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Biotechnology in Thailand

Scientific Capacity and Technological Change

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BIOTECHNOLOGY IN THAILAND

Scientific Capacity and Technological Change

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Introduction

Rapidly changing technology creates one of the most difficult areas of economic and social policy to master in any country. Thailand, as an aspiring newly industrialized country (NIC), has enjoyed substantial economic growth in past years. However, Thailand's impressive export performance has been driven less by mastery of complex production technologies than by low factor prices, a favourable geopolitical situation and comparative advantage in natural resources. Many Thai science and technology (S&T) policy-makers are therefore understandably preoccupied with improving the technological capacity of local economic actors. One major S&T policy thrust is to foster greater technological capability in and for industries that are based on bioresources, including agriculture and agro-industry. Thailand has expended much effort to develop policy and institutional mechanisms to engineer the development of technological capability in this area.

Biotechnology is a promising group of technologies to internalize. Biotechnology has 'given new hope' to developing countries and particularly to Thailand.[1] Many expect biotechnology to reduce the impact of tropical diseases, improve crop yields and result in more value-added use of indigenous resources.

Thailand enjoys certain conditions that may be favourable to the development of advanced bioindustries: ample underutilized bioresources and a number of skilled research and development (R&D) personnel in the biological sciences. Most of the latter are in the public sector. The principal aim of Thailand's biotechnology policy has been to increase the level of biotechnology R&D and teaching activity in universities and public labs, and to stimulate uptake of skills and innovations by the productive sector. This policy entails efforts to devise institutional linkage mechanisms between university and industry, and to increase the ability of firms to absorb biotechnological innovations.

This paper examines problems in translating university-based research capacity into capacity for changing the technological bases of production.[2] First, the reseachers describe the context and goals of Thai S&T policy and situate Thai biotechnology policy within this framework. They review available diagnoses of the status and problems of plant biotechnology in Thailand, focus on explanations for observed patterns of activity and describe patterns of funding of biotechnology in Thailand. Salient features of this funding system are that projects, rather than programmes, constitute the framework within which biotechnology R&D is funded; most projects are executed in universities, and involvement of users in the productive sector varies; a large amount of R&D resources flows through bilateral or multilateral development assistance channels. The authors illustrate some of the sociological and structural conditioners of technological change in Thailand by focusing on the utilization of Thai university research in tissue culture propagation and plant genetics by two industries in Thailand, the ornamental flower and seed industries. These industries generate significant income for many small producers in central Thailand and are foci for government science investments.

Analyses of Thai research activity and utilization in biotechnology and in specialities of plant genetics related to vegetable, corn and ornamental flower production are presented below. Findings indicate that:

- university staff are prominent producers of basic as well as applied scientific research
- it is not unusual for Thai university staff in biotechnology to become involved in outreach or entrepreneurial activities
- although much Thai research is published locally in the vernacular, it frequently remains invisible outside of the close personal networks that exist within the Thai research community
- the traditional training functions of universities are significant in disseminating skills in biotechnology to the private sector
- the nature and dynamics of the funding system strongly influence the scope and direction of biotechnology research, as well as strategies for communicating research results
- several strategies for directing university attention to the private sector are being contemplated, including greater governmental steering of university research funding and support for university industrial extension or brokerage services.

1. Encouraging science-based innovation

National technological capability is not simply thousands of individual technological capabilities developed in isolation; it is determined by the various skill endowments of firms, cultural traditions, the structure of incentives and markets, and the quality of policies, leadership, and infrastructures. The determinants of national technological capability most often described are also those most amenable to measurement: the rate of growth of physical capital and human capital, technological effort and policies, trade and competition policies, and the macroeconomic environment.[3]

Innovation occurs in complex organizational and social systems, the dynamics of which are an important factor in any technological development effort. Modern institutional systems for innovating technology are comprised of disparate configurations of actors, public and private. These include domestic and foreign firms of various sizes; institutions involved in education, research and training; financial institutions; organizations from all three levels of government with planning, policy-making or programme functions; and public laboratories. Good linkages among producers and users of innovations are a crucially important feature of 'structurally competitive' economies.[4] The notion of structural competitiveness does not refer to the aggregate competitiveness of individual firms: it is related to a wide array of economic and institutional phenomena and represents either externalities or diseconomies for the individual firm. In particular, structurally competitive economies are able to learn more effectively than others. This feature of competitive economies points to the importance of interactive linkages among components in an innovative system because it is through interaction that learning takes place and capability diffuses to industrial sectors. A publicly-supplied technological infrastructure can be a strategic factor in competitive industrial innovation. Effective use of public technology infrastructure is a critical task in every kind of economy.[5]

Thailand's interest in S&T is a response to the critical problem of sustaining the development of an economy in which growth in the past three decades concentrated on massive export of low-wage manufactured goods. The Thai manufacturing sector grew at an average rate of 8.3 per cent in the period 1975–1985; from 1987 to 1989 the annual increase was 13.3 per cent, 16.8 per cent and 17 per cent.[6] Exported industrial goods include textiles, canned foods, assembled automotive vehicles, assembled electronics devices, ceramics and some rubber and plastic products. In 1987, the top ten Thai manufactured exports in terms of revealed comparative advantage were tin, undergarments, leather, gold and silvery jewellery, women's outerwear, precious and semiprecious stones, wood, mens' outerwear, textiles and knitted undergarments.[7] The growth of the sector is due primarily to foreign direct investments, low-wage labour, high rates of domestic protection and access to large markets in industrialized regions.

Agriculture, which still provides employment for about 67 per cent of the labour force, generated only 16 per cent of the Gross Domestic Product in 1988, declining from 27 per cent in 1975.[8] However, the value of agricultural goods and services tripled during this period, increasing 22 per cent between 1987 and 1988. Agriculture's share of total exports dropped from almost half in 1982 to a quarter in 1990. Rice and rubber are still among the country's most important commodity exports. The value of these traditional exports still exceeds that of textile products. Export earnings for rice and rubber have declined in recent years, although the decline is not as dramatic as it is for maize which fell by half since 1985.[9] The decline in value of commodity agriculture exports reflects increased competition from other agricultural producers in the Asian region, poor prices and difficulties in securing access to markets in Europe and Japan.[10]

The competitiveness of the Thai development model may prove difficult to maintain, given the emergence of countries in the region with similar endowments of low-wage labour and agricultural potential, such as Malaysia, Vietnam and Indonesia. Thailand's sixth development plan (1987–1991) emphasizes the importance of investments in science and technology: 'serious and continual development . . . coupled with good management and services are vital if Thailand is to increase her standing in the intensely competitive world markets which she faces today, and raise the standard of living of her people.'[11]

Export-led growth has had a particular kind of impact on national scientific and technological capacity. Thailand's industrial base remains shallow and dependent on transfer of foreign investment and foreign technical inputs of all kinds. Only .17 per cent of GNP was spent on R&D from 1975 to 1987.[12] Most of this was public money to finance R&D in the public sector. Consequently, 'adaptive and innovative capabilities mainly reside in universities and government laboratories while operative capabilities, to the extent that they exist, reside in producing firms.'[13] Thailand's private sector conducts little R&D. As discussed below, public universities suffer from lack of funds. Low salaries in the education system have created problems in attracting and retaining primary and secondary teachers. Local capital markets are not deeply involved in manufacturing, and steeply rising land values have encouraged speculation and threatened agriculture. However, rapid growth of assembly operations for export of manufactured goods has led to a shortage of engineers and technical personnel which 'is posing the most serious bottleneck for the further industrial and economic development of Thailand.'[14] Some demand also appears to be developing for technical services and technology management skills. These trends will put pressure on Thai manufacturing firms to upgrade their technological capabilities.

Many studies of Thai technological capacity have been carried out by the Thailand Development Research Institute (TDRI), the Ministry of Science, Technology and Energy (MOSTE), and by foreign donors. In the aggregate, these studies provide a better than average portrait of the national innovation system of this lower-middle income developing country. The diagnoses reach similar conclusions: most firms in the modern sector have adequate ability to operate production technology, but they 'are weak in searching for, acquiring, and adapting foreign technology. They are even weaker in developing their own technology.'[15]

Studies usually propose various policy remedies to trigger a process of technological accumulation in Thailand so that the country can break out of its current technological trajectory and provoke changes away from agriculture toward industry. Two principal groups of constraints to technological development are identified. For many Thai S&T planners, the main policy problem is to raise private sector research and development expenditures. The emphasis is therefore on identifying and removing disincentives to investment in R&D in a fast-growth, export-led economy in which most major production facilities are branch plants. Analysts believe that in this sort of economy, fast growth sharply reduces the need to increase production efficiency. High tariff protection has resulted in low domestic levels of competition, and certain fiscal disincentives such as import taxes on capital equipment, income taxes on foreign consultants and absence of positive fiscal incentives for R&D such as tax credits are held to hamper the deployment of R&D activities in the private sector. The system of direct financial incentives to stimulate industrial innovation also needs strengthening.[16]

Whatever the cause, industry in Thailand is not eager to invest in high level skills. Only about 14 per cent of R&D expenditures was financed by productive enterprise in 1985.[17] A 1982 survey of Thai firms showed that research budgets represented a meagre .01 per cent of sales revenue, a figure that is well below private sector spending for technology development in any Asian NIC.[18] Firms judged to have some capacity for technological innovation had, on the average, fewer than two staff assigned to this work, most of whom did not possess any university level scientific or technical training. Although lacking significant research capacity themselves, the firms were not using the resources of universities and government scientific institutions; only 2 per cent of research expenditures were contracted out to these institutions or their staff.

