

# The dynamic tension between public and private plant breeding in Thailand

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# **The dynamic tension between public and private plant breeding in Thailand**

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

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## Abbreviations and acronyms

ACIAR	Australian Center for International Agricultural Research
APSA	Asia and Pacific Seed Association
ASEAN	Association of Southeast Asian Nations
AVRDC	The World Vegetable Center
BIOTEC	National Center for Genetic Engineering and Biotechnology
BRRD	Bureau of Rice Research and Development
CAB	Center for Agricultural Biotechnology
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
DoA	Department of Agriculture (MoAC)
DoR	Department of Rice (MoAC)
DUS	distinctness, uniformity and stability
FCRI	Field Crops Research Institute
FY	financial year
GDP	gross domestic product
GIPB	Global Partnership Initiative for Plant Breeding Capacity Building
IACIP	Inter-Asian Corn Improvement Program
IRRI	International Rice Research Institute
ISTA	International Seed Testing Association
MAS	marker-assisted selection
ME	Ministry of Education
MoAC	Ministry of Agriculture and Cooperatives
MoST	Ministry of Science and Technology
NCSRC	National Corn and Sorghum Research Center
NESDB	National Economic and Social Development Board
NIA	National Innovation Agency
NRC	National Research Council (Thailand)
NSTDA	National Science and Technology Development Agency
OPV	open-pollinated variety
PVP	plant variety protection
QTL	quantitative trait locus
RDPB	Royal Development Projects Board
RFCRC	Rayong Field Crops Research Center
RGDU	Rice Gene Discovery Unit
SAT	Seed Association of Thailand
SIG	special interest group
TDRI	Thailand Development Research Institute
TISTR	Thailand Institute of Scientific and Technological Research
TRF	Thailand Research Fund
TTDI	Thai Tapioca Development Institute
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

## Executive summary

This report reviews the development of plant breeding and seed systems in Thailand as part of a six-country study of plant breeding capacity in developing economies. Thailand's agricultural sector has been built around export markets, and plant breeding has played a key role in maintaining competitiveness in the global market place. At the same time the seed sector itself has become an important industry in the country, producing a dynamic tension between public sector investment and an evolving private-sector capacity in plant breeding. The public sector plays a key role in providing the human capital and research base to underpin continued technical change but within the context of evolving private-sector capacity in plant breeding and seed systems. Thailand is developing as a regional hub for seed production, exporting to other countries in the Association of Southeast Asian Nations (ASEAN). Biotechnology is seen as a principal investment area for maintaining Thailand's competitive edge. However, better linkages are needed between the emerging biotechnology programmes, more-traditional plant breeding programmes and seed systems.

These issues are analyzed through a review of the history and current status of plant breeding and seed system development in three principal crops, namely maize, cassava and rice. The very dynamic history of plant breeding in Thailand provides insights into capacity issues that are only just emerging in other medium-sized countries in the developing world. These issues are explored in terms of shifting institutional and policy arrangements, especially in relation to both an expanding private sector and the potential to exploit new science in the form of genomics and molecular biology. These shifting balances are summarized below.

**Breeding and associated changes in crop management have been central to maintaining competitiveness of Thai agriculture in international markets with varying strategies across crops reflected in government investment priorities.** Thailand became highly competitive in international markets with the development of its road infrastructure in the 1960s and the consequent opening up of land in the northeast of the country. The early 1970s saw the development of strong public-sector capacity in plant breeding, which provided the basis for continued competitiveness of Thai production of field crops, particularly maize, cassava, sugar cane and irrigated rice. Rapid industrialization and urbanization in the last couple of decades has increased rural wages, increasing costs in field crop production. This has shifted government policy toward meeting increasing urban demand for livestock products and horticultural crops, as well as an increased policy emphasis on rice production. More recently there has been policy support for biofuels. Of the three crops covered by this study, this has impacted most on maize, and is reflected in priorities in public-sector research.

**Redefining the public sector's role in plant breeding in the context of expanding private-sector capacity in maize, horticulture and, most recently, hybrid rice has faced difficulties in shifting long-established research capacities that have been successful in the past.** The investment in public-sector plant breeding in the 1970s provided the varieties and thus market potential for the development of private-sector seed companies. Many of these companies subsequently moved into plant breeding, first into producing maize hybrids, then horticultural crops and most recently hybrid rice. The market for hybrid maize seed became particularly competitive, attracting investment by a range of regional and multinational seed companies. That market has matured; competition is now for market share rather than servicing an expanding market. This has led to competition rather than complementarities between public- and private-sector breeding programmes developing maize hybrids. The public sector never entered into developing breeding programmes in horticulture, while the private sector has not developed capacity in cassava breeding. In rice, the private sector focuses on hybrid rice for the irrigated area and the public sector focuses on jasmine rice for rainfed, lowland ecologies. To fulfil its public goods objective, the public sector must evolve its strategy in relationship to an expanding private sector.

**Thailand is investing significantly in agricultural biotechnology but is doing this through the Ministry of Science and Technology (MoST) and not through the Ministry of Agriculture and Cooperatives (MoAC). This has resulted in a lack of effective linkages between conventional breeding capacity and molecular breeding efforts.** Investment in new science, in particular agricultural biotechnology, is seen as necessary to maintain Thailand's future competitive position in international trade, as well as to develop new markets in areas such as biofuels and modified starches. MoST initiated investment in biotechnology through competitive grants. These went primarily to universities, which were building both research and teaching capacity in this area. MoST has since developed some dedicated genomics and molecular biology research laboratories working in particular crops, primarily rice and cassava. These have developed a more coherent research agenda, and, for rice, some capacity in molecular breeding with linkages to conventional breeding programmes in the MoAC. Effective application of molecular biology will require such links to conventional breeding capacity, but this is often limited by scientific cultures, as well as institutional barriers. Achieving effective product development from investments in agricultural biotechnology will require closer institutional linkages in the future.

**With further trade liberalization within ASEAN, Thailand is well placed to develop as a regional seed hub. Investments in diagnostic and phytosanitary capacity are supporting this development.** Thailand's strong position in private-sector breeding of maize and horticultural crops, its emerging capacity in breeding hybrid rice for tropical conditions, the investments made by regional and international seed companies, and the sophistication of farmers and smaller companies in seed production position the country well to become a major exporter of certified seed to regional markets. The increasing differentiation and specialization in breeding and

seed systems in Asia is patterns similar to those followed in Europe and North and South America.

**Difficulties in synchronization in capacity development between public- and private-sector plant breeding and between conventional and molecular plant breeding is most obviously reflected in the increasing shortages of conventional plant breeders.** Thailand is one of the few countries in which agricultural universities maintained their breeding capacity, with obvious spillover into the training of plant breeders. However, this capacity has declined in the last decade with shifts in funding away from conventional plant breeding and the increase in student fellowship opportunities in molecular biology. The Thai university system has built significant capacity in molecular biology and biotechnology, and this is reflected in student enrolments and numbers of graduates. This has come at the expense of training in conventional breeding, at a time when the first and second generations of plant breeders trained at Thai universities are retiring and demand for conventional plant breeders remains strong. Achieving synchrony at an overall system level in meeting evolving capacity needs has proved difficult and will remain so into the medium-term future.



## Introduction

Since the Second World War Thai agriculture has been export oriented. The sector has been very successful in gaining world market share in key commodities such as rice, cassava, sugar and rubber. As a result, agricultural growth has not been constrained by domestic demand, as has been the case of many African countries. Rather, agricultural production has responded to changes in international market prices and to changes in internal factor prices driven primarily by the rapid growth in the industrial sector over the last three decades. Between 1960 and 1980 agricultural gross domestic product (GDP) grew at a little over 5 percent per year (Poapongsakorn 2006) and the sector was in many ways the engine of growth of the Thai economy during that period. Growth in agricultural GDP was principally driven by expansion of the area under agricultural management as a result of migration into the northeast of the country and forest clearance. This was facilitated by the investment in road infrastructure in the 1960s.<sup>1</sup> High international prices for commodities in the early 1970s, combined with relatively cheap labour and land and low-cost access to international markets, drove this dramatic growth.

