Postharvest Technology in Asia: ACIAR's Framework for Collaborative Research and Development

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Abstract

As we enter the 21st century, the need to become more effective in bringing home the harvest of the Green Revolution has become increasingly apparent. The Strategic Plan of the Australian Centre for International Agricultural Research (ACIAR) for 1997-2001 contains the following statement:

"Recognising the urgent need to reduce losses and maintain acceptable quality of harvested agricultural products, ACIAR will increase its investment in research on postharvest technology relevant to crops, livestock, aquatic resources and forest products. Resources will be diverted from research on production aspects of these commodities if necessary." (ACIAR, 1997a)

In seeking to implement this part of the Strategic Plan, ACIAR has devoted considerable effort to defining the rationale for this investment and developing a framework for collaborative research and development in postharvest technology with partner countries. This paper outlines the rationale and framework for the plan, and indicates the opportunities for interface between our developing country partners and other agencies involved in international agricultural research for development. Collaboration and cooperation can maximize effective use of those agri-research resources that postharvest scientists and marketing specialists glean from the production specialists!

The need for postharvest research and development

As postharvest scientists and engineers, we are well aware of the value and importance of postharvest research and development. But in comparison to production research, international investment in postharvest research has been very low, a reflection of post-war priorities for achieving World Food Security by producing more grain.

Over the last 40 years, remarkable increases in agricultural production have occurred worldwide. During the same period, socio-economic changes driven by population growth, land shortages, urbanization and community standards have increased product handling and storage standards, and the requirements for product quality and safety. The changes in standards and expectations have occurred across the spectrum of products harvested for use as food, fiber or shelter. As well, food security policies, and the drive for disposable income from the export of commodities, have also increased the demand for storage and transportation of both perishable and durable products.

So: there has been a dramatic change in the rationale and requirements for progress-much more research in the postharvest sector is needed to address the real changes in community/

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world priorities. Among the critical issues that urgently require attention by researchers are the following:

- **Loss management**. Postharvest losses remain unacceptably high, particularly in developing countries. More than 20% of agricultural produce worldwide does not reach consumers or is of unsatisfactory quality, resulting in increased costs.
- **Chemical replacement**. Changing regulatory standards have seriously reduced the availability of highly effective agents for control of pests and spoilage.
- **Production surpluses and trade**. In many countries in the Asia-Pacific region, the Green Revolution has led to the production of grain surpluses which can be stored, or exported. However both require additional technological inputs. Trade is the means by which farm surpluses are converted into income. Food reserves and savings from income provide security against crop failure, natural disasters and health emergencies. And it is postharvest technology which enables both storage of produce and trade.
- **Market access**. Export markets have become more competitive and discriminating, leading to increased emphasis on Quality Assurance, and food hygiene.
- **Nutritional security**. Achievement of "rice security" coupled with urbanization and moves away from the land has led to the need for "nutritional security" the transport and consumption of fruit and vegetables, dairy products, seafood and meat as sources of vitamins, minerals and protein. These more perishable commodities need effective postharvest technologies.
- **Food hygiene / environmental impact**. Aquaculture and livestock feed-lotting have increased the potential for production of fish and meat, but intensive production and processing create new challenges in managing food hygiene, transport and storage, as well as waste disposal.
- **Salvaging damaged timber stocks**. When fires damage forests, timber salvaged from the trees needs to be stockpiled to maintain supply continuity. Successful long-term storage requires attention to log drying rates and pest and pathogen control.
- **Quality maintenance and contaminant reduction**. Poor product quality impairs human health and nutrition, and reduces the durability of clothing and shelter. Contamination by mycotoxins, excessive levels of agricultural chemicals and microbes is particularly undesirable. Microorganisms can cause serious and acute health problems. Mycotoxins accumulate in body organs over a number of years, weakening the immune system and predisposing consumers to carcinomas. The annual social cost of mycotoxins in maize and peanuts in Southeast Asia alone exceeds $500 million (Lubulwa and Davis, 1996). Pesticides and other undesirable chemicals in produce can arise from both direct application to the agricultural system or from non-target accumulation in agricultural soil or water followed by uptake by crops or livestock.
- **Cost efficiencies**. A major portion of producer and community costs occurs in the post-production sector. These include the impact of postharvest handling and processing on the environment. For example, postharvest processing facilities can produce waste products which pollute agricultural land and water systems. As well, aging populations and labor shortages in rural areas have increased the need for cost-effective and labor-saving postharvest technologies.

The role for the Australian Centre for International Agricultural Research (ACIAR)[1]

The Australian Centre for International Agricultural Research (ACIAR) is an Australian Government Statutory Authority that operates within the portfolio of Foreign Affairs and Trade. It was established in June 1982 to assist and encourage Australia's agricultural scientists to use their skills for the benefit of developing countries, and at the same time, work to resolve Australia's own agricultural problems. ACIAR also has responsibility for Australia's contribution to the International Agricultural Research Centres (IARCs).

ACIAR-funded research aims at helping developing countries to help themselves, thus contributing to their well-being and general economic growth. For ACIAR the term "agricultural research" has a broad meaning. It includes research and development activities relevant to production and management of animals and crops, land and water, fisheries, forestry and postharvest technology, and economic analysis of agricultural and natural resource policies and technologies. ACIAR does not undertake research itself, but commissions research groups in Australian institutions including the universities, CSIRO, and the State agriculture, forestry and fishery departments to carry out research projects in partnership with their counterparts in developing countries.

