The Australian Centre for International Agricultural Research (ACIAR) was established in June, 1982 by an Act of the Australian Parliament. Its mandate is to help identify agricultural problems in developing countries and to commission collaborative research between Australian and developing country researchers in fields where Australia has a special research competence.

ACIAR TECHNICAL REPORTS SERIES

This series of publications contains technical information resulting from ACIAR-supported programs, projects, and workshops (for which proceedings are not being published), reports on Centre-supported fact-finding studies, or reports on other useful topics resulting from ACIAR activities. Publications in the series are distributed internationally to a selected audience.

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ACIAR Grain Storage Research Program

Research Report 1983-84

Australian Centre for International Agricultural Research
Canberra, 1985

CONTENTS

PREFACE

This is the first general report on ACIAR-sponsored research in the grain storage field. It covers the period from the start of the research program early in 1983 until the middle of 1984. Since this is a first report it details the organisational matters associated with the establishment of the program and its constituent projects, as well as reporting on the considerable progress that has been made in research.

ACIAR's task is to help solve the major agricultural problems of developing countries by sponsoring research that allows their scientists and Australian scientists to work together in strategically planned, collaborative programs. The importance of collaboration in the research sponsored by ACIAR cannot be overstressed. The Centre is founded on the belief that research partnerships are the most effective way to harness Australian and developing country expertise to meet well-defined research and technical objectives.

With the help of its Policy Advisory Council, ACIAR undertook a program of consultations with developing country scientists and planners to identify priority areas for research. The safe storage of grain in the tropics was identified as one of these priority research areas. The importance of this field was stressed during ACIAR's consultations in the ASEAN countries and Africa. The economic importance of post-harvest losses in grain is evident from available data and from the best estimates of developing country authorities responsible for the storage of grains. Losses due to deterioration in quality exacerbate the problem. Even a small reduction in the percentage of losses would yield high rewards.

While ACIAR has accorded grain storage research a high priority in all its spheres of operation, initial activities have been directed at storage problems in the ASEAN countries, particularly in the Philippines and Malaysia, but with extensions proposed into Thailand and Indonesia as appropriate. Within the framework of the national research programs formulated, and being implemented by, the responsible agencies in those countries, specific bilateral co-operative research projects between the agencies and relevant Australian institutions have been developed.

In every assessment made of post-harvest grain losses in these countries, the management of grain moisture and pests in humid climates has been identified as having the highest priority for attention. Against this background, ACIAR, together with scientists from Australia and the ASEAN countries concerned, has prepared a series of interrelated projects that have been grouped together in a research program entitled *Safe Storage of Grain in the Tropics*. This program, as well as addressing the two major problems of grain moisture and losses from pests, seeks to develop, through co-operative research with Australian scientists, the technical capacity needed by the developing countries to maintain their own research programs.

J.R. McWilliam
Director
ACIAR

OVERVIEW OF THE PROGRAM 1

Objectives and Organisation

The primary thrusts of the ACIAR Grain Storage Research Program are to achieve first an understanding of, and then the ability to manage, grain moisture and pest activities under the humid conditions characteristic of many tropical countries.

The technology of maintaining quality and preventing losses in grain harvested and stored in developing countries with dry climates is relatively well understood. The major problems there relate to implementation of existing knowledge through training, extension, and concurrent socio-economic assessments of needs and of the appropriateness of the various systems available.

Maintaining quality in the more humid tropical areas is less well researched and there are major problems requiring solution if safe storage is to be attained. These problems relate primarily to excessive moisture and pests. To address these problems, the program seeks to exploit Australia's acknowledged expertise in grain storage research and technology in central handling systems through collaborative studies involving Australian and overseas scientists. These studies are designed to complement existing initiatives in the region, such as the work of the ASEAN Food Handling Bureau and various bilateral and multilateral activities which give particular emphasis to farm and village level problems.

Four core projects have been established in Australian research institutions and linked with research institutions in Malaysia, the Philippines, and Thailand. They concern grain drying (Project No. 8308), storage of grain under plastic covers (8307), and integrated use of pesticides (8309, 8311). In addition, three other projects, designated support research, have been established to enhance understanding of moisture movement in grain (8310) and its measurement (8307D), and the effect of various protective treatments on grain quality (8314).

The formulation and implementation of the ACIAR Grain Storage Research Program has been achieved by contracting with the CSIRO Division of Entomology for a project covering Program Co-ordination, a Research Information Network, and conduct of workshops (Project 8312).

Project 8312 will provide an operational framework for the development and co-ordination of ACIAR's activities in the grain storage area. This is seen as an essential component of the program in maximising its effectiveness both in terms of use of resources and research output. It has an initial duration of 3 years.

GRAIN STORAGE RESEARCH PROGRAM

Objectives of Project 8312

Program Co-ordination and Research Information Network

1. To develop and co-ordinate a program of research to ensure grain can be stored safely.
2. To develop a Grain Storage Research Information Network with participation by all relevant organisations in Australia and overseas.
3. To publish a regular newsletter to disseminate information.
4. To provide a literature search and information retrieval facility.
5. To conduct workshops as appropriate in co-operation with local organisations and publish proceedings of these workshops.
6. To produce, as required, publications relevant to grain storage in developing countries.

The Grain Storage Research Information Network and associated activities will materially increase the availability of information on existing technology to relevant organisations in South East Asia, expedite conduct of the ACIAR program, increase the impact of the program in overcoming storage problems in the area, and facilitate co-operative activities both within the ACIAR program and with other groups working in the same general field.

ACIAR GRAIN STORAGE RESEARCH PROGRAM

Objectives

1. To develop initially a program of core projects relevant to expressed needs of developing countries for safe storage of grain in tropical climates, specifically:—
   (i) The drying in bulk storage of high moisture grains in tropical climates.
   (ii) Long term storage of grain under plastic covers.
   (iii) Integrated use of pesticides in grain storage in the humid tropics.
2. To support the core program with basic studies on:—
   (i) Moisture movement in grain.
   (ii) Ad hoc aspects of pesticide relationships in integrated pest control systems, viz:
   - kinetics of decay of candidate pesticides for integrated control programs,
   - prediction of potential for development of pesticide resistance to candidate materials,
   - behaviour of fumigants in grain.
3. To develop the technology for application in the first instance in the Philippines and Malaysia but to include other countries, specifically Indonesia and Thailand, when appropriate.
4. To carry out cost-benefit studies of the relevance of the program to the needs of the developing countries.
5. To carry out feasibility studies on the transition from bag to bulk handling.
6. To develop a Grain Storage Research Information Network relevant to the needs of the program and to promote interchange among groups participating in the program or with common interests.

Core Projects

The grain drying project (Project 8308) is a joint research project of the University of New South Wales and Ricegrowers' Co-operative Mills Ltd. The University is responsible for studies on the principles of drying (Project 8308A) and the Co-operative for the application technology (Project 8308B).

The project on long term storage of grain under plastic covers (Project 8307) is contracted in Australia with the CSIRO Division of Entomology. Work on integrated use of pesticides is another joint research effort. The Queensland Department of Primary Industries is responsible for biological and toxicological aspects (Project 8309), and the CSIRO Divsion of Entomology for studies of the kinetics of decay of the candidate pesticides (Project 8311).

All projects extensively involve research institutions in Malaysia, the Philippines, and Thailand. Agreement has been reached on specific activities in all countries and the cooperating institutions and individuals have been identified. Memoranda of Understanding have been exchanged with the Philippines and Thailand, and project activities have commenced. Initial activities are directed to a detailed definition of the local grain handling and storage systems, assembly of all relevant data available, precise specification of problems, determination of research methodology, procurement of equipment, and establishment of research facilities.

The first of the Philippines and Thai project personnel have visited Australia for familiarisation and advanced training in the Queensland Department of Primary Industries, the University of New South Wales, and Ricegrowers' Co-operative Mills Ltd. Memoranda of Understanding with Malaysia have not yet been completed.

Support Projects

In addition to the collaborative research in Australia and South East Asia in each core project, further support research is required in a number of specialised areas. These support projects include studies on the responses of pests to the altered atmospheres contained in grain stored under plastic covers (Project 8307B, CSIRO Division of Entomology), the movement of moisture by the natural convection processes that occur during such storage (Project 8310, CSIRO Division of Chemical and Wood Technology), and any changes in grain quality that may result (Project 8314, CSIRO Wheat Research Unit). Techniques for remote monitoring of grain moisture and moisture relationships within sealed storaged are also receiving attention (Project 8307D, CSIRO Division of Entomology).

Proposed Economic Studies

There are significant moves to bulk handling in the grain industries of most of the South East Asian countries involved in the Program and indeed it is stated national policy to incorporate bulk handling into their storage systems. It is essential that the technology be introduced on a sound basis that takes into account local conditions. The technology is not well-researched for application in the humid tropics and while the ACIAR program will provide information on which to base the necessary changes, detailed feasibility studies are essential if costly mistakes and losses of foodstuffs are to be avoided.

A project proposal for a study on the transition from bag to bulk handling of paddy (unhulled rice) and rice in Malaysia is being developed as part of the ACIAR Socio-Economic Program. It is hoped to extend this, as opportunity permits, into the handling of other commodities in the Philippines.

Studies of the social and economic impact of proposed changes in grain handling and storage technology will be an integral part of the ACIAR Grain Storage Research Program.

GRAIN STORAGE RESEARCH PROGRAM

Projects, Collaborators, and Commencement Dates

8307*	Long term storage of grain under plastic covers A. Field assessment B. Effects of low carbon dioxide atmospheres on insects C. Moisture regimes of bulk commodities.	
	CSIRO[1] Division of Entomology, Australia	4/11/83
	MARDI[2], Malaysia	†
	NAPHIRE[3], Philippines	6/6/84
	Department of Agriculture, Thailand	1/5/84
8308*	Drying in bulk storage of high moisture grain	
	A. Principles — University of New South Wales, Australia	24/5/83
	B. Application technology — Ricegrowers' Co-operative Mills Ltd, Australia	25/3/83
	MARDI, Malaysia	†
	NAPHIRE, Philippines	23/8/83
	King Mongkut's Institute of Technology, Thonburi, Thailand	6/7/84
8309*, 8311	Integrated use of pesticides in stored grain in the humid tropics Biological and toxicological aspects (8309)	
	Queensland Department of Primary Industries, Australia	5/4/83
	MARDI, Malaysia	†
	NAPHIRE, Philippines	23/8/83
	Kinetics of decay of candidate pesticides (8311)	
	CSIRO Division of Entomology, Australia	30/7/84
	An Australian University	†
	MARDI, Malaysia	†
	NAPHIRE, Philippines	†
8310	Moisture movement in grain	
	CSIRO Division of Chemical and Wood Technology, Australia	3/5/83
8314	Effect of controlled atmospheres on quality of stored grain	
	CSIRO Wheat Research Unit, Australia	11/7/84
	NAPHIRE, Philippines	†
8312	Program co-ordination and Research Information Network	
	CSIRO Division of Entomology, Australia	13/3/83

* Core Project † Agreement not yet signed

1. Commonwealth Scientific and Industrial Research Organization
2. Malaysian Agricultural Research and Development Institute
3. National Post Harvest Institute for Research and Extension

Closely related to this is the objective assessment, by cost-benefit studies, of the relevance of the ACIAR Grain Storage Research Program and its component technologies to the needs of developing countries and to the order of priority for attending to these. These studies involve some measure of (a) the losses that are occasioned by the problems addressed by the program, (b) the appropriateness, acceptability, and efficacy of the technologies developed to overcome the problems, and (c) the social and economic impact of proposed changes. The development of suitable methodology and generation of meaningful data will require specific case studies. These will be available from feasibility studies of bulk handling in Malaysia.

Review of Research and Related Activities

In the short time since its inception the program has established itself as a significant research resource in the South East Asian area and, through the development of new and soundly based technology, is providing a framework for systems for safe storage of grain that will have application in many parts of the world. A major factor in the success of the program will be the high calibre of the research staff selected to participate in it.

Research on Schedule

Research activities in Australia are approximately on schedule allowing for unavoidable delays in finalising agreements between ACIAR and the contracting organisations. These delays have led to revision of target dates for completion of some projects.

All staff concerned with the grain drying and the pesticide projects have been deployed or appointed to project activities. There have been delays in appointments of staff to Project 8307 (Long Term Storage of Grain Under Plastic Covers), arrangements for which were not finalised until 4 November 1983.

There have also been delays in finalising the chemical support (Project 8311) for the pesticide project (Project 8309).

Pilot Plant Studies Suggest Drying Strategies

Studies are in progress with the pilot drying plant at the University of New South Wales and with quality assessment of aeration and drying strategies at Ricegrowers' Co-operative Mills (Project 8308).

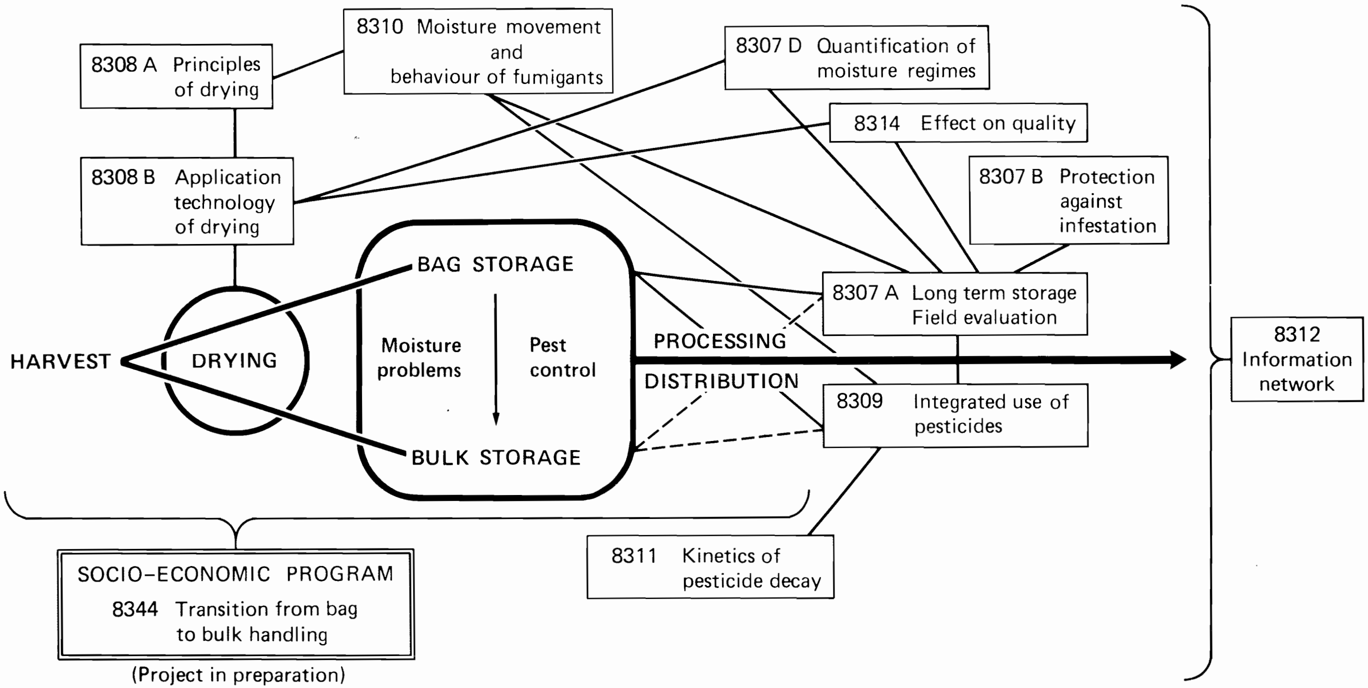
Practical results have already emerged from the work on grain drying. The findings of pilot drying bin studies, coupled with an examination of long-term weather records, have shown that during the dry season harvest in the Philippines, grain harvested at moderate moisture contents could, in fact, be dried using ambient air. For the wet season harvest, however, supplemental heating will be necessary.

Because of the high grain moisture contents at receival in the Philippines, supplemental

The development of irrigation systems to allow the growing of a second, dry season crop has added to the stresses faced by storage systems in some parts of the South East Asian region.

ACIAR GRAIN STORAGE RESEARCH PROGRAM

Safe Storage of Grain in the Tropics — Projects 8307 – 8312, 8314, 8344



Research strategy - Safe Storage of Grain in the Tropics heating will, in practice, be needed in both seasons. A two stage or 'combination drying' system for grain, in which a fast drying stage is followed by unheated or minimal-heat air drying in storage, has been proposed for that country.