The significant decrease in agricultural activities in the northeast in the mid-1980s coincided with a significant increase in Japanese manufacturing investment in Thailand. As Poapongsakorn (2006) points out, "Manufacturing value added grew at double-digit rates for seven consecutive years from 1987 to 1993." This in turn led to significant rural-to-urban migration and an increase in rural wages. A fixed exchange rate and declines in international commodity prices in the early 1990s put a further squeeze on the profitability of agriculture. Growth slowed during this period, but at the same time there was significant restructuring, with investments in both machinery and irrigation. All of this positioned Thai agriculture very well to take advantage of the financial crises of 1997, when the Baht was devalued and agricultural exports increased significantly. In the period leading up to the devaluation, capital investment was the major factor contributing to agricultural growth, whereas after the devaluation agricultural growth was driven by growth in total factor productivity, especially in the crops sector; between 1998 and 2003 total factor productivity in the crops subsector increased by 5.5 percent per year (Poapongsakorn 2006).

Over the last decade Thai agriculture has depended on increased productivity as the principal source of growth, especially given restrictions on area expansion, rising cost of labour, increasing competition for water and the need to stay competitive in international markets. A range of factors contributed to this increase in productivity. There has been a shift to higher-value crops, especially fruits and vegetables, as well as livestock products and fisheries. At the same time as there has been diversification at the sectoral level, individual farmers have tended toward greater specialization. This has been motivated

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<sup>1</sup> The northeast of Thailand is broadly classified as Guinea Savannah. A recent publication (World Bank 2009) argues that the large Guinea Savannah areas of sub-Saharan Africa could experience similar growth.

by a significant increase in contract farming (Poapongsakorn 2006), greater efficiencies in marketing and substantial expansion in processing and agribusiness in general. Finally, there was significant expansion in agricultural research and extension budgets through the 1990s, but with a marked levelling off after the 1997 financial crisis. Starting in the early 1990s there was also a significant expansion in support to agricultural research through the Ministry of Science and Technology (MoST). With the restrictions on budgets, government had to choose how to allocate support to agricultural research across different funding arms.

## **The institutional framework for public-sector plant breeding**

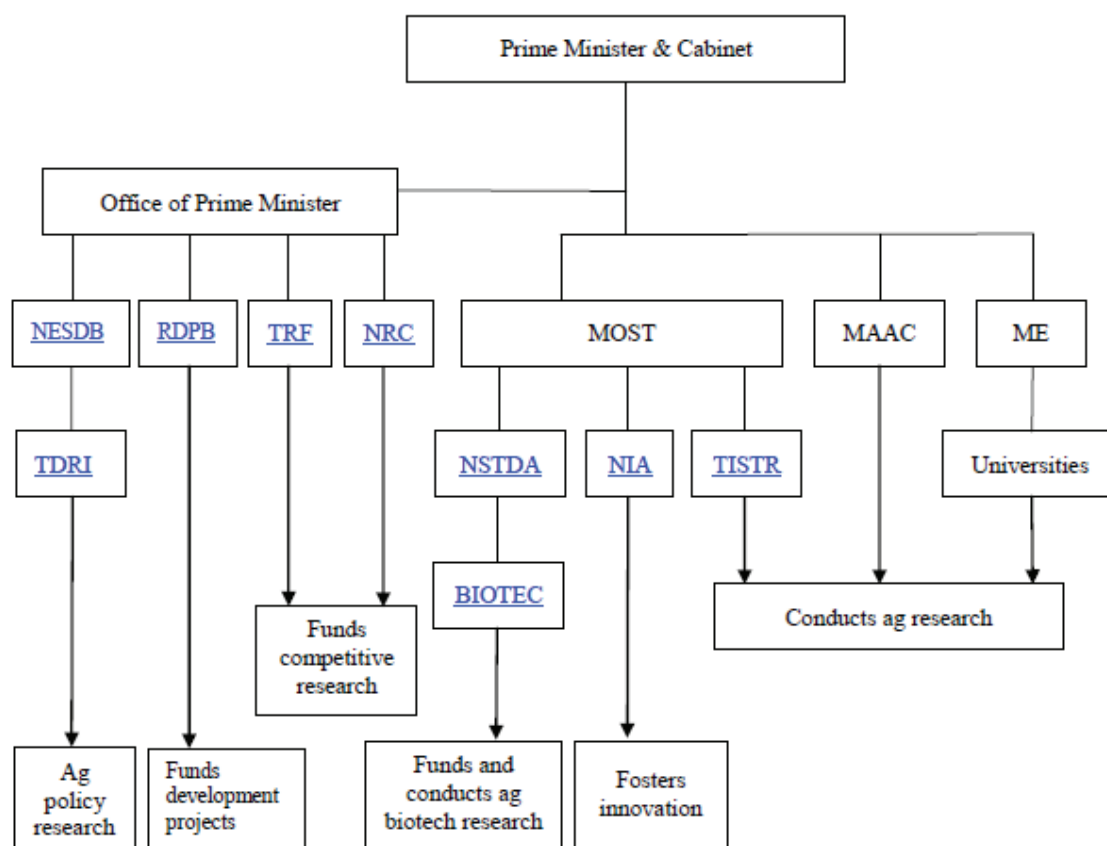
Plant breeding in Thailand began in 1950 with the request by the Thai government to the United States Department of Agriculture (USDA) to send Dr H.H. Love as an advisor on rice research. In 1950 there were two rice research stations; by 1970 there were 20, today there are 27. Maize breeding began in 1962 with the establishment of the breeding programme at Kasetsart University's Suwan farm with support from the Rockefeller Foundation. This programme later evolved into the International Maize and Wheat Improvement Center's (CIMMYT) Asian regional programme and collaboration with Kasetsart. This was a period of wide-ranging import of germplasm from various parts of the world and an intensive period of assessing what worked best under Thai conditions. From the 1960s through to the early 1980s Thai scientists were trained in plant breeding in the US under programmes supported by both Rockefeller and the United States Agency for International Development (USAID). (Most of these breeders have now retired or will soon do so.) Many Thai cassava researchers were trained at the International Center for Tropical Agriculture (CIAT) in the late 1970s and early 1980s, and most of these have also retired.

Suwan-1, an open-pollinated variety (OPV) of maize, was released in 1974 and a series of releases, evolving into hybrids, have followed. Of the two most popular rice varieties, KDML 105 (jasmine rice) was selected from germplasm accessions and released in 1959, and RD 6 (an irradiated mutation of KDML 105) was released in 1977. The first Thai cassava variety, Rayong 1, was released in 1975.

The 1970s was a period of major expansion in Thai field crop exports, particularly maize, sugar and cassava. Research support in Thailand has tended to follow export growth markets and as a result has been in support of private-sector development.

Agricultural research in Thailand has significantly diversified over the last two decades. Whereas prior to 1990, most research was done within the Ministry of Agriculture and Cooperatives (MoAC) and the agricultural universities, since then research has expanded in both the private sector and MoST. The National Science and Technology Development Agency (NSTDA) was established in 1991 under MoST, and the National Center for Genetic

Engineering and Biotechnology (BIOTEC) became one of the NSTDA. A number of other agencies were also created within MoST, each of which has an agricultural component and whose strategies are defined within periodic national science and technology development plans. MoST focuses primarily on upstream, frontier science, often in partnership or co-investment with businesses. Research within MoAC tends to be more applied and with more direct contact with the farming population. In many ways this creates two very distinct cultures within the agricultural research community, with particular implications for plant breeding. The current structure of agricultural research and development is presented in Figure 1.



