crop varieties. The Department of Biochemistry and Molecular Biology is using molecular markers to develop salt-tolerant rice varieties for the coastal region. The Department of Botany, in cooperation with Hanover University, Germany, has made progress in incorporating insect and disease resistance in pulse varieties.

4 Rice

Rice breeding in Bangladesh has taken on a new dimension as private companies and NGOs have been investing significantly in what until recently had been exclusively in the public sector. This section gives a background to rice research with emphasis on rice breeding, its challenges, organization, current priorities, seed supply, issues of concern and future prospects.

4.1 Brief history of rice research in Bangladesh

Rice research in Bangladesh started with the establishment of the Agriculture Research Station at the Dhaka farm in 1910. Early research focused on selection of pure lines; limited genetic manipulation; and development of improved agronomic practices. A number of indigenous cultivars were identified as having comparatively high and stable yield, including Hashikalmi, Kataktara and Dular for *aus*, Latishail, Raghushail and Nigershail for T-*aman*, Gabura, Baishbish and Maliabhangar for broadcast *aman*, and Tepi Boro and Kaliboro for *boro*.

Rice breeding efforts intensified in 1970 with the establishment of BRRI (then the East Pakistan Rice Research Institute) at Joydebpur Farm in present-day Gazipur district, near Dhaka.

4.2 Early challenges and breeding strategies

In the 1960s population growth was widening the gap between food requirements and domestic production. The East Pakistan Accelerated Rice Research Project was launched in 1966 to promote three varieties from IRRI (IR5, IR8 and IR20) and a Chinese variety renamed Purbachi. These releases were regarded as short-term measures and BRRI began crossing IRRI lines with the best local lines to develop varieties adapted to local edaphic and agro-ecological conditions (EPRRI, 1971). During the early 1970s, *aman, aus* and *boro* accounted for 55 percent, 35 percent and 10 percent, respectively, of total rice production. *Aus* rice was mostly direct seeded under rainfed conditions and often suffered from pre-monsoon drought. *Aman* suffered from flooding at various stages during the monsoon. BRRI's breeding strategies, therefore, aimed at developing varieties with both drought and submergence tolerance. In 1973, BR3 was released for use in all three seasons.

The long straw of local rice varieties has traditionally been used for thatching roofs and as fodder for livestock. The short-strawed HYVs from IRRI and China were higher yielding than the local varieties, but did not meet farmers' needs for straw. Therefore, BRRI opted for intermediate plant height of between 120 and 125 cm. Breeding objectives were expanded to address pest and disease tolerance, especially for brown plant hopper (BPH) and bacterial leaf blight, and shorter field duration, as well as higher protein content.

4.3 Roles of institutions in rice breeding in Bangladesh

4.3.1 The public sector

Until recently rice breeding was located exclusively within the public sector. BRRI, under BARC/MOA, has remained at the centre of rice research, carrying out breeding, conservation and development since its establishment in 1970. Currently BRRI has nine regional stations in various parts of the country. The other major actors are BINA and three agricultural universities: Sylhet Agricultural University, BSMRAU and SAU. BRRI has so far released 52 varieties including hybrid varieties. BR 11 released in 1980 became the most popular of the HYVs, followed in the mid-1990s with release of BRRI dhan 28and 29. Its recent releases, such as BRRI dhan 43 is recommended for drought prone areas, while BRRI dhan 47 is a salt-tolerant variety. BINA has been continuously involved in rice breeding and has released seven varieties to date. BAU was a marginal player, developed two varieties, but no longer works on rice breeding.

BRRI currently has a team of 15 breeders, including two chief scientific officers, two principal scientific officers, three senior scientific officers and four scientific officers. Four of the scientists are currently away on training in PhD and MSc programmes. BRRI has developed 57 *Aman* varieties, 66 *Boro* and 25 *Aus* rice varieties.

BINA employs 14 breeders, seven with PhDs and seven with MScs. Three to five scientists are involved in rice research.

So far, BINA has released seven rice varieties. BINA dhan 7 is a salt-tolerant variety, which BINA claims to be higher yielding and more tolerant to salt than the previously recommended BRRI dhan 47. Another salt-tolerant variety, BINA dhan 8, is in the process of being approved.

Among the universities, BAU released one rice variety. Breeding programmes in the universities have generally been a part of postgraduate research studies.

4.3.2 The private sector

The private sector entered rice breeding when the Supreme Seeds Company Limited (SSCL) started their activities in 2004. Lal Teer, ACI, Getco and some other private companies also have breeding activities. The private companies' breeding activities focus on development of hybrid rice varieties, an evolving trend from their initial entry point of mainly multiplying and marketing the varieties developed by the public sector institution, BRRI.

SSCL brought parent materials from India and China. Its hybrid rice variety, Heera dhan, has been well received by farmers. Lal Teer has invested heavily in hybrid rice breeding in recent years. It has established seed-processing facilities and laboratories to carry out biotechnology work, hybridity tests, etc. Similarly, ACI and Getco expect to release their own hybrid rice varieties in 2010.

4.3.3 NGOs

Among the NGOs, BRAC pioneered R&D activities in agriculture and started breeding rice even before the private companies. It has a team of 20 scientists and 20 assistants. BRAC has released four hybrid varieties, and five more are in the pipeline. It has developed very good links with Chinese institutions and breeders of late and is testing a number of lines from them. BRAC is a partner in a long-term IRRI–China collaborative research project on Green Super Rice, partially funded by the Bill and Melinda Gates Foundation.

4.4 Research support from IRRI

IRRI has been a significant source of support for rice research in Bangladesh. It has an office in the country to coordinate all the research collaborations and support programmes. The latter include short-, medium- and long-term training in research and research support services. MSc and PhD training was offered in collaboration with the University of the Philippines.

Most of the rice varieties released by BRRI have IRRI parentage. BRRI participated in all of IRRI's international programmes as part of the networks for pests and disease resistance, problem soils, upland rice, deep water rice and farming systems research. BINA also received support from IRRI. In addition, IRRI spearheaded several innovative efforts in seed production and marketing through the PETRRA project beginning in the mid-1990s (Van Mele *et al*. 2005).

4.5 Extent of expansion of modern rice varieties

Although a number of varieties have been released since the late 1960s, their diffusion remained very slow for many years. The main reasons for this slow adoption were the inadequacy of prevailing public policies and marketing arrangements for inputs, notably fertilizers, pesticides, irrigation equipment, machinery and seed. The liberalization measures initiated in the 1980s and 1990s stimulated the adoption of improved practices. Rice production grew at a compound rate of 2.17 percent annually between 1974 and 1985 and by 3.06 percent annually between 1985 and 2002 (Hossain *et al*. 2003). By 1996/97, modern rice varieties covered more than 50 percent of the total rice area (BBS 2000). According to BRRI, its varieties (mainly BR28 and 29) covered 66 percent of the *boro* rice area 57 percent of the *aman* area and 25 percent of the *aus* area in 2008/09 (Table 2). Hybrid rice covered over 18 percent of the *boro* area, while local varieties accounted for 20 percent of the *aman* area and 24 percent of the *aus* area.

Table 2. Percentage of area covered by rice varieties from BRRI and other sources, 2008/09

Season	BRRI varieties		Other modern varieties				Local varieties
	Total (all varieties)	Major varieties	Hybrids	Indian varieties	Pajam + Purbachi	BINA varieties	
Aman	57	BR11 – 32	<1	17	5		20
Boro	66	BR28 – 31 BR29 – 26	18	13		<2	<1
Aus	25	BR28 – 11	<2	13	2		24

Source: BRRI Agriculture Economics Division, 2010 (Personal communication).
N.B. *Aus* varieties not classed above, having various other names, constitute the remainder of the 100 percent

4.6 Current challenges and research priorities

Bangladesh still faces the challenge of feeding its ever-increasing population. Although it is close to achieving self-sufficiency in cereals in normal years, any disruption in production caused by unfavourable conditions can result in significant shortfalls. Recent variety development efforts have focused on tolerance of abiotic (drought, submergence and salinity) and biotic stresses (including bacterial blight, rice tungro virus, green and brown leaf hoppers and other insect pests). BR40 and BR47 withstand considerable levels of salinity, while BR42 and BR43 have some degree of drought resistance. BRRI estimates that these varieties will yield at least 20 percent more than earlier BRRI varieties. BINA dhan 7 and BINA dhan 8 are salt-tolerant and can produce more than 3 t/ha in areas where popular varieties produce little or no yield.