ACIAR is based in Canberra, Australia, with offices in China, Indonesia, Malaysia, Papua New Guinea, the Philippines, South Africa, Thailand and Vietnam. ACIAR allocates its bilateral research resources to developing countries in Australia's area of interest on a regional basis which reflects the geographical focus of Australia's broader aid program. During the next five years, ACIAR will maintain a regional allocation of research resources within the following percentile bands (Table 1):

Table 1 Regional allocation percentile bands of ressources for ACIAR projects (ACIAR, 1997a)

Region	% of bilateral research budget
Southeast Asia	50−60
Papua New Guinea and Pacific Island Nations	10−20
China	10−20
South Asia	10−20
Africa	5 −10

In developing research projects for these regions, ACIAR places emphasis on priorities determined in consultation with partner countries, and communicates these priorities to research providers in Australia (Annex 1)[2]. Allocation of ACIAR's resources to partner countries in Southeast Asia reflects their changing circumstances. As partner countries become

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more affluent, technical cooperation will replace development cooperation as the primary mode of assistance. We anticipate that such countries will contribute more of the cost of the joint research projects, and will increasingly help us to help less affluent countries. In Indonesia, we will look particularly for collaborative opportunities in eastern Indonesia. Within the South-west Pacific region, ACIAR's resource allocation will recognize Australia's particular interest in, and obligations towards Papua New Guinea, and we will seek to strengthen Papua New Guinea's research capability so that ACIAR's research partnership model is more accessible to them. In southern Africa we aim to increase our bilateral research allocation towards the top of the 5-10% percentile band.

Will an increase in postharvest research lead to greater capture of benefits?

Cost-effective postharvest technologies on an appropriate scale have a very high rate of adoption because they are driven by demand. Population growth, urban migration, trade liberalization and income growth are spurring demand for improved transport and storage of harvested products. There are strong links between postharvest technologists and the marketing, trading and processing sectors and domestic consumers. These ensure that research is market-driven and that technologies are relevant to the market-place.

While post-production research directly benefits traders, marketers and manufacturers, the services and employment opportunities they provide benefit many in the community. In ACIAR, greatest emphasis will continue to be directed towards the early (near-farm) steps in the processing and marketing chain, where public benefits are likely to be high. Benefit/cost analyses of ACIAR's postharvest technology projects in that part of the chain indicate internal rates of return of 21-48%.

R & D potential

Because there has been a low investment in postharvest research relative to commodity production research worldwide, there is a plentiful supply of problems that can be easily solved by research. The adaptation of existing technologies to local conditions offers plenty of scope for innovative research at a level immediately relevant to scientists in developing countries, and chances of technical success are very high. Conversely, the application of advanced research methodologies to postharvest quality control is in its infancy. There is excellent scope for research on materials science, product physiology (e. g. control of ripening), novel chemicals (fumigants), biological control, management of chemical residues and mycotoxins, hygiene management, molecular biology and modelling. There are particular research challenges in improving the efficiency of energy utilization and of product recovery; devising safe, effective, reliable and cost-effective alternatives to chemicals; reducing the reliance on refrigeration; and improving food safety.

In addition to the research issues that ACIAR can support, many improvements in the postharvest sector will also be obtained by development assistance to introduce existing technology and improve rural and urban infrastructure.

R & D capacity in Australia and developing countries

Australia's R & D capacity is strong in some fields. These include:

- drying, fumigation, storage, pest management and bulk handling of grains and pulses;
- disinfestation, controlled atmosphere packaging, disease management and transport of fruit and vegetables;
- measurement and management of mycotoxins and chemical residues;
- wood treatment, storage, processing and transport;
- postharvest technologies for wool, dairy products, wine, cotton and sugar;
- policy and legal aspects of marketing and product quality standards;
- primary processing and food technology;
- and applications of molecular biology and information science (e. g. expert systems).

R & D capacity in developing countries is variable. Some countries have well endowed research facilities but require inputs to help in the formulation of research and development activities. Others have progressed to the stage that partnerships involving other less developed countries should be considered to capitalize on the gains of previous partnerships. A third group of countries is at the earliest stages of application of postharvest technologies, and urgently needs technology transfer and training.

The framework

Interventions to reduce risks associated with these factors to enhance food and nutrition security and minimize costs will involve:

- research and development,
- policy adjustments,
- social or cultural changes and
- infrastructure development.

ACIAR has developed a strategic plan for postharvest technology (ACIAR, 1997b). The goals and outcomes of the plan are summarized in Fig.1.

Of the goals and outcomes and the strategies for achieving them, four areas can be highlighted:

- The prospects for application of molecular biology,
- Food safety and nutrition,
- Systems approaches to postharvest research and development and
- Collaboration with other international development assistance agencies, National Agricultural Research Systems (NARS) and the International Agricultural Research (CGIAR) Centres.

Fig.1 ACIAR postharvest technology strategic plan: goals & outcomes

Goals

1 To improve application and efficiency of postharvest systems for food, wood and fibre products and animal feeds;
2 To optimize the quality and suitability of produce for market requirements;
3 To assure food security and improve trade and market access, and
4 To minimize losses or undesirable health, environmental and social impacts of the products or technologies.

Outcomes

1 High quality, robust produce suited to market requirements.
2 Postharvest technology systems and packaging which reduce losses, minimize costs and optimize produce suitability and quality.
3 Improved environmental safeguards in postharvest systems.
4 Enhanced food security, trade and market access, delivering improved returns to producers, traders and processors, and better value to customers.
5 Improved consumption of healthy and nutritious food and animal feed.
6 Increased postharvest research capability in the National Agricultural Research Systems (NARS) and international agencies.

Applications of molecular biology

The techniques of molecular biology offer particular promise in relation to maintenance of produce quality. Molecular techniques can be used to:

- turn off undesirable physiological processes such as browning of fruit following chilling injury or oxidation,
- slow down processes such as ripening,
- enhance mechanisms such as the resistance of fruit, grain or wood to pests and decay, and
- ensure a closer match between product and processing requirements such as he development of wheat cultivars more suited to noodle manufacture.

Developments arising this way can be delivered widely provided intellectual property and patent rights are managed. ACIAR is currently supporting two molecular biology projects in the Postharvest Technology Program. One is on the control of physiological browning and crown deterioration in pineapples (PHT/94/07). The other concerns the regulation of ripening in papaya and mango (PHT/94/45). Both projects offer prospects for producing fruit that is less subject to postharvest deterioration, a benefit to producers, marketers and consumers.