One-stage Drying of Grain a Possibility in Thailand

Project work in Thailand has assessed, by computer simulation, the extent of supplemental heating that will be required to dry grain under various weather conditions. Under average conditions as determined from long-term weather records, ambient air must be heated by from 0.5 to 1.7°C to dry grain. Under the worst conditions recorded, a temperature rise of up to 5.2°C will be needed. Nevertheless, these and other findings suggest that it may be possible to consider a one-stage drying process in Thailand. Pilot drying bin studies currently under way will clarify this.

Capacitance Moisture Sensors Developed

Capacitance moisture sensors have been developed as part of Project 8307D. They are being subjected to a rigorous test program in the laboratory and, with the cooperation of Bulk Grains Queensland and the Queensland Department of Primary Industries, some 20 have been installed in storages for evaluation under field conditions. Early results are most promising, with the devices appearing to be both sensitive and stable.

Effects of Moisture on Pesticide Efficacy Revealed

Experiments in the pesticide project (Project 8309) have revealed dramatic differences in the efficacies of different compounds used on high moisture grains. For example, the potency of fenitrothion measured in terms of mortality of young adults of *Tribolium castaneum* exposed for 3 days at 25°C to treated grain of 18% moisture content was less than one-fifth its potency on 10% moisture content grain.

Insecticide Potency Varies with Grain Species

There have also been interesting revelations from studies of pesticide efficacy on different grain species. Comparison of the potencies of a range of candidate grain protectants on maize and wheat at 14% moisture content indicated that fresh deposits of most chemicals are about twice as potent on maize as on wheat.

Enhanced Understanding of Moisture Movement

Although in much more abstract terms, considerable progress has also been made in studies of moisture movement in grain (Project 8310). Mathematical analyses have considerably enhanced understanding of the basic heat and mass transfer phenomena that occur in bag and bulk stored grain.

Research Information Network Develops Rapidly

The Research Information Network, part of Project 8312, has developed rapidly.

The first *ACIAR Grain Storage Newsletter* was published in May 1984 and numerous literature searches have been carried out for program personnel both in Australia and overseas. Two internal workshops for program personnel have been held and strategic visits by non-project personnel have been funded within South East Asia in support of program objectives.

The program has maintained direct involvement in the ASEAN Food Handling Sub-Committee's Grains Working Group, the ASEAN Crops Post-Harvest Programme, GASGA, the International Working Conferences on Stored Product Protection, and the *Journal of Stored Product Research*. Two seminars in South East Asia are planned for 1985, one concerning pesticides, the other aeration and in-store drying of grain.

GRAIN STORAGE RESEARCH PROGRAM

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Long Term Storage of Grain under Plastic Covers (Project 8307)

A. The field assessment of grain storage in sealed plastic enclosures
B. The effects of relatively low (<40%) carbon dioxide atmospheres on insects

Commissioned organisation — CSIRO Division of Entomology

Background

Large amounts of grain and similar commodities stored in the tropics are held in warehouses as uncovered stacks of bagged product. Insect control in bag stacks is a difficult and often expensive operation, usually consisting of repeated fumigations and regular spraying or fogging with insecticides. Such treatments often leave survivors that may form a basis for future resistance to the control measures.

Research work carried out by the CSIRO Division of Entomology on a variety of sealed storages in Australia and in tropical areas overseas has shown that, after an initial disinfestation by fumigation (with either carbon dioxide or a conventional fumigant), grain will remain free of detectable insects and of good quality for periods of several months without any further treatment.

A method has been developed for the disinfestation and prolonged storage of bag stacks under sealed plastic sheeting after an intitial disinfestation with carbon dioxide (CO_2). The recommended dosage regime for disinfestation is an initial CO_2 content of greater than 80% which remains greater than 35% for longer than 10 days. In limited field trials in Australia, Indonesia, and Papua New Guinea, this process has been shown effective for the storage of infestable commodities including milled rice for up to 4 months under tropical conditions. These trials have also shown that relatively low contents of CO_2 (between 10% and 35%) are maintained in the enclosure for long after the disinfestation period and that these contents may themselves be of value in disinfestation and prevention of reinfestation.

For the process to become acceptable for wider routine use, it is necessary to understand some of the basic biological principles involved and evaluate it in extensively replicated and well-managed field trials. This project was developed to carry out these field trials and to provide the necessary laboratory research support that would define the parameters for design of a successful technique.

The project will be carried out in cooperation with research and grain handling authorities in Malaysia, the Philippines, and Thailand, and will be extended as appropriate to Indonesia. The work in Malaysia will involve the Malaysian Agricultural Research and Development Institute (MARDI) and the National Paddy and Rice Authority. In the Philippines, it will involve the National Post Harvest Institute for Research and Extension (NAPHIRE) and the National Food Authority. In Thailand, it will involve the Entomology and Zoology Division of the Department of Agriculture.

Expected Benefits

1. The development of a reliable method of storing bagged commodities, free from insect infestation, that does not require the repeated use of chemicals.
2. A reduction in quality degradation of commodities during long term storage in tropical areas.

Work in the field will be supported by parallel laboratory studies to develop a quantitative model of the toxic effects of carbon dioxide over levels ranging from those found in the normal environment of the insects (up to 10% CO_2), through currently advocated minimum effective contents (35–40%), and on to 100%, and to define the protective value of low carbon dioxide levels in sealed storages. This knowledge will help in optimising treatment regimes and the degree of sealing of the storage that is required.

Project Objectives and Operational Schedule

The field trials already carried out by the CSIRO Division of Entomology in Australia, Indonesia, and Papua New Guinea, supported by further trials carried out by the United Kingdom Tropical Development and Research Institute with Badan Urusan Logistik (BULOG) at Tambun in Indonesia, and commercial experience in China, confirm the potential of the method of storing bag stacks of infestable commodities.

It is essential that an evaluation be made of the reliability of the method over the wide range of conditions that would be encountered in commercial use. Moreover, the design parameters must be precisely defined taking into account such factors as moisture, optimal sealing, and dosing levels for pest suppression and quality maintenance.

The objectives of the project thus include the following:

1. To determine the applicability of plastic covers for storage of grain in warehouses and in the open.
2. To liaise closely with Project 8310 on Moisture Movement in Grain to optimise consideration of moisture as a storage constraint.
3. To determine design and size of enclosure, maximum permissable moisture contents, and storage periods.
4. To carry out field evaluation in Australia, Malaysia, the Philippines, and Thailand, and to liaise closely with BULOG, Indonesia in similar activities.

The initial program is to concern bagged food and feed grains but will involve support research relevant to both bagged and bulk grain. Four areas of study have been identified.

(a) The field assessment of grain storage in sealed plastic enclosures (Project 8307A).

which will require support research on:

(b) The protection against infestation offered by relatively low (less than or equal to 40%) CO_2 atmospheres (Project 8307B).

(c) The effects of controlled atmospheres on the quality of stored grains (Project 8314).

(d) Quantification of moisture regimes in stored grain and related commodities (Project 8307D)

Subject to satisfactory realisation of objectives 1 - 3 of this project and the objectives of Project 8310, this project would be expanded to include storage of seed and bulk commodities under plastic covers.

The planned duration of Project 8307 is 3 years.

Field Studies

Specific objectives for the field studies (Project 8307A) are:

1. To determine the reliability of the sealed sheeting method of storage, in terms of protection from reinfestation by insects and maintenance of the quality of rice and other commodities.
2. To monitor gas holding and humidity within the stacks during the storage period, as a means of detecting adverse changes within the atmosphere contained in the enclosure.

To achieve these objectives, a series of four trials will be carried out in each of the overseas participating countries.

During the course of 4 periods of 6 months, a total of about 25 stacks (each 100-200 tonnes) of bagged grain, mainly milled rice but including paddy (unhulled rice), will be used for evaluation of the enclosure techniques. Samples of the grain will be analysed for pre-trial quality and insect infestation. The stacks will then be sheeted, the level of sealing tested, and the stack fumigated with CO_2. Batches of test insects for bioassay will be included as appropriate.

During the storage period, the enclosure fabric will be inspected regularly and CO_2 levels, temperature, and relative humidity recorded within the stack. Insect trapping will take place in covered untreated stacks and treated stacks to assess the reinfestation pressures after CO_2 concentrations have fallen below a nominal level.

Batches of stacks will be opened at predetermined intervals and assessed for changes in quality (moisture, mycotoxins, and user assessment) and insect infestation. If the quality is unchanged at a given opening time, the balance of the stacks will remain sealed until the next opening time. Comparison of the covered stacks with unsealed stacks will give an objective measure of the advantages of the method. If reinfestation occurs, the relationship between degree of gastightness and reinfestation will be examined.

The schedule of trials will consist of 4 experiments starting at intervals of 6 months. The first two experiments are to investigate shorter term storage (2–9 months) of milled rice. These two experiments are designed to replicate each other in time. Experiment 3 is designed primarily to study long term storage (6–12 months). Experiment 4 is to study grains other than rice. The actual timing of the opening of stacks will be under continuous review and will depend on the results of quality analysis of samples for previous stack openings. Trapping studies will be carried out in stacks that have decayed to very low CO_2 concentration during experiments 2, 3, and 4.

Experiments on grain storage in sealed enclosures made of plastic sheeting have been carried out at a number of locations. This enclosure, containing bagged, milled rice, is at Griffith, New South Wales. ACIAR Project 8307 seeks to realise the full potential of this form of storage in the region.

Experiment 1 on short term storage will be established six months after the start of the project and stacks sampled at five, two-monthly intervals until completion of the experiment. Test cultures will be placed in stacks after 4–6 months storage, and insect traps after 6–8 months storage.

Experiment 2 will be established at the beginning of the second year and essentially will repeat experiment 1.

Experiment 3 on long term storage will be established 18 months after commencement of the Project and will continue for approximately 12 months, again with test cultures and traps inserted during the course of the trial.

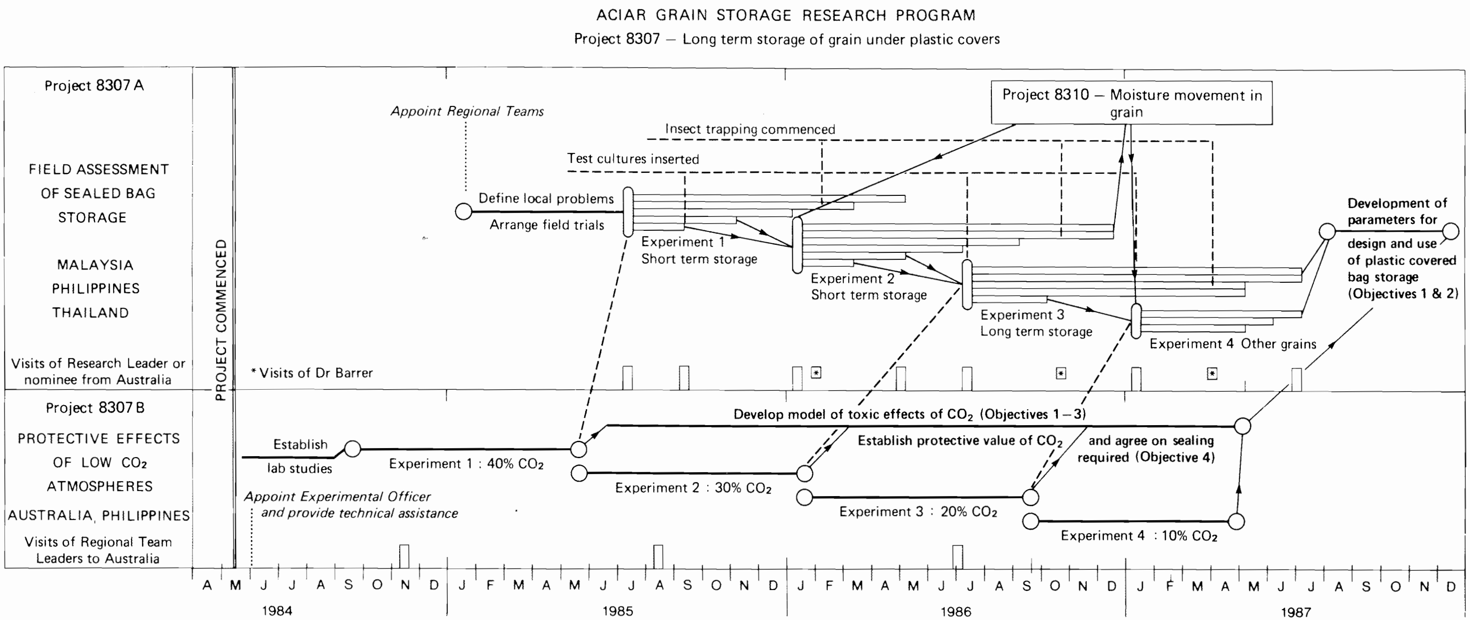
During the third year of the project, experiment 4 will evaluate the technique for commodities other than milled rice, paddy, and maize.

Additional stacks, as available, will be established in each experiment, and fully instrumented for measurement of temperature and moisture profiles, which will be used in the development of models for moisture movement (Project 8310) with the object of determining optimal storage conditions.

Laboratory Studies

Specific objectives of the laboratory studies (Project 8307B) are:

1. To quantify the response of various developmental stages of some of the insect pests of stored grains to relatively low CO_2 contents.
2. To confirm laboratory results in parallel field assessment of mortality with the stacks used in Project 8307A.
3. To integrate these data with those currently being obtained for high CO_2 contents, and thus contribute to the development of an overall quantitative model for the toxic response of insects to CO_2.
4. To produce an optimal dosage regime for the use of CO_2 and thus to determine the degree of sealing required to maintain this regime.



Research schedule - Project 8307

These objectives will be achieved by a series of experiments carried out in Australia and complemented with similar, but less comprehensive studies in other species, undertaken by NAPHIRE in the Philippines.

The data from Australia will be based on the responses of *Sitophilus oryzae* over a range of CO_2 contents between 10% and 40%. Batches of insects of known age will be exposed on grain in the laboratory to constant CO_2 contents for various time periods. The effects of this treatment will be assessed in terms of mortality, delay in adult emergence, and changes in fecundity.

Four laboratory experiments will be conducted sequentially, each involving the exposure of insects to one of four treatments: 40%, 30%, 20%, and 10% CO_2. Each experiment will take about eight months to complete. Results obtained midway through each experiment will be tested under field conditions using caged test cultures introduced into those stacks in the field trials whose CO_2 contents have decayed to the appropriate level.

Organisation and Staff

The Record of Understanding between ACIAR and CSIRO was signed on 4 November 1983.

Mr P.C. Annis, Experimental Officer, was nominated by CSIRO as Research Leader, Mr J. van S. Graver, formerly an Entomologist with the Papua New Guinea Department of Primary Industry, was appointed in May 1984 as an Experimental Officer to work jointly on both projects (8307A and 8307B), supervising overseas operations as required and carrying out laboratory experiments on the effects of low carbon dioxide atmospheres on insects. Dr P.M. Barrer, Senior Research Scientist, was nominated as a collaborator within the CSIRO Division of Entomology, to be responsible for insect trapping studies associated with the project.

Agreement for overseas operations in Thailand became effective with the Department of Agriculture, Thailand on 1 May 1984, as an Institute to Institute arrangement pending a formal Memorandum of Understanding between the governments of Australia and the Kingdom of Thailand. Agreement with NAPHIRE in the Philippines became effective on 6 June 1984, but finalisation of arrangements with MARDI have been delayed pending completion of a general agreement between the Government of Malaysia and ACIAR.

Research teams have been appointed in the Philippines and Thailand, and provisionally in Malaysia.

The leaders of these teams are:

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Thailand	Department of Agriculture	Mr Montri Rumakom/ Mr Chuwit Sukprakarn
Malaysia	MARDI	Mr Ahmad Robin Wahab

GRAIN STORAGE RESEARCH PROGRAM

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Mr Enrico Corvera, Team Leader
Ms Gloria Sabio, Entomologist

Thailand (Department of Agriculture)

Mr Montri Rumakom, Team Leader and Director of the Entomology and Zoology Division
Mr Chuwit Sukprakarn, Entomologist and Project Co-ordinator
Ms Lamaimaat Khowchaimaha, Agriculturist

Research Activities in Australia

The delays in appointment of the Experimental Officer precluded an effective start to the project until May 1984.

Assessments have been made of various

polyvinyl chloride (PVC) fabrics to select the material most suited for use in construction of the sealed enclosures. A nylon-reinforced PVC has been chosen and arrangements made for the supply of the necessary enclosures.

Research Activities in South East Asia

Mr Annis, together with the Program Coordinator, visited Malaysia, Thailand, and the Philippines during October 1983 to discuss Memoranda of Agreement covering project activities for those countries. As indicated earlier, arrangements for overseas operations were not finalised until May 1984 in Thailand, 6 June 1984 in the Philippines, and had not been concluded with Malaysia at the time this report was compiled.

Mr Annis visited Indonesia from 3-6 July 1983 to participate in the assessment of trials conducted by BULOG at Tambun in which rice had been stored in bag stacks for periods of up to 16 months.