**Figure 1.** Agencies funding and undertaking agricultural research in Thailand.

BIOTEC – National Center for Genetic Engineering and Biotechnology; ME – Ministry of Education; MoAC – Ministry of Agriculture and Cooperatives; MoST – Ministry of Science and Technology; NESDB – National Economic and Social Development Board; NIA – National Innovation Agency; NRC – National Research Council; NSTDA – National Science and Technology Development Agency; RDPB – Royal Development Projects Board; TDRi – Thailand Development Research Institute; TISTR – Thailand Institute of Scientific and Technological Research; TRF –Thailand Research Fund

Source: Johnson *et al.* (2008)

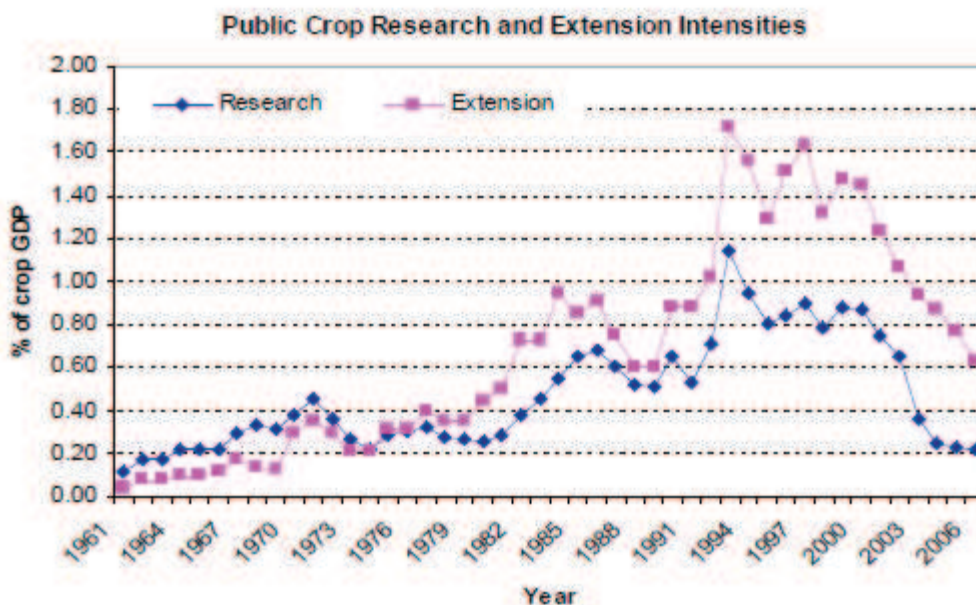
Thailand is pursuing two tracks in the linkage between biotechnology and plant breeding, one in MoAC and the other in MoST,. The impacts of biotechnology investment depend critically on breeding capacity, and hence

how these linkages are developed becomes critical to the success of these investments. The growing capacity for plant breeding in the private sector would tend to strengthen the public–private partnership orientation of MoST.

Over time BIOTEC has moved from being a funding source for biotechnology, primarily directed to the universities, to building its own research capacity; in 2008 funding of biotechnology research moved to NSTDA, since when BIOTEC has functioned purely as a research institute. BIOTEC's principal focus is on rice and cassava. The Rice Science Center and Rice Gene Discovery Unit (RGDU), works on genomics, gene discovery and molecular breeding methods. It has also developed some capacity in plant breeding. The Cassava and Starch Technology Research Unit focuses primarily on understanding starch properties and starch modification.

MoAC covers most crops produced in Thailand and focuses on farm-level application. Crop research within the MoAC is conducted within the Department of Rice (DoR) and Department of Agriculture (DoA), which were under one department up until 2005. Within the DoR research is conducted by the Bureau of Rice Research and Development at 27 rice research centres. The Bureau of Rice Seed provides capacity for seed multiplication. Within the DoA research is primarily conducted by the Field Crops Research Institute (FCRI). Cassava, sugar cane and oil palm are currently the top priorities for the DoA, reflecting the government's priority on biofuels. Maize is the fourth priority, and includes research on waxy maize for potential application in biofuels. There is no specific budgetary line for plant breeding in either the DoA or the DoR. Budget allocations are made at the level of the department from allocations from central government and are distributed across a range of research areas.

Government funding for crop research within MoAC, as measured by research intensity, peaked in 1995 but has since declined to levels similar to those in the 1960s (Figure 2). The overall budget for MoAC has stayed more or less constant in nominal terms over the last decade, but the budget for research and extension has declined slightly. By comparison the budget for NSTDA rose from 1762 million Baht (approximately US\$57 million at January 2011 exchange rates) in financial year (FY) 2000 to 3,606 million (US\$116 million) in FY 2008. In FY 2005 the budget for BIOTEC was about 600 million Baht (US\$19.4 million), similar to that for the DoR. Thus, research budgets in the MoAC remained flat or declined over the last decade while those for more advanced research tended to increase. These trends were reflected in declines in plant breeding capacity in the MoAC and expanding capacity in agricultural molecular biology and biotechnology in BIOTEC and the universities.



**Figure 2.** MoAC crop research and extension budget relative to crop GDP.  
Source: Suphannachart and Warr (2009)

## The private seed sector and public policy

Over the last couple decades Thailand has developed as a major regional centre for private-sector plant breeding and seed trade. Between 2003 and 2008 the value of seed exports virtually doubled, with the value of exports of hybrid maize seed almost equalling that of the Thai domestic market. As of 2009, there were 284 companies involved in the seed business in Thailand. Of these, 139 were essentially trading companies, specializing either in the import and marketing of seed or in the production and export of seed. The 34 larger companies, many of which are multinational, also had research and development activities, principally plant breeding. Of these, eight firms had breeding programmes in field crops and 26 in vegetable crops. Finally, 11 companies specialized in contract production of seed, which they then sold to seed trading companies (Suwantaradon 2009).

The diversity of private seed companies reflects an ongoing process of specialization of seed business operations within Thailand, as companies sought the lowest production costs while maximizing access and competitiveness in growing seed markets. A free-trade agreement is expected among ASEAN countries in the next year, which will further stimulate seed trade and move breeding and seed production toward more regionally integrated programmes among the private seed companies, which now operate in many of the countries in the region. In preparation for this change, the Thai parliament passed a new plant quarantine act and is attempting to position itself as a regional hub for seed certification, seed health and seed quarantine in support of increased seed trade in the ASEAN region. The 2007 Plant Act also governs both internal seed quality standards and much more

rigorous control on the import of seed. Most private companies have their own quality assurance which usually exceeds these standards.

The East-West Seed Company's laboratory in Chang Mai received accreditation from the International Seed Testing Association (ISTA) in 2009, and the DoA's central seed testing laboratory has applied for ISTA accreditation. Seed of different crop species is produced in different parts of the country, and to facilitate this satellite seed certification labs are being set up in universities in various regions of the country under the oversight of the DoA's central laboratory. More than 200 technicians have been trained in seed health to staff these facilities.

The interaction between the growing private sector and the government has been mediated by the establishment of seed associations. The Crop Seed Association of Thailand (now the Seed Association of Thailand, SAT) was established in 1990, primarily as a vehicle for the development of plant variety protection (PVP), especially on the part of the horticultural industry. Thailand's PVP law was passed in 1999. SAT has worked in coordination with the Asia and Pacific Seed Association (APSA) since it was formed in 1994. APSA's committee structure reflects both the interests of its member companies and the direction of the seed business in the region, with standing committees on international trade and quarantine, seed quality and intellectual property rights and special interest groups (SIG) on vegetables, hybrid rice, field crops, and forage and amenity seeds. The vegetable SIG is the longest running and most cohesive, with an emphasis on cooperation rather than competition. The vegetable SIG is organizing collective investments in research, mostly with The World Vegetable Center (AVRDC) but also with other research entities. The SIGs are becoming a connecting point between the private sector in the seed industry and the international centres, particularly AVRDC, CIMMYT and the International Rice Research Institute (IRRI).

## **Rice breeding in Thailand**

Rice breeding in Thailand is organized around a combination of production systems and market segments. Rice breeding focuses essentially on two principal production systems, namely irrigated and rainfed lowland systems. Upland systems account for approximately 2 percent of total area and there is virtually no breeding programmes for these systems. Irrigated systems account for 1.6 million hectares of a total of 9.2 million hectares under rice cropping and are primarily located in the Central region. The breeding focus in this system is on low cost and a number of quality requirements, especially a minimum grain size. Rainfed lowland systems account for by far the largest area under rice cropping and are located principally in the northeast and the Lower North region. These systems produce aromatic jasmine rice and maintaining quality is a key criterion in any breeding programme.