Food safety and nutrition

Food safety The contamination of food by chemicals, mycotoxins and microorganisms, and the

presence of toxic constituents in food such as cassava can seriously affect the health of consumers and livestock. Research to develop simple tests for detecting the contaminants, or treatments to eliminate them, along with the establishment of reliable monitoring networks and appropriate regulatory mechanisms, will reduce risks to consumers and enhance export opportunities.

ACIAR recently supported research on the development of simple test kits to detect pesticide residues in plant foods (PHT/93/09), in a collaborative project involving the Central Food Technology Research Institute (CFTRI) in India and the CSIRO in Australia.

ACIAR also supports research on mycotoxins in grains and cyanide in cassava.

Nutrients in food Two important factors contribute to a decline in nutrition, despite the progress towards food security. These are the reductions in vitamin content during storage and processing, and changes in human dietary patterns. To address the decline in consumption of subsistence/artisanally produced food crops of high nutritional values in some Pacific Island Nations, ACIAR will support collaborations which address the sociological and technical factors contributing to the trend.

Systems approaches to postharvest research and development

The postharvest area involves producers, transport providers, marketers and processors as well as consumers. In addition, government and semi-government authorities may have significant responsibility for marketing and storing all or some portion of the total production of important commodities.

In many agri-enterprises, the whole system approach to managing produce quality and matching consumer expectations is being recognized as a means of consolidating and improving returns (Anon, 1996; Johnson *et al.*, 1997). Quality assurance systems are being developed and implemented in many Australian enterprises and have become an important theme in partner countries as they become more involved in storing and trading produce. Implementation in practice is a challenge, and will be addressed within ACIAR activities which aim at improving the adoption of agricultural policy and technology using participatory processes (ACIAR, 1997b).

In Asia, grain storage and marketing is an important aspect of food security. Government and semi-government authorities are involved in grain storage and marketing. Managing grain quality and pests in storage is a complex and important issue, and involves large numbers of personnel. In recognition of the complexity and importance of the issue, ACIAR has funded collaborative research (PHT/93/21) involving the CSIRO, the Indonesian grain authority BULOG and the Queensland Department of Primary Industries in the development of pest control recommendations and training materials for use in large centrally managed storage facilities. The training material has been developed in a CD-ROM package in both Bahasa and English, and is being used to "train the trainers". The advantage of a CD-ROM-based system is that text, sound, drawings and photographs and video clips can be incorporated and referred to as necessary to ensure accurate diagnosis and treatment of pests (Fig. 2). The training package has attracted the interest of other grain authorities in the region, and funding is been provided from ACIAR and the Australian Agency for International Development (AusAID) to

extend the scope and uptake of the project outcomes to Vietnam and the Philippines (Project PHT 97/131).

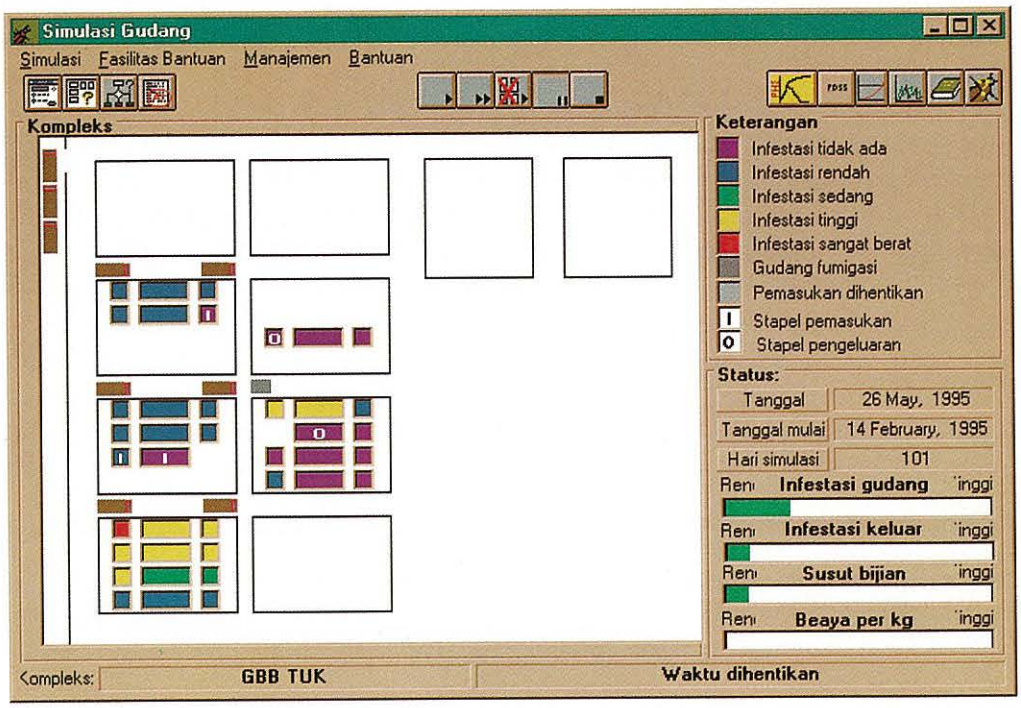

Fig. 2 A typical screen from the Simulator program in the training package, showing the layout of a warehouse complex in Indonesia.
Each stack within each warehouse is monitored by the software, so that management processes, such as inloading and outloading of grain, sampling, chemical treatment and fumigation are recorded. A population growth model runs within each stack and insect densities are indicated by different colors. Grain losses and treatment costs are shown in the lower right of the screen (Longstaff, 1997)

Collaboration with other development assistance agencies, National Agricultural Research Systems (NARS) and the International Agricultural Research (CGIAR) Centres

The research networks of the International Centres and their close contact with NARS provide an ideal mechanism for delivering postharvest technology more widely. For example, the International Rice Research Institute (IRRI) Crop and Resource Management Network (CREMNET) has played an important role in wider evaluation of grain drying technology developed in collaborative research between the University of Agriculture and Forestry in Vietnam, the German Agency for Technical Aid (GTZ) and IRRI.