Preliminary experiments on sealing bag stacks were carried out in Bangkok in June 1984. It did not prove practical to fabricate the sealed enclosures on site and arrangements were made for factory prefabricated covers to be sent from Australia. During this visit Mr Annis also visited Singapore to assist the Ministry of Trade and Industry and Intraco in local trials of sealed enclosures for rice storage.

PROJECT 8307D

Moisture Regimes of Bulk Commodities (Project 8307D)
Commissioned organisation—CSIRO Division of Entomology

Background

The rate of deterioration of a foodstuff in storage is determined to a considerable extent by moisture. Moisture related characteristics of many commodities and their associated organisms, however, are poorly understood. In particular, reports of the water relationships between commodities and their interstitial atmospheres are scattered through the literature and confined largely to static equilibrium conditions. These data differ widely and reflect, in addition to biological variability, the effects of hysteresis, the inappropriateness of static analysis of dynamic systems, the difficulty of measuring moisture, and the consequent diversity of experimental methods that have been employed.

While the moisture content of commodities themselves, rather than that of their interstitial micro-environments, has traditionally been of primary interest, the latter is more directly relevant to quality preservation and pest management procedures. Better understanding of the interaction of commodities with their immediate environment, particularly of moisture fluxes, the associated forces, and transport mechanisms, is therefore of considerable scientific and economic significance. This is especially the case in sealed and semi-sealed storage where the detrimental effects of biological activity and moisture movement are difficult to detect and may become cumulative.

No generally applicable methods are yet available for the precise *in situ* (remote) determination of the moisture content of bulk grain or similar commodities. Recent technology does, however, offer promise of good measures of the humidity of interstitial air. Coupled with improved understanding of the moisture relationships between the diverse range of commodities stored in bulk (grains, legumes, oil seeds, etc.) and their interstitial air, these measures offer non-intrusive monitoring of product quality, and early warning of the activities of deleterious organisms. As sealed and semi-sealed storage (e.g. plastic sheeted stacks, bunkers, or structures intended for use of controlled atmosphere or efficient fumigation) to which human access must be minimised, becomes more common, the importance of remote moisture monitoring will increase still further.

Successful conduct of the field trials in Project 8307A on storage of bag stacks under plastic covers depends on adequate monitoring of conditions in the sealed stacks, as indeed will any commercial developments of the technique. The objects of Project (8307D) are to provide adequate data on the water relationships of the commodities used in Project 8307A and to develop the monitoring techniques that will enable moisture changes to be followed during the course of the experiments.

Expected Benefits

1. Information on the moisture related properties of bulk stored food products will be collated and interpreted systematically in terms of standardised experimental and measurement procedures.
2. A test facility will be established to allow generation of the further data required to complete the data bank necessary for the studies on moisture related phenomena in Projects 8307, 8308, and 8310.
3. Techniques for *in-situ* measurement of interstitial atmospheric moisture will be developed that are compatible with general experimental work, mathematical modelling of the storage environment, and commercial usage.

Project Objectives and Operational Schedule

This project is designed to provide basic support to other ACIAR projects on matters relating to storage moisture characteristics and their measurement in cereal grains, legumes, and oil seeds.

Activities within this project include the following:—

1. (a) A comprehensive catalogue will be compiled to provide in readily accessible

form a listing of the diverse moisture sorption, desorption, and equilibria data at present scattered through the literature. (b) A critical assessment of existing data will be undertaken with a view to explaining differences and assessing their reliability, and pointing to the most appropriate techniques for quantifying moisture related variables of bulk stored commodities.

2. A standard test facility will be established and used to rectify deficiencies in the information emerging from the above and to improve its quality. Attention will concentrate on dynamic testing to provide, in addition to rapid determination of equilibrium parameters, information on non-equilibrium conditions, equilibration rates, and the forces involved.

3. A small dew-point sensor will be developed using newly available semiconductor peltier devices, to allow precise remote measurement of interstitial moisture, in order that the information derived above be directly applicable within the bulk storage industries.

4. Close contact will be maintained with Projects 8307, 8308, and 8310 in both theoretical and practical development of moisture control technology in stored grain.

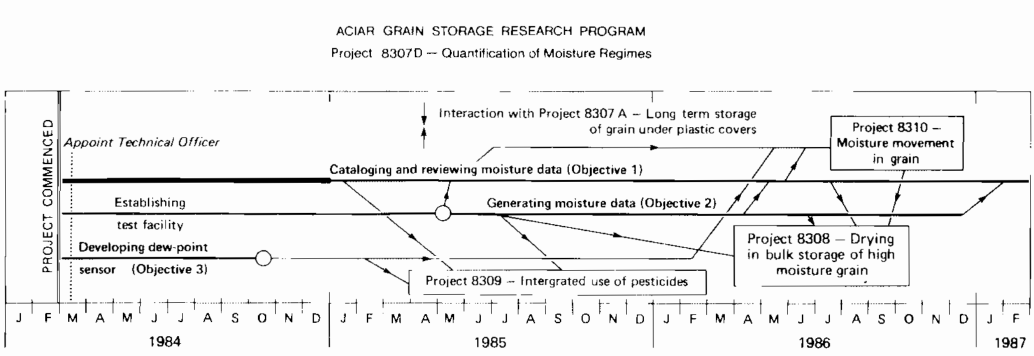
The project has a term of 3 years.

Emphasis is being given to the cataloguing and appraisal of existing data during the first year of the project but will continue throughout its term (Objective 1).

The test facility for determining commodity moisture characteristics will be fabricated, also during the first year, and then operated continuously thereafter throughout the project to generate the required data as outlined for Objective 2. The facility will enable moisture-conditioned air to be passed through commodity samples to determine their rates of moisture uptake and release. Variables will be monitored and controlled by a microcomputer so that test conditions imposed on samples may be varied according to the samples' responses.

The integration of computer managed measurement and programmable control of the micro-environmental chambers will allow automatic adjustment of the test conditions in the light of progressive results, and hence rapid determination of both dynamic and equilibrium moisture properties of samples. The computer will also engage in real-time analysis and the mathematical modelling of its findings.

The development of a cheap, robust, dew-point sensor for *in situ* atmospheric moisture measurement (Objective 3) will follow evaluation of the few commercially available possiblities. In essence, the temperature at which dew (frost) is formed on a cooled heat



Research schedule - Project 8307D

sink is determined and used either directly as a measure of absolute water concentration or, in association with ambient temperature, to define relative humidity or water activity. This approach to precision moisture measurement is not new, but it is only recently that the availability of cheap semiconductor devices for cooling and for sensing and controlling temperature has encouraged its application outside the laboratory.

Organisation and Staff

The Record of Understanding between ACIAR and CSIRO was incorporated in the Record covering Project 8307A which was signed on November 1983. Mr J.R. Wiseman, Experimental Officer, was nominated by CSIRO as Research Leader. Mr S.A. Rogers, was appointed on 28 March 1984 as Technical Officer to commission and operate the standard test facility for determining commodity moisture characteristics and generally assist in project activities.

A six-month delay in appointment of a Technical Officer was partially offset by employing casual assistance.

Research Activities in Australia

The delays in the appointment of the Technical Officer precluded an effective start until March 1984.

Commodity Moisture Characteristics Data Bank

Data pertaining to moisture exchange characteristics of a diverse range of agricultural commodities have been obtained by numerous researchers using differing apparatus and techniques. Cataloguing this information in a systematic manner has commenced and will continue as material becomes available.

Generation of Commodity Moisture Characteristics Data

The test facility for determining the uptake and release moisture characteristics of commodities has been operated in prototype form and after extensive delays in acquiring equipment, is expected to be fully operational on schedule within three months.

The apparatus consists of a number of monolayer and bulk sample chambers through which conditioned air is circulated. Thirty-two samples can be accommodated. Each of them can be subjected, under microprocessor control, to independently programmable air flow rates and temperature and moisture regimes. Moisture uptake and release are measured using a pair of precision dew-point meters, monitoring downstream and upstream of the samples, with the expensive meters being shared among the sample chambers under the microprocessor control.

Development of Remote Measuring Sensors

Two types of temperature/moisture sensors have been investigated, one employing a capacitance-sensitive device responding to water molecules in grain, the other a dew-point detector for determining the moisture content of interstitial atmospheres. Although the latter has proven most successful in laboratory trials, it costs about $Aust.45. The capacitance-sensing devices are far cheaper (about $Aust.12) and some hundreds have been constructed for evaluation.

The capacitance moisture sensors are being subjected to a rigorous test program in the laboratory and, with the cooperation of Bulk Grains Queensland and the Queensland Department of Primary Industries, 20 have been installed in storages for evaluation under field conditions. Early results are most promising, with the devices appearing to be both sensitive and stable.

GRAIN STORAGE RESEARCH PROGRAM

Project 8307D Staff

Australia (CSIRO Division of Entomology)

Mr S.A. Rogers, Technical Officer
Mr J.R. Wiseman, Research Leader

PROJECT 8308

The Drying in Bulk Storage of High Moisture Grains in Tropical Climates (Project 8308)
A. Principles
Commissioned organisation — University of New South Wales
B. Application technology
Commissioned organisation — Ricegrowers' Co-operative Mills Ltd

Background

Drying is the most effective method of preservation of grain in storage. Time of drying (pre- and post-harvest) and methods used vary widely. Methods developed for in-store drying of paddy in Australia have proven very successful for local conditions. They are cost efficient and have yielded significant commercial gains in terms of improved grain quality.

The research effort supporting these developments has been carried out jointly over the past five years by the School of Food Technology of the University of New South Wales and at Ricegrowers' Co-operative Mills Ltd, Leeton, New South Wales. Research on the theory and principles of drying has been the responsibility of the University, with the Co-operative's effort concentrating on commercial verification of research findings and application of the technology.

The success of this joint venture suggested that a similar research effort, built upon the expertise and research equipment and facilities of the two organisations, would provide a basis for extending the technology into the humid tropics. Accordingly, a project was developed with responsibility shared as previously between the University and the Co-operative, but also including overseas research teams. Its aim is to study the needs of particular countries and the potential for in-store and batch drying using ambient aeration, and to carry out pilot-plant experiments and field trials under various tropical conditions.

Overseas activities have been confined to Malaysia, the Philippines, and Thailand. The principal collaborators are the National Paddy and Rice Authority (Lembaga Padi Dan Beras Negara, LPN) in Malaysia, the National Post Harvest Institute for Research and Extension (NAPHIRE) of the National Food Authority in the Philippines, and King Mongkut's Institute of Technology (KMIT) at Thonburi in Thailand.

Expected Benefits

1. The development of in-store drying methods for paddy (unhulled rice), maize, and other grains, that reduce losses and maximise both quality on outturn and yield in any subsequent processing.
2. A basic knowledge of the characteristics of grain bulks and the movement of moisture and temperature profiles through grain during drying. This will allow application of the technology to drying and storage in all tropical countries. Drying controllers appropriate for local conditions will be designed and commissioned in each of the countries concerned.
3. Applicability of the system for multiple use of a facility for a range of grains at different times of the year, e.g. paddy, maize, and legumes.
4. Development of technology for use of rice hulls and solar energy as energy sources where preheating of ambient air is required.
5. Potential for development of central monitoring systems for storage conditions and stock assessment.

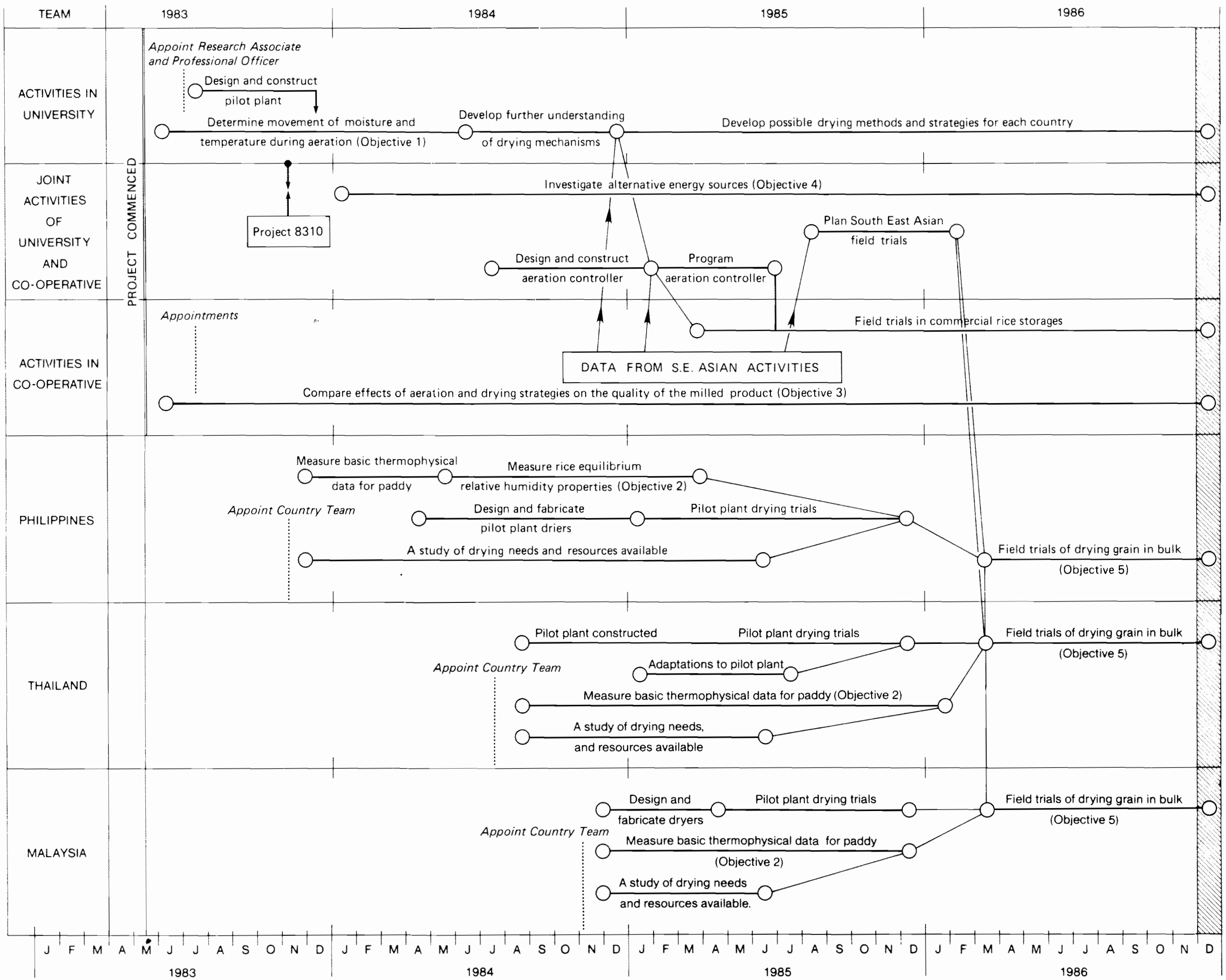
Project Objectives and Operational Schedule

The project is designed to investigate safe methods of drying grain in tropical countries, either by batch driers or more particularly in aerated bulk storage. In Australia, where the technology was originally developed, little or no supplementary heating is required. Drying strategies involve low flow rates of air and have low energy requirements, and the method is therefore very cost effective. In humid tropical countries, however, supplementary heating is necessary. Moreover, undried paddy deteriorates much more quickly than under Australian conditions.

For these reasons, a sound theoretical understanding of the heat and mass transfer processes occurring in a grain bed is required and it is necessary to simulate the movement of drying fronts in computer models. These simulations must be compared with data obtained from rice drying in pilot plants,

ACIAR GRAIN STORAGE RESEARCH PROGRAM

Project 8308 — Drying in Bulk Storage of High Moisture Grain



Research schedule - Project 8308

and with basic data relating to grain properties such as water activity levels, drying rates of thin layers of grain, physical properties such as grain size, grain types, and with weather records from the various tropical countries. These data are the input for the models to optimise rate of movement of moisture drying fronts and so the development of safe drying methods.

The objectives of the project thus include the following:-

1. A study of the movement of moisture and temperature profiles through bulk stored grain when aerated and dried under various conditions.
2. Measurement of basic thermophysical data for paddy and other grains, relevant to the design of bulk storage/drying facilities for tropical climates.
3. A study of the effect of various aeration and drying strategies on the quality of stored paddy and other grains.
4. A study of various energy sources (rice hulls, solar energy, etc.) as a means of improving the drying of stored grain.
5. Field trials in Australia, Malaysia, and the Philippines of the procedures developed in this project.

The Project has a duration of 3 years.