The irrigated systems focus on low cost production of relatively low-quality rice. The varieties grown are non-photoperiod sensitive, non-aromatic and

long grain. The irrigated areas are under continuous cultivation and produce five crops every two years. Because of the continuity of rice production and the dormancy of rice seed (six to eight weeks), the timely availability of rice seed is crucial. These systems are the focus of hybrid breeding programmes in both the public and private sectors. Varietal turnover is relatively quick.

Rainfed lowland systems, on the other hand, focus on the production of high-quality jasmine rice. These varieties are photoperiod sensitive and are divided into glutinous varieties for home and local consumption and long-grain, non-glutinous varieties for export. Of about 32 million tonnes produced each year, about 16 million tonnes is non-aromatic rice (two crops), 6 million tonnes is glutinous aromatic rice and 10 million tonnes is non-glutinous long-grain jasmine. Jasmine rice sells for 50 to 100 percent more than long-grain white rice; prices on the Bangkok commodity exchange at the end of 2009 were 30 Baht per kg for jasmine rice compared with 17 Baht per kg for non-aromatic rice (US\$1 = approximately Baht 31 [February 2011]). Given the price differential, maintaining quality is essential in breeding for rainfed lowland systems. Millers and exporters, working through the Ministry of Commerce, enforce quality standards. It has been difficult to develop varieties that meet the quality standard and at the same time increase yield potential; to date the Ministry of Commerce has approved only two varieties, KDML 105 and RD 15, a gamma-ray-irradiated variant of KDML 105. This is one of the major reasons why there has been limited uptake of IRRI varieties over the past 30 years. However, Thai exports are facing increasing competition from a lower-quality, cheaper fragrant rice from Viet Nam, which is increasing demand to reduce cost and increase yields in the rainfed lowland system.

### ***Overview of rice breeding in Thailand***

The Bureau of Rice Research and Development (BRRD) in the DoR has 27 research centres, but only seven have rice breeding programmes. About 15 years ago the network of research centres was organized into one or two centres in each region and a set of satellite stations. There are two regional stations in each of the central and upper north regions and one each in the lower north, northeast and south. In the northeast the breeding programme for the rainfed lowland system is based at Ubon, with seven satellite stations conducting observational, yield and on-farm evaluations. However, two years ago, with the separation of the DoR and the DoA, each of the stations was made independent. While this may facilitate agronomic, farming-systems and soil-management research, it undercuts the scale economies and efficiencies in plant breeding. The satellite stations are restricted in their ability to develop breeding programmes by a freeze on public sector hiring that was imposed about six years ago and by budget constraints. The sense among breeders is that budgets allow only the maintenance of current crossing and selection programmes.

A hiring freeze and constrained budgets within the BRRD is in stark contrast to expanding capacities and access to competitive grants for rice researchers working at the molecular level in the universities and BIOTEC. There is a subjective judgment that only two or three rice breeders within the DoR can write a research proposal that would be competitive within funding

programmes of the National Research Foundation, much less international funding sources, and there is an increasing divide between conventional and molecular breeding, rather than the development of an effective interface between the two. This divide is reinforced by the trends in training. In 1999 the ME established the Center for Agricultural Biotechnology (CAB) with a loan from the Asian Development Bank; the third phase of this programme was being designed in 2010. CAB coordinates a consortium of universities in training in biotechnology and to date has enrolled 642 MSc and 178 PhD students. It also conducts short courses, such as the course on pre-breeding developed by the Global Partnership Initiative for Plant Breeding Capacity Building (GIPB). By comparison, Kasetsart University's conventional breeding programme enrolls about 10 MSc and one PhD student each year. There is a growing need for applied breeders with an understanding of molecular breeding and for molecular biologists with limited understanding of conventional breeding techniques, but current funding trends will not serve to meet this need. This gap between institutions, skill levels in plant breeding and experimental cultures is best examined within breeding for rainfed lowland rice systems.

### ***Lowland rainfed rice breeding in Thailand***

The breeding programme for the rainfed lowland rice has over the last decade or so augmented its budget through international support. This included a 10-year project supported by the Australian Centre for International Agricultural Research (ACIAR) which ended in 2005, Rockefeller Foundation support for participatory breeding and marker-assisted selection (MAS) which ended in 2006, IRRI's shuttle rice breeding programme for rainfed lowland rice (also ended) and most recently the collaborative programme with RGDU of BIOTEC. These programmes have added a valuable research support component to the structure and organization of the breeding programme. In particular, the ACIAR work funded the work on genotype–environment (G×E) interaction, the agro-ecological zoning of the rainfed lowland systems and the development of the rapid generation advance system. The last was developed to get over the photoperiodism of KDML 105, which required a full year for each generation, i.e. seven years to get to the observational yield trial stage. A darkroom technique was developed that overcame the photoperiod problem and allowed three generations per year within intrastation crossing and selection. At the same time interstation yield evaluation and on-farm participatory evaluation were organized around the results of the zoning and G×E work, introducing potential efficiency gains in the breeding programme. However, access to research funding has significantly reduced.

The DoR allocates the budget received from the government to activities based on work plans and budgets. The Ubon programme in 2008 requested 15 million Baht as operational funding for the breeding programme for rainfed lowland rice but received only about half of that. Three million Baht are utilized for intrastation crossing and selection at Ubon and another 5 million Baht are allocated across the seven stations for interstation yield and farmer evaluation. This gives a good idea of the relative costs of crossing and early selection and varietal yield testing network.



The programme is organized around about 15 parental combinations a year, based on KDML 105 and RD 6. Some six principal sets of genotypes, comprising about 200–300 lines, get to the observational yield trial. About 150–200 lines then go out for the preliminary yield trial across the eight stations (including Ubon). Farmer participatory selection involves 15–20 varieties, with about 15 farmers per station. The latter is a two-step process of selection from a wide set of varieties in the first year and then yield and quality evaluation by farmers of a limited set in the second year. A marker lab was established at Ubon in 2003, but it is not systematically utilized in the breeding programme.

In 2006 two varieties were released, RD 12 (glutinous rice with blast resistance and early maturity for drought avoidance) and RD 33 (KDML 105 characteristics with photoperiod insensitivity and blast resistance, developed within IRRI's shuttle breeding programme). New varieties are released by the DoR; there is no formal or required release system in Thailand. However, RD 33 has not yet been approved by the Ministry of Commerce, even though it has been evaluated by farmers, millers and exporters, and the Bureau of Rice Seed is reluctant to multiply the variety for sale to farmers without this approval. The lack of a formal release system, combined with internal and overlapping ministerial mandates for varietal approval, creates a significant bottleneck in the effective uptake of new varieties of export-quality jasmine rice.

The RGDU within BIOTEC is also focusing on rainfed lowland systems but is following a strategy of pyramiding genes for yield stability into the preferred cultivars, KDML 105 and RD 6. The institute is by far the best-developed functional genomics research programme for crops within BIOTEC and has recently developed its own breeding programme. The breeding programme rests on an extensive research programme in marker development focused on production constraints in rainfed lowland systems. Markers have been developed for aroma, brown plant hopper resistance and tolerance of submergence and markers are being worked on for blast, salinity, bacterial blight and drought tolerance. The focus is stabilizing yield of high-quality, commercial varieties and increasing average yield over time. The research approach is very systematic. For example, the research characterized the existing blast diversity in Thailand into 15 groups. Five quantitative trait loci (QTLs) for blast resistance were identified and resistance sources for each QTL were found in three varieties, two in a variety from South China, two in an IRRI variety and one in a local variety. The programme is testing combining the sources in a multi-line variety versus pyramiding all the sources into a single variety, all through backcrossing into RD 6 and KDML 105. Similar work on establishing marker–locus–trait associations is underway for the other constraints. The programme works on systematic accumulation of genetic information, appropriate phenotyping and validation across multiple locations and actual validation within breeding programmes.