Farm rice yields are still below potential yields, partly because of problems in the timely availability of fertilizers and quality seed. Liberalization and the involvement of the private sector have helped to address this issue. There are also crop management and cultural issues but much of the yield gap is due to unfavourable growing conditions, particularly drought, salinity and submergence. Climate change is making these problems worse. The current breeding efforts focus on developing varieties tolerant of early flooding, submergence and salt.

4.7 Seed requirements and production

Rice farmers in Bangladesh plant more than 300 000 tonnes of seed annually, 60 percent of which consists of farm-saved seed. Official figures for seed requirements and supply are maintained by BADC with the help of DAE. Through a very centralized approach, DAE estimates the requirement for various crop seeds with the help of its offices in the regions, districts and *upazilas* (subdistricts). These estimates are utilized to formulate the national food production plan, and BADC prepares its seed production plan accordingly. Most of the rice seed purchased by farmers are supplied by BADC. In 2008/09, BADC rice seed and TLS (the farmer-to-farmer seed programme of DAE, supplying mostly uncertified seed) accounted for 44 percent of seed purchases. For 2009/10, the rice seed requirement has been estimated at a little over 303 000 tonnes and supply at nearly 120 000 tonnes, including TLS (Seed Wing, DAE, personal communication). It has, however, been difficult to obtain seed production estimates for private companies.

4.7.1 Production and supply of seed of hybrid rice

Cultivation of hybrid rice in Bangladesh started to accelerate from 1999/2000. Private companies initially imported seed of hybrid varieties mainly from China and India but are now producing hybrids locally. BRRI introduced its first hybrid variety in 2001 but its acceptance by farmers was limited (M. Hossain, personal communication). BRAC developed its R&D capacity for hybrid seed during 1999–2001 and has since been increasing its supply. Production of seed of hybrid varieties in Bangladesh grew from 300 kg in 1999/2000 to over 2 000 tonnes in 2007–2008 (Table 3). Estimates for 2008/09 are between 3 000 and 4 000 tonnes.

Table 3. Supply of hybrid rice seed and area coverage in Bangladesh, 1999/2000 to 2007/08.

Year	Import (t)	Local production (t)	Total Supply (t)	Estimated area (000 ha)
1999/00	150	0.3	150	9.7
2000/01	200	27	227	15
2001/02	215	143	320	23
2002/03	350	206	556	36
2003/04	621	182	803	52
2004/05	1 080	392	1 472	95
2005/06	2 250	685	2 935	189
2006/07	4 ,650	1 874	6 524	421
2007/08	7 755	2 271	10 26	647

Source: M. Hossain, unpublished data.

4.8 Issues and future prospects for rice research and breeding in Bangladesh

Though recent achievements in rice production are impressive and both public and private sectors are active in rice breeding, there remain several issues of concern. Public-sector rice breeding has been dominated by BRRI. However, much of the germplasm for the released varieties came from IRRI, indicating an inherent weakness in the ability of BRRI to develop material independently. High staff turnover and fluctuations in budgets for breeding are part of the problem. Research activities were funded mainly from external sources, and often have been tied to IRRI breeding programmes. In recent years BRRI has not produced varieties that can rival those that were released more than a decade ago (notably BR11, 28 and 29). Furthermore, varieties from India appear to be more popular in several areas of the country (not only the border areas) than those that have been locally developed (A. Hossain, personal communication) and cover 13 percent of the planted area.

The other issue of concern is a low level of motivation among public-sector researchers. Public-sector rice breeding declined during the early 1990s, when many scientists emigrated because of poor pay and conditions in local institutions and lack of recognition for their work. BRRI alone lost about 25 breeders and other scientists associated with breeders, including five very senior principal scientific officers with an average of 20 years of experience who received either PhD or MSc training abroad. Seven senior scientific officers with an average of 15–18 years of experience also left. In contrast, BINA has not lost any breeders since 1994. However, vacancies have remained unfilled for several years, including five senior positions, and thus the excellent research facilities are not being used to their full potential.

Part of the reason for the low morale and loss of staff can be attributed to the ARI's management procedures, which are very top-down and old-fashioned. Decision-making on research formulations are at best arbitrary and follow traditional orientations. Farmer participation in the breeding programmes exists, at least in theory, but is not as systematic or effective as it could be. Perceptions of the problems to be addressed by breeding solutions are based on limited interaction with farmers. Because of limited funding, there is a tendency to defer ventures that may appear complex and costly. As a consequence, there is a lack of clarity concerning the role and effectiveness of BRRI in facing the major challenges facing rice production in Bangladesh.

On the other hand, farmers are increasingly open to new varieties and technologies that address their needs. The involvement of the private sector in rice breeding should place more emphasis on farmer (customer) needs and preferences. Private companies are already approaching ARIs and universities to explore collaboration in breeding and seed production. Private companies first sourced hybrid varieties from abroad and hence have developed close links with public and private organizations in China, India, Thailand and other countries. An example is the current collaboration on Green Super Rice. These developments are bringing about significant changes to the rice breeding landscape. It is only a matter of time before the area planted to hybrid rice varieties will surpass that planted to OPVs, with private companies playing key roles in developing, multiplying and marketing hybrid varieties. In order to expand hybrid rice production, ARIs and universities will need to collaborate with private companies and NGOs in varietal development, seed multiplication and provision of support services. The mechanism for such collaboration will need to be clearly spelt out between the parties to avoid contention. However, competition can also be healthy and is a major feature of private sector involvement. Given the traditional orientation of ARIs, it may be some time before there is any meaningful collaboration in rice breeding between the public and private sectors. It is hoped that NATP programmes will be successful in fostering this process.

5 Vegetables

5.1 Public-sector vegetable research in Bangladesh

Vegetable research in BARI started in 1980 and gained momentum in 1989 with the start of a project supported by the Asian Development Bank enabling collaboration with AVRDC. BARI created the HRC in 1994 with World Bank assistance. The United States Agency for International Development (USAID) later joined forces in strengthening HRC, which now has about 120 researchers and excellent field and laboratory facilities. The Centre has 16 breeders in its vegetable breeding programme and has utilized about 15 percent of its resources in making crosses locally and evaluating its own segregating populations over the last five years. HRC has not yet started using tissue culture or marker-assisted selection, nor does it keep an electronic database of its breeding records.

BINA conducts research to develop improved tomato varieties using a combination of radiation-induced mutation, biotechnology and traditional breeding. The Institute has developed three tomato varieties, including two summer varieties released in 1997. BAU and BSMRAU also carry out research related to vegetable breeding as part of their postgraduate programmes.

5.1.1 Collaboration with AVRDC

The collaborative research programme on vegetables between BARI and AVRDC started in 1991 with USAID funding, which continued through 2000. Under the programme, AVRDC provided a total of 3 454 varieties of 59 different vegetable crops to BARI, other NARS institutions, private seed companies and NGOs. The project also supported the collection of indigenous germplasm of pointed gourd and drumstick (*Moringa oleifera*) at Ishurdi. Varieties of newer crops such as long melon, muskmelon, round melon, asparagus and baby corn were also introduced to bring diversity and sustainability into vegetable production. During 1993–2000, a total of 42 vegetable varieties were released, 34 by BARI, seven by BINA and one by BSMRAU. Dozens of promising lines of several crops are in the pipeline. All 13 varieties of tomato released by BARI and BINA during this period were developed from AVRDC material; some of these varieties are rich in beta-carotene. An okra variety resistant to yellow vein mosaic virus (YVMV) replaced all other popular varieties on about 80–85 percent of the area (AVRDC 2001).

HRC’s current research focuses on the collection and evaluation of germplasm; evaluation of segregating lines; and selection of advanced lines of Solanaceae, Cruciferae, Cucurbitaceae, Leguminaceae and other vegetables. Selection criteria include high yield and resistance/tolerance to diseases, insects and various abiotic stresses, with plans to add nutritional quality . Development of hybrid vegetables is a priority for some crops such as tomato and eggplant. BARI has released four hybrid varieties of tomato and two of eggplant.