Thailand's national industrial structure does not lend itself to private investment in R&D or technological innovation. There are said to be too many small, family-owned firms that cannot afford to invest in R&D. There may be too many large foreign firms and joint ventures which rely on R&D by the parent company. These particular patterns of entrepreneurship discourage long-term investments in product innovations and improvements in manufacturing or distribution processes.

The second group of constraints has to do with inadequacies of S&T infrastructure. One important shortcoming is the weak technical service sector to provide S&T consultancy, information, calibration, testing and prototyping. Few free-standing organizations exist to service sectoral technical problems. Existing S&T information centres do not know the R&D conducted in the country, or the technical and consultancy resources available in universities.[19]

The education system does not produce enough S&T manpower. Unfavourable quantitative and qualitative characteristics of the labour force are viewed as constraints to science-based technological innovation in the private sector. There are serious S&T manpower shortages, especially at the university degree level. Supply of human resources does not match demand. Many firms do not possess a high level of scientific and technological competence.[20]

Government policies affecting the private sector were made to be facilitative. For instance, the Ministry of Science, Technology and Energy provides loans to key industries at concessional rates to support technology development, as does the Science and Technology Development Board and the International Finance Corporation of Thailand. The belief is that if tax and other incentives are improved, firms will increase their commitment to R&D. However, an emerging strand of thinking emphasizes the disincentives to innovation afforded by the structure of the domestic market. In this view, the protection afforded to firms in Thailand beginning in the 1960s accomplished its goal of stimulating import-substitution, but now a more competitive local environment must be created. This might entail some discrimination in favour of indigenous firms.[21]

In contrast to the facilitative policy role of government with respect to the industrial sector, policies affecting the university and public laboratories tend to be directive. This is most clearly seen in the case of policies designed to make public sector scientific activities more relevant to industry needs. Linkages between producers and users (particularly public producers and private users) are considered too weak. Some consider that public research organizations ought to be restructured to increase their responsiveness to the private sector. Frequently proposed remedies include establishment of mechanisms to ensure greater policy direction of the R&D activities of government scientific institutes and universities, which have so far failed to satisfy the needs of the manufacturing sector. The sixth development plan programme for development of S&T proposes that 'topics of national importance should be determined and the users of the research results identified before any research project is supported.' Implementing mechanisms involve increasing private sector representation in the management of government scientific institutions and universities. The focus is away from academic research towards self-financing through sales of services and contract research and commercializing units within the principal research institutes.[22]

The belief that university and other public sector research activities require closer policy direction is understandable, considering that most R&D in Thailand is performed in the public sector. However, attempts to optimize the harvest of innovations produced by Thai universities must confront fundamental dynamics of the university system. The strategy of donors and research sponsors is to use universities as platforms for research that is funded on a project-by-project basis. Although fairly abundant resources are available on a project basis, this type of institutional arrangement contributes only indirectly to the teaching and apprenticeship relations that are crucial to the reproduction of a scientific community. Universities, the backbone of Thailand's research system, are losing their ability to sustain research activity as the system becomes depleted of practising doctoral-level scientists, which are in short supply in Thailand. Also, while the emphasis on achieving applications in the short term has provided a harvest of useful results, it has also deflected attention away from the need to build institutional and human capacity for the next, molecular, generation of plant biotechnologies.

2. Importance of universities

In Thailand, as in many other Asian countries, indigenous universities account for a very high proportion of research scientists and engineers. They are the locus of most basic and applied scientific research, and they are the institutional home of most practising scientists. In 1979, the last year for which such information is available, educational institutions employed 36 per cent of all trained scientific and technological personnel, 62 per cent of the scientists and engineers with master's degrees and 75 per cent of those qualified with doctorates. Many Thai scientists with advanced degrees have been trained abroad, particularly in the United States. Between 1977 and 1987 Thai contribution to international scientific literature increased by 79 per cent. University authors produce most of Thailand's mainstream scientific papers.[23]

Thailand has a large, rapidly expanding and highly differentiated university system. In 1987, 637,000 students were enrolled at 16 public universities and 25 private universities and colleges. Ramkamheng and Sukhothai Thammathirat universities, open universities that began instruction in the early 1970s, have absorbed most of the dramatic increase in tertiary level enrollment. They are several times larger than all the other government universities combined (about 140,000 in 1989). These, nevertheless, were growing at a rate of about 10 per cent per annum throughout the 1980s. Private colleges, which mostly offer courses in arts and commerce, account for an expanding proportion (about 7 per cent) of university enrollment. Some have recently established engineering programmes in response to the highly publicized shortage of personnel in these fields. A new private university for scientific and technological studies has been proposed.[24]

The first universities in Thailand were founded before the Second World War to provide professional training in public administration and in scientific and technical fields. The first agricultural university, Kasetsart University, was formally established in 1943 by merging existing colleges of agriculture, forestry and irrigation engineering; it offered training for entry into government extension services. The creation of regional universities at Chiang Mai (1964) in the north, Khon Kaen (1965) in the northeast and Songkla (1968) in the south accelerated expansion of programmes in agricultural sciences.

Kasetsart University in suburban Bangkok, assisted for many years by the United States Agency for International Development as well as by American philanthropic foundations,[25] is the country's premier agricultural university. It has the largest enrollment in agriculture (about 600 undergraduate and 400 postgraduate students in 1990) and the most postgraduate programmes in agricultural sciences (six doctoral and more than ten master's programmes). In addition, the university is the site of several laboratories and research institutes administered by the Ministry of Agriculture and Cooperatives such as the Horticultural Research Institute, the National Center for Corn and Sorghum Research, the Field Crop Research Institute and the Brackishwater Fisheries Research Institute, among many others.

The rapid expansion of higher education in Thailand has resulted in a significant increase in research capacity in some fields and in some universities (notably the medical and health sciences in Mahidol and Chulalongkorn universities), but not in others. In 1986, less than ten per cent of students in Thai universities and colleges (about 57,000 of a total of 678,000) were studying scientific and technical subjects. Masters and doctoral students in scientific and technical fields were very few until recently (many postgraduate programmes were established in the 1980s) and remain concentrated in the medical and health sciences. In 1986 218 doctorate or equivalent degrees were awarded, 188 of them in the medical and health sciences.[26] The most common qualification of academic staff at Thai universities is the master's degree; the highest concentrations of doctorates are to be found at Chulalongkorn, Kasetsart and Mahidol universities (see Table 1). Most of the master's degrees were obtained from Thai universities. In contrast, most university staff with doctoral degrees, as noted above, have received foreign training, usually as part of staff development programmes at universities such as Chulalongkorn, Mahidol, Kasetsart and Chiang Mai, which have been designated by the government as centres of advanced training in scientific fields. They are important centres of research activity. The staff of these four universities produce a majority of all Thai scientific papers in international journals and are the most prolific producers of local scientific literature as well.[27]

Table 1 Qualifications of academic staff, selected Thai universities, 1987

Institution	Total	PhD	(%)	Master's	(%)
Chiang Mai	4634	458	9.9	992	21.4
Chulalongkorn	3995	672	16.8	1481	37.1
Kasetsart	2440	365	14.4	901	35.5
Khon Kaen	3206	275	8.6	848	26.5
Mahidol	8826	527	6.0	1434	16.2
Prince of Songkla	3158	218	6.9	725	23.0

Source: MUA, 1988, Table 14.

Thai S&T policies encourage expansion of scientific and technical training and the establishment of specialized institutions to commercialize innovations produced in public research labs and universities. Examples of institutional initiatives in the higher education sector which government science policies presently encourage include the proposed Suranaree University of Technology which is to be established as a self-financing public university in the northeastern part of the country, and the recent upgrading of Rangsit College in Bangkok to university status. Rangsit University is a private university financed by endowments and student fees; it provides undergraduate training in science, medicine, engineering and commerce.

Public universities have been encouraged to establish commercialization units on the successful model of UNISEARCH at Chulalongkorn University. UNISEARCH, an adaptation of a similar organization at the University of New South Wales in Australia, has grown exponentially from modest beginnings in 1986. The value of the unit's projects and services has grown from a little more than 1.4 million Baht to more than 17 million Baht in 1989 (25 Baht = $US1, 1989). Its most important activities are consultancies and contract research which account for more than 70 per cent of the income from external sources. Language and management training activities account for 12 per cent of the unit's income. Testing, technical translation and software development account for most of the rest. The unit has so far had little success in commercializing inventions of university researchers, such as an instrument for artificially inseminating Asian honey bees, an x-ray locator for intra-ocular foreign bodies, a laryngeal prosthesis and an anti-ulcer drug extracted from a Thai medicinal plant. Many customers for UNISEARCH's services and projects are government, parastatal and regional organizations including the Ministry of University Affairs, the Science and Technology Development Board and the National Center for Metals and Materials. Significant private sector projects utilize the management and social science expertise of the university; these include a Textile Industry Association-sponsored project examining the tax burden on the textile industry.