It was planned that Objectives 1-3 be achieved within the first year of the Project by the University (Objective 1), the country teams (Objective 2), and the Co-operative (Objective 3). These studies would provide data to enable estimation of the movement of temperature and moisture profiles through bulk grain in tropical climates and thereby permit prediction of the effects on grain milling quality.

During the second year, pilot plant driers will be tested by the country teams in South East Asia, while joint field trials on commercial rice bins will be carried out in Australia by the Co-operative and University. The data obtained will be used to improve the models describing the drying mechanisms. Additionally, the University and Co-operative, in collaboration with the country teams, will investigate alternative energy sources for providing supplemental heating during drying (Objective 4).

At the end of the second year, all of the pilot plant work on development of drying methods will be completed and detailed planning of South East Asian field trials will be finished. Controllers to implement the required drying program will be completed for delivery to South East Asia.

During the third year of the Project, field trials will be carried out in all countries, to test and improve the method (Objective 5).

By the end of the third year, it is anticipated that grain will have been dried in bulk storages in Malaysia, the Philippines, and Thailand.

Organisation and Staff

The Record of Understanding between ACIAR and the University of New South Wales (Project 8308A, Principles) was signed on 25 May 1983, and between ACIAR and Ricegrowers' Co-operative Mills Ltd (Project 8308B, Application Technology), on 25 March 1983.

Dr R.G. Bowrey, Senior Lecturer, was nominated by the University of New South Wales as Research Leader for Project 8308A (Principles). Dr R. Driscoll was appointed to an ACIAR-funded position in the University as a Research Associate on 18 July 1983, to be primarily responsible for developing the theoretical understanding of the drying mechanisms and for computer software used in the project. Mr T. Adamczak was appointed as a Professional Officer on 4 August 1983, also to an ACIAR-funded position, to be primarily responsible for the pilot plant equipment. Mr Mohd Mochtar, a chemical engineer from Indonesia, has been carrying out postgraduate studies within the project on the drying of grain in bulk storage in tropical climates.

Dr Bowrey resigned from the University effective 17 June 1984 and was replaced by Dr R. Driscoll as Research Leader.

GRAIN STORAGE RESEARCH PROGRAM

Project 8308 Staff

Australia (University of New South Wales)

Mr T. Adamczak, Professional Officer
Dr R.G. Bowrey, Research Leader (until 17 June 1984)
Dr R. Driscoll, Research Leader (from 18 June 1984)
Mr Mohd Mochtar, Postgraduate Student

Australia (Ricegrowers' Co-operative Mills Ltd)

Mr L.D. Bramall, Research Leader (from 23 February 1984)
Mr R. Corner, Research Assistant
Mr J. Darby, Storage Research Officer
Mr M. Goldring, Research Leader (until 22 February 1984)
Mr G. Pym, Project Supervisor

Malaysia (LPN)

Mr Loo Kau Fa, Team Leader

Philippines (NAPHIRE)

Mr Justin Tumambing, Team Leader

Thailand (King Mongkut's Institute of Technology)

Dr Ratana Putranon, Team Leader
Dr Somchart Saponronnarit
An M.Sc. student

Mr M. Goldring, Technical Services Manager, was nominated by Ricegrowers' Co-operative Mills Ltd as Research Leader for Project 8308B (Application Technology). Mr L.D. Bramall, Development Manager (Technical) was also nominated to the project on a part-time basis as Project Supervisor. Mr G. Pym was appointed on 4 July 1983 as an ACIAR-funded Development Engineer to be primarily responsible for the design and construction of pilot aeration facilities and for trials to test the effect of various aeration strategies on the quality of the paddy and rice milled from it. Mr R. Corner was seconded to the project as a full-time ACIAR-funded Research Assistant on 4 July 1983.

Following the resignation of Mr Goldring from the Co-operative on 22 February 1984, a reorganisation of personnel assigned to the project was necessary. Mr L. Bramall, as the new Technical Services Manager of the Co-operative, was nominated Research Leader. Mr G. Pym, in promotion to Development Manager (Technical), assumed the part-time position of Project Supervisor on 9 April 1984 when Mr J. Darby took up appointment as Development Engineer (redesignated Storage Research Officer).

Agreements for overseas operations became effective with NAPHIRE in the Philippines on 22 November 1983 and with King Mongkut's Institute of Technology in Thailand on 6 July 1984. Finalisation of arrangements with LPN in Malaysia has been delayed pending completion of a general agreement between the Government of Malaysia and ACIAR.

Research teams have been appointed in the Philippines and Thailand and provisionally Malaysia. The leaders of these teams are:

Philippines	NAPHIRE	Mr Justin Tumambing
Thailand	KMIT	Dr Ratana Putranon
Malaysia	LPN	Mr Loo Kau Fa

Research Activities in Australia

Simulation Models of Grain Drying

During drying, moisture and temperature fronts move through grain bulks at speeds which are dependent on inlet air conditions, flow rate of air, and grain conditions, and when the inlet conditions vary, successive fronts propagate at different speeds. Computer simulations allow the many possible situations in grain drying to be studied quickly and accurately.

There are at present three computer simulation models of grain drying being studied at the University of New South Wales. The first is a complex model based on non-equilibrium transport and transfer theory, developed by Dung, a Ph.D. student at the

University, from the work of Whittaker at the University of California at Davis. Although this model is accurate, it requires large amounts of computing time. A faster model was needed.

The next model developed was based on work by Sutherland, Banks, and Griffith in 1971. It is based on the conservation equations of heat and mass applied to a differential unit of the bed, assuming both thermal and moisture equilibrium between the grain and the air. The model was extremely fast but, because of its assumptions of heat and mass equilibrium, of only reasonable accuracy and reliability. Nevertheless, it was very beneficial for the development of a greater understanding of grain drying.

Consequently, a further model was constructed, based on the development in the United State of a third line of approach, which was to assume that there was thermal equilibrium between the grain and drying air, but not moisture equilibrium. Instead, an equation relating the change in moisture content of the grain to the air variables at each point in the bed was incorporated. This form of approach has been called the near-equilibrium model.

The third model has shown good agreement with the model developed by Dung and with other experimental and theoretical work reported in the literature. It is capable of simulating varying inlet conditions and a non-uniform initial bed state. It also enables a wide variety of drying strategies to be tested, and has therefore enhanced the growth understanding of the complex interactions between moisture and temperature fronts which occur in a grain bed.

Pilot Drying Bin Studies

The theoretical simulations of the drying process must be tested at pilot scale to confirm the models being developed and to verify the design of field trials of in-store drying. Initially, pilot drying bins will be

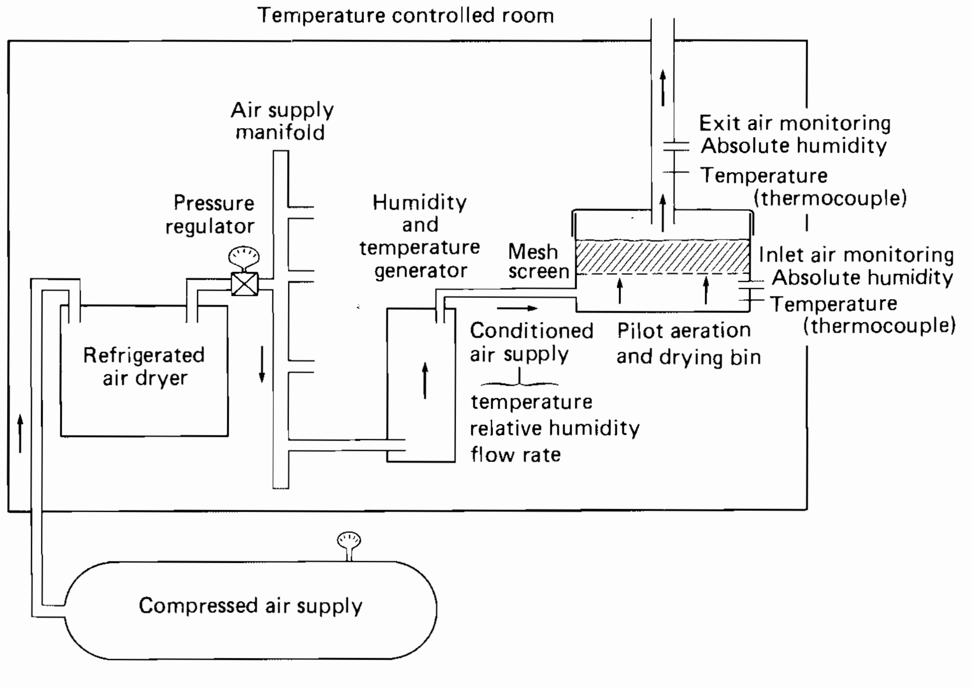


Diagram of the pilot aeration facilities established at Ricegrowers' Co-operative Mills in Leeton, New South Wales to determine the effects of various drying strategies on grain quality.

operated at the University and the Co-operative, and subsequently at each of the overseas collaborating institutions.

The first, a 1-tonne experimental paddy bin, 1 m in diameter by 2 m high, has been commissioned at the University to provide, in the first instance, experimental data on front speeds. The bin is insulated with fibreglass wool to prevent thermal loss through the bin walls and is connected to a conditioning system which will allow the air conditions to be held constant or varied continually to simulate climatic conditions likely to be present in South East Asia. The unit has the following capacity:

flow rate of air	1 to 20 m^3/min
temperature	10° to 45°C
relative humidity	10 to 90%

Provision has been made to measure temperature using thermocouples, moisture content using sensors or by sample removal using specially designed probes, temperature and relative humidity of the air moving into and out of the bin, and air flow rate.

The equipment has been tested at high- and mid-range flow rates for ambient air drying simulations in preliminary evaluation of the theory described in the previous section.

Acquisition of Weather Records

Because of the influence of inlet air conditions on front speeds, it was necessary to study the climatic conditions in the regions in which the grain to be dried is stored. Weather records for Australia and Thailand for the last 20 years have been obtained on computer tape, together with written records from the Philippines. Data from northern Australian areas, Malaysia, and Indonesia will also be obtained.

The data for the last 10 years show little year to year variation in the overall pattern over the period March to July. March tends to be good drying weather, but the weather is likely to deteriorate after March making drying more difficult.

The tropical weather data reflect the increased temperatures and humidities prevailing in South East Asian countries. The Philippines weather data show that during the first (dry) season harvest, the grain could be dried using ambient air, but that during the second (wet) season, supplemental heating is necessary. In practice, due to the higher grain moisture contents at receival, supplemental heating is a prerequisite in both seasons.

Effect of Aeration and Drying Strategies on Quality

A series of pilot aeration facilities was established at the Co-operative's Leeton plant to determine the effect of various physical drying parameters on grain quality. Twelve, fully monitored test beds consisting of insulated cylinders 400 mm diameter and 100 mm high with a nominal capacity of 5 kg of paddy are each supplied with air from separate humidity/temperature generators. The generators condition the inlet air by mixing dry and saturated air and operate over a temperature range of 10–55°C and at relative humidities of 0, 10, 30, 40, 60, 70, 90, and 100%, using air flow rates up to 20 L/min.

The rice quality parameters that relate directly to the effects of aeration and are currently under investigation include:

(i) percentage of total grains discoloured
(ii) extent of discoloration
(iii) percentage of mould infiltrated grains
(iv) extent of mould infiltration
(v) head yield or milling yield
(vi) extent of breakage

Quantifying the quality parameters has presented problems. Techniques for measuring discoloration and mould biomass lack reproducibility, accuracy, or sensitivity. Three techniques for measuring discoloration are being investigated. These are: hand picking affected grain from a sample to give the percentage of discoloured grains; using a colour sorting machine similarly; and using a whiteness meter to determine the comparative reflectance of a ground sample and so the extent of grain discoloration.

The measurement of microbiological activity also involves evaluating three techniques. The percentage of mould infiltrated grains is being estimated by direct plating of surface sterilised grains, and the extent of mould proliferation either by dilution plating of homogenised samples or by measuring the amount of ergosterol present. The milling yield and extent of brokens are being determined by standard laboratory milling procedures.

Delays were experienced in supply and commissioning of the equipment. Experimentation began in June 1984 and is progressing satisfactorily. The complete quality estimates are expected to be available by the end of 1984.

Energy Sources for Supplemental Heating

The Co-operative has used manually controlled gas-fired burners for some years for supplemental heating of air for drying. Control systems for automatic operation of these burners are being developed. They can be integrated into strategies being developed by the project for drying paddy harvested in the wet-season in South East Asia.

Studies are also in progress on fluidised-bed and other types of rice hull combustors as alternatives to gas-fired units.

Drying and aeration of bulk stored paddy in Australia is progressively being brought under computer control. Storage managers can call up information on grain temperature and moisture content in individual bins.

A typical aerated bulk store for paddy in Australia. Many countries of South East Asia plan to move from bag to bulk storage. ACIAR Project 8308 will tap Australian expertise in the in-store drying of bulk grain.

Field Trials in Australia on Commercial Paddy Stores

Data have been obtained on the performance of two computer-controlled aerated storage depots operated using different control strategies. This information, together with data from both manual and automatically controlled gas-fired supplemental heating trials, is being evaluated as a basis for the design of the aeration controllers for South East Asia. These observations will be continued through the 1985 harvest to confirm and optimise the performance of the control strategies being modelled.

Opportunity has been taken to monitor the conditions and quality of grain within a 3000-tonne, plastic-covered temporary storage. The method appears promising. Such storage may provide a valuable option for storage of paddy that is surplus to immediate requirements.

Research Activities in South East Asia

The work schedule proposed for the first year of operation of the project in South East Asia required that each country team prepare a report on the current situation in their rice industry from production of grain to consumption, that they review existing information on all matters relevant to the project, and that they summarise the various data needed for the project, including weather records, information on energy resources for supplemental heating in drying, and thermophysical data for local varieties of rice. On completion of these reports, the Team Leaders would visit Australia to inspect project activities in the University and the Co-operative and to discuss construction of pilot drying bins. After this visit, they would finalise the design, fabrication, and commissioning of the bins to enable the pilot-plant drying trials to be carried out during the second year of the project.

Mr Geoff Pym, Mr Justin Tumambing, Dr Robert Driscoll, and Mr Lindsay Bramall at a Project 8308 planning meeting in Manila.

Philippines

The Australian Project Leaders, Dr R.G. Bowrey and Mr M. Goldring, together with the Program Co-ordinator, visited NAPHIRE in Manila from 2–5 June 1983 to discuss the Memorandum of Agreement covering project activities in the Philippines. The agreement was finalised on 22 November 1983. Dr Bowrey visited the Philippines again during January 1984 for further discussions and finally on 7-9 June 1984 with Mr L. Bramall, who had replaced Mr Goldring as Research Leader in the project group at Ricegrowers' Co-operative Mills Ltd.

Following extensive studies on local rice-drying and storage practices, Mr Justin Tumambing, the Philippines Team Leader, visited the University in Sydney and the Co-operative in Leeton from 15–24 February for scheduled discussions on pilot drying in the Philippines.

Rice post-production systems. The Philippines produced 8.1 million tonnes of paddy in 1982 of which approximately 40% was consumed in rural areas, 50% retailed by commercial traders, and 10% channelled through the government storage system as buffer and security stocks.

An account of rice post-production practices in the Philippines has been prepared[1]. This comprehensive overview of the rice industry outlines the various components of the handling system: harvesting and threshing, which are carried out manually; cleaning; drying, either traditional sun-drying or by use of small fixed-bed or large continuous-flow driers; storage on farms or in commercial facilities; milling; grading; transport; and finally marketing.

Lowland cropping usually involves two crops per year with the second crop being harvested during the wet season at a moisture content of 26–28% compared with a dry season harvest at 20–21% moisture content. Rapid drying is essential to prevent sprouting and mould growth.

Drying strategy. Because of the high moisture content of the paddy and the unfavourable weather conditions during harvest in the wet season, the grain moisture content must be brought down quickly to a level low enough to prevent grain deterioration. Current emphasis on grain quality and energy conservation suggests that the drying be done in several stages, each stage within the allowable storage time.

A two stage or "combination drying" system, in which a fast drying stage is followed by unheated or minimal-heat air drying in storage is proposed. The fast drying could be achieved by use of a

1. Tumambing, J. 1984. Rice post-production practices in the Philippines. 45 p. Manila, National Post Harvest Institute for Research and Extension.

continuous flow dryer, a batch dryer, or a flash dryer. In one or other of these devices the grain would be dried rapidly to moisture contents of 18% wet basis (w.b.) or less, at which it would be safe to begin in-store drying. In-store drying using ambient or minimally heated air would then be used to bring the grain moisture content to the safe storage and milling level of 13.5–14% w.b. over a period of days of weeks.