Twenty-five BARI scientists were trained in research skills at AVRDC for between 4 weeks and 7 months. Three BSMRAU students conducted part of their PhD research work at AVRDC. Several other researchers have been trained through various donor projects.

5.1.2 Collaborative Research Support Program on vegetable integrated pest management

USAID's vegetable Collaborative Research Support Program (CRSP) supports a collaborative effort among BARI, BRRI, BSMRAU, AVRDC, IRRI and several universities, including Virginia Polytechnic Institute and State University, United States. Support to Bangladesh from the CRSP started in 1998–99 and will continue at least until late 2010. Current activities in vegetable breeding include evaluation of eggplant and tomato germplasm for resistance to fruit and shoot borer, jassid, bacterial wilt, virus diseases and nematode root knot; evaluation of cucumber germplasm for *Fusarium* wilt resistance; development of pumpkin varieties resistant to papaya ring spot virus and watermelon mosaic virus-2; development of virus-resistant cucumber varieties; evaluation of okra germplasm to develop variety resistant to YVMV; and development of hyacinth bean (*Dolichos lablab*) varieties resistant to pod borer and virus diseases. Key successes include grafting against bacterial wilt in eggplant and tomato, soil amendment practices to control soil-borne diseases in vegetables, biological control of eggplant fruit and shoot borer and diamondback moth of cabbage, and the use of pheromone bait traps to reduce fruit fly in gourds. NGOs such as CARE and the Mennonite Central Committee were involved in farmer field demonstrations and farmer training. Several scientists have received training in integrated pest management under this programme.

5.1.3 Collaboration on Bacillus thuringiensis eggplant

Fruit and shoot borer (*Leucinodes orbonalis*) (FSB) is the most widespread and devastating pest of eggplant, causing up to 70 percent crop loss. The FSB larvae feed inside the shoot and fruits, retarding the vegetative growth of the plant and decreasing the marketability and edibility of the fruit. Crossbreeding eggplant varieties with FSB-resistant wild varieties has not been successful. *Bacillus thuringiensis* (Bt) produces proteins toxic to many species of insects, including FSB. The lethal Bt protein is ingested by the insect and the activated protein perforates the lining of the gut, killing the insect.

Under a USAID/Cornell University project, Maharashtra Hybrid Seed Company (Mahyco) of India received the 'Bt cry1Ac gene technology' for insect-pest management from Monsanto and transferred it to several public institutions in India, Bangladesh (BARI) and the Philippines for use in breeding regional eggplant varieties. The public institutions received it on a royalty-free basis; however, East-West Seeds (currently Lal Teer in Bangladesh) is using it on commercial royalty-bearing terms.

At present BARI is conducting limited field trials of Bt eggplant in the regional research stations. It will be several years before any variety is ready for release. Indian institutions were ready to release a Bt eggplant variety; however, in February 2010 the Indian Government, facing severe opposition from state governments, farmers and environmental groups, imposed a moratorium on the release of Bt eggplant for farmers until the time when "independent scientific studies establish, to the satisfaction of both the public and professionals, the safety of the product from the point of view of its long-term impact on human health and environment" (Rediff Business 2010). There is an intense debate going on in India concerning possible effects of Bt technology on biodiversity, health and environment which may affect public opinion in Bangladesh. Both governments are signatories of the Cartagena Protocol on Biosafety, which is a subsidiary agreement to the Convention on Biological Diversity.

5.2 Private-sector involvement in vegetable research in Bangladesh

The demand for vegetable seed in Bangladesh is growing every year. The Government is encouraging private sector involvement in seed production and there has been an enthusiastic response from private companies. Several companies have established vegetable breeding facilities, notably Lal Teer Seed Ltd (formerly East-West Seeds) and ACI Ltd.

Lal Teer, a Dutch/Bangladesh joint venture begun in 1995, breeds OPV and hybrid varieties of vegetables, including bitter gourd, bottle gourd, radish, pumpkin, eggplant and tomato. The company also produces seed of BARI varieties. Lal Teer has an 18-ha experimental farm in Gazipur district with facilities for seed drying, cleaning, controlled dehumidified storage and seed packaging and a mini-gene bank with more than 3 000 accessions of local and foreign germplasm. It employs 16 breeders (for all crops) and nearly 25 000 contract growers for seed multiplication; through these contracts it provides employment to about 100 000 female labourers for cross-pollination. Lal Teer has succeeded in developing some 70 varieties of various vegetables, including nine hybrid varieties. It has established a marketing system featuring dealers, retailers and farmer plot demonstrations for promotional purposes. The company now meets approximately 10 percent of demand for vegetable seed in Bangladesh and expects to cover about 30 percent of the market in the next five years. It is involved in research on Bt eggplant together with BARI and collaborates directly with AVRDC. The leadership of Lal Teer has also played an active role in promoting standards and self-regulation of seed production and marketing through the seed associations.

ACI initiated production of rice, potato and vegetable seed in 1997 on a small farm in Bogra and has established collaboration with BAU, BSMRAU and private companies from China, India, Italy and Thailand. It employs six breeders. Its vegetable breeding programme includes selections from local germplasm, adaptive trials of exotic lines and development of hybrids of tomato, eggplant, radish, cauliflower and various cucurbit vegetables.

Supreme Seed started operations in 2005. It employs a total of ten breeders and works on short-duration summer tomato in addition to rice and maize hybrids. Recently it secured funds from the International Finance Corporation to develop stress-tolerant rice and vegetable varieties.

Getco Seeds, established in 2006, has at least three breeders and an 8-ha farm in Trishal. It works primarily on vegetables and rice. It is evaluating exotic hybrid varieties of vegetables and at the same time making crosses to develop hybrids locally.

Aftab Seed and nearly a dozen of other established businesses, including Ispahani, Energypac, Square, Paragon, Northern and Partex, have recently started producing vegetable seed.

5.3 NGO involvement in vegetable research in Bangladesh

There are about 20 NGOs involved in vegetable seed production and marketing in Bangladesh. The major NGOs in this field are BRAC, GKF, Proshika, RDRS, Gono Kollan Trust, Agricultural Advisory Society and Helen Keller International.

BRAC's seed enterprise was established in 1996 and consists of two processing centres and 18 seed production farms. Most of the seed is produced through contract growers and distributed through 22 marketing outlets involving 260 dealers. It is involved in rice, maize, potato and vegetable seed production. Its vegetable research centre is in Gazipur, with vegetable seed farms in Meherpur, Dinajpur and Thakurgaon. Main activities are: adaptation trials; hybrid development; parent-multiplication; and pre-foundation seed production. BRAC has a tissue-culture laboratory with four greenhouses that are used for micropropagation. In addition to its links with public-sector research and development agencies in Bangladesh, BRAC has direct connections with a range of international and national public and private organizations in other countries. BRAC has released five hybrid varieties – two of eggplant and one each of tomato, pumpkin and bitter gourd. In 2007, BRAC produced 1 337 tonnes of seed of hybrid rice varieties and 61 tonnes of inbred rice seed; 868 tonnes of hybrid maize seed; 71 tonnes of vegetable seed and 3 815 tonnes of potato seed.

5.4 Vegetable seed production

About 70–80 percent of vegetable seed used in Bangladesh for commercial production are imported. There are about 50 private importers of vegetable seed. BADC also imports a small quantity of vegetable seed and produces a small quantity on its farms. Japan supplies nearly 80 percent of the imported seed; other countries supplying seed include India, the Netherlands, South Korea, Taiwan, Thailand and the United Kingdom. Many multinational seed companies have representatives in Bangladesh.

BADC started vegetable seed production on a small scale in 1986 with assistance from FAO/Danida under the Strengthening of the National Vegetable Seed Program. A second phase of the project (1990–1993), with additional support from the Belgian Government, promoted the development of the private seed industry, including strengthening BARI and BADC in basic/foundation seed production activities; stimulating the participation of NGOs and farmers' groups to develop efficient market-oriented vegetable production; and training national staff, seed farmers and entrepreneurs in modern seed technology. This project helped in developing physical facilities for seed production on BADC farms and breeder seed production in BARI. The latter supplied almost all the breeder seed of vegetables. In 2004/05, HRC/BARI distributed 1 635.83 kg of seed for seed production. In 1993, in accordance with the new national free-market seed policy, the project began helping the private sector to produce quality seed.