Historically, the emphasis in agricultural research within CGIAR Centres has been on crop production and genetic improvement, and great gains have been made in these areas. Gains

have not been as great in the postharvest sector, a reflection of lower net resource and personnel allocations to postharvest research, and the availability and effectiveness of blanket chemical for control of stored product pests. The need for alternatives to grain fumigants and other treatments has created the need for a quantum leap in research effort in the postharvest sector.

In 1995-96, the Technical Advisory Committee (TAC) to the CGIAR Centres concluded that there was considerable need and scope for Centres to increase activity in the postharvest sector (Arnold, 1996). However, funding shortages, together with existing program commitments by CGIAR Centres, have limited opportunities to implement the recommendation.

ACIAR can help by encouraging applications from Centres for ACIAR-IARC Restricted Project Grant or Special Purpose Grant funding for postharvest research activities of mutual benefit. Opportunities exist for building on ACIAR funded research in grain drying and pest management, and for capitalizing on new bilateral initiatives on mycotoxin and pesticide residue research and the improvement of postharvest systems for tuber crops and bananas.

Group for Assistance on Systems relating to Grains After-harvest (GASGA)

ACIAR is a member of GASGA so that it can maintain dialogue with other agencies involved in postharvest R & D to identify opportunities for collaboration and to reduce overlap or duplication of effort.

For example, revisions of the ACIAR/ASEAN Food Handling Bureau Fumigation Manuals produced as outcomes of ACIAR research in Southeast Asia, will be published by FAO as a replacement for their standard reference, the FAO Munro/Bond Manual. FAO and ACIAR will contribute to the cost of the revisions, and wide uptake and adherence to the recommendations is assured via the FAO and GASGA member networks.

As a member of GASGA, ACIAR can more effectively promote dialogue with the CGIAR Centres about mechanisms for increasing their involvement in postharvest research and development. GASGA members already have considerable involvement in collaborative ventures with CGIAR Centres. For example,

- FAO collaborated with IRRI to conduct an E-mail conference on rice post-production technologies. Interesting debate occurred on the adoption of high-yielding rice varieties, the use of combine harvesters, grain drying and storage issues (De Padua, 1997; Bell, 1998).
- NRI is working in collaboration with ICRISAT and NARS to investigate the postharvest constraints to sorghum in southern India, in particular to identify the factors that are leading to the decline of this crop. Three projects have been initiated to achieve this: (a) an overview of the sorghum commodity system; (b) processing and utilization issues; and (c) postharvest losses and quality deterioration with special reference to improved and high-yielding varieties (Haines and Hodges, NRI, Chatham, personal communication, 1997).

Postharvest technology for grains, fruits and vegetables

ACIAR has an ongoing commitment to support R & D that will benefit the Australian rural industries, through initiatives to improve quality and reduce losses in Australia and improve the

capability of partner countries for storage, transportation and management of their grain reserves. Recent, current and pipeline initiatives include:

Recently completed projects:

Applications of in-store drying in the grain industry in Southeast Asia (Project PHT/90/08). Completed 31 December 1996. This project extended two-stage grain-drying strategies for cereal grains in the humid tropics from large-scale, mainly government operations to the small-scale private sector (mainly traders, millers and farmer cooperatives) (Srzednicki, 1996; Champ *et al.*, 1996).

Commissioned Organization: University of New South Wales (R. Driscoll and G. Srzednicki). **Collaborators:** National Postharvest Institute for Research and Extension, Philippines; King Mongkut's Institute of Technology, Thailand; University of Agriculture and Forestry, Vietnam.

Development of quarantine disinfestation protocol for an oriental fruit fly (*Bactrocera papayae*) with hot air (Small Project PHT/94/937). Completed 30/6/1997. This small project developed an oriental fruit fly quarantine disinfestation protocol based on the hot air treatment, to the standards required for fruit export to Japan and New Zealand. Working in Malaysia, the scientists tested a hot water protocol on Australian mango as an early response to the 1995 Australian outbreak of *B. papayae*. They compared the disinfestation parameters established for another fruit fly species, *Bactrocera tryoni*, to determine the suitability of these protocols for *B. papayae*, and looked for side-effects on fruit quality that could arise from application of the disinfestation schedules.

Commissioned Organization: Queensland Department of Primary Industries (R. Jordan); **Collaborators:** Australian Quarantine and Inspection Service (AQIS). Malaysian Agricultural Research and Development Institute (MARDI), Malaysia.

Development and application of simple test kits for pesticide residues in plant-derived foods (Project PHT/93/09). Completed 30 June, 1998. This project developed and introduced a range of simple, affordable tests using specific antibodies and enzyme-pesticide complexes for individual pesticides that already cause concern in the collaborating countries (India and Australia) (Skerritt, 1997; Karanth, 1998).

Commissioned Organization: CSIRO Division of Plant Industry (J. Skerritt).

Collaborators: University of Sydney; Central Food Technological Research Institute, Mysore, India.

Disease control and storage life extension in tropical fruit (Project PHT/93/13). Completed 31 December 1997. Previous research between Australia and Thailand (projects PHT/88/44 and 83/56) has identified disease agents in some tropical fruits. This project built on that research, combined with new findings by other research groups, to improve prospects for developing non-chemical controls for the diseases anthracnose and stem end rot. Project scientists also studied how postharvest storage potential was affected by environmental stresses that occur during development, and also focus on factors determining disease incidence and severity (Johnson, 1997; Hofman *et al.* 1998; Joyce *et al.*, 1998).

Commissioned Organization: CSIRO Division of Horticulture (L. Coates QDPI) **Collaborators:** Queensland Department of Primary Industries; Kasetsart University, Thailand; Chiang Mai

University, Thailand.