Despite the concentration of national research capacity in the university sector, a very small proportion of national research and development expenditures goes to university scientists. Only 9 per cent of such expenditures supported university research in 1986, and even this small amount represents a tripling since 1981.[28]

3. Biotechnology policy in Thailand

Thailand is considered to have made a serious commitment to apply science and technology to national development. The Ministry of Science, Technology and Energy was established in 1979. Since 1982, the five-year economic and social development plans have S&T policy sections. It was hoped that such policy would help Thailand achieve NIC status by 1991. However, the policy is still generally inadequate and ineffective for enhancement of technological capability. The principal problem of policies articulated in the recent plans is lack of effective mechanisms for implementation.[29]

Thailand has targeted three strategic technologies for development: biotechnology, advanced materials and electronics/computers. Compared to other developing countries, Thailand's infrastructure for biotechnology is relatively well developed. About twenty major institutions, virtually all in the public sector, house about 500 researchers at the MSc level and above. Thailand has strengths in biomedical and agricultural biotechnology and weaknesses in bioprocess biotechnology. The Thailand Institute for Scientific and Technical Research conserves microbial genetic material. The National Gene Bank of Thailand is a seed/germplasm storage facility. Other specialized rice and tree collections are available. In 1986 the National Center for Genetic Engineering and Biotechnology (NCGEB) sponsored the establishment of a tissue culture network which involved periodic meetings and launching of a plant biotechnology newsletter.

In 1989, five Thai universities offered undergraduate degrees in biotechnology: Kasetsart, Chulalongkorn, Mahidol, King Monkut Institute of Technology (KMIT)-Lat Krabang and Khon Kaen. Three universities offered master's programmes: Chulalongkorn, KMIT-Thonburi and Kasetsart. Thai universities produce about 2,000 biotechnology-related bachelor graduates and about 450 master's graduates per year. However, there is very limited activity at the doctoral level.

Substantial private demand exists for graduates at the BSc level in biotechnology. The demand comes principally from the agro-food sector, especially food and feed processing. Graduates with MSc and PhD degrees in biotechnology experience limited demand from the private sector.[30]

No comprehensive data on biotechnology R&D expenditures in Thailand exist, but available evidence indicates that biotechnology R&D is funded primarily by the public sector and that much of it is provided via international development assistance. Table 2 reproduces the best information available on biotechnology R&D expenditures in Thailand.

Government biotechnology policy is made and research investments are monitored, directed and co-ordinated by the NCGEB, which was established by MOSTE in 1983 following Thailand's unsuccessful bid to host the International Center for Genetic Engineering and Biotechnology (ICGEB) being established by UNIDO. NCGEB's mission is to promote 'research and development from the laboratory scale to the pilot scale' for subsequent adoption by the private sector.[31] NCGEB manages biotechnology funding programmes, selects projects for support and co-ordinates policy analysis, formulation and implementation. It organizes joint ventures with firms, sponsors conferences and seminars and supports graduate studies in biotechnology. NCGEB also provides support for information, training, university-industry links and international links. Between 1984 and 1990 NCGEB funded 80 R&D projects in biotechnology worth about US$4.4 million.

Table 2 Sources of biotechnology R&D expenditures in Thailand

Source	FY	No. projects	(%)	Value (M$US)	(%)	avg.(K$US)
STDB	87–90	42	(19)	7.1	(26)	169
NCGEB	84–90	80	(35)	4.4	(26)	55
ATT	85–90	38	(17)	8.0	(29)	211
UICRD	85–90	19	(8)	1.5	(5)	79
PSTC	83–90	48	(21)	6.5	(24)	135

STDB: Science and Technology Development Board. NCGEB: National Center for Genetic Engineering and Biotechnology. ATT: Agricultural Technology Transfer Project. UICRD: US-Israeli Cooperative Research and Development Program. PSTC: Program in Science and Technology Cooperation.

Source: Chulawatanathol, 1990.

A second major source of biotechnology R&D support is the Science and Technology Development Board (STDB), established in 1985. STDB is a bilateral Thai-American programme which offers 'grants and low-interest loans to the private sector to prompt it to develop its R&D&E capabilities and enable the private sector to apply the R&D of local institutions and organizations to commercial and industrial uses.'[32] STDB initially received US$2.25 M from USAID; US$.75 M from the Bangkok Bank, the Thai Military Bank and the Industrial Finance Corporation and US$.75 M from the government. It promotes scientific and technological research in the three groups of targeted technologies mentioned above. Between 1987 and 1990, STDB supported 42 projects in biotechnology at a cost of US$7.1 million.

Three other important sources of biotechnology R&D support in Thailand are available in a bilateral assistance framework with the United States. The Agricultural Technology Transfer Program (ATT) is a USAID programme that supports R&D projects conducted by the Ministry of Agriculture and Cooperatives of Thailand. Between 1985 and 1990, 38 biotechnology programmes worth US$8.0 million were supported. The US-Israel Cooperative Development Research Program (UICDR) is USAID-funded and gives support to bilateral R&D projects jointly undertaken between Israeli scientists and those from the developing world. Between 1985 and 1990, 19 biotechnology R&D projects were funded for a total of US$1.5 million. The Program in Science and Technology Cooperation (PSTC) is a USAID programme supporting innovative research in the developing countries on a competitive basis; 48 research projects were supported in biotechnology in Thailand between 1983 and 1990 at a cost of US$6.5 million.

These five major funding sources supported a total of 227 major R&D projects in biotechnology between 1983 and 1990 at a total cost of about US$27 million. The average project cost ranged from US$55,000 for projects funded by STDB to US$211,000 for projects funded under the ATT programme. Funding was typically spread over an average project life of three years. Observers estimate that Thailand currently has the human and institutional capacity to conduct 90 to 120 biotechnology R&D projects of this magnitude at any one time, implying that 30 to 40 new projects are funded each year.[33]

Several other international arrangements promote biotechnology in Thailand. The Regional Network for Microbiology in Southeast Asia was established in 1975 under UNESCO. It trained 80 Thais in basic and applied microbiology between 1975 and 1984. Member countries of the network are Australia, Hong Kong, Indonesia, Japan, Republic of Korea, Malaysia, New Zealand, the Philippines, Singapore and Thailand. Developed country participation has increased contact between Thai and foreign scientists. There exists a UNEP-UNESCO world network of microbiological resources centres (MIRCENs). The MIRCEN in Bangkok serves Southeast Asia. A co-operative arrangement established in 1978 between the Japanese Society for the Promotion of Sciences and the Thai National Research Council (NCR) has focused on microbial technology and, more recently, on a broader range of biotechnologies. Work is co-ordinated at the International Center of Cooperative Research in Biotechnology at Osaka University. Eight Thai universities, 13 Japanese universities and research institutions and over 150 Thai scientists have participated in study visits, technical seminars and co-operative research projects, 'some of which have served as PhD research for Thai scientists.'[34]

Other sources of funding for biotechnology R&D exist in the public, private, bilateral and multilateral arenas in Thailand. Canada, Australia, Japan, Belgium, Holland and the United Kingdom are known to be partners in science-related projects in Thailand. Japan, for instance, has provided important support for infrastructure in plant biotechnology at Kasetsart University. The above data therefore underrepresent the true volume and distribution of R&D activity in biotechnology, but they do capture the primary resource flows. They indicate that the principal financing system for biotechnology R&D in Thailand has the particular characteristics of being primarily in the public sector and heavily dependent on the policies and programmes of foreign partners, especially the United States.

Table 3 shows the distribution of 227 major projects by field of biotechnology. The 75 projects in plant biology represent a third of the entire set of biotechnology projects. All five sources of funding provided support in this area. Twelve plant biotechnology projects focused on rice, seven on oil palms, four on rubber, three each on rubber and corn, two each on coconut, papaya, halophytes, durian, orchids, tamarind, rattan, cashew nuts, banana and tomato; the following crops had one project: soybean, drybean, eucalyptus, pineapple, herbs and spices, bamboo, weeds, cassava, teak, cowpea, ginger, sesame, peanuts, cut flowers, medicinal plants, plant seeds, mungbean, wheat, coffee, passion-fruit, pepper, cocoa and citrus fruits. The group 'Others' includes research on generic techniques such as tissue culture. This group was primarily funded by NCGEB.

Table 3 Distribution of major R&D projects by biotechnology field

Type	STDB	NCGEB	ATT	UICRD	PSTC	Total	(%)
Plant	15	22	16	4	18	75	(33)
Health	2	9	–	6	20	37	(16)
Industr	5	16	2	3	4	30	(13)
Livestock	3	7	8	1	–	19	(8)
Aquacult	8	–	7	–	2	17	(8)
Environ	3	7	2	4	1	17	(8)
Fertiliz	4	7	–	–	3	14	(6)
Sericul	2	–	1	–	–	3	(1)
Others	–	12	2	1	–	15	(7)
Total	42	80	37	19	48	227	

For meaning of acronyms see Table 2.

Source: Chulawatanathol, 1990.

Table 4 shows the institutional affiliation of principal investigators of 78 plant biotechnology projects. It includes all projects in plant biotechnology *per se* and a small number of others that focus primarily on generic plant biotechnology techniques such as tissue culture. The importance of universities as platforms for the deployment of biotechnology R&D in Thailand is evident. Of 78 projects, 59 (75.5 per cent) were organized in a university setting. Four of the five programmes catered almost exclusively to universities. On the other hand, ATT was directed almost exclusively to government agencies.

Table 4 Institutional affiliation of plant biotechnology research projects

Institution	NCGEB	STDB	PSTC	UICDR	ATT
Kasetsart U	13	10	4	–	–
Mahidol U	4	–	–	–	–
Chulalongkorn U	2	1	1	1	–
Chiang Mai U	–	–	1	–	–
Prince of Songkla	–	1	2	–	–
Khon Kaen U	–	1	3	1	–
King Mongkut's IT	–	–	1	–	–
Srinakarinwirot U	–	1	–	1	–
Asian Inst. Tech	–	–	1	–	–
Dept of Agric	–	–	–	–	17
TISTR*	1	–	–	–	–
Teak Center	–	–	1	–	–
others	7	2	1	–	–
Totals	27	16	15	3	17

For meaning of acronyms see Table 2. Source: compiled from Chulawatanathol, 1990.