BADC continues to produce foundation seed of improved vegetable varieties for distribution to seed producers. In 2004/05, BADC produced 7 tonnes of foundation seed and 14 tonnes of quality seed of 33 varieties of 22 vegetable crops, all OPVs (Vegetable Seed Wing, BADC, Dhaka, personal communication). As demand for hybrid seed grew in recent years, demand for BADC-produced vegetable seed declined and BADC is no longer expanding its vegetable seed operations. BADC's seed is sold at subsidized rates, which is a concern for private companies. However, the role of BADC will gradually be restricted to the production of foundation seed. It has also been decided that some of BADC's facilities will be made available to the private sector.

At a recent seed conference in Dhaka, M.N. Huda presented an estimate of the demand and supply of vegetable seed in the last 3 years (Figure 5).

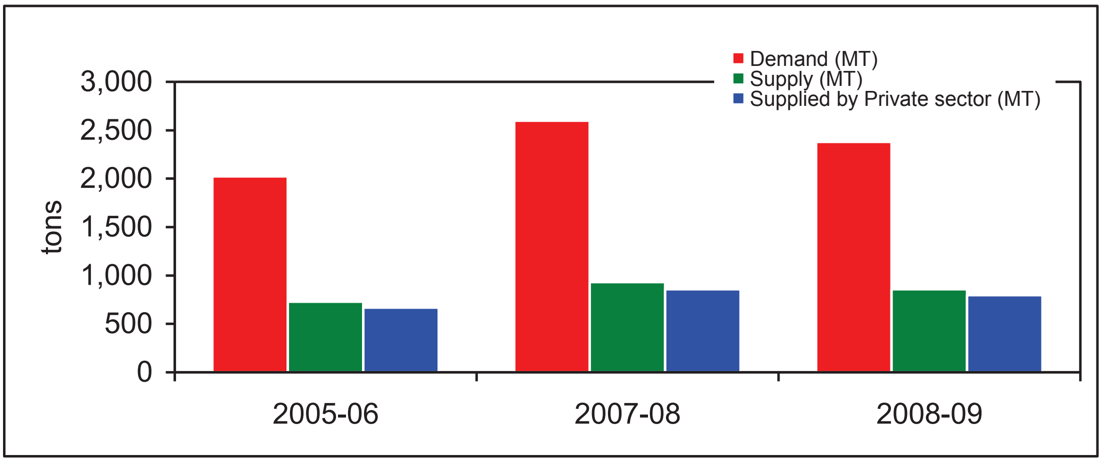

Figure 5. Demand and supply of vegetable seed from 2005/06 to 2008/09.
The difference between demand and supply is met by imports.

Available data on sources of vegetable seed are neither complete nor reliable. However, it appears that local production of vegetable seed has been increasing gradually and imports may have started to decline. Most of the local supply comes from private companies, with BADC producing only a small share.

The locally produced seed are mainly those of tropical vegetables. The climatic conditions in Bangladesh are not suitable for producing seed of temperate vegetables; the winter is mild and short and cool temperatures do not last long enough for these crops to flower or for the seed to ripen. However, some crucifers, such as cabbage, cauliflower and radish, can produce seed at around 20° C and BARI has developed some varieties of this type. The northwestern part of Bangladesh typically has colder weather, and most agencies are concentrating vegetable seed activities in this area. Some companies have begun to consider establishing collaboration with other countries such as Nepal and Bhutan, where climatic conditions are more favourable for vegetable seed production.

5.5 Issues and future outlook for vegetable research and breeding in Bangladesh

There is a growing market for vegetable seed in Bangladesh, with more farmers buying improved seed than ever before. With two growing seasons and a large variety of vegetables, there is enormous scope for research and development activities. Organized vegetable research started only about 20 years ago, although breeding for hybrid seed was initiated by BARI and private companies in the late 1990s. Use of biotechnology as a breeding tool is not well established, but is emerging, as illustrated by the progress in developing Bt eggplant. In the public sector, HRC has manpower and facilities. With proper leadership, high-quality and consistent staffing, a sound strategy, funding and incentives, HRC could continue to make significant contributions to the improvement of vegetables in the country, although its role is expected to change over time.

As most vegetable seed is imported, the cultivars available have been bred and selected for other target regions. There is a need for breeders with both public and private agencies to develop cultivars that grow well under local conditions in Bangladesh and meet market requirements. One service that BARI can offer is a system for testing imported cultivars to determine whether they meet the needs of the local farmers.

There are nearly 100 vegetables grown in Bangladesh. This offers private companies considerable scope for identifying market niches and developing their identities in the process. BARI and other public agencies might continue to support the development of private breeding capacity and upstream research. The use of biotechnology, e.g. marker-based technology for breeding, can be developed to meet the main requirements and opportunities for the most important crops, but not for all vegetables. Even if private companies, BARI or an NGO were to utilize markers for only important crops they are likely to require a partner such as AVRDC. HRC might also attend to any crops that are nutritionally important but neglected for whatever reason by the private sector.

Public and private agencies involved with vegetables might assist with the development of high-quality rootstocks, especially for tomato and some of the cucurbits. With a good rootstock that is disease resistant and tolerant of abiotic stresses, e.g. salinity, a wide range of scions can be grafted onto the plant, giving cultivars that can be used to address specific target production areas. This approach works well in many woody fruit crops and some vegetables (F. Bliss, personal communication).

The private sector and NGOs have been involved in plant breeding over only the last 5 years. Collaboration between public and private sectors may lead to more meaningful investment in areas where each has a comparative advantage, resulting in less competition and more specialization. However, in order to realize the potential benefits, improvements are required in policies and their implementation, many of which are not specific to vegetables. These issues are discussed in the concluding section.

6 Maize

6.1 History of maize research in Bangladesh

In the early 1950s the Economic Botany (Fibres) Division of the East Pakistan Directorate of Agriculture (EPDOA) introduced some popcorn and sweet corn lines from the United States, with a view to developing hybrid maize for the area. However, after the introduction of HYV wheat and rice in the 1960s and 1970s maize research was not considered a priority and those materials were ultimately lost. The government dairy farm at Savar, Dhaka, introduced some composite maize cultivars, Savar-1, Savar-2 and JC-1 for fodder. In the early 1970s, the EPDOA also received some composite varieties (Sadaf, Sarhad and Amberpop) through the Inter-Asian Crop Improvement Programme.

With the establishment of BARI in 1976, systematic research on maize was initiated in collaboration with CIMMYT. Some varieties tested through CIMMYT’s International Variety Testing Program yielded well under Bangladeshi conditions. Initially BARI concentrated solely on OPVs and between 1986 and 2002 released eight varieties, including one each of popcorn and sweet corn. However, the area planted to maize remained small for several reasons: maize was not consumed as human food; its cultivation cost was considered high; shelling of ears was a tedious job owing to the lack of a suitable mechanical sheller; hence there was little demand for the crop.

In the 1990s the poultry industry expanded rapidly, resulting in increased demand for poultry feed. Demand was initially met by imported feed. Two seed companies, Kushtia Seed Store and ICI Seed International and the International Fertilizer Development Center imported small amounts of seed of hybrid varieties for testing. One of these was Pacific-11, imported from Thailand, which produced much higher yields than the BARI varieties and was grown in some parts of the northwestern region (Chowdhury and Islam, 1993). Other seed companies subsequently imported hybrid seed, as did BRAC for use in its poultry programme. The seed was distributed to growers together with loans and a contract to buy the grains back at a fixed price, thus minimizing farmers' risk.

The area under maize peaked at about 400 000 ha in 2007/08 (Figure 6) but has since declined because of the reduction in demand for poultry as a result of avian flu. Yields increased from less than 1 t/ha in the early 1990s to over 6.5 t/ha in 2007/08.