The development of decision-support tools for managing pests in grain storages (Project PHT/93/21). Completed 31 December, 1997. This project established information on best practices for pest management in gain storage facilities in Indonesia and Australia. The data formed the basis for decision-support systems to help practitioners to make the correct choices for maintaining grain quality through judicious use of grain protectants and fumigants. A CD-ROM-based training package was produced, with the intention of refining and implementing it in a follow-on small project (PHT/97/131) co-funded under the AusAID APEC program (Longstaff, 1997).

Commissioned Organization: CSIRO Division of Entomology, Canberra. (B. Longstaff). **Collaborators:** Centre for Tropical Pest Management, Queensland; Queensland Department of Primary Industries; Badan Urusan Logistik (BULOG), Indonesia.

Active projects

Phosphine resistance in stored grain (Project PHT/94/15). Active 1 January 1997 to 30 June, 1998. This project aims at developing and implementing management practices that will delay further development of phosphine resistance for stored grain pests in China, Australia and India.

Commissioned Organization: Queensland Department of Primary Industries (M. Bengston, G. Daglish). **Collaborators:** CSIRO Stored Grain Research Laboratory, Division of Entomology; Ministry of Internal Trade, Beijing; Chengdu Grain Storage Research Institute, China; Zhengzhou Grains College, China; Guangdong Institute of Cereal Science Research, China; Central Food Technology Research Institute, Mysore, India.

In-store drying of grain in China (Project PHT/94/37). Active 1 January 1997 to 31 December 2000. This project aims at designing safe grain-drying systems that overcome the problems caused when wet maize and rice are stored in northeastern and subtropical southern China. Project staff will assemble existing data on economics, weather and grain handling. The data will form the context for computer models of the effects of various drying systems on grain quality and efficiency of grain handling. On the basis of model results, project staff plan to design, recommend and test specific drying systems with technical and economic characteristics to suit the various grain-handling depots. Finally, they will assess the systems on commercial scale and educate all users, by extension and training. **Commissioned Organization:** University of New South Wales (R. Driscoll and G. Srzednicki). **Collaborators:** Ministry of Internal Trade (MIT), China.

Pineapple quality improvement (Project PHT/94/07). (Active 1 January 1996 to 31 December 1998). This project will first determine the enzyme(s) responsible for blackheart injury, then apply successive techniques of molecular biology to develop a genetically transformed pineapple that inhibit the expression of blackheart. In separate studies scientists will use conventional methods to determine the physiology of tissue breakdown that leads to crown deterioration, then develop strategies to prevent its occurrence. The project objectives include production of a transgenic pineapple ready for glasshouse evaluation, a molecular transformation system for pineapple and practical solutions to reduce the incidence of crown deterioration.

Commissioned Organization: Queensland Department of Primary Industries (M. Smith). **Collaborators:** CSIRO Division of Horticulture, Adelaide; Queensland Agricultural Biotechnology Centre; Malaysian Agricultural Research and Development Institute (MARDI).

Control of ripening in papaya and mango by genetic engineering (Project PHT/94/45). Active 1 July 1997 to 30 June 2000. This project will use genetic engineering techniques to extend fruit storage-life of papaya. The project researchers will identify, isolate and clone two important genes in the ripening process: 1-aminocyclopropane 1-carboxylate (ACC) synthase and polygalacturonase (PG). They will then prepare antisense constructs, and introduce the altered genes back into the plant using a previously developed transformation system. Also tissue culture and embryogenesis systems that will facilitate genetic manipulation of mango will be produced.

Commissioned Organization: University of Queensland, Botany Department (J. Botella). **Collaborators:** Queensland Department of Primary Industries; Queensland University of technology; Malaysian Agricultural Research and Development Institute (MARDI); Institute of Plant Breeding, University of the Philippines at Los Banos (UPLB).

Postharvest handling and disease control in melons (Small project 96/152). Active 1 July 1997 to 31 December 1998. This small project will document the harvest, handling and marketing of melons in Western China and assess the feasibility of using novel "defence eliciting" treatments for postharvest disease control. Novel strategies are urgently required to replace benomyl, withdrawn from postharvest use in Australia at 31/12/1996. The aims will be approached by the following means:

1 Documentation of postharvest melon handling systems and the major causative agents responsible for postharvest melon loss in China.
2 Investigation of the factors affecting the resistance of melons to the diseases. These include a) test of resistant cultivars, b) evaluation of systemic inducing resistance (SIR) agents and c) understanding of environmental factors on the expression of host resistance;
3 Preliminary development of biocontrol methods for control of postharvest melon diseases.

Commissioned Organization: The University of Sydney (Y Huang). **Collaborators:** China Agricultural University; Ganshu Melon Research Institute; Sichuan Pomological Institute and the Sydney Postharvest Laboratory.

Cocoa fermentation, drying and genotype product quality assessment (Project PHT/95/136). Active 1 January 1998 to 31 December, 2000. This project is one of a group of ACIAR-PNG projects proposed for funding by the Australian Agency for International Development (AusAID). The project will evaluate the effects of minibox (250kg) fermentations and solar drying technology and cocoa genotype on cocoa quality in PNG. The fermentation boxes will allow growers to prepare smaller volumes of harvested cocoa beans for fermentation and drying. The scale of the technology is well suited to household and village/family group cocoa production volumes. Complementary activities on cocoa product evaluation will be undertaken in Australia (Hollywood *et al.*, 1997).

Commissioned Organization, Queensland Department of Primary Industries, Centre for Food Technology (N. Hollywood). **Collaborators:** University of New South Wales, Department of Food Science and Technology; Papua New Guinea Cocoa and Coconut Research Institute, Papua New Guinea.

Projects approved by ACIAR and scheduled to start from 1/1/1998 to 1/7/1998.