MAS is employed in a programme backcrossing resistance sources with the two commercial varieties. This has led to the production of a number of varieties with resistance to various combinations of constraints. The difficulty

is that the RGDU has no capacity to multiply and distribute the seed. This is the function of the Rice Seed Bureau, and they only multiply varieties developed within the BRRD and released by the Rice Department. The RGDU has therefore established a collaborative programme with the rainfed lowland rice breeding programme in the BRRD. The varieties coming out of the RGDU go through the yield evaluation programme at Ubon and then are potentially released by the DoR, for subsequent multiplication by the Bureau of Rice Seed. The RGDU's first variety, which incorporated submergence tolerance in KDML 105, was not released because it was not resistant to blast, even though KDML 105 is not either.

To a certain extent the current institutional arrangements dictate a level of collaboration between the two breeding efforts. However, this is limited by quite different breeding approaches, which introduces some level of competition. However, both approaches need to prove themselves in terms of providing a variety that will replace KDML 105.

### ***Hybrid rice breeding in Thailand***

Varietal adoption and turnover are more rapid in the irrigated sector than in the rainfed lowland sector, and are set to become even more rapid with the increased investments being made in the development of hybrid rice varieties. The prospects in this market have resulted in a significant increase in private-sector breeding of hybrid rice. A major motivation for private-sector investment in Thailand is that policy does not permit either import or export of rice seed for sale, only for research and evaluation. Moreover, the DoA regulates varietal release through the PVP law and the distinctness, uniformity and stability (DUS) testing requirement.

Five private companies are developing rice hybrids in Thailand, namely Pioneer, Bayer, Syngenta, Pacific and CP. CP has been working on hybrid development for about 10 years, mainly drawing on its Chinese expertise and germplasm. However, Chinese hybrids are not well adapted in Thailand and they are having difficulty with their breeding programme. The three multinationals draw primarily on their breeding programmes in India, where the competition is stiff but the market size justifies large investments. These companies have had operations on the ground only for the last three to four years and are in the initial phases of organizing their breeding programmes.

Bayer is a good example of this process. It started four years ago by importing varieties from its programme in India for evaluation. Its breeding programme in Thailand started two years ago. The sole focus is on long-grain, non-aromatic varieties for the irrigated sector. Bayer currently has three breeders. The goal is to release their first hybrid variety in three to five years. Next year, Bayer will start selecting and training contract farmers in hybrid rice seed production. The ability of the private sector to develop quality control in hybrid seed production using male sterility technology gives it a particular advantage over the public sector in the effective uptake of varieties.

Bayer is developing a regional capacity in rice hybrid development, as are the other companies. It uses MAS extensively in its breeding, mostly for yield and

quality traits. The company has recently opened a marker lab in Singapore, which serves all their breeding programmes in the region. Markers are both developed in-house and acquired from other sources. Double haploids are an integral part of the breeding system.

The five companies are now in negotiations with the Rice Department to set up a national yield trial system for evaluation of hybrids. The five companies work through the SAT in these negotiations and are joined by the RGDU and the BRRD. The plan is to have seven locations, all under irrigated conditions.

The DoR has not prioritized development of hybrid rice, although there have been some hybrid breeding efforts in four of its centres for over 10 years. Expansion of efforts in the private sector appear to be motivating increased interest. The Rice Department is establishing a marker laboratory to support hybrid breeding efforts. However, little effort has been given to organizing the seed system, an area in which the private sector usually has the comparative advantage. Moreover the private companies have the advantage of being able to build on successful breeding and seed programmes in India and do not need to draw on public-sector germplasm.

The RGDU in BIOTEC has taken a more strategic approach to hybrid breeding, which it started in 2004. The programme has been able to incorporate male sterility into Thai germplasm and to demonstrate up to a 30 percent yield advantage. However, the focus is not as much on yield advantage as on quality, which has been a continuing issue with hybrids and is especially important for varietal entry in the Thai market. Moreover, breeders feel that the effect of heterosis on yield is much less in shorter-season, tropical materials. RGDU puts a lower priority on hybrid development than on breeding OPVs but is maintaining its capacity in case there are spin offs in the molecular work on quality. RGDU's work on quality spans from incorporating the aromatic gene for jasmine rice to development of high-iron, low-glycaemic-index rice for diabetics. The principal research thrust continues to be on producing a "super KDML 105" with tolerance to all the principal production constraints.

The prospects for development of hybrid rice in Thailand will remain in the irrigated sector and be led by the private sector. This may result in the public sector focusing its breeding efforts on the rainfed lowland system and, potentially, on upland rice as well. Restructuring the public system is difficult, however, because existing capacity becomes a basis for locking in budgets. The BRRD faces competition from both the private sector and from RGDU. Improved coordination with RGDU, however, has the potential for exploiting the comparative advantages in both institutions. The major impact of hybrid development in the private seed sector may be on the organization of rice seed production in Thailand.

### ***The Bureau of Rice Seed***

The release of new varieties in the 1970s gave impetus to the development of a public-sector seed system. In 1972 the Department of Agricultural Extension created a Seed Division and established a seed production programme, which

was launched with outside assistance. Between 1976 and 1995, 23 seed centres were established around the country, each with a production capacity of 1 500 to 2 000 tonnes per year (increased to 4 000 tonnes in 1998). These centres focused on grain crops and had a range of programmes for production and distribution of seed. With the creation of the DoR in 2005, the 23 seed centres came under the Bureau of Rice Seed within the DoR. The Bureau now produces about 100 000 tonnes of seed per year. About 70 percent of the seed produced is for the irrigated sector in the central region. Continuous cultivation and seed dormancy create the principal market for rice seed in this region and the Bureau multiplies about eight varieties, of which Chai Nat 1 (released in 1993) is the dominant variety. Seed production in the other regions serves more as reserves and primarily consists of RD 6 and KDML 105. The rice seed is sold to farmers, millers or seed merchants at 20 Baht per kg.

The multiplication and distribution of new varieties is in the hands of the Bureau of Rice Seed. Currently 16 or 17 varieties are multiplied by the Bureau, with each centre having a target for each variety based on reports from the Bureau of Rice Promotion and Extension. The Bureau of Rice Seed adopts a very conservative stance as regards the multiplication and distribution of new varieties, multiplying only those varieties that come through the BRRD. Thus varieties coming out of the BIOTEC programme will not be considered unless they are advanced through the Research Department and then approved by the release committee in the DoR. The Bureau is also taking a conservative approach to the multiplication of the new hybrid produced by the Research Department. The current policy is to produce 50 tonnes for farmer and extension evaluation and then make a decision as to whether to scale up multiplication and distribution. However, such scaling up will require new skills and capacities that will essentially compete with the private sector. With the restructuring and creation of the DoR, the seed unit withdrew from seed production of upland crops. How it defines its role in relationship to the expected uptake of hybrid technology will determine its future effectiveness.

### ***Looking forward***

By the standard of a continuous flow of new varieties adopted by farmers, rice breeding in Thailand has been only moderately successful. Because of the position of Thailand in international rice markets, quality has been of primary concern. Thailand's competitive advantage against lower-cost producers, particularly Viet Nam, will continue to be on the basis of quality, including the development of new markets. However, Thailand cannot discount the importance of production costs and price, especially in an environment of rising labour costs. Moreover, Thailand's positioning as a regional seed hub does not apply within the rice sector. Strategic plant breeding will thus continue to have a role within the rice sector but there will have to be some institutional restructuring in order to assure its effectiveness. This will be driven by the increasing role of the private sector in the development of hybrid varieties for the irrigated areas on the one hand, and the need for better integration of conventional and molecular capacities in breeding for the rainfed lowland ecologies on the other. Pyramiding tolerance or resistance

genes to principal constraints into preferred varieties, such as KDML 105, is a sound, short-term strategy given the difficulty in the past in meeting the required quality standard. However, further progress beyond that will depend on wider population development. The next generation of rice breeding in Thailand needs to build on the very strong capacity that has been developed in molecular markers but extend that from sole application within a backcrossing breeding programme to their application within a larger population development programme. Such a two-track approach bets on the success in developing a “super KDML 105” but at the same time builds the basis for future varietal development. However, this will require moving from a somewhat competitive mode between the BRRD and the RGDU to a much more functional cooperative mode.