* Thailand Institute of Scientific and Technical Research

While government research investments are meant to yield future economic returns, this is not to say that research priorities for biotechnology are rigorously established to respond to industrial requirements for technology. Indeed, there is no mechanism for that to occur. The NCGEB, STDB and other funding agencies active in supporting biotechnology have governing structures which require private sector representation. They identify and select projects based on scientific advice received primarily from scientists working in other public sector scientific institutions, many of whom have been seconded from universities to administer these agencies. Such staff really need help in evaluating projects. Officials do not have the financial and expert resources to identify technology needs of private sector firms in the many industries amenable to biotechnology use or to monitor their technological activities on an ongoing basis. Conversely, few collective industrial mechanisms are available to articulate needs to policy-makers.

4. Universities and technological innovation in Thailand

A recent survey of 36 biotechnology-related firms in Thailand (in the aquaculture, dairy, flower, seed, alcohol, feed, biomedical and organic acid industries) found that firms had moderate ability to acquire, operate and adapt technology but weak innovative capacity. Weakness in acquisitive capability is attributed to 'deficiences in infrastructural agents, to the existence of barriers to technology transfer and to deficiences in technical manpower for industry.'[35] Firms with internal R&D activity not surprisingly had higher technological capacity than the others; however, alcohol and health-related industries had relatively low technological capability. Thai biotechnology-related products have been given high protection, especially in the food, beverages and speciality chemical industries.

Analysis of the source of core technologies in use by Thai biotechnology-related firms showed that about half obtained their technology locally. These were mostly firms using generic process technology in the aquaculture or flower industries. Of four seed and four ornamental plant companies, three of each obtained most of their production technology locally.[36]

In the strategies adopted by Thai biotechnology-related firms, technological advantages are given much less importance than market potential or raw material availability. Small and medium-size firms consider the main purpose of R&D to be adaptation of raw materials. In four seed companies, product market potential and raw material availability was considered to be important in all cases, and technological advantages in only one case. However, in four plant companies, markets, materials and technological advantages were considered to be equally important.

Remedies advocated by science policy analysts for innovation of biotechnology-related firms include import substitution, subcontracting, public procurement, improvement of financial resources in smaller firms, promotion of R&D, strengthening key institutions and targeted biotech manpower training. Establishment of linkages between producers and users of biotechnological innovations is a prime area of concern. As mentioned earlier, Thailand has what are probably the strongest indigenous assets in advanced biotechnology of any Southeast Asian country. That these assets appear weakly integrated into production complexes gives policy-makers and donors alike cause for concern. Because most of Thailand's strength in biotechnology lies in the research and supply side, there still needs to be substantially improved linkage between public institutions and industries.[37]

One might consider that the concentration of advanced research activity in the university sector is a normal step in the development of a modern knowledge-intensive economy in an industrializing country. However, in the case of Thailand, the concentration of biotechnology R&D investments throughout the 1980s in university-based research projects is also a consequence of particular collaborative arrangements established with foreign donors, especially the United States. They may reflect assumptions about how science and technology relate to each other and also about how investment opportunities should be pursued. In the design of co-operative science projects, American policy-makers in USAID and the National Academy of Sciences implicitly favoured a model of technological innovation in which universities drive the innovation process, a model recalling the biotechnology innovation system in the United States in the early 1980s. This model focuses attention on certain key problems, especially transfer or commercialization of university-produced innovation. Other approaches to industrial innovation, such as upgrading the technological capability of firms through the improvement of quality and efficiency and the removal of bottlenecks, are not supported by such funding.

The strategy of selectively funding research conducted by senior university-based researchers in areas of perceived economic importance seems to have resulted in a number of useful outputs, including commercialization of several new plant varieties. However, relatively few cases of North American style technology venturing have occurred. How bountiful should the crop of potential investment opportunities in bio-industries be? Is the bottleneck to economic development a low supply of commercializable university-produced innovations? Are Thai life science researchers as remote from the productive sector as conventional wisdom suggests?

The experience of a foreign technology venturer in Thailand is illustrative of the complexities of life science-based innovation in that country. The Resources Development Foundation (RDF) is a US-based nonprofit foundation dedicated to leveraging private resources to promote the advancement of developing countries through the stimulation of life science-based enterprises. RDF, under the initial co-sponsorship of the Rockefeller Brothers Fund and USAID, began in 1986 to prospect for life science-based business venturing opportunities, primarily in Asia. RDF sought to identify opportunities in which it could take a substantial minority equity position, help the company grow through contribution of capital, technical expertise and management, and then disinvest. The profile of the potential partner sought by RDF was clearly defined: the company should be professionally managed, it should have substantial local operations, it must be experienced in the use of modern agribusiness technology, it should share RDF's interest in certain areas of technology, and it should have a good reputation with financial institutions and the business community.[38]

In 1988 RDF, with partial funding from USAID, screened nearly two hundred biotechnology research projects in five developing countries, including Thailand. Most of the screened projects were USAID-supported. RDF conducted field investigations and identified those projects that offered potential for commercialization. It identified five promising projects in Thailand. Each already enjoyed corporate involvement, and each was felt to require further investments in R&D and management for commercial activities to take place. An analysis of these projects sheds light on some of the characteristics of successful university involvement in innovation.

A project funded under the UICRD programme at King Mongkut Institute of Technology, Thonburi, involved the culture of the algae Spirulina as a source of linolenic acid and other chemicals. The researcher had already established a semi-commercial operation in which cassava processing waste-water was used as a medium to produce Spirulina as a source of xanthophyll for the poultry industry. Plans were underway to scale up the process and produce brine shrimp feed in collaboration with a Thai firm.

A project funded under PSTC at Mahidol University, with additional funding from the World Health Organization and the Rockefeller Foundation, concerned the development of genetically engineered cyanobacteria to express *Bacillus thuringiensis*, a biological toxin to control dipteran insects. This project had linkages with three American universities, the US Department of Agriculture, the University of Ghent and a commerical collaborator (a Belgian biotechnology company) which was developing the clone.

A professor at Chulalongkorn University, recipient of an STDB grant and loan, had developed improved broodstock maturation techniques for pond-raised giant tiger prawns. These techniques involved manipulation of hormones, acclimatization, improvement of artificial insemination techniques and hybridization. The researcher was working in collaboration with colleagues in universities in Hawaii and Texas. No formal relationships existed with commercial interests, but local marine shrimp culture firms were aware of the researcher's work.

Researchers at the Ministry of Agriculture and Cooperatives, working with an ATT programme grant, had transferred to Thailand a Belgian technique for producing brine shrimp cysts in existing salt-producing ponds. Brine shrimp are used as feed in marine shrimp culture. A locally based company had formally indicated interest in forming a venture to go into commercial production. One perceived bottleneck was the lack of technical expertise among salt pond operators; extension services were necessary.

With a grant and loan from the ATT programme, a researcher at Srinakarinwirot University developed technology for extracting agar from local seaweed. Agar has wide commercial uses. The researcher had established pre-pilot scale production and was working with a local company that intended to produce agar on a commercial scale, and foreign companies had also expressed interest.

Two other Thai R&D projects were considered commercially promising but were not pursued by RDF because the researchers had already made commercial commitments. One project involved a technique developed at Kasetsart University to produce virus-free potatoes using tissue culture technology. The other involved a technique, also developed at Kasetsart University, to produce citric acid through high-yielding, hybridized strains of Aspergillus.

The examples cited above illustrate that innovation dynamics are present in Thai university-based biotechnology research. Most Thai bioresearchers are sensitive to the commercial potential of their work; most are in touch with or collaborating with private sector interests. RDF's diagnosis of the gaps in the Thai bioscience innovation system directs attention not to the supply of innovations but rather to the manner in which they are taken to market. Specifically, RDF observes the 'haphazard' attempts by universities to develop commercial opportunities and attributes this to inexperience and the academic outlook of linkage managers. RDF considers that the key missing element is that of 'concept stage' funding for adaptation and optimization of innovations.[39]

This haphazardness of the process of technology venturing from Thai universities may be a temporary phenomenon attributable to the relative novelty in Thailand of technology venturing as a socioeconomic response to technological opportunity. Nevertheless, the pattern of university-industry relations that is developing, while definitely favouring entrepreneurial activity on the part of Thai university scientists, has not resulted in waves of knowledge-intensive firms spinning out of Thai universities. Nor has it led to significant private investments in Thai universities. Thai academic entrepreneurs appear most comfortable in the role of consultants or suppliers of technical assistance to existing Thai or foreign firms. The patterns of entrepreneurship that presently characterize Thai university researchers in the plant biosciences are conditioned by two factors: the supply of research opportunities delivered by the policy system and the demand for services (including information) on the part of diverse user groups. While policy-makers are primarily concerned with stimulating the growth of firms' absorptive capacity, successful Thai scientist-entrepreneurs are concerned with building a network of patrons, peers and users.