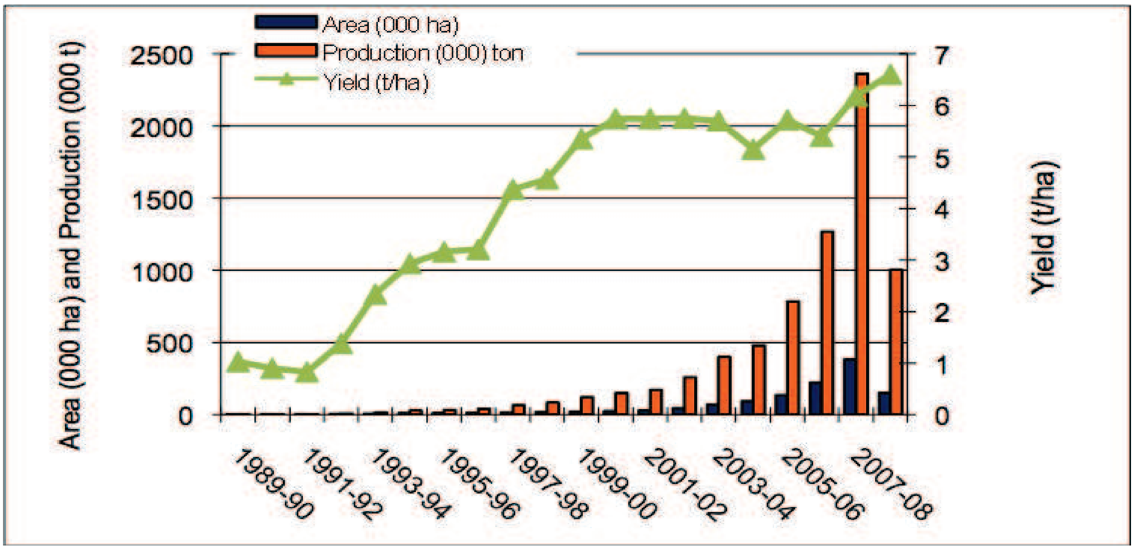

Figure 6. Area, production and grain yield of maize in Bangladesh (1990–2008).
Source: BBS and DAE.

During the 1990s, farmers started to grow more hybrid varieties than OPVs. In response, BARI started its hybrid maize research programme in the mid-1990s to develop disease- and pest-resistant varieties suitable for both *rabi* and *kharif* seasons. The main activities were:

- testing CIMMYT and the Tropical Asian Maize Network (TAMNET) maize hybrids through the International Hybrid Testing Program;
- introduction, maintenance and testing of inbred lines obtained from exotic sources;
- extraction of inbred lines, mostly through recycling;
- development and selection of single crosses and three-way-cross hybrids using exotic and local inbred lines;
- development of appropriate production technologies for farmers;
- transfer of technologies through training, seed distribution and demonstration;

- seed production, mainly of hybrid varieties.

In addition, a number of inbred lines were introduced from CIMMYT, the International Institute of Tropical Agriculture and Kasetsart University (Thailand). In 2001 BARI released its first hybrid variety. Since then 11 hybrid varieties have been released, including BARI Hybrid Bhutta-5, which is a quality-protein maize (QPM). Most of the BARI varieties can produce about 10–11 tonnes/ha under favourable conditions.

All the maize varieties cultivated in Bangladesh are yellow seeded, and are not well-suited for human consumption as flour. To overcome this, BARI has initiated the development of hybrids between QPM and white-seeded varieties. BRAC is also working along the same lines.

In multilocation testing in 2008/09 BARI hybrid varieties matured 2–5 days earlier than the 20 imported hybrids tested (overall mean ranged from 137–142 days for all entries) but produced slightly lower or similar yield compared with the imported hybrids (overall mean: 10.12 tonnes/ha, range: 7.98–10.81 tonnes/ha). Owing to the intensive cropping systems of Bangladesh early maturity is an important selection criterion in breeding.

6.2 BARI's current and future maize research plans

The current focus of BARI's maize breeding is a continuation of its efforts to develop hybrid varieties with tolerance/resistance to various stresses and diversifying into sweet corn and baby corn, the latter for export. BARI plans to introduce newer techniques such as genetic engineering and biotechnology. Its short-, medium- and long-term plans for maize variety development are summarized below:

Short-term (up to 2015):

- Develop inbred lines with multiple resistances for high yielding hybrids
- Screen and evaluate hybrids for their adaptation to biotic and abiotic stresses
- Enhance and ensure production of quality seed of new maize varieties
- Disseminate modern technologies to the farmers
- Research resource conservation technologies
- Develop improved management of moisture, heat, drought, salinity, etc.

Mid-term (up to 2020):

- Strengthen facilities to screen against abiotic stresses
- Initiate newer approaches in the variety improvement programme, such as marker-assisted selection, gene mapping and sequencing, gene transformation, haploid breeding, biofortification, etc.

- Develop improved crop management approaches for managing abiotic stresses
- Develop staff skills for addressing foreseeable issues
- Enhance technology transfer activities

Long-term (up to 2030):

- Develop high-yielding maize varieties tolerant to biotic and abiotic stresses
- Research integrated soil and crop management, resource conservation tillage, etc.
- Introduce farm machinery appropriate to small-scale mechanization
- Improve nutritional and industrial quality of new maize varieties
- Implement biotechnological interventions

6.3 Private sector maize breeding in Bangladesh

At least 15 private companies import seed of hybrid varieties and test them under local conditions. Some of them bring parental lines of the selected hybrids and produce hybrid seed locally for sale in the local market. Notable among these companies are SSCL and Lat Teer Seed Ltd, which have both committed resources for breeding hybrid maize. Lal Teer obtains materials from BARI. SSCL started to collaborate with CIMMYT about 5 years ago and received CIMMYT materials for testing; it is keen on developing its own hybrid varieties and establishing its own brand in the market.

6.4 NGO involvement in maize breeding in Bangladesh

Several NGOs, including BRAC and Bangladesh Chashi Kollan Samity, import hybrids from abroad, mainly Thailand and India. They evaluate imported varieties under Bangladeshi conditions and select those that are most promising.

Among the NGOs only BRAC is involved in breeding work on maize. Its breeding activities are an outgrowth of its efforts to promote poultry production. BRAC established a feed business which in turn led it to pay attention to improving the supply of maize and maize production. The NGO started maize research in 1996, with initial work limited to synchronization trials, grow-out trials, variety screening and performance trials of hybrids selected from local and exotic varieties. BRAC carries out research at four locations, has 18 seed production farms and two seed processing centres (for all crops). BRAC established linkages with CIMMYT with a view to strengthening its research activities, and since 2000 has received trials and inbred lines through CIMMYT's international hybrid testing programme. BRAC also received some TAMNET hybrid trials, from which it identified a few promising tropical late hybrids. In 2008, BRAC released two hybrids (Uttaran and Uttaran-2), with some others in the pipeline. These hybrid varieties are comparable to the exotic hybrids in terms of yield. BRAC processes the maize it grows in run three feed mills, using some of the feed on its own poultry farms and selling the rest on the local market. BRAC has established a feed analysis laboratory to support its feed business.

6.5 CIMMYT's role in maize research and development in Bangladesh

CIMMYT started to provide maize germplasm and technical support to Bangladesh in the mid-1970s and established its local office in 1982 to support BARI in wheat and maize research. BARI released several synthetic maize varieties during the 1980s and 1990s using CIMMYT germplasm. During the early 2000s, CIMMYT made important contributions to the expansion of maize production through the provision of germplasm, strengthening hybrid-based maize breeding and crop management research, policy-level dialogue, marketing and a national programme that has provided hands-on training to about 11 000 farm families on production technology; it also distributes good hybrid seed among the trained farmers in collaboration with BARI, various NGOs and DAE (CIMMYT 2008).

Both BARI's and BRAC's maize breeding programmes were able to use large numbers of CIMMYT inbred lines and other materials. Six out of the seven maize hybrids released by BARI contain CIMMYT maize lines, and there is significant use of CIMMYT maize by private companies. BRAC released one maize hybrid using CIMMYT inbreds.

Over the last 30 years CIMMYT has provided both short- and long-term training to researchers and staff from BARI and other organizations.

6.6 Production of seed of maize hybrids

Almost all the maize grown in Bangladesh is now hybrid varieties. Prominent varieties include 900M, introduced in 2000 by Krishi Bunijjo Center, and Pacific-11 and Pacific-60, introduced in the early 1990s by BRAC. These varieties cover about 80–90 percent of the maize area. BARI hybrid maize-5 and hybrid maize-7 occupy about 5–6 percent, and there are a few other varieties, for example from Syngenta (NK 40) and Monsanto.