Rice breeding capacity in Thailand is an increasing concern. The current generation of rice breeders is about to retire without trained breeders to take their place. Moreover, the divide between molecular breeding and conventional breeding is becoming wider, although molecular breeding is being constrained by the limited resources it can devote to wide testing and conventional breeding is constrained by the budget constraints within MoAC. There is potential to overcome the latter by effective restructuring of the 23 research stations within the BRRD toward a sharper definition of the public sector’s role and its associated breeding priorities. However, what is most evident is that rice breeding and seed deployment does not function as a system, but rather as uncoordinated elements, often working at cross purposes, with the end result being the lack of new varieties available to farmers. This situation is exacerbated by the involvement of three different ministries in the system, each with quite different objectives. The dictates of the market as expressed by millers and exporters will continue to drive breeding strategy and varietal acceptance and their involvement in this process would complete the institutional arrangements that are necessary for the continuing competitiveness of the Thai rice sector in international markets.

## **Maize breeding in Thailand**

Maize was introduced in northeast Thailand in the 1960s to promote agricultural development. However, exports faced stiff competition from both North and South America and market development focused on the domestic animal feed market, especially in compound feeds for poultry and pigs. Area planted to maize grew quite rapidly from the 1960s through to the mid-1980s, when it peaked. Since then there has been a continual downward trend in maize area; by 2008 the area planted to maize was similar to that in 1970. Yield levels were quite variable in the 1960s and 1970s and averaged about 2 tonnes per hectare. Yields have grown from about 2.5 tonnes per hectare in the late 1980s to almost 4 tonnes per hectare by 2008. Total production peaked at 4.6 million tonnes in 1998; over the last five years production levels have oscillated between 3.7 and 4.1 million tonnes.

The maize sector competes for land with cassava and sugar cane on the production side and with a range of feed ingredients on the demand side. Thai maize must also compete with imports from Laos and Cambodia, which come in duty free. Production cost is thus a major factor in the ability of maize to compete within an agricultural sector that is both dynamic and attempting to restructure towards higher-value production.

Downy mildew was identified in Thailand in 1968 and reached pandemic proportions by the early 1970s. The first downy mildew resistant variety, Suwan 1, was released in 1975 by Kasetsart University. In 1981, 40 tonnes of hybrid seed were released to farmers for planting (Jampatong and Rungchang 2000). By 1990, 20 percent of maize farmers planted hybrids; this was the period when national average yields started to rise consistently. During the 1980s, hybrids were double crosses and three-way crosses and there was argument about the yield advantage of these hybrids over OPVs (Jampatong and Rungchang 2000). In 1991 private-sector companies introduced single-cross hybrids and adoption increased dramatically. Hybrids were also developed for sweet corn and baby corn. By 2000 85 percent of the maize area was planted to hybrids. This was a period of virtual saturation in the maize hybrid seed market in Thailand; total sales peaked in 2000 at 21 000 tonnes and have been relatively constant ever since.

The private seed sector has been very dynamic in Thailand. Although the hybrid maize market is mature, there is an increasing orientation toward exporting to the Asian regional market. Exports of hybrid maize have increased from 4 400 tonnes in 2000 to 15 600 tonnes in 2008; 18 400 tonnes were sold on the Thai market in 2008 (Tripetchpisal 2009). Exports of seed of sweet corn and baby corn hybrids have risen more quickly than exports of seed of field corn over the past decade. The export market is expected to continue to grow as Thai varieties are competitive in the rest of the region and Thai farmers and seed companies can produce good-quality seed at a competitive price. This regionalization, however, shifts the comparative advantage in breeding to the private sector, albeit building on a research base developed by the public sector.

### ***A short history of maize breeding in Thailand***

The success of maize breeding in Thailand has been built on the research capacity in the public sector. Maize breeding was initiated at Kasetsart University in the 1960s with USAID support.<sup>2</sup> In 1966 the Rockefeller Foundation transferred its Inter-Asian Corn Improvement Program (IACIP) from India to Thailand, where it was based at the National Corn and Sorghum Research Center (NCSRC, commonly called Suwan Farm). After an early period of evaluating a wide range of maize germplasm from different tropical regions, the IACIP focused on the development of an adapted population,

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<sup>2</sup> As in most developing countries, university capacity in plant breeding in Thailand has relied on outside funding. Funders of the Thai maize breeding effort have included the Asian Development Bank, FAO, the Rockefeller Foundation and USAID. The Kasetsart programme now depends on either its own resources or mobilizing funds from university or other grant programmes within Thailand.

Thai Composite #1. With the pandemic in downy mildew, two resistance sources from the Philippines were backcrossed into this population and a downy mildew resistant OPV, Suwan 1 was released in 1975 (Jampatong and Rungchang 2000). This variety, because of its adaptation and its genetic diversity, became the basis for private-sector plant breeding in the 1980s. In the late 1990s, seven private companies reported that they still used Suwan 1 in their breeding programme (Ekasingh *et al.* 2001).

NCSRC established a hybrid breeding programme in 1978. Initially the Suwan 1 population was used for inbred line development. In 1982, 19 inbred lines were released. At the same time, 40 tonnes of hybrid seed were produced by the station for sale to farmers, along with about 300 tonnes of OPV seed. Throughout the 1980s the centre produced seed for sale as the conduit for getting its varieties adopted by farmers. Four of the 20 seed centres operated by the Department of Agricultural Extension also produced OPV seed, which was distributed primarily through government programmes. However, during this period production and distribution of hybrid seed was quickly expanded by private companies. During the 1980s the public sector released four hybrid varieties compared with eight varieties released by the private sector, whereas in the 1990s the public sector released nine hybrid varieties compared with 50 varieties released by the private sector (Ekasingh *et al.* 2001). Kasetsart started by licensing its hybrids to seed companies. However, as the seed companies developed their own breeding capacity the university moved to licensing inbred lines. Between 1982 and 1997 the university released 46 inbred lines, which were primarily taken up by small companies. By 2009, it had released a total of 52 inbred lines.

In the late 1970s and early 1980s five multinational companies established hybrid maize breeding programmes in Thailand, namely Pioneer, Cargill (purchased by Monsanto), Novartis (now Syngenta), Pacific Seed (from Australia and now part of Advanta), and CP (a Thai multinational with previous links to Dekalb). Two more recent companies have entered the market: Seed Asia, incorporated in 2005 from the research division of AgriSource, and Siram Bioseed from India. The major expansion in breeding programmes in the 1990s was oriented toward competing in the Thai market. However, over the last decade this has turned to competing in a regional market and sourcing seed production from the most competitive source. Indian firms are showing particular interest in establishing breeding programmes for tropical maize in Thailand, primarily for development of varieties for export to India.

The FCRI of the DoA began breeding maize in the 1980s at the Nakhon Sawan research centre in northeast Thailand. The programme focused primarily on breeding hybrid varieties, and began with developing inbred lines from two populations, one based on Suwan 1 and the other on a CIMMYT population. In 2000 the programme released its first hybrid, a single-cross hybrid named Nakhon Sawan 72. The variety yielded only slightly less than the commercial hybrids produced by CP and Pioneer, i.e. 5.9 tonnes versus 6.3 tonnes. Nakhon Sawan 2 was released in 2006 and another hybrid which utilized drought-resistant lines from CIMMYT was released in 2008. However,

as with Kasetsart University, the DoA has no capacity for seed production. This has resulted in limited uptake of the varieties and a need for more effective partnership with private-sector seed producers.

### ***Current maize breeding programmes in Thailand***

The two public-sector maize breeding programmes face the difficult question of how best to serve the public interest in the face of increasing maize-breeding capacity in the private sector. The first step in answering this question is to define the clientele that will be served by these programmes. Maize farmers now almost exclusively plant hybrids, which are in turn provided by private-sector seed companies. Any social benefit from public-sector breeding programmes would have to come from providing adoptable varieties to new seed companies, germplasm products to private-sector breeding programmes or development of next-generation molecular breeding techniques that would either improve performance of public-sector breeding programmes or would be used in private-sector breeding programmes.