5. Biotechnology innovations in the seed and ornamental flower industries

Thailand's aspirations to become a NIC emphasize the classical model of export-led expansion of manufactures. However, unlike Japan and other NICs, Thailand has the option of developing a dynamic science-based agro-food sector, thereby becoming a newly agro-industrializing country (NAIC). The country possesses considerable potential for introducing science-based innovations in agro-industrial production systems. Thailand has a relatively large pool of agricultural scientists: more than two thousand in 1988, as well as a relatively large public and higher education infrastructure for agricultural training and research. Expenditures for agricultural research have grown as a proportion of agriculture's contribution to the Gross Domestic Product from .65 per cent in 1975 to .82 per cent in 1984. Substantial national and foreign support for the development of programmes in agriculture, especially at the postgraduate level, accounts for the fact that while only 2 per cent of university students study agriculture, agricultural scientists comprise about 38 per cent of research scientists. Not surprisingly, a very high proportion (32 per cent) of national research and development expenditures is invested in agricultural research.[40]

Agriculture is a domain in which science policy-makers hope to facilitate technological change through a combination of private sector R&D incentives and efforts to link the public sector research capability, particularly in universities, to user needs. Applications of recent advances in plant genetics and biotechnology are considered to have much potential in strengthening the international competitiveness of existing agricultural production systems.[41]

The seed and ornamental flower industries are among the most important potential users of biotechnology research. These industries illustrate the potential as well as the difficulties of making the transition to science-based production. As noted above, most Thai firms in both industries are capable of operating production technology but have weak capacity for searching, acquiring and adapting technology. Their product and process innovation capacity is correspondingly weak.

In both industries, Thailand has considerable numbers of university research scientists with relevant expertise. Many projects on commercial crops and tissue culture have received funding via the biotechnology research support system. Much of the resulting research on seed production and tissue culture techniques is considered by evaluators of Thai public sector-produced scientific literature to have strong potential for absorption by producers.[42] However, neither the seed nor orchid industry has benefited from significant targeting of university-based biotechnological research or of 'downstream' innovation support services.

The two industries illustrate different patterns of interaction between the public and private sector research systems. The seed industry is one of the country's oldest agricultural industries. It is dominated by Chinese immigrants and their descendants who moved out of vegetable farming into seed trading in the early decades of this century. After the Second World War, expansion of government investments in agricultural training and research (supplemented by Rockefeller Foundation, USAID and other donor investments in both Thai and regional scientific institutions such as the International Institute for Rice Research) led to substantial public sector involvement in the production and distribution of seeds. The Seed Law of 1965 established quality standards for 'controlled seeds' and, indirectly, gave government a pre-eminent role in the distribution of seeds for many field crops, especially rice which for many years was the most important source of foreign exchange. This legislation and the lack of protection for plant variety rights discouraged foreign private investment in the seed industry.

Thai firms moved into markets with low government competition, such as vegetable seeds. Some larger firms expanded into related activities such as the manufacture of fertilizers and agricultural chemicals. Few private firms engaged in any seed research and development until 1978 when the government's investment promotion scheme was extended to the seed industry. This attracted foreign private investment as well as joint ventures and stimulated some R&D activities. One result of the late development of seed improvement programmes is the continued reliance on foreign seed supply. The value of imported seeds greatly exceeds exports.

The seed market is at present limited by a combination of factors: the poverty of the rural population, high input costs relative to rural incomes and poor commodity prices for many staples. Most Thai farmers use open pollinated varieties, retaining seed from the previous crop for future planting. Vegetable producers purchase the highest proportion of seeds (about 50 per cent) followed by corn and sorghum producers (about 30 per cent). Seeds purchased for these crops are often imported, mainly from the United States, Japan and Taiwan. Imports of corn and sorghum seeds also account for a high proportion of privately traded seeds.[43]

Seed improvement is the joint responsibility of the public and private sectors. Public sector research institutes produce new varieties, multiply improved seeds, and process and certify seeds for distribution by the Seed Division of the Ministry of Agriculture and Cooperatives and the government extension system, as well as by private seed companies which are supplied with foundation seeds. Corn, soybean, mungbean, groundnut and some vegetable varieties are disseminated in this way. In the case of the most popular open pollinated variety of corn, Suwan 1, private companies are the principal suppliers to farmers.[44]

Since 1976, varietal improvement, production and distribution in the public sector has been co-ordinated by the National Seed Program whose 20 seed centres and seed processing facilities were developed with financial support from foreign and local sources. Seed production increased by 75 per cent between 1983 and 1987.[45] With significant exceptions, improvement of open pollinated varieties has been emphasized. Corn and sorghum hybrids (e.g. corn hybrids KSX 2301 and 2602 and Sorghum KU 8501) were developed by the National Corn and Sorghum Research Center at Kasetsart University and released commercially. Their development resulted from successful collaboration of the Department of Agriculture and the Rockefeller Foundation. Work on the production of hybrid vegetable varieties in public sector institutions began only in the late 1980s, but none has been commercialized. Recent seed research has been stimulated by the entry of foreign seed companies. Plant breeding programmes require large investments of human and material resources. Much time is needed to recover the costs of these investments. Foreign private investment has provided the capital and expertise needed to produce new hybrid varieties for tropical conditions.

There are some fourteen companies engaged in seed production and 128 firms registered as traders of vegetable, corn and sorghum seeds. Most companies, both traders and producers, collect and import seeds and do not specialize in particular crops. Sale of imported vegetable seeds, the area of least public sector involvement, is the core activity of most of these businesses, especially the smaller Thai trading firms. Typically, a few firms control particular seed markets. For instance, 90 per cent of the vegetable seed market is controlled by six companies.[46]

Foreign firms have acquired a dominant position in the marketing of hybrid seeds, most of which they import. Five of the six firms selling hybrid corn and sorghum seeds in 1988, for instance, were either subsidiaries of foreign seed companies or local companies with joint ventures. Four of the five largest distributors of vegetable hybrids were subsidiaries. The other, Chia Tai, is the largest Thai seed producer with interests in fertilizer and agricultural chemical manufacture, production of crops, livestock and fisheries, and food retailing. It has a joint venture with an American seed company.[47]

The research programmes of some of these firms have developed very rapidly. For instance, the Ciba-Geigy pharmaceutical company, which entered the seed business by purchasing the Funk Seed Company in 1974, acquired a research station in Nakonsawan Province in 1981. A seed production department with a seed development programme for corn and sorghum research was founded a year later. By 1990, the company's research station had a combined staff of about thirty scientists and technical workers. Since 1987, the company has been marketing hybrid corn seeds developed at its experimental station.[48]

Several corn hybrids are presently available to farmers, including the two public sector varieties and at least three developed by private seed companies in Thailand. Nevertheless, the market for imported and locally developed hybrid corn seeds is poor. Only 5 per cent of farmers use hybrid seeds. There are several constraints on increased use of hybrid seed. The first private sector hybrids were less uniform than open pollinated varieties, they cost more to purchase, and although the yield was greater, they required more costly inputs at a time of declining corn prices. The low skill level of the farming population is another constraint on the production and use of hybrid seeds. This is a recurrent complaint of plant breeders in the public and private sectors. Seed production requires much technical support. Contract farmers must be closely supervised to ensure proper use of inputs, quality control and reduction of post-harvest damage to the seeds they produce.[49]

Seed companies place great importance on farm demonstrations in marketing hybrid seeds.[50] To obtain the higher yields promised by promoters of hybrid varieties, farmers who use such varieties must understand the different requirements of open pollinated and hybrid varieties. They must be particularly sophisticated in their use of agricultural chemicals and inorganic fertilizers. Unfortunately for private sector seed companies, vegetable, corn and sorghum producers are among the most poorly educated farmers.

Three facts stand out from this analysis. First, although public and private sector seed improvement activities overlap in the case of some vegetables and field crops, their research programmes have different foci. Second, the impetus for innovation in open pollinated and hybrid varieties was provided by the participation of foreign donors in seed research or by foreign private investment. Third, the most important user of university seed research is the public sector seed production and distribution system.

In contrast, firms in the ornamental flower industry use locally developed technologies and have close relationships with public sector scientific institutions. Production has always been controlled by indigenous firms which use generic techniques developed locally and market most cut-flowers and plants overseas.

In the mid-1960s, large scale nursery production of Dendrobium Pompadour orchids and other ornamental flowers began around Bangkok for export to Europe. Prior to that, ornamental flowers were grown on a small scale mainly for the local market or, in the case of many exotic species of orchid, harvested in the wild for sale locally or for export, resulting in depletion of many indigenous varieties. Commercial harvesting of wild orchids was reduced by Thai legislation in 1962 which restricted collection of indigenous plants and, later, adherence to the 1973 international convention on endangered species. At first the new industry earned an extremely good income for orchid growers because there was little competition and the supply was limited. As lucrative export markets developed, the number of producers and the land under cultivation increased. By the early 1980s, more than three thousand farmers were growing orchids and other cut-flowers, most in metropolitan Bangkok and Nakorn Pathom Province. About half the production was exported. In 1978, export demand weakened. By 1980, prices fell by 50 per cent and exports declined by 25 per cent, prompting the government to request the Food and Agriculture Organization and experts at Kasetsart University to prepare an action plan to save the cut-flower industry. The industry was revived by two measures which were not foreseen in the action plan: application of tissue culture propagation techniques and expanding export markets in the Far East.[51]

At least nine hundred varieties of orchids have been identified in Thailand.[52] Several varieties of orchid are propagated by tissue culture, principally Dendrobium Pompadour, White, Fancy, Pink and Dendrobium Caesar. Of these, production of Dendrobium Pompadour accounts for almost half of all plantlets.

Propagation of orchids and sale of orchid plants and flowers is the most important activity of most firms in the industry and the basis of its prosperity. Clonal propagation of orchids began in the United States and Japan in the mid-1960s.[53] The technique was disseminated to Thailand by Thai students who had undertaken postgraduate training in horticulture in these countries. Most returned to take up positions in horticulture at Kasetsart University. Tissue culture techniques were transferred to the private sector initially by staff who either established tissue culture laboratories of their own or joined larger cut-flower companies to establish R&D programmes. In recent years, university graduates have established quite a few tissue culture labs, as the entry costs are low and the demand for orchid plantlets was until recently very high.