Computer-aided learning as a tool to improve training standards in grain storage management in ASEAN countries (Small Project PHT/97/131). Awaiting sign-off (1 January 1998 to 31 December 1999). The major objective of the small project and the complementary AusAID (APEC) funding is to demonstrate the benefits of employing Computer-Assisted Learning (CAL) tools in the education of grain-storage personnel. A training course will utilize the group of bilingual (English/Bahasa), multimedia Computer-Assisted Learning (CAL) tools, called "Pest Management Workbench", that were developed in ACIAR project PHT/93/21 in order to facilitate the rational and sustainable management of pests in grain storages in Indonesia, Vietnam and the Philippines. An important secondary objective of the small project/ AusAID activity is to assist collaborating institute personnel in identifying and developing the mechanisms by which this new approach can be integrated into the training infrastructures of their organizations.

Commissioned Organization: CSIRO Division of Entomology, Canberra (B. Longstaff). **Collaborators:** Badan Urusan Logistik (BULOG), Indonesia; BIOTROP, Indonesia, Postharvest Technology Institute, Ho Chi Minh City, Vietnam; Bureau of Postharvest Research and Extension (BPHRE), Philippines.

Low-cost disinfestation systems for fruit (Project PHT/93/877). Active 1 January 1998 to 31 December 2000. This project will investigate alternative (low-cost) heat systems to the currently available expensive heat treatments for the disinfestation of fruit. It will reduce the complexity of the technology and lead to major reductions in cost, opening up the treatment to use at the farm level. Outcomes of the project will be

- prototype equipment built, tested and demonstrated in Australia, Thailand and Vietnam.
- modified conditions for the disinfestation heat treatment of the priority crops in Thailand and Australia, which will allow treatment to be undertaken using simple low-cost equipment.
- disinfestation research work commenced in Vietnam.
- development of facilities and expertise in Vietnam for undertaking horticultural quarantine treatments, and postharvest storage research.

Commissioned Organization: Queensland Department of Primary Industries, Brisbane (R. Jordan). **Collaborators:** Department of Agriculture, Thailand; Department of Plant Protection, Quarantine Section, Vietnam (disinfestation treatments) and the Research Institute for Fruit and Vegetables, Vietnam (fruit quality responses).

Shelf-life extension of leafy vegetables (Project PHT/94/16). Active 1 July 1998 to 30 June 2001. This project aims to improve procedures in the Chinese handling system and thus reduce postharvest wastage of leafy vegetables. The scientists will determine which agronomic and postharvest handling procedures increase shelf-life, and identify what physiological factors limit shelf-life so that they can focus on them in future biotechnological control and breeding strategies. The specific commodities for study are Chinese cabbage, pak choi, broccoli, asparagus and oriental bunching onions. Saving will occur through reduced wastage and access to further markets, and minimal processing will add value to these commodities.

Commissioned Organization: Queensland Department of Primary Industries, Brisbane (T.O' Hare). **Collaborators:** Beijing Vegetable Research Centre, Beijing; Hangzhou Institute of

Commerce, Hangzhou; University of Adelaide; Institute for Horticultural Development, Victoria Agriculture.

Management of Phytophthora diseases of durian (Project PHT/95/134). Active 1 July 1997 to 30 June 2001. This project will develop strategies to control fruit rot, patch canker and dieback of durian (*Durio zibethinus* M.) caused by *Phytophthora palmivora*). The primary objective will be to improve orchard sustainability and the consistency of fruit supplies and quality in Vietnam, Thailand and Australia, by developing an integrated program of orchard and postharvest management of *P. palmivora*. Key elements of the strategy will be definition of the biological interactions involved and the development of integrated control strategies based on biological and environmental variables, and include the application of phosphonate derivatives by Trunkz: University of Melbourne, School of Botany (D. Guest). **Collaborators:** Kasetsart University, Thailand; Southern Fruit Research Institute, Vietnam, Northern Territory Department of Primary Industry and Fisheries and the Queensland Department of Primary Industries.

Identification, biology, management and quarantine systems for fruit flies in Papua New Guinea (Project CS2/96/225). Active 1 January 1999 to 31 December 2001. This project will define the fruit fly pest species occurring in PNG, the distribution of each within the country, and the host fruit range of each. Work will also be undertaken on preharvest field control strategies including bait spraying and physical control. Project scientists will conduct pest risk assessment studies to determine the chances of spread of different species within, from and into PNG, and the losses that might then occur. They will also develop quarantine procedures in PNG to restrict the spread of fruit flies. They will work in collaboration with other agencies in PNG on postharvest disinfestation in relation to fruit flies, and will maintain close contact with regional agencies interested in fruit fly control.

Commissioned Organization: Griffith University, Brisbane, (R. Drew); **Collaborator:** Department of Agriculture & Livestock, Papua New Guinea.

Projects under development for possible commencement in 1999 or 2000

Fruit resistance to disease (Project PHT/97/94). Phase 1 approved, start date not yet set. This project will continue research to develop novel and improved controls for anthracnose and stem end rot diseases in tropical fruit (PHT/88/44, PHT/93/13). This project will monitor antifungals in fruit as they are subjected to a variety of elicitor treatments (heat, microbial challenges; UV, antioxidants), and assess the potential for utilizing or enhancing cultivar resistance by classic and molecular techniques.

Commissioned Organization: The University of Queensland (D. Joyce). **Collaborators:** Queensland Department of Primary Industries, University of Peradeniya, Sri Lanka.

Replacements for methyl bromide in timber for quarantine fumigation (Project PHT/94/06) Phase 2 in preparation, start date not set. This project will seek replacements for methyl bromide for the commercial fumigation of timber, with the selection made from amongst: sulfuryl fluoride, phosphine, hydrogen sulfide, carbonyl sulfide, methyl ithiocyanate and carbon bisulfide for control of timber pests. Rapid methods to measure fumigant sorption and penetration through timber will be tested, and the methodology verified on tropical hardwoods using