This drying system would provide flexibility in meeting drying requirements imposed by different seasons and variable weather conditions. When the grain matures early during favourable field drying weather, especially during the dry season, the fast phase of the drying operation could be reduced and most of the grain dried in storage. On the other hand, the high-speed dryer could be run overtime to handle grain maturing late or during the wet season when the weather in inclement.

Physical properties of local rice varieties. The basic data on grain properties that are required for simulating the drying process are being determined for six local rice varieties (IR36, IR42, IR50, IR52, IR56, and Sinang-Domeng).

Bulk density was measured over a range of moisture contents from 10% to 22% w.b. and this, together with grain density, used to calculate the grain porosity. Bulk densities ranged from 539 kg/m^3 (Sinang-Domeng) to 580 kg/m^3 (IR-56), grain densities from 1683 kg/m^3 (IR-56) to 1130 kg/m^3 (Sinang-Domeng), and hence porosities from 0.523 (Sinang-Domeng) to 0.465 (IR-56).

Equilibrium moisture contents of the local rice varieties (equilibrated over supersaturated salt solutions) were measured at three temperatures (21.1, 26.7, 32.2°C) and three humidities (60, 75, 90% R.H.). The data varied by as much as 1.4% at a given temperature and relative humidity, with higher values in the varieties which were relatively more glutinous (IR-42, IR-52, and Sinang-Domeng).

Pilot drying bin studies. Following discussions in Australia on the provision of an appropriate pilot drying facility for the Philippines, a final design for the dryer has been prepared based on the two stage "combination dryer" system.

Mr Lindsay Bramall and Mr Justin Tumambing inspect experiments at the laboratories of NAPHIRE in Manila to determine the equilibrium moisture contents of various local rice varieties.

The dryer will comprise two drying bins, of similar diameter but differing height. The first will be a fast drying bin designed to take 43% moisture content (dry basis, d.b.) grain at 28°C to less than 18% w.b. in 20 hours. It will have a base area of 0.79 m^2 and be filled with grain to a depth of 0.36 m. Inlet air at 28°C and 72% d.b.R.H. will be supplied at a velocity of 30 m/min by a Richardson HV-B1 fan with a 1 kW motor and a 4.5 kW heater to supply the 260 kJ/min heat requirement. The in-store simulation bin will be designed to dry 22% d.b. grain at 26°C to 14% w.b. in 21 days. It will contain a bed of grain 2.2 m deep (1 tonne). Inlet air at 28°C and 68% d.b.R.H. will be supplied at a velocity of 7.8 m/min using the same equipment as the fast-drying bin.

The pilot plant will be installed at the National Food Authority storage complex at Isabela, 325 km north of Manila, and should be operational by the end of October 1984.

Thailand

The Australian Project Leaders, Dr R.G. Bowrey and Mr M. Goldring, together with the Program Co-ordinator, visited the Department of Agriculture in Bangkok on 10–11 June 1983 to discuss implementation of the project in Thailand, including agreement on a Memorandum of Understanding between Thailand and Australia. This memorandum was signed by representatives of both parties on 6 July 1984 but not finally accepted by the Australian participants until November 1984. Nevertheless, progress has been made. Dr Bowrey visited Thailand again on 2–5 June 1984 with Mr L. Bramall who had replaced Mr Goldring as Research Leader in the project group at Ricegrowers' Co-operative Mills.

The Thai team leader, Dr Ratana Putranon, and Dr Somchart Saponronnarit, visited the University of Sydney and Ricegrowers' Co-operative in Leeton from 4–11 May 1984 for discussions on progress of the project in Australia and Thailand, and to plan pilot plant studies scheduled for Thailand.

Rice post-production systems. Thailand produces 16 million tonnes of paddy each year, of which approximately 13 million tonnes is consumed locally and the balance exported. A report has been prepared covering post-production aspects of the industry[1].

Attention has been given to farm size, rice varieties, and yields, all of which vary in different regions of the country. The methods of harvesting, threshing, drying, and storing are also considered in the report, particularly in the context of single- and double-cropping. Whereas a single crop is grown during the rainy season and harvested in the dry season, when a second crop is produced it is grown in the dry season and harvested in the wet season. The wet season harvest presents many problems and these are essentially the targets for this project. The general practices in grain selling and milling are described and the technical data available for drying grain in Thailand are reviewed.

Drying strategy. Drying in Thailand has been by traditional sun-drying, except for the second crop which, although grown in the dry season, is harvested in the wet season and hence is difficult to dry by the conventional methods. The problem is becoming more serious because of the expansion of the irrigation systems which have promoted production of the second, dry season crop. Nevertheless, two factors affect Thailand differently from other countries in the region. The first is that grain is reputedly received at lower moisture contents than in other parts of the region, and secondly, the weather pattern around Bangkok (the major rice-growing area of Thailand) is more uniform throughout the year. These two factors allow consideration of a one-stage dryer, whereas in general, a two-stage drying process appears necessary in other parts of the region. Irrespective, conventional sun-drying, with its minimal investment and technology requirements, will remain the standard against which alternative methods are assessed.

Pilot drying bin studies. Some preliminary computer modelling of the grain-drying process in Thailand has been carried out as a basis for the design of the pilot drying facilities. The relatively simple Hukill model was used. By assuming a unique relationship between the rate of moisture lost in a deep bed of grain and the temperature gradient, it is possible to predict the moisture content at any depth in the grain mass after a specific drying time and, similarly, to predict grain temperature at any depth and time.

The data and relationships required for these grain-drying simulations included the

1. Ratana Putranon and Somchart Saponronnarit. 1984. Drying in bulk storage of high moisture paddy. 14 p. Thonburi, Bangkok, King Mongkut's Institute of Technology.

thin layer drying equation published by Wang and Sing in 1978, which was used to obtain the moisture ratio, an equilibrium moisture content correlation valid over the range 6.1-99.3% d.b. at 15-45°C, the bulk density of a medium grain paddy, and the latent heat of vaporisation of water from paddy reported by Brook and Taylor in 1979 for a range of different varieties of this grain.

Dry matter loss from grain respiration, calculated using an equation published by Seib and others in 1980, was used as a criterion of grain quality.

Temperature and relative humidity data used for the simulations were the monthly average values of Bangkok from 1951 to 1983. Based on the worst, second worst, and average weather conditions, the air available would not reduce the moisture content of the grain to a safe value in an acceptable time, and ambient air must be heated by from 0.5 to 1.7°C under average conditions and up to 5.2°C under the worst conditions recorded.

A simulation of deep-bed drying using the basic model and the data relationships that had been developed showed, for the weather conditions in Bangkok and for initial moisture contents from 20-26% w.b., that: —

(1) For a bed depth of 1 m, the air flow rates required to reduce the moisture contents to 13.5-14% w.b. varied from 2-10.4 $m^3/min/m^3$ of paddy and drying took 4-12 days.

(2) For equal quantities of paddy with different bed depths, drying using the same air conditions required approximately equal drying times and air flow rates.

(3) Under the worst drying conditions, the average moisture content decreased linearly and there was a rapid loss before a constant value was reached. The drying rates of various depths of grain were not constant and the moisture content of the top layers decreased slowly. The average grain temperatures increased with time, particularly in the bottom layers. The maximum dry matter loss occurred after 36 hours drying or at about 23.5% moisture content (d.b.).

This preliminary work shows that supplemental heating of the drying air is necessary and provides the basic data such as grain temperatures, moisture contents, drying times, and air flow rates for drying under Thailand's climatic conditions.

Based on these results, a pilot drying plant has been designed with a capacity of 1 tonne of paddy and a bed depth of 1 m. Construction will be completed in time for trials with the second crop in July-August 1984.

Pilot bin built at King Mongkut's Institute of Technology, Thonburi, Thailand for studies on the drying of bulk paddy.

Malaysia

The Australian Project Leaders, Dr R.G. Bowrey and Mr M. Goldring, together with the Program Co-ordinator, visited LPN in Malaysia in June 1983 to discuss the Memorandum of Agreement covering project activities in Malaysia. This agreement was not concluded until late in 1984. During a scheduled visit to other project activities in South East Asia, a further visit was made to Malaysia by Dr Bowrey and Mr L. Bramall from 5-7 June 1984, following Mr Bramall's appointment as joint Australian Project Leader.

Integrated Use of Pesticides in Grain Storage in the Humid Tropics (Projects 8309 and 8311)
Commissioned organisations—
Queensland Department of Primary Industries (8309)
CSIRO Division of Entomology (8311)

Background

Insects are a major constraint to safe storage of grain and other foodstuffs in warm, humid climates. Serious losses occur unless effective pest control procedures are implemented. The problem has been given high priority for attention both by international agencies such as FAO and by the relevant authorities in the developing countries.

Pesticides are a major weapon against grain pests and Australia is recognised as leading the world in studies on these materials for the protection of stored grain. Thus, in response to general initiatives by ACIAR, Malaysia and the Philippines identified collaborative studies on pesticides with the relevant Australian organisations as a research field with high priority. The requirements specified for these studies were (1) development of pesticide programs for use under local conditions and, within these studies, (ii) development of the research capability necessary to support continuing programs.

In Australia, following the development and implementation over the past 10 years of a system of integrated use of pesticides, losses in central storages are negligible. This system came about as a response to the critical problems faced by the grain industry when resistance to malathion emerged in the major storage pests.

To meet the crisis, the Australian Wheat Board formed a Working Party on Grain Protectants in 1973. Its objective was to identify effective alternatives to malathion and a program for their use. In this arrangement (which continues to function very successfully), basic studies on the biological efficacy of candidate materials against typical, resistant strains were carried out by the Queensland Department of Primary Industries and sister laboratories. Parallel studies on the chemical aspects of pesticides and their use were based in the CSIRO Division of Entomology. Field evaluation of successful compounds (involving both biological activity and residue levels) was carried out in collaboration with personnel from bulk handling authorities in each mainland State.

The Working Party concentrated on the comparatively dry grains (e.g. wheat at less than 12% moisture content) typical of Australian conditions. Relatively little is known about the behaviour of pesticides at high moistures and high temperatures, or on commodities of little significance in Australia but very important in South East Asia. To develop strategies for using pesticides under these conditions in South East Asia, a "Working Party" has been established within Projects 8309 and 8311. It will exploit the expertise developed by the various research groups working in this field in Australia.

Project 8309, which has been commissioned in the Queensland Department of Primary Industries, is concerned with biological and toxicological aspects of the investigations and Project 8311, which has been commissioned in the CSIRO Division of Entomology, centres on chemical aspects. These activities are being carried out in cooperation with research and grain handling authorities in Malaysia and the Philippines, and will be extended as appropriate to Indonesia. The work in Malaysia will involve the Malaysian Agricultural Research and Development Institute (MARDI) and the National Paddy and Rice Authority (Lembaga Padi Dan Beras Negara, LPN). In the Philippines, it will involve the National Post Harvest Institute for Research and Extension (NAPHIRE) of the National Food Authority.

Studies in the Queensland Department of Primary Industries will be carried out by a group consisting of a research fellow and three research assistants working with the Project Leader. They will be responsible for basic studies on the performance of grain protectants and fabric treatments at high grain moisture levels. The group will also be responsible for studies on the comparative efficacy of grain protectants on a range of commmodities and for theories to describe variability in the behaviour of pesticides in this context. From the data will emerge minimum effective doses for candidate grain protectants.

Parallel and complementary studies on the kinetics of decay of the pesticides will be carried out in collaboration with the CSIRO Division of Entomology and the University of New South Wales. These studies will provide data and decay models adequate for establishing dose levels for the treatments that result in acceptable residue levels.

In Malaysia and the Philippines, research teams consisting of a country research leader and a research assistant will be established for each project and these teams will be responsible for project activities in their respective countries.

The research teams associated with Project 8309 will be responsible for the field trials of candidate pesticides and associated development work. These activities will include surveys of the pesticide-resistance status of major pest species, establishment of typical strains in laboratory culture, and use of this material for verification of minimum effective doses on local commodity varieties.

The research teams associated with Project 8311 will be responsible for verifying active constituents of materials used in field trials, monitoring residue levels from all treatments applied, and estimating deposits of pesticides on building fabrics and on bags. Residue monitoring will extend to the final products processed from commodities used in the trials. The data from these trials will be used to enhance and verify the decay models proposed from the laboratory studies in Australia.

The findings of these two projects will provide a basis for the design of application schedules for a wide variety of pesticides and commodities stored under a variety of conditions. Moreover, in achieving this, the studies will fulfil the following prerequisites to use of pesticides in developing countries.

- The pesticides used are acceptable both to the regulating authorities of the country and to the end-users of the commodities.
- The pesticides and their manner of use conform to the requirements of Codex Alimentarius in terms of both domestic acceptability and that of overseas customers if the commodities are exported.
- Sufficient data are generated locally to provide the supporting evidence to expedite favourable consideration by local authorities and by Codex Alimentarius.
- The technical capacity of the country is developed through cooperative research to enable continuing studies that will maintain acceptable and effective pest control programs.

Expected Benefits

The results of Projects 8309 and 8311 will bring the following major benefits to the region.

1. The development of systems of integrated use of pesticides that will reduce losses due to pest infestation during storage of commodities of high moisture content in humid tropical environments.

2. Acquisition of basic understanding of the influence of grain moisture and grain species on the biological activity and residual behaviour of pesticides used to protect stored grain which, together with the local capability to design and conduct proving trials for new materials and techniques, will allow future development of the technology.

3. The technology developed in these projects will be applicable throughout the grain storage sectors of Malaysia and the Philippines, particularly in the central handling systems, but also in the cooperatives and village stores and, if neccessary, on farms. It will also be relevant to other countries in the region, providing systems for control of pests that should be acceptable both locally and in international trade.

Project Objectives and Operational Schedules

Cooperation between research and industry groups in Australia has led to the development and implementation of integrated pest control programs which have virtually eliminated losses due to pests in bulk-stored cereals here. The overall objective of Projects 8309 and 8311 is to extend the Australian studies to develop effective pest control programs for the humid tropics by determining data relevant to storage of high moisture grains and legumes in such environments.

Project 8309 is concerned with biological and toxicological aspects of the study. It will have the following specific objectives.

1. Determination of the effect of high levels of grain moisture on the biological activity of grain protectants and fabric treatments, including treatment of bag stacks.
2. Determination of the comparative effect of a range of cereal and legume species on biological activity of grain protectants.
3. Determination of the effect of phosphine on germination of seed fumigated at high moisture levels.
4. Conduct of field trials in Australia, Malaysia, and the Philippines to evaluate fabric and grain protectant treatments developed in the project and integrated as necessary with fumigation and other control measures.

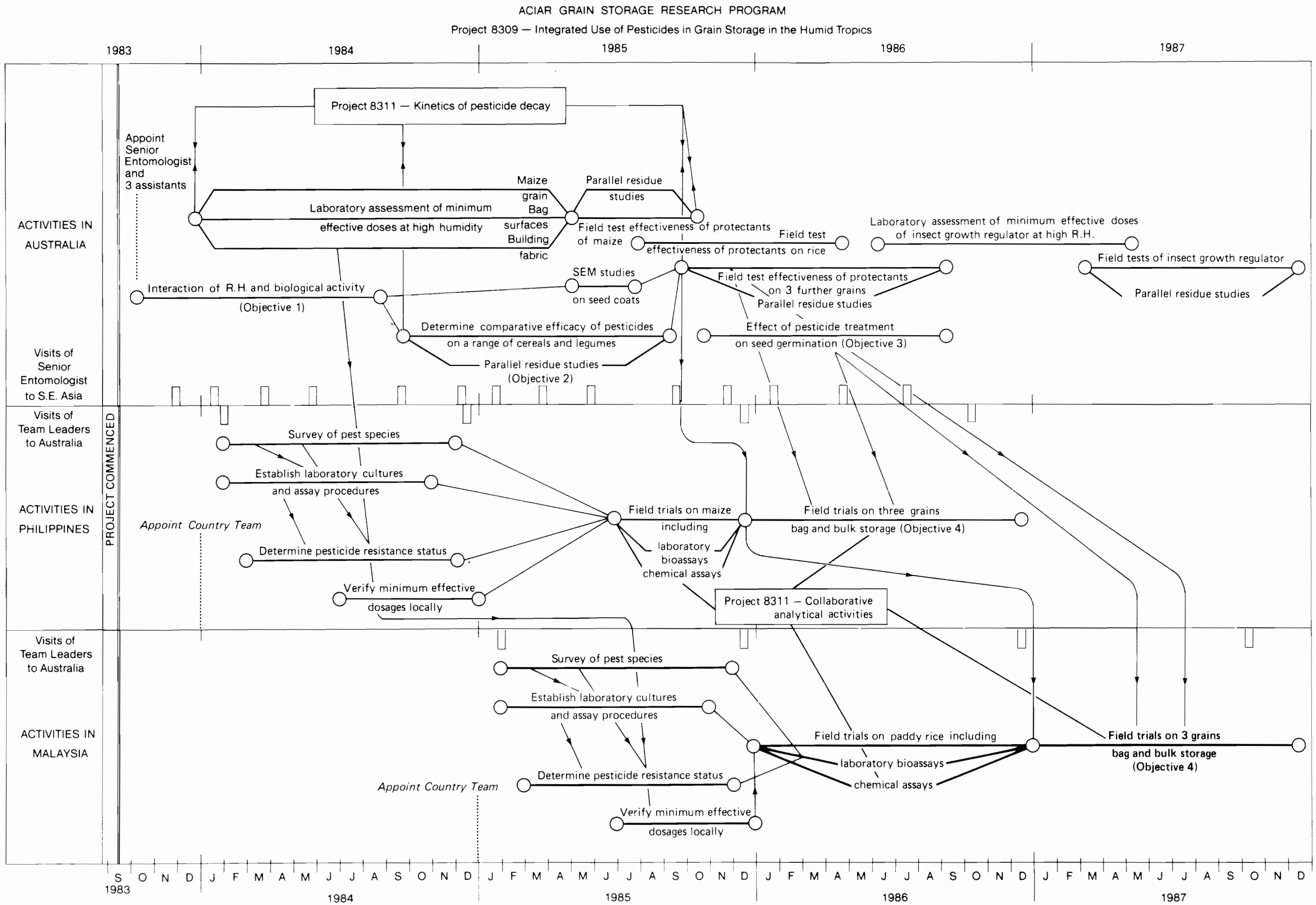
Project 8311 will provide support data from a laboratory study of the kinetics of loss of insecticides during storage and processing, including systematic investigations of the effects on pesticide stability of oil content, protein content, and "critical moisture level" of commodities. The project will also contribute expertise in analytical chemistry to project operations in South East Asia to monitor pesticide residue behaviour and otherwise service the chemically oriented requirements of Project 8309. All data will be unified, as far as possible, by the use of models from physical chemistry, so that, in conjunction with biological data from Project 8309, correct application rates can be calculated for each commodity, having regard to storage period, temperature, relative humidity, and method of processing.