A major constraint to increasing the area under the BARI varieties is lack of seed. BARI does not have its own seed production capacity and BADC's capacity to produce maize seed is limited to about 200–300 tonnes per year. Currently BARI has limited collaboration with private companies in seed production and there do not appear to be any plans to expand this significantly; thus BARI's maize breeding programme may not realize its potential for impact. This situation is in sharp contrast to rice, for which a significant number of local companies obtain breeders' seed from BRRI for multiplication.

Although private seed companies and NGOs are involved in producing seed of hybrid maize, not all of them produce significant quantities. GKF began producing seed of maize hybrids in the 1990s, but in recent years its activity has declined. BRAC started production of hybrid seed in 1997–1998 using parent materials of Pacific Seed Company, Australia. BRAC produces seed through contract growers; all inputs, such as parent seed, fertilizers, pesticides and training, are provided by BRAC to the contract growers. BRAC's production of seed of hybrid maize since 1998 is shown in Figure 7.

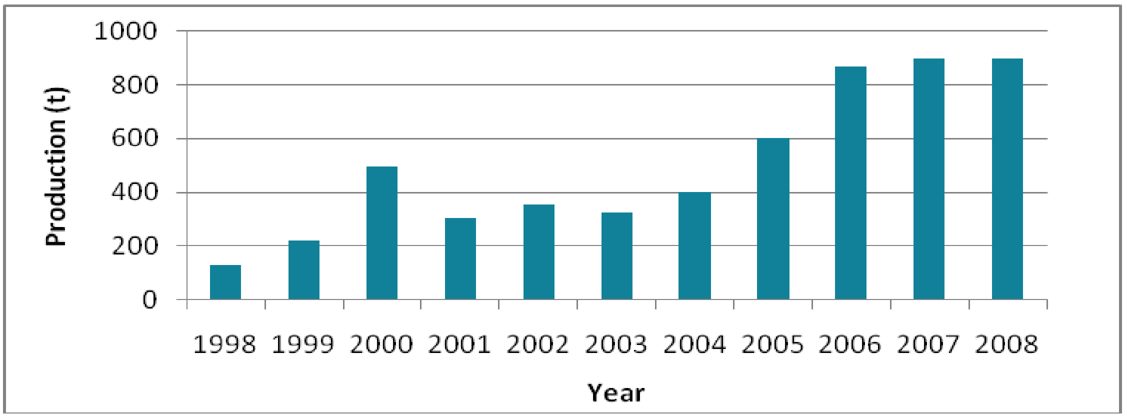

Figure 7. Production of seed of hybrid maize by BRAC, 1998–2008.

The rapid growth in BRAC's seed production suggests that the alliance between Pacific Seed and BRAC is working well. In addition, BRAC has been developing its own hybrids and expanding its seed production capacity. Other companies, particularly SSCL, are developing their own breeding and seed production programmes. In collaboration with BARI, CIMMYT may play a vital role by providing training, germplasm and technical assistance to these companies and NGOs in the future. BADC may also continue to support the private sector with technical assistance and access to its cleaning and storage facilities.

In 2007/08, more than 4 000 tonnes of seed of hybrid maize varieties were sold, of which 1 300 tonnes were produced locally by BADC and BRAC. The remainder was imported. In 2008/09, about 5 770 tonnes of maize seed were sold, and again nearly two-thirds of it was imported. Thus there is an opportunity for a large increase in local production of seed of maize hybrids, which BARI and the private sector have not yet fully pursued. This is in contrast to what is happening with vegetables. One reason for this reticence seems to be the large amount of seed needed in the case of maize and consequently the large field area necessary for producing such high volumes.

6.7 *Issues and future prospects for maize research and breeding in Bangladesh*

Future prospects for maize will continue to be strongly influenced by the size and character of demand in the domestic market. Maize has experienced significant growth in Bangladesh in recent years in response to an expanding demand for poultry and poultry feed. CIMMYT estimates that the deficit in supply of grains for poultry feed may continue beyond 2030. However, this is assuming that the poultry industry recovers quickly from the setbacks caused by avian flu.

Besides being used for poultry feed, maize is used as feed for cattle and fish, and is mixed with wheat flour to make *chapatti* or flat bread. Green cobs and popcorn are also consumed as food; the latter has seen significant growth in recent years as a snack food in urban areas. Sweet corn might be a target of future interest for BARI. If the food uses of maize expand there will be additional opportunities for companies to develop new hybrids in response to growing differentiation in demand for maize. A large part of that demand will still be for animal feed (yellow dent) and will require improved yielding ability under stress conditions, so breeding for multiple abiotic stress tolerance will continue to be important. Moreover, breeding for increases in lysine and tryptophan content (QPM) will improve the quality of animal feed. Increasing the protein quality of white flint varieties could also improve the nutritional value of white maize, which is preferred for human consumption.

Maize grain yields per hectare appear to have levelled in recent years and may be declining. This may be due to declining soil fertility (hybrid maize has high nutrient demands), emerging micronutrient problems, an unbalanced use of fertilizers, unsuitable and inadequate use of irrigation, and late planting in the winter season (CIMMYT 2008). However, more studies are needed to confirm and quantify these constraints.

The future position of maize will be determined by several factors, including the shrinking cultivable area of Bangladesh, the dynamic cropping system and changes in rice technologies and productivity. If the poultry industry resumes its pre-avian flu expansion and there is growth in the food use of maize, the demand for improved varieties with a broader range of characteristics could expand significantly in the medium term and create opportunities for the private sector.

As with vegetables, the rapid growth in recent years of seed production by private companies should also strike a note of caution. Eventually there could be a shake-out as competition becomes intense and demand levels off.

7 Pulses

7.1 Pulses research in BARI

Systematic research on pulses in Bangladesh began in the mid-1960s. However, as a result of increasing demand and dwindling area under pulses, in the 1990s special attention was placed on increasing and sustaining production of major pulses in Bangladesh. Several research institutes and universities are involved in pulses research, including BARI, BINA, BAU and BSMRAU. The leading organization is the PRC of BARI, located at Ishurdi, in a major pulse growing area. PRC was established with support provided by the International Development Research Centre, Canada. The Canadian International Development Agency (CIDA) and FAO have also provided technical support over the years. With the cessation of the CIDA grant, PRC received funding from the Australian Centre for International Agricultural Research.

More than 40 improved varieties of pulse crops with high yield potential were released between 1991 and 2009. BINA released one variety each of grass pea, lentil and black gram, four of chickpea and seven of mung bean. BSMRAU released three varieties of mung bean. The remainder were developed by BARI. Most of these varieties are resistant to major diseases and can yield 35–60 percent more than local varieties.

7.1.1 BARI/ ICARDA collaboration on lentil

The PRC has enjoyed strong collaboration with ICARDA since the early 1980s, when Bangladesh stepped up its research on lentil improvement. A major constraint to lentil breeding in Bangladesh has been the lack of genetic variability for traits of importance in local germplasm (Sarker *et al*. 1991).

BARI has been working to improve lentil through conventional breeding approaches. The main strategy was to develop high-yielding, short-duration varieties by introducing germplasm, mainly from ICARDA. Since 1981, PRC has collected and evaluated more than 500 accessions of local landraces and 2 000 accessions of exotic germplasm, with support from the University of Southampton, United Kingdom, CIDA and ICARDA. PRC also requested ICARDA to make crosses for Bangladesh using improved landraces (Rahman and Sarker 1993). ICARDA supplied early maturing germplasm of various origins, breeding lines and segregating populations developed specifically for Bangladesh using its elite landraces and parents of diverse origin. Lentil genotypes with resistance to rust, *Stemphylium* blight, wilt and drought were obtained. Host-plant resistance has been adopted as a key strategy to combat these diseases. The rust-resistant cultivar Barimasur-2 was released in 1993 and the rust- and blight-resistant cultivar Barimasur-4 was released in 1996.

Recently, new sources of combined resistance have been selected from targeted segregating populations supplied by ICARDA.