methyl bromide and oregon timber as reference standards. In addition, the potential for thermal disinfestation during kilning will be investigated.
Commissioned Organization: CSIRO Division of Entomology, Stored Grain Research Laboratory. **Collaborators:** Forest Research Institute of Malaysia, Malaysia; Papua New Guinea Forest Research Institute, Papua New Guinea.
Reducing mycotoxin and pesticide contamination in grain, fruit and vegetables in Vietnam (Project PHT/96/04). Phase 2 in preparation, start date not yet set. In this project, a range of the commodities produced in Vietnam will be sampled and the incidence and severity of contamination by mycotoxins (esp. fumonisins and ocratoxins) and pesticides will be quantified. Sampling protocols and field-laboratory immunoassays for total mycotoxins and pesticides will be developed and Vietnamese researchers at provincial laboratories will be trained in their use. Following the initial survey, a network for the ongoing monitoring of mycotoxin and pesticide contamination in agricultural produce (food and feed) and fermented foods in regional laboratories will be strengthened.
Commissioned Organization: University of Sydney, Australia (I. Kennedy);
Collaborators: Postharvest Technology Institute, Food and Commodities Control Center, Vietnam ; University of Agriculture and Forestry, Vietnam; CSIRO Division of Plant Industry, Australia.
Pesticide Risk Reduction Strategies for Sustainable Pest Management (Project PHT/98/59). Start date not yet set. In this small project, strategies for pesticide risk reduction will be developed and tested. The current policies, research and development needs and regulatory infrastructure for minimizing pesticide residue risks in food and the environment in the Philippines will be documented. A consultative process modelled on that used to develop Australia's National Pesticide Risk Reduction Strategy will be used, with involvement of government agencies, scientists, producers, pesticide industry personnel and produce marketers. The consultations will be used to define improvements in policy, regulatory infrastructure, training and research and development plans to improve implementation of strategies for minimizing pesticide levels in produce and the environment. High-risk production systems and environmental hazards for priority attention will also be identified, to ensure that the strategies developed will be adequate. Options for the development of National Strategies for Indonesia and the Philippines will be explored using two commodity case-studies - potatoes and leafy vegetables. In Australia, procedures for implementing the National Strategy will be developed using potatoes and leafy vegetables as case studies.
Commissioned Organization: Department of Primary Industries and Energy. **Collaborators:** Agencies in the Philippines; Institute for Horticultural Development, Knoxfield Victoria.

Postharvest technology in all ACIAR programs

ACIAR's postharvest technology research has traditionally been concentrated on crops. A key strategy for increasing investment in postharvest technology research has been to identify relevant opportunities and priorities in other program areas (Table 2). In close consultation with partner countries several current and future research topics have been identified.

Table 2 The relative priority of resource commitment to research strategies across commodity group or ACIAR program area, with* indicating high emphasis, ** indication moderate emphasis, and* indication minor emphasis to the strategy.**

	Grop products	Animal products	Forest products	Fishery products	Agricultural & natural resource economics	Land and water impacts
Outcome 1 High quality, robust produce suited to market requirements.						
1) Through strategic (or basic?) research and genetic modification, improve or modify produce quality, utility and resistance to decay or deterioration.	***					
2) Consider and optimize the impact of production environments and technologies on postharvest quality & safety, and product suitability.	**	*	**	**		*
3) Develop postharvest technologies that conserve and promote the vigorand viability of seed and planting material.	*		*			
Outcome 2 Postharvest technology systems and packaging which reduce losses, minimize costs and optimize produce suitability and quality.						
1) Through modelling, systems analysis and technology development, introduce affordable harvesting, drying , handling, packaging and storage systems to conserve the suitability and quality of produce and improve temporal and energy efficiencies and effctive pest management in the postharvest system.	***		**	**		
2) Devise effective Quality Assurance (QA) protocols or improvements to work practices which improve (1) personnel performance and the operating effectiveness of postharvest systems and (2) uptake of appropriate technology at the farmer and household level, to reduce losses and improve returns.	**	*	*			
3) Devise first stage processing treatments or technologies which improve and optimize product suitability.	*	***	**			
Outcome 3 Improved environmental safeguards in postharvest systems.						
1) Develop technologies and systems to detect, eliminate or reprocess pollutants arising as by-products or waste from postharvest treatment or processing facilities.		*	*			*
2) Develop monitoring and remediation systems which minimize the risk of agrochemicals or environmental pollutants contaminating produce during production, transport and processing.	***	***		*		*

Table 2 Continued

	Commodity group or ACIAR Program area					
	Grop products	Animal products	Forest products	Fishery products	Agricultural & natural resource economics	Land and water impacts
Outcome 4 Enhanced food security, trade and market access delivering improved returns to producers, traders and processors.						
1) Develop and test novel treatments, technologies or management systems to assure product quality, satisfy regulatory requirements of reduce produce losses.	***	**	**			
2) Develop and apply technologies and systems to (a) monitor or minimize risks of product contamination by pesticides, mycotoxins microorganisms and (b) confirm the identity of species or varieties.	**	*	*			
3) Devise and promote trade and regulatory policies which promote consumer confidence and facilitate market improvements.	**	*			***	
Outcome 5 Improved health and nurition of consumers and livestock.						
1) Investigate the socio-economic, institutional and technical constraints to the marketing and consumption of nutritious food.	*				*	
2) Establish and promote effective monitoring and remediation systems to eliminate mycotoxins, pesticides, pathogens and toxic principles from food and feed.	**	**				
Outcome 6 Increased postharvest research capability in the National Agricultural Research System (NARS) and international agencies.						
1) Promote dialogue within CGIAR of postharvest research imperatives.	*		*		*	
2) Develop opportunities for interagency collaboration and complementarity through the Group for Assistance on Systems relating to Grains After harvest (GASGA), a research collaboration group involving ACIAR, NRI, CIRAD, FAO and GTZ.	***				*	
3) Develop complementary projects between NARS and international agencies which improve the postharvest impact of their research.	*	*	*	**	*	

These include:

- Production of particle-board using acacia and eucalypt pulp in the Philippines (Forestry Program, FST/95/00) (Outcome 1)[2].
- Management of rodent pests in Southeast Asia and Vietnam (Animal Sciences 1, AS1/94/20 and AS1/96/79) (Outcome 2).
- Management of tannery waste in India (Land and Water 1 Program, LWR1/93/22) (Outcome 3)
- Wool processing and treatment of scouring effluent, with China and India (Animal Sciences 1 Program, AS1/97/49; AS1/97/70) (Outcome 3)
- Studies on the nutrient content of some Pacific Island Foods (Crop Sciences 2, CS2/93/06) (Outcome 5)
- Constraints to production and consumption of nutritious foods in Fiji, a joint feasibility study by the ANRE, PHT and Crops Science Programs (Outcome 5).