The specific objectives of Project 8311 are as follows. The numbering of these objectives continues from those of Project 8309.

5. Establishment of suitable procedures for analysis.
6. Laboratory studies on the effects of such parameters as temperature and moisture content on the stability of various insecticides during storage.
7. Laboratory studies on the effects of processing on the stability of various insecticides.
8. Laboratory studies on model compounds relating stability in storage and processing to physical parameters such as partition coefficients.
9. Comparisons in field trials of data obtained commercially with that predicted from laboratory models.

Basic studies to determine the effect of high levels of grain moisture on the biological activity of grain protectants and fabric treatments, including treatment of bag stacks, will be completed by the Department of Primary Industries during the first year of operations (Objective 1). This work will involve detailed studies to determine basic relationships between relative humidity and the biological activity of pesticides, and laboratory studies to determine minimum effective doses at high humidities on one grain, building fabric, and bags. Concurrently, analytical procedures for organophosphorus compounds and the pyrethroids will be evaluated in the CSIRO Division of Entomology (Objective 5) and modelling commenced of the rate of loss of insecticide under various storage conditions (Objective 6).

During the first year of operations in South East Asia, the country teams will define local parameters of the storage problems and prepare for detailed field evaluation of potential control programs. This work will



Research schedule - Projects 8309 and 8311 involve surveys of the pest species in existing storages and an examination of the pesticide resistance status of the pest populations present.

Laboratory cultures of representative target species and strains will be established for use in laboratory toxicological studies and for bioassay of samples of grain from field tests. Procedures for the laboratory testing will be evaluated and the teams will verify the minimum effective dosages suggested by Australian data. Arrangements for residue analysis will be finalised and a trial collaborative analytical program for organophosphorus compound residues on maize and paddy will be undertake in all three countries (Objective 5).

During the second year of the project, studies at the Queensland Department of Primary Industries will be carried out to determine the comparative effect of a range of cereal and legume species on the biological activity of grain protectants (Objective 2). This work will be supported by studies, using the scanning electron microscope, of the seed coats of test species.

Also during the second year, the laboratory studies on one grain carried out in the first year will be extended to testing of the candidate materials as fabric and grain protectant treatments of that grain in the field in Malaysia and the Philippines. These studies will involve laboratory bioassay and chemical analysis of samples collected progressively from the trials and will include estimation of losses resulting from milling and cooking rice and maize (Objective 7). Collaborative analytical work on organophosphorus insecticides will continue and collaborative work on pyrethroids will commence. The modelling work on storage kinetics will continue in Australia, supplemented by data from the field trials (Objective 9), and a start will be made on the study of losses, using model and radioactive compounds (Objective 8).

During the third year, the field testing in Malaysia and the Philippines will be expanded to include three further grains as in Australia and will include progressive examination of residue levels (Objective 4, part). Studies will also be made on the effect of phosphine fumigation at high moisture contents on germination of seeds to enable full integration of fumigation into control programs covering both food and seed grain (Objective 3). The modelling work will be completed in Australia with respect to losses on storage, losses on processing, and losses on model compounds. Collaborative analytical programs between the three countries will continue and data from the field trials monitored in Malaysia and the Philippines will be used to verify the models of pesticide decay.

By the end of the third year, it is anticipated there will be sufficient data to enable firm recommendations for integrated pest control programs for bulk and bagged grain under existing storage conditions. These programs will be supported by a knowledge of pest/pesticide relationships in the humid tropics detailed enough to enable further development of the technology with changing storage patterns, pest abundance, and pesticide resistance status of the strains of pests concerned.

Organisation and Staff

The Record of Understanding between ACIAR and the Queensland Department of Primary Industries (Project 8309) was signed on 5 April 1983, and between ACIAR and CSIRO (Division of Entomology, Project 8311) on 30 July 1984, the latter falling outside the period covered by this report.

Dr M. Bengston, Assistant Director, Entomology Branch, was nominated by the Queensland Department of Primary Industries as Research Leader for Project 8309. Dr P.R. Samson, entomologist, was appointed to an ACIAR-funded position in the Department on 19 September 1983 to be responsible for detailed technical implementation of the laboratory studies and field experimentation. Three laboratory technicians, Ms J.A. Keating, Ms G.B. Marshall, and Mr R.J. Parker, commenced duty in August 1983. They will carry out the laboratory bioassays and chemical assays associated with the project.

Dr J.M. Desmarchelier, Principal Research Scientist, Division of Entomology, has been nominated by CSIRO as Research Leader for Project 8311. It is proposed that the laboratory studies in Australia on kinetics of decay of pesticides be contracted out from the CSIRO to a university and that post-graduate university scientists carry out the detailed investigations. These arrangements have not been finalised.

Agreement for overseas operations in Project 8309 became effective with NAPHIRE in the Philippines on 23 August 1983 but the research program did not commence until January 1984. The agreement for Project 8311 in the Philippines is awaiting finalisation of arrangement between ACIAR and CSIRO.

Research teams have been appointed in the Philippines for Project 8309 and provisionally for Project 8311. Mrs P. Sayaboc is Team Leader for Project 8309. She is supported by another entomologist, Ms M. Amoranto. Mr C. Mordido Jr. has been nominated as Team Leader for Project 8311.

Finalisation of arrangements for both projects with MARDI has been delayed pending completion of a general agreement between the Government of Malaysia and ACIAR. Mr A. Rahim Muda has been nominated provisionally as leader of the team for Project 8309 and Mr Ong Seng Hock for Project 8311.

GRAIN STORAGE RESEARCH PROGRAM

Project 8309/8311 Staff

Australia (Queensland Department of Primary Industries)

Dr M. Bengston, Research Leader, Project 8309
Ms J.A. Keating, Laboratory Technician
Ms G.B. Marshall, Laboratory Technician
Mr R.J. Parker, Laboratory Technician
Dr P.R. Samson, Research Fellow

Australia (CSIRO Division of Entomology)

Dr J.M. Desmarchelier, Research Leader, Project 8311

Malaysia (MARDI and LPN)

Mr A. Rahim Muda, Team Leader, Project 8309
Mr Ong Seng Hock, Team Leader, Project 8311

Philippines (NAPHIRE)

Ms M. Amoranto, Entomologist
Mr C. Mordido, Jr., Team Leader, Project 8311
Mrs P. Sayaboc, Team Leader, Project 8309
Chemist, Project 8311

Research Activities in Australia

Relation Between Moisture and Biological Activity of Pesticides

The effect of grain moisture on the biological activity of grain protectants has been investigated at the Queensland Department of Primary Industries using maize. Laboratory experiments established that the potency of newly applied deposits of grain protectants from conventional emulsifiable concentrate formulations was reduced at high grain moistures. This was true for both chlorpyrifos-methyl and fenitrothion against two test species. In the extreme case, the potency of fenitrothion measured in terms of mortality of young adults of *Tribolium castaneum* exposed for 3 days at 25°C to treated grain at 18% grain moisture was only 0.15 that at 10%. Within the moisture range more typical of industry conditions potency at 16% was 0.47 that at 11%. Chemical analyses confirmed that this was not due to differences in the deposit rate. Initial attempts to measure responses to topically applied doses under different conditions of relative humidity gave inconclusive results and the work is continuing.

Experiments with deposits of chorpyrifos-methyl, also from conventional emulsifiable concentrate formulations but on a filter paper substrate, indicated that the potency increased with relative humidity, as has been reported by other workers.

Experiments involving the FAO resistance test method, in which insects are exposed to the insecticide in a film of non-volatile oil on filter-paper, are in progress.

Grain Species and Biological Activity

Comparison of the potencies of a range of candidate grain protectants on maize and wheat at 14% moisture content indicated that fresh deposits of most chemicals are more potent (×2) on maize than on wheat. This finding will be highly relevant when integrated control programs for maize are being devised.

Differences in response between insect species have also been noted. The maize weevil, *Sitophilus zeamais*, is more susceptible to grain protectants that the related rice weevil, *Sitophilus oryzae*.

Using application rates suggested by these comparative studies, a further series of experiments has been commenced with the aim of determining the minimum effective application rates for each compound on maize over a storage interval of 9 months.

Impregnated-paper assays showed that Queensland Department of Primary Industries "susceptible" strains of *Tribolium castaneum* and *Rhyzopertha dominica* were more susceptible to pirimiphos-methyl than expected. This suggests that some level of resistance was present at the time of initial collection and that this has declined in culture. Discriminating doses to separate susceptible and resistant strains have been reduce accordingly.

Research Activities in South East Asia

The schedule of work proposed for the first year of operation of the projects in South East Asia required that the country teams from Malaysia and the Philippines prepare reports on the current situation in pest control in the rice and maize industries of their respective countries. These comprehensive reports were to consider production, end use, storage, handling, and transport of the commodity, its pest problems, use of pesticides, relevant legislation, and a review of all research carried out. On completion of these reports, the Team Leaders would visit Australia to inspect project activities there, including familiarisation with laboratory procedures for pesticide toxicity testing and field spray application techniques and equipment. After this visit, the pesticide testing laboratories would be commissioned, surveys of pesticide resistance carried out, and the acute toxicity of candidate pesticides evaluated on grain. Minimum effective dosages for grain treatment would then be established and arrangements for field trials finalised.

Philippines

The Australian Leader of Project 8309, Dr M. Bengston, together with the Program Coordinator, visited NAPHIRE in Manila from 30 May to 5 June 1983, to discuss the Memorandum of Agreement concerning project activities in the Philippines. The agreement was finalised on 23 August 1983. Dr Bengston visited the Philippines again from 16–19 October 1983 for further discussions on implementation of the project and to introduce Dr P.R. Samson, the project entomologist in Australia. During this visit, they were accompanied by the Program Coordinator and Dr J.M. Desmarchelier, the nominated Australian Leader of Project 8311, for discussions with NAPHIRE on the integration of that project with Project 8309. Dr Samson made further scheduled visits from 19–24 February 1984 and 27 May to 3 June 1984 for co-operative project activities.

The project entomologist at NAPHIRE, Ms P. Sayaboc, visited the laboratories of the Queensland Department of Primary Industries from 4–18 December 1983 to study appropriate laboratory techniques.

Post-harvest systems for storage and protection of maize. The Philippines produced 3.3 million tonnes of maize in 1982, made up of white varieties used for human consumption and yellow varieties for animal feed or for production of corn oil, gluten, or starch.

Harvesting is carried out manually and shelling may be delayed for up to 3 days. Sun-drying takes 1 to 3 days, depending on conditions. Mechanical dryers are little used by farmers.

A small amount of the maize is stored for up to 3 months by farmers as ear corn in cribs. The initial moisture content is 23%, reduced to 15% by air drying.

Most of the maize is sold as dried shelled grain to wholesalers, with the National Food Authority handling around 9% of the total. Grain is held in buying stations from a few days to a month before shipment to Cebu or Manila for warehouse storage which may last up to 3 years. Grain moisture averages 14% with temperatures around 30°C. Some grain is held in bulk, but most is in jute or polypropylene bags of either 50 or 100 kg capacity.

In 1977, losses were estimated at 14.5% for 13 months storage, with *Sitophilus zeamais* the dominant pest species.

Pesticide usage in warehouses. Data on warehouse management, pest control practices, pest abundance, and damage to commodities were secured from 29 warehouses in Ilocos, Southern Tagolog, and Mindanao. These storages had a total capacity of 3.6 million bags. The commodities stored were principally paddy, milled rice, maize, and wheat flour in Luzon, and paddy, maize, and maize grits in Mindanao.

The insecticides used were limited to malathion, dichlorvos, pirimiphos-methyl, permethrin, and bioresmethrin. Malathion ($0.5 g/m^2$), pirimiphos-methyl ($0.25 g/m^2$), and permethrin ($0.03 g/m^2$) were used throughout the country for protecting bag stacks, treatment intervals varying from a week to a month, except in western Mindanao where dose rates are doubled. Malathion (at $1 g/m^2$), and to a lesser extent permethrin as before, were used for structural spraying. Fogging involved dichlorvos or, more commonly, bioresmethrin which was used over a range of application rates from 0.003 to $0.15 mg/m^2$, with the higher rates again in Mindanao. Fumigation with phosphine was widely practised, either as required or on a 2–3 monthly schedule, using dose rates between 0.5 and $5 g/m^3$.

Survey of pesticide resistance. Insect material for resistance testing was collected from representative warehouses in 27 provinces in Regions I (Ilocos), III (Central Luzon), IV (Southern Tagalog), IX (Western Mindanao), X (North Eastern Mindanao), XI (South Eastern Mindanao), and XIII (Metro Manila). The species recorded included, in order of abundance, *Tribolium castaneum*, *Sitophilus zeamais*, *Rhyzopertha dominica*, and *S. oryzae*.

Susceptibility to malathion was determined using the method recommended by FAO[1].

Twenty-seven strains of the commonest pest, *T. castaneum*, representing each of the provinces, were tested and all were resistant to malathion. Eighteen of these did not respond completely to malathion synergised by triphenyl phosphate, indicating a non-specific type of resistance that conferred cross-resistance to other organophosphorus compounds. The strains showing non-specific resistance occurred in all regions except south eastern Mindanao (4 strains) where the initial treatments with grain protectants in the field trials were to be carried out.

Fourteen strains of *S. zeamais* representing six of the regions were tested. All samples of this species, which is the major *Sitophilus* pest in the Philippines, were susceptible.

Only two strains of *R. dominica* were collected, both from Luzon. The strain from Bataan in central Luzon was susceptible, while that collected from a warehouse in Metro Manila was resistant to malathion but responded to treatment with the synergist triphenyl phosphate, indicating a resistance specific to malathion.

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1. Anon. 1974. Recommended methods for the detection and measurement of resistance of agricultural pests to pesticides. FAO Method No. 15. Plant Protection Bulletin FAO, 22, 127–137.

Malaysia

Dr M. Bengston, together with the Program Co-ordinator, visited Malaysia from 5–11 June 1983 and discussed with MARDI and LPN the Memorandum of Agreement concerning project activities. Dr Bengston visited Malaysia again from 11–16 October 1983 in company with Dr P.R. Samson (project entomologist in Australia), Dr J.M. Desmarchelier (nominated Australian Leader of Project 8311), and the Program Co-ordinator, to discuss integration of the two projects into MARDI's research activities. To facilitate an early start to operations when formal arrangements between Malaysia and Australia were complete, Dr Samson made further visits for MARDI from 19–24 February 1984 and 27 May to 3 June 1984 while in South East Asia on scheduled project activities. The proposed agreements with Malaysia were not finalised during the year.