Recently, government emphasis has been on upland crops with potential as biofuel feedstock. The FCRI thus puts cassava, sugar cane and oil palm as higher priorities than maize. These priorities are also reflected in MoST and funding through both BIOTEC and the National Research Council. Thus, there is nothing comparable to the RGDU for maize. There are a few grants to universities to work on molecular markers on downy mildew but nothing with direct linkage back to the maize breeding programmes. The maize breeding programme in the DoA collaborates with the Generation Challenge Programme in the development of molecular markers for drought tolerance but the programme primarily is involved in phenotyping. Certainly there is nothing comparable to the molecular breeding capacity that currently exists in the large, private-sector companies.

Suwan Farm coordinates a national cooperative maize hybrid trial that has been running since 1987. It now includes 10 companies and 12 locations; each company plants and maintains the trial at one or two sites. The average yield of single-cross hybrids in 1987 was 7.5 tonnes per hectare, compared with last year's yield of 11 tonnes per hectare. The public-sector hybrids are usually in the lower rank of tested hybrids and the breeder at Suwan Farm attributes this to the lack of wide-area testing, which the private companies can now do through their regional programmes.

The two maize breeding programmes also have much smaller budgets than the breeding programmes in the private sector. The Kasetsart University programme has developed its own income sources, particularly the sale of sweet corn seed. The DoA programme looks to outside sources to fund its new research directions, such as into drought. Without capacity to move into molecular approaches and given the inability to compete with the large private-sector companies in hybrid development, the two programmes are each focusing on supplying small Thai companies with either inbreds or hybrids with which to enter into the maize seed market. The Suwan Farm breeder has trained staff of 12 small companies in participatory selection. The DoA breeder also works with small companies in testing and distributing his



inbred line. The public-sector breeders maintain a broad germplasm base, which will be invaluable as the private sector seeks out traits that will improve existing lines. If the small companies can carve out a niche in the market, through providing locally adapted varieties, there is the potential to further develop the material.

For this strategy to succeed a foundation seed intermediary would be needed to bridge the public-sector breeding efforts to the private-sector companies. This could be a private company, modelled on the Holden Foundation Seed Company in the US which markets foundation seed of inbred lines to seed production companies. An alternative model is the Indian Foundation Seed and Services Association, a non-profit set up as a link between the Indian public-sector hybrid rice breeding programmes and private seed companies (Joshi 2009).

The idea would be to increase cooperation across Thai maize breeding through a common marketing facility for inbred lines, focusing on small Thai seed producers. This would keep open broader-based approaches to maize varietal development in the country.

## **Cassava breeding in Thailand**

Thailand is the world's largest exporter of cassava products. The Thai cassava industry was developed around the European animal feed market in the 1960s, when cassava entered European countries at a lower tariff than grains. Exports of hard pellets peaked at 7.7 million tonnes in 1992, after which cassava lost its price advantage relative to grains following reform of the European Union's Common Agricultural Policy. Since then Thailand has been restructuring its market for cassava products toward starch production, regional trade (especially with China), increased domestic consumption in animal feeds and development of cassava as a feedstock in bioethanol production. Market diversification towards higher-value products has been very successful, especially in the case of starch, where there has been an increasing shift to modified starches. The ability to diversify end markets has given cassava a particular advantage over maize.

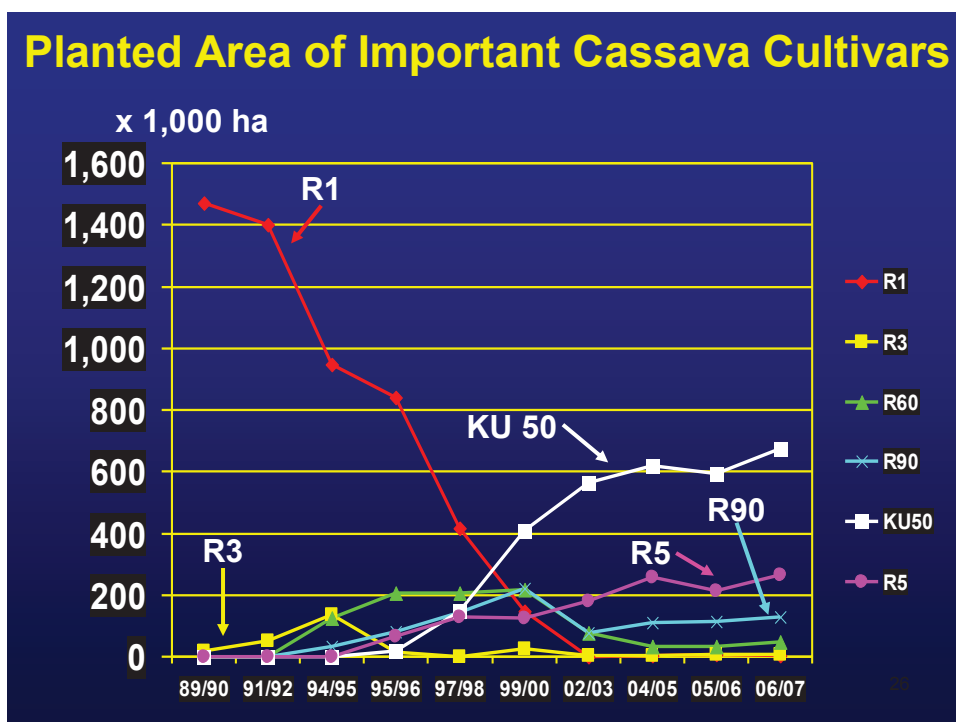
Area planted to cassava peaked in 1988/89 at 1.6 million hectares and then declined to a little less than one million hectares in 2002. Since then it has started to trend back upward. Yields started to trend upwards quite markedly in 1999 from a long-term average of about 15 tonnes per hectare to 23 tonnes per hectare in 2008, resulting in a record root production of 27 million tonnes. The yield increase resulted from both significant increases in fertilizer application and adoption of improved varieties. Improved efficiencies in root production together with improvement in processing have resulted in rapid expansion in starch trade, primarily in the Asian region, and parity in the price of maize and cassava starch since about 2005, before which cassava starch sold for less than maize starch. One tapioca-based ethanol plant is currently in operation, with nine more under construction (USDA 2009). An increasing

market price together with a continuing expansion in demand for cassava will provide incentives for further increases in cassava yields.

### ***A short history of cassava breeding in Thailand***

Research on cassava in Thailand began with the establishment of the Rayong Field Crops Research Center (RFCRC) in 1954. From the 1950s through the early 1960s the programme focused on collecting local clones and assembling them in a germplasm collection. In 1963 seven clones were introduced from Indonesia; 43 clones from the Virgin Islands were introduced in 1965. One of the local accessions became the principal variety planted and was released as Rayong 1 in 1973. From 1970 onwards almost all of the introductions were from CIAT, and CIAT crosses began to be introduced in 1977. A crossing and selection programme was started at RFCRC in 1975 and at Kasetsart University's Sri Racha research station in 1983. Kasetsart's breeding programme was transferred to the new Thai Tapioca Development Institute (TTDI) in Huay Bong in the late 1990s. The development of both programmes was closely tied to the CIAT cassava breeding programme. Between 1975 and 2002 seven Thai cassava breeders were trained at CIAT and a cassava breeder from CIAT was based in Thailand from 1983 to 1998.

The first cassava variety from the crossing programme was released in 1990 as Rayong 3. This was a selection from CIAT F<sub>1</sub> hybrid seeds and had significantly higher root starch content than existing varieties, a key root characteristic demanded by cassava processors. Rayong 60 was released in 1987 and was quite widely adopted in the later part of the 1990s, although Rayong 1 remained the most widely planted variety until 1999. Four more varieties were released in the 1990s, including Kasetsart University's first variety, KU 50, in 1992. Uptake of these varieties provided the basis for the consistent rise in cassava yields over the last decade. KU 50 became the most widely planted variety during this period, although four varieties were widely planted and essentially replaced Rayong 1 (Figure 3). At the same time the germplasm base of these varieties significantly narrowed, as previous releases were increasingly used as parental material.