Priority topics for collaborative research funding are listed below.

Crop products

- Controlling deterioration, disease and defects by genetic modification of fruit, vegetables and grain.
- Phosphonate injection technology and other novel treatments for disease control or storage life extension in fruit and vegetables.
- Postharvest technology for cocoa, coffee and other smallholder cash crops.
- Low-cost systems for fruit fly control and disinfestation.
- Pest and product quality management during drying, storing and marketing.
- Replacement treatments for methyl bromide and sulfur dioxide fumigation.
- Improving dietary intake of nutrients and reducing intake of toxins and digestion inhibitors.
- Technology for detection and remediation of produce contamination.
- Policy and regulatory interventions to monitor and control food contaminants.

Agricultural and natural resource economics

- Developing recommendations for policy and institutional reforms to
- Facilitate international trade and harmonize food safety and quarantine regulations,
- Assure food and nutrition security, promote postharvest quality maintenance and loss reduction, and encourage consumer confidence,
- Promote gender equity and occupational health and safety.

Animal products

- Feed quality enhancement and contamination control.
- First stage processing to improve wool quality and utilize livestock by-products.
- Species confirmation tests.
- Meat quality enhancement.

[2] Outcomes of the ACIAR Postharvest Strategic Plan (Table 2).

・Reducing adverse environmental impacts of processing facilities.

Fish products

・Reduction of contaminants in fish products.
・Technology that preserves the texture and flavor of aquatic produce and extends shelf-life.

Forestry

・Synchronization of harvest rate of forest trees with processing and kilning capacities.
・Improving the yield of useable timber and extending timber product life.
・Developing policies, monitoring and handling systems and technologies in forests, mills and timber processing facilities and timber structures which minimize environmental pollution.

Land and water management.

・Minimizing offsite pollutants from postharvest enterprises.
・Productive use of crop residues.

Conclusions

I have briefly outlined the rationale of ACIAR's framework for research and development on postharvest technology, and the scope of the current series of projects. ACIAR's strategic emphasis on postharvest R & D during 1997-2000 will help producers and marketers to achieve greater efficiencies and reduced losses in postharvest systems in Australia and its partner countries. Exploiting opportunities for co-funding and synergistic collaborations are important mechanisms by which the "quantum leap" of effort can be made. ACIAR welcomes comments and suggestions on priorities for future research and collaboration that would be of regional significance and which would match the national priorities of partner countries.

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Annex 1 :

Areas for priority attention as summarized in ACIAR-Country consultations 1994 to 1998 (dates of consultations are indicated)

The priorities are not considered as officially sanctioned priorities of partner country Governments. They are priorities expressed by participants at a consultation at a particular point in time. ACIAR uses them as a framework when assessing proposals for collaborative projects to be supported by ACIAR, subject to further advice and information from the proposed partner countries.

China 22-23 April 1996

- Processing of dairy products
- Postharvest technologies for vegetables
- Grain storage technologies

India 10-11 July 1997

- Feasibility studies on bulk handling and storage systems for grain, including socio-economic aspects
- Postharvest technologies for meat, wool, fish products, fresh grapes, mango and dry fruits, including increased cooling efficiency of low-cost environment-friendly cool chambers
- Storage pest management for pulses
- Drying, testing, processing and storing seeds for sowing by farmers, including pre- and postharvest seed quality aspects
- Postharvest technology for cotton (ginning, cotton seed oil)
- Disinfestation and postharvest technology for tropical fruit including quarantine aspects
- Mycotoxins

Indonesia 20-21 June 1994

- Improvement of handling or ornamentals
- Improvement of processing of highly perishable produce (roots and tubers, vegetables, fruits and fish)

Papua New Guinea 5-6 October 1995

- Postharvest technology (with special emphasis on downstream processing of crops);

Philippines 26-27 February 1998

- Innovative approaches to quality management in plant products
- Development of appropriate postharvest systems to include:
- establishment of sanitary and phytosanitary guidelines and capacity building in pest-risk analysis (PRA) for fruits and vegetables
- postharvest technologies for marine fisheries involving community level SMEs processing for value-adding through development of diversified products
- Pesticide risk reduction strategy (policy, regulation, monitoring, research)

Thailand 14-25 February 1997

- Improved safety and utility of agricultural products, including reduced use of chemicals
- Improved suitability and efficiency of postharvest systems
- Understanding and manipulating the biological basis of postharvest quality

Vietnam 16-17 May 1996

- Minimization of pests, chemical residues and mycotoxins in agricultural produce
- Extension of storage life in fruits and vegetables (clean, green food)
- Efficient drying and storage of grain
- On farm, small scale processing and value-adding for farm produce (including mobile units)
- Development of animal feed formulations
- Cooperative marketing and postharvest technology transfer
- Animal and seafood products: reduction of spoilage, value-adding

Priorities set at regional meetings also help guide ACIAR in the development of research programs. Those listed below were set at the 18th ASEAN Grain Postharvest technology Seminar, "Postharvest technology towards attaining food security", Manila, March 11-13, 1997.

- Strengthening of farmer cooperatives
- More aggressive and deliberate extension and diffusion of improved postharvest technologies and systems,
- Increased infrastructure and support systems for farmers,
- Encouragement of greater private sector participation in commercial scale farming and buffer stocking,
- Strategic positioning of buffer stocks, transport and communication facilities,
- Better coordination among concerned agencies in the government and the private sector and
- Commitment of more resources to postharvest research especially in priority areas such as wet grain handling, mycotoxin prevention and control, marketing, processing and education and training.