Grain in storage in South East Asia is liable to infestation by a complex of major and minor pests. The rust-red flour beetle (Tribolium castaneum) *is a major pest in all countries of the region and attacks a range of stored products. It is shown here infesting bags of milled rice.*

Moisture Movement in Grain (Project 8310)
Commissioned organisation—CSIRO Division of Chemical and Wood Technology

Background

When grain at normally safe moisture contents is stored in sealed enclosures such as a plastic envelope, a closed environment is created which, under certain circumstances, can result in redistribution of the grain moisture. This problem is intensified in tropical areas where moisture contents may exceed the desirable levels for safe storage.

If techniques of using sealed enclosures to reduce pest problems are to be exploited, the processes by which moisture is redistributed must be fully understood so that container design, storage management, and the characteristics of commodities to be stored can be defined. This is essential to provide the high probability of quality maintenance that is required in commercial practice.

Over and above this, current techniques of storage in sealed enclosures must be seen as steps in the development of practices that are more cost effective. For example, moving the enclosures out of the storage sheds and into the open would reduce costs and increase the flexibility of the system. It must also be kept in mind that while current studies in developing countries are focussed on storage of bagged commodities, bulk handling of grain will increase in importance there and demand commensurate attention.

For these reasons, the Agricultural Engineering Group of the CSIRO Division of Chemical and Wood Technology was commissioned to study, in Project 8310, natural convective movements of moisture in grain. This project interfaces not only with Project 8307 (Long Term Storage of Grain under Plastic Covers) but also with Project 8308 (Drying in Bulk Storage of High Moisture Grains in Tropical Climates), which considers forced convective movement of moisture.

The CSIRO Agricultural Engineering Group has already been deeply involved in studies on moisture migration in grain and works very closely with the Division of Energy Technology, which has a program of research on natural convective processes with condensing vapours in non-hygroscopic porous media. These interactions will prove invaluable to the project.

Overseas activities are being carried out in association with the field assessments of sealed enclosures for stacks of bagged grain in Project 8307A.

Expected Benefits

Long term storage of grain and other foodstuffs under plastic covers is potentially a very useful and cost effective method of maintaining stategic reserves of these commodities in good condition. High ambient temperatures and humidities require that storage conditions be defined precisely. The studies outlined here will enable adequate definition of the storage parameters and design of storage systems that minimise losses due to moisture problems. The information will be just as relevant to short term storage of high moisture grain whether stored in bags or bulk.

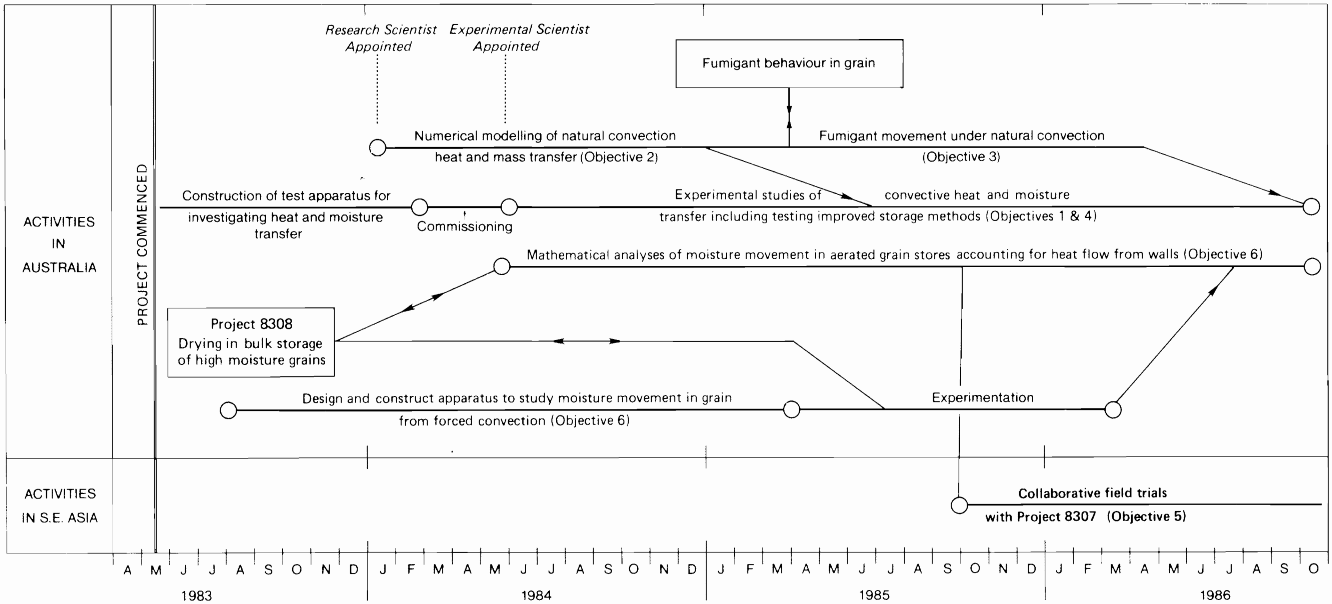
Project Objectives and Operational Schedule

The project is designed to provide a basic understanding of moisture movement in grain stored in sealed enclosures. The general case of movement through hygroscopic porous media will be considered and followed through to full-scale field experimentation to validate models and optimise storage techniques.

The initial experimental investigations will be carried out in a specially constructed apparatus designed to promote heat and moisture transfer to porous media. By changing the variables within the apparatus, heat and mass transfer will be studied in the commodity under test. Well-established dimensional laws will be used to scale the results. Concurrently with the experimental studies, a mathematical analysis of the phenomena will be carried out, as has already been done in outline for the case of heat and moisture transfer by natural convection in non-hygroscopic media. Using the results from the experimental and mathematical studies, improved grain storage

ACIAR GRAIN STORAGE RESEARCH PROGRAM

Project 8310 — Moisture Movement in Grain



Research schedule - Project 8310

methods will be developed and tested on a laboratory scale and then in the field.

The objectives of the project thus include the following: —

1. To conduct extensive experiments on heat and moisture transfer by natural convection in porous hygroscopic media.
2. To carry out numerical analyses of buoyancy forces in grain bulks, and determine their influence on the micro-environment.
3. To determine the effects, if any, of fumigants on the degree of natural convection.
4. To devise and test in the laboratory improved methods of storing commodities in bags and bulk.
5. To carry out full-scale field trials of promising improved storage methods and determine the efficacy with which commodity quality and an environment hostile to insects is maintained.

The project has a duration of 3 years.

It is planned that the fundamental studies on heat and mass transfer by natural convection in porous hygroscopic media will continue through the first two years of the project (Objective 1). These studies will be carried out in conjunction with the CSIRO Division of Energy Technology which, as mentioned previously, is investigating similar problems in non-hygroscopic porous media. Construction of test apparatus for the moisture and heat transfer studies was completed and the apparatus commissioned early in the second half of 1983.

Quantification of the mechanisms of moisture movement in grain (Objective 2) commenced at the end of 1983 and will be completed by July 1985. The effect of fumigants on natural convection will also be studied during the second year of the project (Objective 3).

Analysis of forced convection mass transfer in bulk grain will commence on commissioning of test apparatus towards the end of 1983 and will be completed during the second year of the project. This work will be carried out in close collaboration with studies in Project 8308 (Drying in Bulk Storage of High Moisture Grains).

Work on devising and testing improved storage methods will begin in the laboratory (Objective 4) and the field (Objective 5) in January 1985. These studies will be carried out in conjunction with Project 8307 (Long Term Storage of Grain under Plastic Covers).

By March 1986, these studies on moisture transfer from natural and forced convection should provide a basic understanding of the processes involved and have been transferred to practical technology in grain drying, aeration, and long-term storage of bagged grain. Further studies, using the basic technology developed, are foreshadowed on long-term storage of bulk grain at marginally high moisture contents.

Organisation and Staff

The Record of Understanding between ACIAR and CSIRO on Project 8310 was signed on 3 May 1983.

Dr G.R. Thorpe, Principal Research Scientist, was nominated by CSIRO as Research Leader. Dr T.V. Nguyen was appointed to an ACIAR-funded position in CSIRO on 5 December 1983 to be primarily responsible for studies on the fundamental processes of convective and diffusive heat and moisture transfer as applied to grain. Mr S.G. Wilson was appointed as an Experimental Scientist on 5 March 1984, also to an ACIAR-funded position, to be responsible for the design, installation, and calibration of the apparatus for studying moisture migration, various monitoring instruments, and data processing. Mr T.F. Ghaley, an Experimental Scientist in the Agricultural Engineering Group, was seconded half-time to assist with devising and constructing apparatus for the moisture migration studies both in the laboratory and in the field. The delays in appointing staff to the project have resulted in it running behind schedule.

Research Activities in Australia

The new and very powerful techniques for studying the processes of heat and mass transfer by free convection in the bag stacks are being developed and exploited to the full. The physics of the following processes are being elucidated:—

(i) Combined heat and moisture transfer with simplified boundary conditions, to enable basic data on effective conductivity to be determined.
(ii) Combined heat and moisture transfer with boundary conditions corresponding to actual grain storage types.
(iii) Combined heat and moisture transfer with finite mass transfer resistance, as is anticipated will occur in bags of grains.
(iv) Effects of heating due to insects, microbial respiration, and external environment on the physical conditions within the grain store.
(v) Convection in circular silos, i.e. with "cold finger" and asymmetrical heating.
(vi) The combined influence of thermal and concentration buoyancy effects on the distribution of fumigants.

Experiments are also being carried out to quantify the influence of basic physical parameters such as effective thermal conductivity and packing geometry on moisture migration.

Mathematical Modelling of Moisture Movement by Natural Convection

Considerable progress has been made on this aspect of the work, which is fundamental to the success of the project. It has been possible to develop a generalised mathematical model of the combined heat and mass transfer phenomena that occur under free convection in stored grains. For example, the equation describing the air flow pattern is written in dimensionless variables:

GRAIN STORAGE RESEARCH PROGRAM

Project 8310 Staff

CSIRO Division of Chemical and Wood Technology
Mr T.F. Ghaley, Experimental Scientist (part time)
Dr T.V. Nguyen, Research Scientist
Dr G.R. Thorpe, Research Leader
Mr S.G. Wilson, Experimental Scientist

$$\frac{\partial^2 \psi}{\partial y^2} + \left(\frac{H}{L}\right)^2 \frac{\partial^2 \psi}{\partial x^2} + \left(\frac{H}{L}\right) Ra^* \frac{\partial T}{\partial x} = 0. \qquad (1)$$

where ψ is a stream function which yields the velocity of the circulating air, x and y represent dimensionless horizontal and vertical distances, respectively, H and L are the height and length of the grain store, and T represents grain temperature. Ra^* is a Rayleigh number which relates to isotropic porous media, i.e. paddy, wheat, sorghum etc.

The temperature distribution as a function of time, t, and spatial coordinates (x,y) may be written as

$$\frac{\partial T}{\partial t} = \phi_1(W)\left\{\phi_2(\Delta T,H,L)\left(u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y}\right) - \phi_3(w,H,L)\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) + \left(\frac{H}{L}\right)^2\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right\} \qquad (2)$$

where ϕ_1, ϕ_2 and ϕ_3 are functions of grain properties, W and w are grain and air moisture contents respectively, u and v are horizontal and vertical velocities respectively, and T is the temperature difference between the hottest and coldest region of the grain.

The equations are presently being encoded and solved by a well-documented computer program that advances the solution in time and space by the Peaceman-Rachford alternating direction implicit method.

Experimental Studies to Validate the Mathematical Models

The above analyses are best validated under well-controlled experimental conditions. Working closely with a research team in the CSIRO Division of Energy Technology, heat transfer experiments have been carried out on packed beds. The experiments indicated that height of packing affects the rate of heat tranfer in a manner that was previously little understood. With the help of the mathematical models, it was inferred that so-called inertial effects are important only in shallow beds of porous media. It can be concluded from the work that inertial effects must be considered in grain storage situations.

Apparatus has been built and commissioned to enable characterisation of heat and moisture transfer by free convection in bagged and bulk grain. The apparatus consists of a 1.75 m diameter cylinder with a wall height of 0.5 m which can be filled with a porous medium such as grain, or miniature bags of grain. Heat is supplied to the base of the system via an isothermal platen heated by electrical elements with a total capacity of 25 kW. Heat is removed from the porous medium by means of an upper platen cooled by refrigerated water. The walls and the lower platen are electrically guarded to render heat losses negligible. The equipment has been instrumented to allow both transient and steady-state heat and mass transfer phenomena to be measured. The instrumentation system is based on a data logger supplemented by a microprocessor operating to control the system, and a 100 channel extender chassis. Data are scanned at up to 600 channels per second, and are stored in 8in. floppy disks before being processed off-line and displayed in tabular and graphical form.

Dr Tuan Nguyen and Mr Steve Wilson of the CSIRO Division of Chemical and Wood Technology working with one of the microcomputers which are playing a big part in studies of moisture movement in Project 8310.

Plans are well advanced to carry out experiments with scale size bags of paddy in order to determine the heat and mass transfer behaviour under controlled conditions.

Studies on Forced Convection and Boundary Layers

Aeration with ambient or conditioned air is an effective method of cooling grain, and reducing moisture migration in bulk grain. Aeration gives rise to the little-studied phenomenon of thermal and moisture boundary-layer development at the walls of grain stores exposed to solar radiation for example. This wall-heating phenomenon has a profound effect on the ecosystems at the peripheries of the grain store, and affects insect behaviour, pesticide decay, and grain quality. The effect could be beneficial when grain in the centre of the store is kept cool and grain at the periphery is warm but dry. In this way, it may be possible to maintain conditions throughout the grain mass inhospitable to insect pests, and the variations in grain moisture content and temperature may be such that the rate of decay of any pesticides applied to grain would be radially uniform.

In order to investigate these phenomena under controlled conditions, an apparatus has been constructed to study forced convection in grain stores with heated walls. Conditioned air from an air-conditioned cool room with a high thermal ineria is saturated with steam before entering a heat reservoir. The air is then electrically heated to achieve the required relative humidity, and its mass flow rate is measured by means of an orifice plate, before flowing into a cylinder. The cylinder is fitted with a wall isothermally heated by water, and is filled with grain. Thermocouples placed in the grain enable the development of thermal boundary layers to be studied, and instrumentation is provided to measure air flow rates and the thermodynamic state of the interstitial aeration air.

The Movement of Fumigants Under Concentration and Thermal Gradients

When storing grains under plastic sheets, it is important to have a clear understanding of the movement of fumigants through the grain stack, and to study the effect of leakage on the concentration of the gas. Again, excellent progress has been made in formulating a mathematical description of these phenomena, and dimensionless (and therefore very general) equations that govern these processes have been defined. It is found that the vorticity transport equation is written as

$$\frac{\partial \zeta}{\partial t} = N_1 \left(\frac{\partial}{\partial x}(\zeta u) + \frac{\partial}{\partial y}(\zeta v)\right) + N_2 \frac{\partial T}{\partial x} + N_3 \frac{\partial T}{\partial y} + N_4 \zeta$$

where ζ is a dimensionless vorticity and N_1, N_2, N_3, and N_4 are well-known dimensionless groups. Similar equations apply to the transport of energy and the diffusing species, i.e. the fumigant. These equations account for the buoyancy effects resulting from concentrations and temperature gradients.

Although the above work has been described in fairly abstract terms, it is believed that the mathematical analyses represent considerable progress in an understanding of the basic heat and mass transfer phenomena that occur in bag and bulk stored grain. The immediate objective is to insert appropriate intial and boundary conditions into the equations in order to model actual physical systems. It is anticipated that it will be possible to lay down guidelines for the most effective fumigation procedures as an outcome of this work.

Research Activities Overseas

Dr Thorpe participated in preliminary discussions with the Malaysian Agricultural Research and Development Institute on ACIAR activities in Malaysia from 13–15 December 1982. He subsequently visited MARDI on 9 April 1984 for discussions on participation in field trials of plastic-covered bag stacks to be arranged within Project 8307.

PROJECT 8314

Effect of Controlled Atmospheres on Quality of Stored Grains (Project 8314)
Commissioned organisation — CSIRO Wheat Research Unit

Background

The safe storages of bagged food commodities has been identified as a priority area for attention in all developing countries in South East Asia and elsewhere. Enclosing bag stacks in gastight plastic envelopes has been demonstrated to have potential for safe storage and there is considerable interest in the technology of the region. ACIAR Projects 8307 (A, B, and D) and 8310 are concerned with developing the technology for application in Malaysia, the Philippines, and Thailand, and have particular reference to overcoming insect and moisture problems that are associated with storage in the humid tropical environment. It cannot be assumed, however, that storage in a gastight enclosure and the alteration of the gas composition in the enclosed atmosphere will not affect the quality of the commodity, particularly if it is held for long periods under these conditions.