Fifteen companies are presently involved in the clonal propagation of orchids and other ornamental flowers from tissue or meristematic culture. Propagation is labour intensive, using inexpensive locally fabricated laboratory equipment, and is adaptable to small and medium-sized firms which sell plantlets to farmers for production of flowers. The largest firms are involved in the sale of seedlings, plants and flowers locally and in overseas markets. About four such firms were conducting in-house tissue culture research in 1990.

Exports of ornamental flowers increased to more than 554 million Baht in 1988. But in 1990, the industry was again in crisis as expanding tissue culture production of orchids drastically reduced prices. For example, the sale price of tissue culture seedlings declined from as much as eight Baht in 1989 to about two Baht a year later.

Many ornamental flowers can be produced by tissue culture propagation, including marigolds, roses, chrysanthemums, carnations, gladiolas and lilies. The techniques for production of adapted varieties have been developed by researchers at the Department of Horticulture and Institute for Horticultural Research at Kasetsart University. Although chrysanthenums and carnations can be produced commercially for local and overseas markets, private sector tissue culture research has tended to focus on other commodities such as coconuts and durian. Larger companies also do some plant breeding, chiefly crossing foreign ornamental plants with local varieties using simple cross-pollination techniques.[54]

6. Information networks and university-industry interaction

Several observers point to deficiencies in the manner in which scientific and technical information circulates in Thailand. Firms believe that university research is not addressing industry needs, but they are uninformed about what is actually occurring in universities. Comparatively few consulting firms or technology brokers are building information linkages in the Thai innovation system. There is deterioration in existing information services. No central formal arrangement exists for archiving and retrieving scientific, technical and research information. Suggestions have been made for a directory or database of current research, achievements or output of research centres. This would assist companies seeking to collaborate with universities or identify local academic consultants.[55]

Tissue culture and seed technology researchers in Thailand do not put emphasis on publication as a means of communicating with the potential users of their work. Personal contacts are the predominant means for communication. Nevertheless, the Thai formal system of scientific and technical communication is relatively well developed. A large amount of literature exists in the vernacular, and indigenous scientific journals and organs of publication ensure that printed media are available. Table 5 shows that scientists in Thailand published 537 papers in 'mainstream' scientific journals in 1989. The overall level of mainstream scientific activity is low in comparison to NICs such as Taiwan which, for example, produced 2,330 in 1988. About 70 per cent of such articles were produced by university-based researchers.[56]

Table 5 International and local scientific publications in Thailand, 1985–89

Year of publication	1985	1986	1987	1988	1989
Type/Subject					
1. Int'l (total)*	420	436	470	611	537
2. Int'l (seed & tissue culture)	3	6	11	16	4
3. Local (total)**	849	881	349***	292***	340***
4. Local (seed tissue culture)	32	42	19***	10***	25***

* papers in journals surveyed by the Science Citation Index

**papers in local journals, conference proceedings, newsletters and project reports

***incomplete survey of local papers

Research on seed and tissue culture technology accounts for a very small proportion of Thai scientific papers published in international scientific journals surveyed by the Science Citation Index, an important indicator of national scientific output of mainstream research. Less than one per cent of Thai papers published in international journals by Thai scientists in 1989 dealt with these topics (see Table 5). However, given the volume of externally-funded research in Thailand, it is likely that not all research of relevance to Thai economic producers is published in Thailand. Furthermore, much research carried out in Thailand is not published in mainstream journals. Many more scientific papers are disseminated in local journals, newsletters, conference proceeding papers, technical bulletins and project reports to funding agencies. Much of this tertiary literature is published in the Thai language.[57]

In a study of the volume, types and languages of scientific literature dealing with plant biotechnology, tissue culture, flowers, vegetables, seeds or horticulture in Thailand between 1984 and 1990, 401 documents were identified. International scientific journals are not the primary vehicle of scientific and technical communication in the above fields in Thailand. The single most important kind of scientific document is an article in a Thai scientific journal, which accounts for about a third of all of the literature identified. Books seem not to be important means of communication.

Only two languages are important in scientific and technical communication in Thailand: English and Thai. About one-third of all documents are in English, and about two-thirds are in Thai. Other languages are negligible. The scientific and technical communication systems centred on Thailand have overlapping and complementary functions that are similar to those in other bilingual Asian scientific communities.[58] Virtually all publications in international scientific journals are in English. Most nonconventional monographs, articles in Thai scientific journals and theses or dissertations are in Thai. About three-quarters of conference proceedings are in English and one-quarter in Thai. This reflects Thailand's role as a regional centre of scientific conferences, virtually all of which take place in English.

Not all scientific and technical communications about Thailand originate in Thailand. Concerning the geographical origins of first authors of scientific and technical documents in the fields described above, over four-fifths (84.5 per cent) of authors have addresses in Thailand. About one-tenth (9.5 per cent) have addresses elsewhere in Asia. Authors in Europe and North America contribute 4.5 per cent and 1.2 per cent of the documents, respectively. Given the elaborate R&D support system in which the United States participates in Thailand, the low level of American scientific production of relevance to Thailand is surprising. It shows that the R&D support system does not nurture collaborative research endeavours between Thai and foreign scientists.

Concerning published research in plant biotechnology, tissue culture, flowers, vegetables, seeds or horticulture in Thailand between 1984 and 1990, university-based authors produced nearly two-thirds (63.4 per cent) of the literature in these fields, and authors in government agencies or labs, 32.7 per cent. Authors in Thai-based international agencies produce only a small percentage of scientific literature: 2.7 per cent. Although a significant amount of advanced bioscientific research in Thailand is funded through international co-operation, this has not led foreign or international agencies to establish an institutional presence in the country. Thai private firms together only produced about one per cent of all literature. About one-fifth of the literature was in English, and the rest was in Thai.

International publications are a relatively minor medium of communication for Thai scientists. Only 11.8 per cent of all publications were in international scientific journals and publication in these journals is shared between university-based authors and those in government agencies and labs. Both groups publish heavily in nonconventional monographs, conference proceedings and Thai scientific journals. In addition, universities are the source of another significant kind of scientific publication: theses and dissertations.

Several factors shape Thai scientific careers in ways that make them more diversified and more eclectic than those of comparable researchers in Europe or North America. An important factor is that career prospects for professors and teachers in the Thai public sector are not presently attractive. Pressures on careers arise from relatively low university salaries, low levels of public investment in university research, and irregular demand from the private sector for productive scientists. Researchers have no special administrative status and are classified and evaluated according to civil service practices.[59] Although the situation is changing through new university rules, seniority rather than performance is still the key to promotion. Salaries are not competitive with those that are offered by the private sector which, as noted earlier, is not an important performer of research and therefore tends to hire at the bachelor's level. Thai scientists develop affiliations with more than one university (the new private universities usually offer better salaries than the public universities) and may have affiliations with government organizations, international organizations and private sector firms as well. In other words, successful university scientists are rarely socially isolated. Highly qualified and highly motivated researchers in the sciences in Thailand must be entrepreneurs who use their university positions and affiliation with policy processes to capture research resources from national, international or private sources, although some university researchers have left the university altogether to establish themselves in industry.

Only firms with the capacity to monitor, retrieve and assimilate tertiary literature can profit from it. Extensive collections of local literature are contained in some of the larger seed and flower firms in Thailand.

However, few firms display information-seeking behaviour which relies primarily on the acquisition of printed information. Typically, firms acquire knowledge of scientific or technical information from intermediaries such as vendors, brokers, extension agents, exhibitors, colleagues, clubs or contacts with scientific or technical personnel in other organizations.

Aside from communication via the formal literature, there are two principal means of communication. One is through informal encounters in meetings, seminars, exhibitions or conferences. A second communication channel is through networks of the former students of an established university researcher. Typically, a foreign-educated Thai scientist with a PhD forms the centre of a social network comprised mainly of younger scientists with master's degrees, many of whom were trained by the senior scientist and who are active in a variety of educational, private or public organizations. According to a recent study of university industrial extension models in South and Southeast Asian countries, UNISEARCH works because of the network of interpersonal relationships between faculty and former graduates, many of whom are in the private sector.[60] A mentor may have ceased active research and moved into a high level administrative position; however, the scientist's advice and assistance remain important in making contacts and in obtaining research support.

The importance of such networks is reinforced by prevailing Thai cultural values that foster deference to seniority and respect and gratitude toward one's teacher. Few senior Thai scientists have national peers in their area of expertise. The scientific community is too small. Because most researchers working in similar research areas know each other and quite possibly have had formal professor-student relationships with each other, information transfer is effective within networks. One has only to ask. Format or place of publication of research results is relatively unimportant because information is retrieved by personal enquiry and by physical transfer of documents. This means that Thai scientists can be fairly nonchalant about publishing as a means of archiving information in libraries. Thai scientists can even be nonchalant about publishing at all. Many senior Thai researchers feel that their time is better spent communicating via newspapers, television programmes, videotaped courses produced for local universities and workshops.

The fact that most available research funds are controlled by national and international public agencies and that most research projects in Thailand are funded by sponsors in the public sector obliges Thai researchers to present research findings in a form that sponsors find significant: the project report. In spite of professed concern among public sector purchasers of research in Thailand to increase the economic and social impacts of science, public sponsors of research do not always actively communicate the R&D results in their possession.

Thai researchers often need to communicate research locally to researchers who might not be in the same network. This is often done through presentation of short papers in Thai at national conferences. Research presented in this form signals activity to others and serves as a territorial marker. Information communicated in national conferences diffuses quickly into the educational system. However, it is virtually invisible outside the Thai scientific community.