**Figure 3.** Area planted to major cassava cultivars in Thailand, 1989/90–2006/07. Source: Rojanaridpiched (2009).

### ***Current cassava breeding programmes in Thailand***

Cassava breeding in Thailand aims to increase starch yield per hectare. Root starch content is an important selection criterion. The goal over the next decade is to increase yields from the current 23 tonnes per hectare to 35 tonnes per hectare. This would consolidate cassava’s role in regional starch markets and to provide a basis for expanded ethanol production. However, the budget allocated to cassava breeding by the MoAC has declined in recent years. The operational budget for cassava breeding in the RFCRC declined from just over 4 million Baht in 2008/09 to 2.9 million in 2009/10. This includes 1.1 million Baht for molecular-marker development at Khon Kaen University. Kasetsart University’s cassava breeding programme depends on the budget of the TTDI, which in turn depends on the return on an endowment, which has been depressed in recent years. The RFCRC also has to maintain a germplasm bank of 613 accessions, all of which have to be replanted in the field each year. These are increasingly maintained in tissue culture, but costs of maintaining the germplasm bank is still much higher than for grain crops.

A further problem facing cassava breeding in Thailand is that the principal cassava breeders will all retire over the next few years. As in rice and maize, there has not been a coherent approach to ensuring training of the next generation of cassava breeders, partly because of a hiring freeze and partly because of the lack of training in conventional breeding techniques.

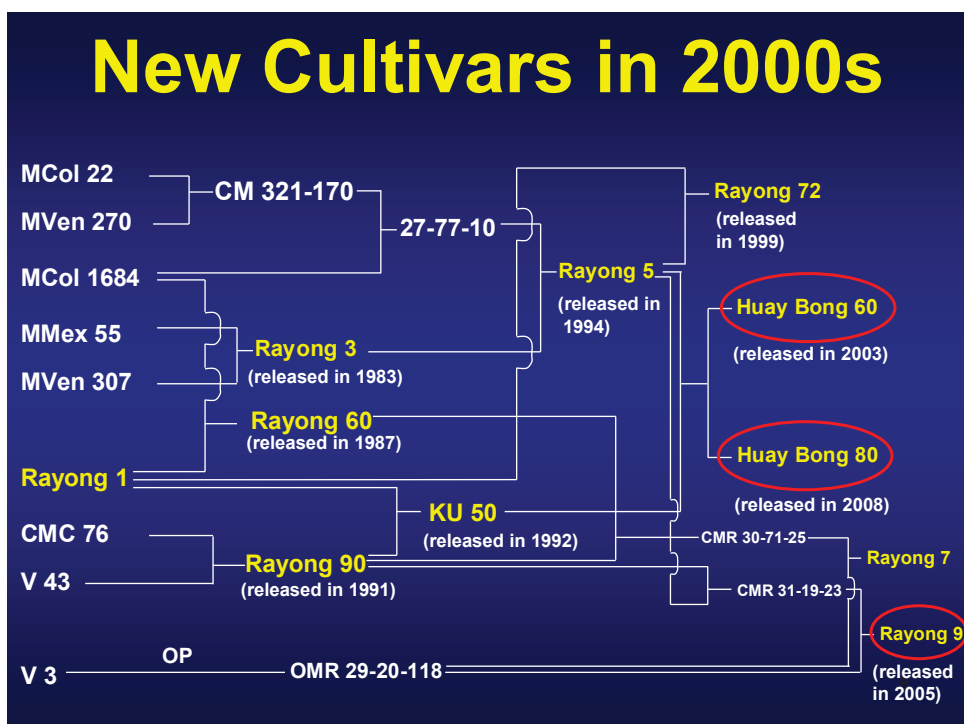
BIOTEC has developed a Cassava and Starch Technology Research Unit, somewhat similar to the RGDU. However, the focus of this unit is almost exclusively on basic work on starch properties and starch modification processes in support of industrial applications within the starch industry. Limited work is done at Mahidol and Khon Kaen universities on developing

markers for starch hydrogen cyanide contents and development of a genetic linkage map. However, this work consists of individual projects and developing a range of effective markers will take a considerable time. Moreover, neither RFCRC nor Khon Kaen University has a marker lab.

In the search for higher-value cassava products, TTDI has contracted CIAT to develop a population of waxy (amylose-free starch) cassava. This trait will make the conversion of starch to sugar much more efficient in bioethanol production. Thai varieties are being crossed with waxy varieties at the CIAT experimental farm in Colombia and two sets of 20 000 seeds will be sent to TTDI for selection and evaluation by staff from Kasetsart University.

Currently both breeding programmes have their own seed production and distribution systems. The Kasetsart University breeding programme has the advantage of being located at TTDI, which multiplies cassava varieties for distribution. Between 1995 and 2006 TTDI distributed on average about 6 million cuttings a year, with a peak of 9 million cuttings in 2006. Only about 10 percent of these were varieties from the Rayong breeding programme. Rather, RFCRC multiplies its own cuttings for distribution to farmers and in 2008 distributed 1.5 million cuttings of its two most recently released varieties. As with the Bureau of Rice Seed, the distribution of new varieties depends critically on decisions made in seed multiplication and distribution.

The genetic base used in the breeding programmes has narrowed significantly over time, especially in the Kasetsart University programme (Figure 4). The recent outbreak of mealybug in Thailand demonstrates the importance of maintaining a wide genetic base for the crop and the need to ensure an effective breeding capacity. Development of new varieties will depend on continued capacity in conventional breeding, although the development of double haploids could be a major advance in cassava breeding. Both programmes are stretched and yet a major industry depends on how these programmes transition over the next few years.



**Figure 4.** Pedigrees of cassava varieties released by Kasetsart University between 1999 and 2008. Source: Rojanaridpiched (2009)

## Conclusions

The Thai agricultural sector is undergoing a restructuring aimed at delivering continued growth in farm productivity, movement to higher-value products and production, and supporting the domestic markets while maintaining competitiveness in export markets. This process is in part driven by increased investment by the private sector, including farmers. Strategic public sector investment will continue to play a critical role this restructuring.

Farm yields have increased in all three crops under review, although less so in the case of rice. The Thai government has made some strategic choices in how it has invested in molecular biology, genomics and biotechnology as the next principal source of increasing yields. This is clearest in the case of rice, where a critical mass of research has been created in the RGDU and the prospects are good for developing varieties that will increase productivity in rainfed lowland rice systems, primarily through a maintenance breeding approach, i.e. pyramiding genes for tolerance of principal constraints in elite cultivars. Building this capacity in BIOTEC within the Ministry of Science and Technology has exposed the difficulty in achieving effective integration with both the breeding programme and the seed production capacity in the Ministry of Agriculture. New molecular technologies need to be integrated into well structured plant breeding programmes, and this is not happening because of the lack of a coordinated, systematic breeding efforts. The investment in new science appears to be coming at the expense of critical capacities in conventional plant breeding. In the other crops, there is insufficient depth in genomics research capacity to make significant progress with these tools. At the same time, there are real concerns about the short- to medium-term

capacity in conventional breeding programmes within the Ministry of Agriculture.

Investments in public-sector breeding capacity have also to be made in the context of the very dynamic private sector. Over the last decade there has been significant regionalization in private sector capacity, particularly among the multinationals, but also in the larger Indian, Chinese and Thai companies (particularly East-West and CP). Thailand's investment in developing as a regional seed hub make sense within a free trade ASEAN market, especially for vegetables and maize. However, there will be continued reliance on the public sector for breeding cassava and sugar cane, which are also targeted as feedstock in an expanding bioethanol industry, both domestically and regionally. Thailand has been very successful in attracting investment from regional and multinational seed companies but critical gaps in public-sector investment in breeding capacity remain. Over the next decade Thailand will need to be able to shift plant breeding investments within a very dynamic market context and yet maintain critical capacities and systemic linkages in matching an effective public-sector role to the needs of an expanding private sector.

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