7.1.2 BARI/BSMRAU/AVRDC collaboration on mung bean

As part of a collaborative programme with AVRDC, BARI received international trials, nurseries, germplasm and segregating generations of mung bean. From this material PRC developed at least three promising mung bean cultivars that are bold seeded, early maturing and resistant to mung bean yellow mosaic virus (MYMV). Efforts were also made to develop high-yielding, short-duration, day-length insensitive and disease-resistant mung bean cultivars for the summer season to replace the low-yielding rainfed *aus* rice, particularly in the northern districts of the country.

AVRDC provided mung bean accessions and advanced lines to BSMRAU for screening for disease resistance and tolerance of drought and excess moisture. BSMRAU released three varieties of mung bean in 2002 and 2003. These varieties are of shorter duration than local landraces and are MYMV resistant.

7.1.3 Other pulses

BARI has released at least nine chickpea varieties, developed through its own efforts and through its collaboration with ICRISAT. In addition, BARI has developed two varieties each of cowpea and grass pea. Under a grant from IDRC, ICARDA has crossed Bangladesh landraces of grass pea with lines with low neurotoxin contents, resulting in segregating populations suitable for testing in Bangladesh. However, owing to the lack of laboratory facilities, neurotoxin analysis could not be carried out.

7.2 Crop diversification projects in Bangladesh

Production of non-cereal crops declined in the 1970s and 1980s as a result of the Government's focus on achieving self-sufficiency in rice. In 1989 a crop diversification project was established with support from CIDA and the Government of the Netherlands. The project focused on research and extension of tuber crops, oilseeds and pulses, including lentil, black gram, mung bean, chickpea and pigeon pea. Pulse breeding received some funds through this and subsequent crop diversification projects. These efforts may have helped arrest the decline in pulses production.

In the 1996/97 cropping season DAE launched the Lentil, Black gram and Mung bean Development Pilot Project (LBMDPP) with funding from the Government of Bangladesh. The project brought together all key research and development organizations working on pulses, including BARI, BINA, DAE, BSMRAU, BADC and local NGOs. The project provided support for several thousand block demonstrations and involved training of farmers, research and extension staff in pre- and post-harvest technologies. It also initiated a massive seed production programme with BADC and contract growers for use in the demonstrations.

Over 5 years yields of lentil, mung bean and black gram from the demonstration plots were about 25 percent, 28 percent and 36 percent higher, respectively, than from the farmers' control plots. Over the life of the project (1997–2003) the lentil area increased by 26 000 ha, the mung bean area increased by 48 000 ha and the black gram area increased by 16 000 ha, resulting in annual production increases of 30 000 tonnes of lentil, 45 000 tonnes of mung bean and 15 000 tonnes of black gram. By the end of the project it was estimated that improved varieties accounted for about 45, 65 and 40 percent of the total lentil, mung bean and black gram area, respectively (Afzal *et al*. 2004).

7.3 Seed system for pulses in Bangladesh

Breeder seed of high-yielding pulse varieties are maintained by PRC, BINA and BSMRAU and supplied to BADC for multiplication. However, BADC produces only a very small portion of the pulse seed used by farmers. Most farmers keep seed from their harvests for use in subsequent years.

Between 1997–2004 BADC produced a total of around 80 tonnes of lentil, mung bean and black gram seed for the LBMDPP, while BARI, BINA and BSMRAU produced about 30, 30 and 13 tonnes, respectively, and the participating NGOs produced another 12 tonnes (BARI n.d.). All of this seed was distributed to farmers who conducted demonstrations under the project.

At present, farmers' demands for improved varieties of pulses do not seem to be strong enough to attract significant private investment in breeding and seed production.

7.4 Future prospects for pulses research and breeding in Bangladesh

In spite of Government efforts to popularize pulses, and the release of several high-yielding varieties in recent years, the area under pulses is largely unchanged and the adoption of the varieties is limited. Yields of the new varieties are higher than those of indigenous varieties, but not high enough to encourage farmers to choose pulses over crops such as maize and vegetables that are grown in the same season.

A lack of genetic potential in the existing germplasm base may be a constraint to developing pest- and disease-resistant, high-yielding varieties of pulses. Hybrid development and application of biotechnological techniques are being explored as means of developing HYVs with desired agronomic characteristics, but until a breakthrough is achieved, investment in pulse breeding by the private sector may not be forthcoming. Therefore, BARI, BINA and the universities may continue to be the main focal points for breeding activities in pulses in the short to medium term.

8 Issues and findings

A review of developments in plant breeding and seed systems in Bangladesh for rice, vegetables, maize and pulses suggests the following major themes:

1. **Farmer demand for new varieties has been growing and crop production has been intensifying.** Government and donor programmes contributed to these changes (e.g. PETTRA project), but rising incomes, land pressures and good prices played major roles.
2. **The private sector is increasingly involved in plant breeding and seed production in response to the opportunity presented by growing demand for new varieties and for production intensification.** There are now more than 400 seed dealers and approximately 50 seed companies in the country and the numbers continue to rise. More young people are attracted to plant breeding and biotechnology. However, with a few notable exceptions, private companies have yet to engage in research and development activities to any significant degree.
3. **Bangladesh has extensive networks of contact with external organizations involved with plant breeding, including IARCs, multinational companies (MNCs) and public- and private-sector bodies outside the country, especially in China, India and Thailand.** Bangladesh has made extensive connections with external organizations to access materials, knowledge, technology, expertise and in some cases finished cultivars that have direct utility. The external organizations are increasingly responsive to demands for materials and technologies specifically adapted to Bangladesh's needs . This is a model for other countries to consider in making more effective use of spill-ins from new technologies and practices.
4. **The response of the public sector to these developments is mixed.** Some public agencies are more responsive and forward-looking than others. There are serious questions about the ability of the public sector to retain good staff and provide leadership in this transitional period when demands are escalating. There is a danger that an inadequate response from the public sector could contribute to a crisis of confidence in the seed sector, as the industry consolidates the rapid progress that has been made to date.

While the entry of the private sector into plant breeding over the past decade has been significant and is likely to continue, we believe that the public sector, including the ARIs and the universities, will remain pre-eminent in agricultural research for years to come. The extent of their pre-eminence will depend on their ability and that of the government to adjust their roles in plant breeding to the challenges and opportunities noted above. The NATP, supported by the government and the World Bank, represents a commitment by the government to a set of reforms and investments that are critical to the effective functioning of the public sector agricultural research system in the years ahead (World Bank 2008).

Successful plant breeding is becoming increasingly demanding and it remains to be seen how effectively the public sector will respond to the challenge this represents. In particular, research that effectively utilizes the growing array of tools such as biotechnology requires collaboration within and across disciplines and organizations. Although this is generally recognised, the public sector institutions in particular lack the leadership and facilitating mechanisms to make such collaboration a regular feature of their research programmes.

Some observers feel that the reforms, particularly those associated with the NATP, do not go far enough. They also raise questions about the will and ability of the government, BARC and ARIs to deliver on the goals and objectives of the NATP. Senior positions in the ARIs and BARC (as well as in other key government agricultural services, including extension and seed services), continue to be filled on the basis of seniority and factors other than merit and ability. Those that are able (and often the most able) leave for positions abroad or in the private sector. There is a large and growing supply of young graduates waiting in line for any opening. However, the combination of senior leadership that may be somewhat out of touch with recent advances in plant breeding and young people of limited experience may not translate into creative and effective research programmes. In order to become effective researchers, the new entrants require on-the-job training and mentoring in the use of both traditional and more recent techniques.

The role of the private sector in plant breeding, seed production and supply and other areas of agricultural research is increasing, but it remains to be seen whether private companies will have the patience and particularly the funds to sustain their research efforts adequately and long enough to produce results that translate into sales and profits. Some commodities and areas are likely to be better served by the private sector than others. That is the main rationale for a continuing public-sector role in plant breeding. The entry of MNCs could well change the situation and affect government policies, but a major shift seems unlikely in the short to medium term.

Some observers note that although Bangladeshi institutes have developed over 50 varieties of rice alone, several imported varieties are more popular among farmers. This suggests that their characteristics better address farmer preferences than those locally developed (A. Hossain, personal communication). While this observation is a challenge to local public and private breeding agencies to make greater efforts to take farmer requirements into account, the willingness of farmers to try out, select and adopt improved varieties from whatever source is an indicator of the success of breeding programmes generally (F. Bliss, personal communication).