Thai researchers sometimes become directly involved with end-users of research. In such cases a researcher may provide training or demonstration services, prepare information brochures or 'how-to' manuals, or develop a programme of site visits. One senior Thai researcher in tissue culture is regularly involved with extension courses, development projects and growers' associations. Another, a well-known corn breeder, participates in annual meetings organized by public extension departments and in on-site seed tests. Some university agricultural researchers mail documents to reading shelters in villages and participate in demonstration plots.

Conclusions

A variety of Thai-language publishing outlets exist which communicate scientific research to specialized audiences. Trade journals, journals of amateur scientists (which may be very serious and highly technical: for example, the bulletins produced by Thai orchid breeders' societies) and regular or occasional publications of government laboratories or universities all provide a rather rich informational universe to Thai scientific writers.

However, Thai researchers do not live in a simple publish-or-perish world. Career trajectories are not so strongly determined by publication records. Many choices of target audiences and formats exist. On the other hand, the retrieval of information is subject to important constraints. Communication strategies reflect these conditions. Present circumstances in Thai universities favour entrepreneurial behaviour on the part of senior Thai university scientists, and entrepreneurial behaviour requires that those scientists who are so inclined cultivate relations with industrial users of technical knowledge and expertise.

Thai university researchers enjoy high social status. However, a general perception of universities has developed which if not corrected will hasten the erosion of Thai scientific potential. Universities are viewed as sources of knowledge, information and innovations which are freely available to the public and to industry. Communication infrequently flows in the other direction because of industrial secrecy. Worse, industry is not putting wealth back into the university system. Few significant cases of private contributions to biotechnological research in a Thai university have been identified. As a consequence, university research lags behind industry because of inadequate supporting infrastructure. University researchers turn to government and, to a much greater extent, to external donors for their research and infrastructure needs.

The effects of the extraverted funding system on the development of Thai scientific and technological capacity need to be better understood. Fluctuation in priorities, delivery schedules and administrative procedures make this system a constantly moving target. Most Thai biotechnology policy efforts have focused on increasing the supply of university-based research. This form of strategic funding naturally raises questions of how targeting is to be organized and evaluated. It has resulted in a multitude of projects rather than programmes. It is not a substitute for a comprehensive biotechnology innovation strategy that mobilizes policy instruments to stimulate technologically dynamic firms.

In addition to the need to create a public R&D support system that links higher educational institutions with industrial needs, there is need to focus support to improve the S&T infrastructure in the public and private sectors. This is especially true with respect to molecular and advanced bioprocessing technologies. One of the goals of Thai S&T policy should be to increase indigenous capacity to produce and assimilate research in areas of technological interest. Objectives in support of this goal would be to increase the supply and quality of research producers in basic and applied scientific institutions in the public and private sector, to increase the private sector's capacity to assimilate basic and applied scientific research and to generate science-based innovations, and to increase the skill level of the labour force to enhance capacity to adopt and utilize new production technologies.

Biotechnology policy for the higher education sector should seek to retain research scientists in the university system through higher salaries, better working conditions and increased support for postgraduate scientific training in Thai universities. Attrition to private industrial and educational sectors and extensive involvement in consulting weaken the research and training capacities of Thai universities. It may be necessary to encourage insitutional stratification within the higher education system through institutional centres of excellence (rather than support for individual projects) as well as through expansion of private higher education as the primary source of undergraduate training in applied scientific fields. A system of evaluation is needed, however, to ensure quality of performance. It is also desirable to develop incentives for industry to invest in universities.

Policy should also encourage foreign research collaboration, increased advanced scientific training overseas and a greater degree of technology-related commercial linkages between Thai and foreign firms. Funds should be found for Thai participation in international research projects, post-doctoral fellowships and sabbatical leaves spent in laboratories in scientifically developed countries and more attractive opportunities for visiting foreign scientists in Thai universities.

Donors wishing to be involved in Thai technological development should review their expectations regarding the outcomes of university-based, project-specific funding. If development of R&D capacity is the objective, then very selective institutional and infrastructural support is likely to be more effective than project-specific funding. If industrial development is the objective, then donors will have to pay much more attention to events 'downstream' from university research. Comprehensive innovation support arrangements and effective policy instruments will have to be developed and mobilized to increase the productivity and technological capability of firms. Most such bottlenecks are not research related. For example, expansion and diversification of the Thai cut-flower industry may better marketing strategies, imaginative product innovation strategies and smart investments instead of university-generated technical inputs. If donors are truly serious about buying into Thai industrial expansion, they should find ways to involve their own firms in Thai firms' technological development through technology venturing, cross-investment, subcontracting, joint production, collaborative marketing and strategic R&D partnering when possible.

Biotechnology policy for industry should also create opportunities for upgrading the skills of technical and R&D personnel in the private sector through part-time training, short courses and workshops organized by private firms or trade associations involving university scientists. Means should be found to improve the flow of scientific and technical information between public and private sectors through better monitoring of research activities by potential users and by establishing better arrangements to identify research with promise for commercialization. Trade associations should be encouraged to develop scientific, technical and co-operative activities and to play the role of intermediaries between government and the private sector in formulating policies for scientific research and delivery of services in support of innovation. Finally, the institutional, economic and S&T policy dimensions of the NAIC model should be much more thoroughly explored.

For farmers and small growers, biotechnology policy should aim to increase support for innovation, especially within the public sector extension system, by adopting some of the practices of the private sector extension model. Farmers should be viewed as potential participants in innovation, not as mere recipients of innovation. Farmers, small growers or hobby producers (as occurs in the case of orchids) are capable of participating in plant selection experiments using tissue culture or open pollination techniques. Ways should be sought to raise farmers' levels of educational attainment and improve scientific and technical education in domains important to agricultural innovation, such as biology and genetics. This entails not only transfer of appropriate technical skills, but also development of requisite business skills and attitudes such as self-reliance, reliability and entrepreneurial outlook.

Notes

1. Atthasampunna *et al.*, 1989, p. 41.
2. The research reported in this paper was supported by a grant to study communication strategies in applied scientific research in Thailand from the Communications Division of the International Development Research Centre (Canada). Fieldwork was carried out under the auspices of a collaboration between McGill University and Mahidol University. The assistance of Susan Hodges of the IDRC library in obtaining some of the data used in the study, and the assistance of Rebecca Lam and Pornpimol Kongtip in organizing some of this data, is gratefully acknowledged.
3. Lall, 1990, pp. 25, 30.
4. Chesnais, 1987.
5. See Radesovic, 1990; Lundvall, 1988; Tassey, 1992.
6. *Bangkok Post*, 1990, p. 13.
7. Dahlman *et al.*, 1990, Appendix Table 2.1.
8. TDRI, 1990b, Tables 3 and 11.
9. TDRI, 1990b, Table 6.
10. *Bangkok Post*, 1990, pp. 16–17.
11. NESDB, 1986, p. 150.
12. TDRI, 1989c.
13. TDRI, 1989c, p. 2.
14. TDRI, 1990a, p. 50.
15. Dahlman *et al.*, 1990, p. 53.
16. NESDB, 1986, pp. 152–155; Kritayakirana and Srichandr, 1990; TDRI, 1990a.
17. Lall, 1990, p. 52.

18. Yuthavong and Sutabutr, 1983.
19. TDRI, 1990a, p. 50; see also, TDRI, 1989b.
20. NESDB, 1986, pp. 155–156.
21. Sripaipan *et al.*, 1990, p. 39; TDRI, 1989b, pp. 165–167.
22. NESDB, 1986, p. 163; Dahlman *et al.*, 1990, p. viii.
23. TDRI, 1989a, p. 12; Gaillard, 1990, p. 50; Eisemon and Davis, 1992.
24. Watson, 1989, pp. 81–82; Watson, 1991, pp. 567, 570; Tuchrello, 1989, p. 113.
25. White, 1990.
26. MUA, 1988, p. 136 and Table 11. Scientific and technical subjects include mathematics, computer science, medical and health sciences, engineering, agriculture, forestry, fisheries or basic science.
27. Yuthavong, 1986, p. 142.
28. MOSTE, 1987, p. 37.
29. See Chulawatanathol, 1990, p. 1.
30. Atthasampunna *et al.*, 1989, pp. 46–47.
31. TDRI, 1989b, p. 180.
32. Bangkok Bank, 1991, p. 18. Until 1992, responsibility for funding research in biotechnology, materials science and electronics and computer technology was mostly under the NCGEB and two analogous centres. The STDB has merged with the national centres.
33. Chulawatanathol, 1990, p. 2.
34. Atthasampunna *et al.*, 1989, p. 43.
35. TDRI, 1989a, p. viii.
36. TDRI, 1989a, p. 183.
37. TDRI, 1989a; Attahasampunna *et al.*, 1989, p. 56.
38. Klausmeier *et al.*, 1988, pp. 179, 183. Current research is investigating the range of outputs of the first generation of university-based plant biotechnological research in Thailand. This account of RDF's assessment of the potential for commercializing results from Thai biotechnology projects relies on Hall and Klausmeier, 1988.
39. Hall and Klausmeier, 1988, pp. 77, 184.
40. Ichikawa *et al.*, 1991; Setboonsarng *et al.*, 1988, p. 13; NESDB, 1986, pp. 151, 156; Gaillard, 1990, p. 51.
41. TDRI, 1989b, pp. vi–x.
42. Yuthavong *et al.*, 1991, p. 6.
43. See Komin, 1989, pp. 21–25; Setboonsarng *et al.*, 1988, pp. 10–12.
44. Setboonsarng *et al.*, 1988, p. 66.
45. Setboonsarng *et al.*, 1988, p. 19.
46. Setboonsarng *et al.*, 1988, pp. 29–30.
47. Setboonsarng *et al.*, 1988, pp. 28–29.
48. Ciba-Geigy, 1990, p. 11.
49. Suwuntharadol, 1989, p. 13; Silapapun, 1990.
50. Setboonsarng *et al.*, 1988, p. 42.
51. See Chauntanaparg *et al.*, 1985, p. 56; Sagarik, 1980, pp. 21–24; Konjing *et al.*, 1981, pp. ii, 1, 3.
52. Chautanaparg *et al.*, 1985, p. 55.
53. Morel, 1964.
54. Chamchong and Thammich, 1988, pp. 28–29; TDRI, 1989b, p. 221.
55. TDRI, 1990a, p. 27–28; TDRI, 1989a, p. 140.