Although there is a continuing need for public-sector involvement in plant breeding and other areas of agricultural research, its future role in the seed sector is likely to be limited to regulation and certification, and this will require more capacity and resource inputs. The government is endeavouring to strengthen the Seed Certification Agency and Plant Quarantine Services, but again there are questions about the adequacy of these measures. Failure on this front could undermine farmers' confidence in seed quality and the commercial seed market generally, which would have serious consequences for the many seed companies that have emerged in recent years.

The government, donors and the private sector have made significant investments in plant breeding and seed systems over the years and that process continues. There is a strong case for building on these investments to enable Bangladesh to face more effectively the challenges of population growth, land scarcity, poverty alleviation, climate change and economic development. Improved varieties are considered the most promising means of addressing the biotic and abiotic stresses that constrain agricultural productivity. These challenges already feature prominently in the criteria of the breeding programmes of public and private agencies and that is likely to continue. Above all breeding programmes need to take into account and reflect farmers' and product-user's priorities and constraints. A farming systems research perspective was a prominent feature of public sector research during the 1980s and 1990s, but is less so today. It is hoped this area will receive renewed emphasis through NATP-supported programmes.

This study has pointed to several promising areas for investment, including biotechnology, human resource development, strengthening regulatory systems and improvements in mechanisms fostering collaborative research. The greatest challenges are in the areas of political and institutional will, necessary to implement successfully the reforms that the government and donor partners have committed themselves to achieve.

9 References

Afzal, M.A., Abdul Hamid, Bakr, M.A., Sarker, A., Erskine, W., Haque, M. & Aktar, M.S. 2004. Technology dissemination to boost pulse production and human nutrition in Bangladesh. *In* T. Fischer, N. Turner, J. Angus, L. McIntyre, M. Robertson, A. Borrell, and D. Lloyd, eds. *New directions for a diverse planet*. Proceedings for the 4th International Crop Science Congress, Brisbane, Australia, 26 September –1 October 2004.

Akhond, M.A.Y. n.d. Biotechnology research at BARI: A shortnote. Gazipur, Bangladesh, BARI.

Ali, M.Y., Waddington, S.R., Hodson, D., Timsina, J. & Dixon, J. 2008. *Maize–rice cropping systems in Bangladesh: Status and research opportunities*. Mexico, D.F., CIMMYT.

Alim, A. 1968. *Rice improvement in East Pakistan*. Dhaka, East Pakistan, Department of Agriculture. 134 pp.

AVRDC. 2001. Project 9. Collaborative research and networks for vegetable production. *In AVRDC Report 2000*, pp. 91–103. Tainan, Taiwan, AVRDC (available at http://www.avrdc.org/pdf/00annual_report/proj09.pdf).

BARI. n.d. *Summary Report 1997–2004*. Lentil, Blackgram and Mungbean Development Pilot Project. Gaipur, Bangladesh, BARI.

BBS (Bangladesh Bureau of Statistics). 1974. *Statistical Yearbook*. Dhaka, Bangladesh, BBS.

BBS (Bangladesh Bureau of Statistics). 1980. *Statistical Yearbook*. Dhaka, Bangladesh, BBS.

BBS (Bangladesh Bureau of Statistics). 2000. *Statistical Yearbook*. Dhaka, Bangladesh, BBS.

BBS (Bangladesh Bureau of Statistics). 2004. *Statistical Yearbook*. Dhaka, Bangladesh, BBS.

BBS (Bangladesh Bureau of Statistics). 2008. *Statistical Yearbook*. Dhaka, Bangladesh, BBS.

BBS (Bangladesh Bureau of Statistics). 2009. *Statistical Yearbook*. Dhaka, Bangladesh, BBS.

BBS (Bangladesh Bureau of Statistics). 2010. Summary crop statistics (available at: http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/Wing/Agriculture%20Wing/Survey_AW/Major_crop-07-09.pdf).

BBS (Bangladesh Bureau of Statistics). n.d. Bangladesh data sheet, Subject matter data index (available at: http://www.bbs.gov.bd/Home.aspx).Boedker, L., Wulff, E. & Torp, J. 2006. *Seed sector country profile: Bangladesh*. *Vol. I: Overview of seed supply systems and seed health issues*. Frederiksberg, Denmark, Danish Seed Health Centre for Developing Countries.

Chowdhury, M.K.& Islam, M.A., eds. 1993. *Production and uses of maize* [in Bengali]. Dhaka, Bangladesh, On-Farm Research Division, BARI. 193 pp.

CIMMYT. 2008. *Achievements of the Bangladesh–CIMMYT Partnership for Agricultural Research and Development*. Dhaka, Bangladesh, CIMMYT.

EPRRI (East Pakistan Rice Research Institute). 1971. *Annual Report, 1970–71*. Joydevpur, East Pakistan, EPRRI.

Halim, A. & Rahman, Z. 2001. *Agriculture: Bangladesh environment outlook 2001*. Dhaka, Bangladesh, Centre for Sustainable Development. pp. 131–147.

Hossain, M., Janaiah, A. & Husain, M. 2003. Hybrid rice in Bangladesh: Farm level performance. *Economic and Political Weekly*, 21 June 2003, pp. 2517–2522.

Huda, M.N. 2001. *Why quality seed? Reality and vision*. Dhaka, Bangladesh, GTZ. 258 pp.

IRRI (International Rice Research Institute). 2009. Rough rice yield by country and geographical region, IRRI world rice statistics. (available at: http://beta.irri.org/solutions/index.php?option=com_content&task=view&id=250).

Mahmood, S.A. 2002. How the Bangladesh garment industry took off in the early eighties: The role of policy reforms and diffusion of good practices. *Alochona Magazine*, Issue 8, Economy.

Mondal, M.K., Tuong, T.P. & Sattar, M.A. n.d.. Quality and groundwater level dynamics at two coastal sites of Bangladesh: implications for irrigation development (available atwww.ifwf2.org/addons/download_presentation.php?fid=1093).

Niaz, M.S. & Miller, G.W. 1952. *Rice situation*. Karachi, Pakistan, Ministry of Food and Agriculture.

Rahman, M.M. & Sarker, A. 1993. Genetic resources and breeding of lentil in Bangladesh. *In* W. Erskine & M.C. Saxena, eds. *Proceedings of the seminar on lentil in South Asia, 11–15 March 1991, New Delhi, India*, pp. 76–80. Aleppo, Syria, ICARDA.

Rediff Business. 2010. *India says no to Bt brinjal, for now* (available at: http://business.rediff.com/report/2010/feb/09/india-says-no-to-bt-brinjal-for-now.htm).

Samad, A. 1999. Private-sector imports of fertilizer and pesticides in Bangladesh. *In* S.S. Sidhu & M.S. Mudahar, eds. *Privatization and deregulation: Needed policy reform for agribusiness development*, pp. 191–204. Dordrecht, The Netherlands, Kluwer Academic Publishers.

Sarker, A., Rahman, M.M., Zaman, W., Islam, O. & Rahman, A. 1991. Status of lentil breeding and future strategy. *In* J. Kumar, ed. *Advances in pulses research in Bangladesh: Proceedings of the 2nd National Workshop on Pulses, Joydebpur, Bangladesh, 6–8 June 1989*, pp. 19–24. Patacheru, A.P., India, ICRISAT.

Sarker, A., Bakr, M.A., Afzal, M.A., Erskine, W., Rahman, M.M. & Saxena, M.C. 2004. Lentil improvement in Bangladesh. Bangkok, Thailand. Asia-Pacific Association of Agricultural Research Institutions (APAARI) Publication 2004/1. APAARI.

Sattar, S.A. 2000. Bridging the rice yield gap in Bangladesh. *In* M.K. Papademetriou, F.J. Dent & E.M. Herath, eds. *Bridging the rice yield gap in the Asia-Pacific region*, pp. 58–68. Bangkok, Thailand, FAO Regional Office for Asia and the Pacific (available at: www.fao.org/docrep/003/X6905e/x6905e07.htm).

Van Mele, P., Salahudin, A. & Magore, N. eds. 2005. *Innovations in rural extension: Case studies from Bangladesh*. Wallingford, UK, CABI Publishing. 320 pp.

World Bank. 2008. *Appraisal report. National Agricultural Technology Project (NATP)*. Dhaka, Bangladesh, World Bank.