56. Yuhavong *et al.*, 1991a, p. 12; Davis and Eisemon, 1989.
57. Yuthavong, 1986.
58. Davis and Eisemon, 1989.
59. Gaillard, 1990, p. 53.
60. Abraham, 1990, p. 3. Many studies have shown that technology flows primarily through personal contacts and informal channels rather than through dedicated technology transfer institutions. *Cf.* Allen (1977) and Sweeney (1987).

References

Abraham, A. 1990. Perspectives on institutional models for the application of university-based research: The Asian experience. Unpublished report to the International Development Research Centre, Ottawa, Canada.

Allen, T.J. 1977. *Managing the Flow of Technology*. Cambridge, Mass.: MIT Press.

Atthasampunna, P., M. Suwana-adth, and A. Bhuiratana. 1989. Current biotechnological developments in Thailand. *Critical Reviews in Biotechnology*, vol. 9, no. 1, pp. 41–59.

Bangkok Bank. 1991. Thailand steps up biotechnology push. *Bangkok Post*, Jan. 11, p. 18.

Bangkok Post. 1990. *Bangkok Post Economic Review: Year-End 1990*. Bangkok: Bangkok Post.

Chauntanaparg, L., P. Aran and W. Huamuangkaew. 1985. Non-wood forest products in Thailand. Field Document No. 5. Bankgok: FAO.

Ciba-Geigy. 1990. History of Ciba-Geigy. Bangkok: Ciba-Geigy.

Chamchong, C. and S. Thammich. 1988. Agricultural biotechnology for commerce. Report to the National Center for Genetic Engineering and Biotechnology, Bangkok.

Chenais, F. 1987. Science, technology and competitiveness. *STI Review*, No. 2, pp. 85–129.

Chulawatanathol, M. 1990. Major research and development programs in biotechnology in Thailand. Paper presented at the US-Asian Pacific Biotech Conference, 21–23 Oct., The Woodlands, Texas.

Dahlman, C., P. Brimble, R. Herz and A. Sibrunruang. 1990. Thailand: Technology strategy and policy for sustained industrialization. Washington, DC: World Bank, Industry Development Division.

Davis, C.H. and T. Eisemon. 1989. Mainstream and non-mainstream scientific literature in four peripheral Asian scientific communities. *Scientometrics*, vol. 15, nos. 3–4, pp. 217–241.

Eisemon, T. and C.H. Davis. 1992. Universities and scientific research capacity in Africa and Asia. *Journal of African and Asian Studies*, forthcoming.

Gaillard, J. 1990. La communaut scientifique Thalandaise: un developpement rapide mais une reproduction difficile. *Inter-Mondes*, vol. l, pp. 43–57.

Hall, P.C. and W.H. Klausmeier. 1988. Opportunities to commercialize life science applications in less developed countries: A strategic plan. Arlington: Resources Development Foundation.

Ichikawa, Nobuko, Michael A. Cusumano and Karen R. Polenske. 1991. Japanese investment and influence in Thai development. *Technology in Society*, vol.13, no.4, pp. 447–469.

Klausmeier, W.H., P.C. Hall, C. Chase-Lansdale and R.J. Parra. 1988. 'Emerging Biotechnology Enterprises in Southeast Asia: Prospects and Challenges.' In

International Symposium on Application of Biotechnology for Small Industries Development in Developing Countries, pp. 179–184. Bangkok.

Komin, S. 1989. Social dimensions of industrialization in Thailand. Bangkok: National Institute of Development Administration.

Konjing, C., P. Gavinlertvatana, P. Paireeparit, S. Vacharotaya, T. Sutabutra, Y. Chiemchairsi, N. Sinchaisri, A. Issariyanukula and C. Pilekuk. 1981. Action plan to save the cut-flower industry, Vol. II. Bangkok: United Nations Food and Agriculture Organization and Kasetsart University.

Kritayakirana, K. and P. Srichandr. 1990. Technological capability of the Thai industry: Status, key issues and recommendations. *ASEAN Journal of Science and Technology*, vol. 7, pp. 15–41.

Lall, Sanjaya. 1990. *Building Industrial Competitiveness in Developing Countries*. Paris: OECD.

Lundvall, B.A. 1988. 'Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation.' In *Technical Change and Economic Theory*, edited by G. Dosi *et al.*, pp. 349–369. London: Pinter.

Ministry of University Affairs. 1988. *General Information*. Bangkok: MUA.

Ministry of Science, Technology and Energy. 1987. *Thailand: Science and Technology Indicators*. Bangkok: MSTE.

Morel, G. 1964. Tissue culture: A new means of clonal propagation of orchids. *American Orchid Society Bulletin*, no. 33, pp. 473–478.

National Economic and Social Development Board, Government of Thailand. 1986. *Program 4: Development of Science and Technology*. Bangkok: NESDB.

Radesovic, S., 1990. The role of small firms in technological development: An interpretive survey. *International Journal of Technology Management*, vol. 5, no. 1, pp. 89–99.

Sagarik, R. 1980. 'Native Orchids of Thailand.' In *Proceedings of the Ninth World Orchid Conference*, edited by M.R. Sukshom Kashemsanta, pp. 21–24. Bangkok: Amarin Press.

Setboonsarng, S., S. Wattanutchariya and B. Phutigorn. 1988. The structure, conduct and performance of the seed industry in Thailand. Paper prepared for the Seminar on Technology Development and Changing Seed Supply Systems, 22 June, Tilburgl, Netherlands.

Silapapun, A. 1990. The farm seed industry of the private sector. Paper presented at the 4th National Seed Conference, 2–5 May, Khon Kaen.

Sripaipan, C., J. Anderson, M. Koasa-ard, P. Siowatana, V. Aphimeteetamrong, P. Brimble, A. Apinunmahakul, J. Rirkniyom and P. Promsavat. 1990. *Enhancing Thai Private Sector Capacity for Research, Development and Engineering*. Bangkok: Thailand Development Research Institute.

Suwantharadol, K. 1989. Corn and sorghum seed business. Paper presented at the 20th National Corn and Sorghum Seed Conference, 23–25 August, Bangkok.

Sweeney, G.P. 1987. *Entrepreneurs and Regional Development*. London: Frances Pinter.

Tassey, Gregory, 1992. *Technology Infrastructure and Competitive Position.* Dordrecht: Kluwer Academic Publishers.

Thailand Development Research Institute. 1990a. *Enhancing Thai Private Sector Capacity for Research, Development and Engineering. Final Report.* Bangkok: TDRI.

Thailand Development Research Institute. 1990b. *Thailand Economic Information Kit.* Bangkok: TDRI.

Thailand Development Research Institute. 1989a. *The Development of Thailand's Technological Capability in Industry: Capability Development for Biotechnology-Based Industries.* Bangkok: TDRI.

Thailand Development Research Institute. 1989b. *Final Report: The Development of Thailand's Technological Capability in Industry, Overview and Recommendations.* Bangkok: TDRI.

Thailand Development Research Institute. 1989c. *The Baseline Data Project: S&T Infrastructure and Development in Thailand.* Bangkok: TDRI.

Tuchrello, W. 1989. 'The Society and Its Environment.' In *Thailand: A Country Study*, edited by B. LePoer, pp. 60–120. Washington, DC: Federal Research Division, Library of Congress.

Watson, K. 1989. 'Looking West and East: Thailand's Academic Development.' In *From Dependence to Autonomy*, edited by P. Altbach and V. Selvaratnam, pp. 63–95. Dordrecht, Netherlands: Kluwer.

Watson, K. 1991. 'Thailand.' In *International Encyclopedia of Higher Education*, Vol. 2, pp. 559–578. New York: Garland.

White, L. 1990. Increasing the relevance of agricultural research: Institution building in Third World universities. *Journal of Developing Areas,* vol. 24, pp. 451–456.

Yuthavong, Y., K. Phornsadja, A. Chungcharoen, H. Chancharoen, W. Lelatanavit, T. Eisemon and C. Davis. 1991a. *Communication Strategies in Applied Scientific and Technical Research in Thailand. Preliminary Report of Research Findings.* Bangkok: National Center for Genetic Engineering and Biotechnology, Ministry of Science, Technology and Energy.

Yuthavong, Y., K. Phornsadja, A. Chungcharoen, T. Eisemon and C. Davis. 1991b. *Diffusion of Biotechnology Innovations in Thailand: Tissue Culture and Seed Technologies.* Bangkok: National Center for Genetic Engineering and Biotechnology, Ministry of Science, Technology and Energy.

Yuthavong, Y. 1986. Bibliometric indicators of scientific activity in Thailand. *Scientometrics*, vol. 9, pp. 139–143.

Yuthavong, Y. and H. Sutabutr. 1983. Scientific and technical manpower and research and development in the private sector in Thailand. *Journal of the Science Society of Thailand,* vol. 9.

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