It is a continuing cause of concern that there is inadequate understanding of the effects of various storage atmospheres on the quality of grains and other durable food commodities in storage. As a result, a project to study the effects of inert-atmosphere storage on the quality of wheat was commenced a few years ago in the Wheat Research Unit, in collaboration with the CSIRO Division of Entomology. This project has confirmed that quality defects may arise from storage under some gas mixtures designed to limit insect infestation. It is likely that deterioration would occur in the quality of other grains under similar conditions. In particular, rice stored at greater than 15% m.c. is said to become tainted when held under carbon dioxide (CO_2). There is some evidence that CO_2 may provide a storage atmosphere that is superior to phosphine, and that this benefit is related to water activity changes. The absence of a definitive study on the effects of altered atmospheres is an inhibiting factor to the more widespread use of CO_2 storage techniques. The present study is designed to remedy this.

The experimental exposures will be carried out at the CSIRO Wheat Research Unit and the quality estimates in collaboration with a research team established at the National Post Harvest Institute for Research and Extension (NAPHIRE) in the Philippines. The teams in Australia and the Philippines will also provide quality testing facilities for other projects in the ACIAR Grain Storage Research Program.

Expected Benefits

1. Development of a quantitative understanding of the interaction of atmosphere composition, temperature, and water activity on the quality of commodities in storage. This information is necessary for efficient and safe utilisation of the storage technology being developed in ACIAR Project 8307 on Long Term Storage of Grain under Plastic Covers, which is being conducted by the CSIRO Division of Entomology.
2. Acquisition of basic data for integration into models of heat and moisture environments in storages (ACIAR Project 8310 on Moisture Movement in Grain) to allow further development of the technology.
3. The activities in the Philippines will provide a model for a quality testing facility to support continuing research programs in that country.

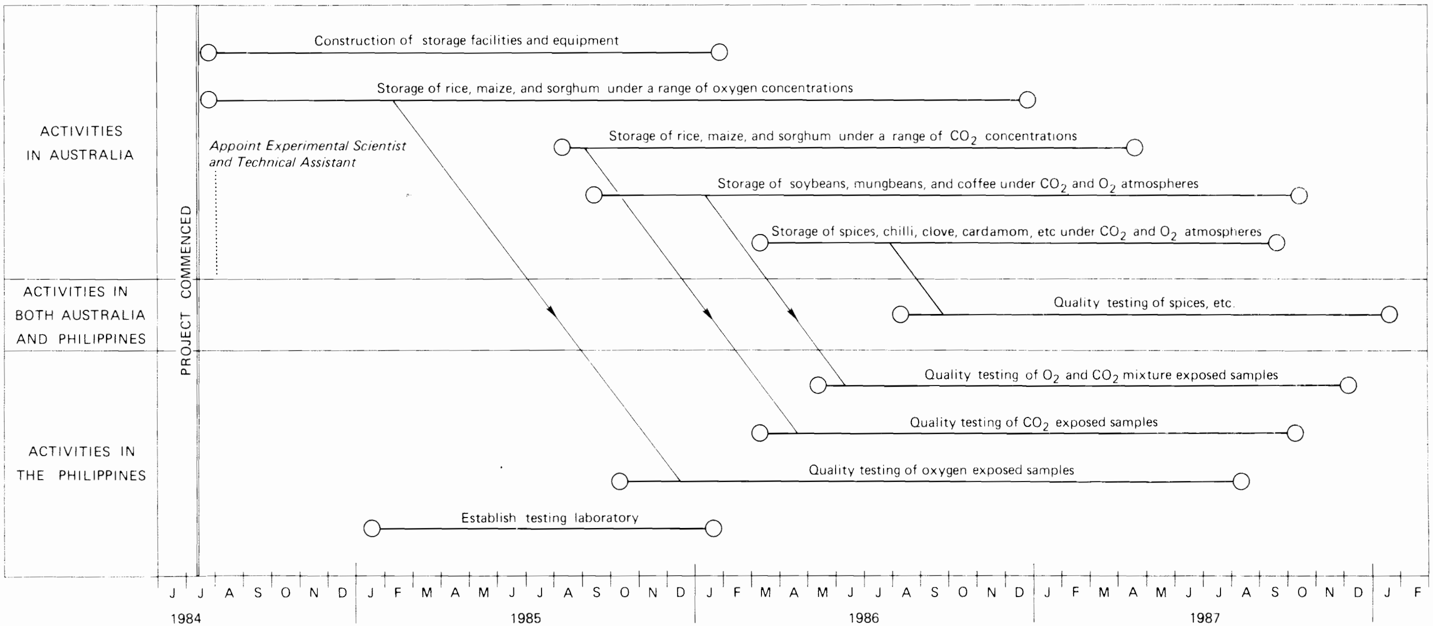
Project Objectives and Operational Schedule

This project is designed primarily to provide basic support to ACIAR Project 8307 on Long Term Storage of Grain under Plastic Covers and to provide data and a grain quality testing facility for other projects in the ACIAR Grain Storage Research Program.

Accelerated storage tests will be used to evaluate various combinations of commodity and storage atmosphere to enable models to be developed of the effects of storage factors on grain quality. These models in turn will be incorporated into more comprehensive models on heat and moisture balance in

ACIAR GRAIN STORAGE RESEARCH PROGRAM

Project 8314 – Effects of Controlled Atmospheres on Quality of Stored Grains



Research schedule - Project 8314

storage systems to enable rational design of storage containers and management procedures.

The specific objectives of the project include the following: —

1. Determination of the influence of oxygen and CO_2 tension in the storage atmosphere, in combination with temperature and water activity, on the viability and end-use parameters of stored grains, spices, and pulses.
2. Provision of these data in a form which can be integrated in an overall model of heat and moisture balance in storage systems.
3. Examination of the relationship between water production and various storage gases (including phosphine) during storage in closed systems.
4. Provision of grain quality testing facilities for other projects in the ACIAR Grain Storage Research Program.

Experiments along the lines proposed are currently in progress on wheat at the CSIRO Wheat Research Unit. Approximately three to four months will be required to set up the additional equipment that is required for this project.

All storage experiments will be carried out in Australia. Quality evaluations will be carried out in both Australia and the Philippines.

Commodity samples of known provenance to be subjected to particular atmospheres under controlled temperature and water activity for various exposure periods include: milled rice (indica), paddy, brown rice, maize, soybeans, various spices (probably pepper, chilli, cardamom), cocoa, coffee, sorghum, and barley. The following experimental parameters will be covered:

Temperatures	30°, 35°, 47°, 60°C
Water Activity	0.40, 0.60, 0.80
Atmospheres	0.2, 2, 21, 100% O_2 in N_2;
	1, 10, 40, 80% CO_2 in air.

After storage for the maximum practicable periods, commodities will be tested in collaboration with the research team in the Philippines for seed viability and for quality characteristics related to the end-use of each commodity. These characteristics will include those quality standards currently used by the Philippines National Food Authority.

Experiments will be carried out over six months to determine the effect of CO_2 and other storage gases on water activity in closed systems. Water output of grains will be measured in the presence of various levels of CO_2 at 14% m.c. and 30°C using the following atmospheres: air; 10, 30, and 60% CO_2 in air; 10% CO_2 + 10% O_2, balance nitrogen; and one reference concentration of phosphine, 0.5 g PH_3/m^3 in air. Plate counts of fungi will be run and water output of unsterilised and surface-sterilised samples will be compared. These studies will be pursued at the CSIRO Division of Entomology in collaboration with ACIAR Project 8307.

It is estimated that 3 years will be required to complete the series of experiments outlined above.

Organisation and Staff

The Record of Understanding between ACIAR and CSIRO was finalised during the current year but not signed until 11 July 1984. An early start is anticipated.

Dr P. Gras and Dr I. Batey have been nominated by CSIRO as joint Research Leaders. The CSIRO Wheat Research Unit has also nominated Mr M. Bason, an Experimental Scientist, to be responsible for conduct of experimental work in Australia and Miss A. Morris, Technical Assistant, as support for these activities. NAPHIRE has nominated Mr Cris Mordido as Team Leader in the Philippines.

GRAIN STORAGE RESEARCH PROGRAM

Project 8314 Staff

CSIRO Wheat Research Unit
Mr M. Bason, Experimental Scientist
Dr I. Batey } Research Leaders
Dr P. Gras }
Miss A. Morris, Technical Assistant
NAPHIRE
Mr C. Mordido, Jr., Team Leader

PROJECT 8312

Program Development and Co-ordination (Project 8312)

Commissioned organisation—CSIRO Division of Entomology

Introduction

The formulation and implementation of the ACIAR Grain Storage Research Program has been achieved by contracting Project 8312 with the CSIRO Division of Entomology. The project will provide an operational framework for the development and co-ordination of ACIAR's activities in the grain storage area. This is seen as an essential component of the program in maximising its effectiveness both in terms of use of resources and research output. Project 8312 has an initial duration of 3 years.

The Grain Storage Research Information Network and associated activities will materially increase the availability of information on existing technology to relevant organisations in South East Asia, expedite conduct of the ACIAR program, increase the impact of the program in overcoming storage problems in the area, and facilitate co-operative activities both within the ACIAR program and with other agencies concerned with post-harvest research and technology.

The objectives of Project 8312 are:—

1. To develop and co-ordinate a program of research to ensure grain can be stored safely.
2. To develop a Grain Storage Research Information Network with participation by all relevant organisations in Australia and overseas.
3. To publish a regular newsletter to disseminate information.
4. To provide a literature search and information retrieval facility.
5. To conduct workshops as appropriate in co-operation with local organisations and publish proceedings of these workshops.
6. To produce, as required, publications relevant to grain storage in developing countries.

GRAIN STORAGE RESEARCH PROGRAM

Project 8312 Staff

CSIRO Division of Entomology

Dr B.R. Champ, Grain Storage Research Program Co-ordinator
Mrs R. Goodwin, Research Librarian
Mr E. Highley, Editor, Grain Storage Newsletter

Organisation and Staff

Dr B.R. Champ was seconded from the Division of Entomology to act as Research Program Co-ordinator for an initial period of three years beginning in May 1983.

Mr E. Highley, Scientific Liaison Officer in the Division of Entomology, was appointed Editor of the *ACIAR Grain Storage Newsletter* on 13 March 1983. It is anticipated that he will spend a total of five weeks per year on the project editing and producing the biannual newsletter and other project publications.

Mrs R. Goodwin, Grain Storage Librarian in the Division of Entomology, will spend 10 hours per week on ACIAR project activities, in particular the provision of the program's literature search and information retrieval facility.

As well as part-time secretarial and administrative assistance, provision has been made in the CSIRO Division of Entomology for an administrative officer to provide dedicated support for the ACIAR Grain Storage Research Program and the Division's other ACIAR projects. The officer will spend approximately half his working time on ACIAR-related activities encompassing:

- the preparation of annual estimates of expenditure for projects, including calculation of advance payments and acquittals of money expended;
- the monitoring of expenditure in each project;
- assistance with the development of systems and computer programs to facilitate the provision of estimates and financial control information;

- assistance with the preparation of new proposals;
- assistance with the preparation and co-ordination of progress reports

The officer will take up duty at the end of August 1984.

Visits to overseas research establishments to facilitate project formulation and establishment were made by the Program Co-ordinator as follows:

Philippines and Malaysia	7-16 December 1982
Thailand and Malaysia	13-20 April 1983
Philippines, Malaysia, and Thailand	2-12 June 1983
Malaysia, Thailand, and Philippines	10-22 October 1983
Malaysia and Singapore	3-9 April 1984

In addition, periodic visits have been made to the prime contracting organisations in Australia.

Internal Workshops

Workshops attended by all project leaders are held twice a year. Two have been held to date.

The first workshop was hosted by the Agricultural Engineering Group of the CSIRO Division of Chemical and Wood Technology at Highett in Melbourne. The one-day meeting on 19 May 1983 enabled the Australian participants in the program to learn the full extent of current activities, and ensured maximum integration of project activities in Australia and overseas, including programming of interaction between projects, collaboration in common activities, provision of facilities to other projects, and optimal utilisation of overseas resources. In addition, participants inspected some of the research activities of the Agricultural Engineering Group and the Division of Energy Technology.

The second workshop was hosted by Ricegrowers' Co-operative Mills Ltd at Leeton on 13 December 1983. Objectives similar to those of the first workshop were achieved and again inspections were made of local research activities. It was agreed at this workshop that one of the two meetings each year be expanded to two days with attendance by all professional staff.

Research Information Network

The full impact of the grain storage program can be realised only if some means of information exchange is established between its separate elements. In addition, all the projects have a requirement for access to databases and other library and information systems. To meet these important needs for information and data exchange, a research information network has been established to work closely with the projects and existing regional arrangements in ASEAN. The network also promotes and extends contact between research organisations in Australia and overseas, and facilitates cooperation between them beyond the immediate scope of the ACIAR program in activities not requiring ACIAR support.

The ACIAR Grain Storage Research Information Network is the communications element in the ACIAR Grain Storage Research Program. A prime component of this network is the twice yearly *ACIAR Grain Storage Newsletter* which is edited and produced by Mr E. Highley. Another important function of the network is in maintaining and providing access to grain storage data bases and information systems. These activities are managed by the Librarian at the CSIRO Grain Storage Research Laboratory, Mrs R. Goodwin. Other functions of the network are to produce publications on grain storage, and to provide a framework for conduct of and participation in workshops and seminars relevant to the development of the program. The various activities within the network are detailed in the remainder of this section.

ACIAR Grain Storage Newsletter

The first issue of the *ACIAR Grain Storage Newsletter*, of 14 pages and about 20 000 words, was published in May 1984, following an excellent response to a request for contributions. Articles were received from ACIAR project groups in the Philippines and

Thailand, and at Ricegrowers' Co-operative Mills, the University of New South Wales, the Queensland Department of Primary Industries, and the CSIRO Agricultural Engineering Group. In addition, there were more general items on, among other things, the Research Information Network, the ASEAN Crops Post-Harvest Programme, rice production in Australia, the development of Ricegrowers' Co-operative Mills Ltd, the Philippines National Post Harvest Institute for Research and Extension, and the ASEAN Food Handling Bureau.

Copies of the newsletter were sent out on a mailing list initially of about 140 addresses, many receiving multiple copies. A prime aim is to get a personal copy into the hands of everybody involved in an ACIAR Grain Storage Research Program project.

Since publication, there have been more than 50 requests from Australia and elsewhere for copies of the newsletter or copies of publications announced in it and for individuals and institutes to be placed on the mailing list. In addition, Ricegrowers' Co-operative Mills Ltd has reprinted the newsletter for distribution to its 2500 shareholders.

The Newsletter Editor, Mr E. Highley visited Indonesia, Malaysia, the Philippines, and Thailand from 24 April to 11 May 1983 to collect material for the Newsletter from the collaborating organisations overseas and to familiarise himself with their operations.

Databases and Information Retrieval Services

The aim of project activities under this banner is to promote the spread of information on stored products by supplying bibliographic references and publications to participants in the ACIAR Grain Storage Research Program, in co-operation with other libraries in this field.

Information sources accessible through the research information network include: —
1. The Stored Products Reference Index

Grain Storage Research Program Co-ordinator, Mr Bruce Champ (centre left) gives the rationale of the Program to representatives of the Malaysian media at a press conference in Alor Setar, Kedah State.

produced by the British Ministry of Agriculture, Fisheries and Food, which covers all aspects of stored products and their pests. An up-to-date copy of this index is held by the Stored Grain Research Laboratory of the CSIRO Division of Entomology.

2. The full range of Lockheed Information Systems' DIALOG Databases, which include CAB Abstracts, AGRICOLA, BIOSIS, Chemical Abstracts, and Food Science and Technology Abstracts. The DIALOG computers are located in Palo Alto, California, but can be readily accessed from Australia via the MIDAS communications satellite and domestic telecommunications networks.
3. The FAO AGRIS Database stored by the European Space Agency, which includes much material from developing countries, and which is also accessible by satellite.

The hard copy Stored Products Reference Index now contains over 300 000 cards. During the year, 655 new references were added to it. These items were included in the Stored Products Reference Information Bulletins (Nos 59-65), which were circulated to all research workers in the program in Australia and overseas.

Over 20 searches of the literature in computer databases were performed. Assistance was provided to research staff in obtaining copies of stored product literature from the CSIRO Stored Grain Research Laboratory's collection, the Black Mountain Library, and other libraries in Australia and overseas. The UK Ministry of Agriculture, Fisheries and Food Library at Slough was very helpful in this regard.

The circulation of the newsletter and the CSIRO Stored Grain Research Laboratory's list of publications resulted in many requests for publications. Requests were received from China, Pakistan, the Philippines, and Thailand, as well as western countries. Where possible reprints were exchanged in order to build up the Canberra collection of stored product reprints.

It is expected that these information provision activities of the research information network will increase markedly as the program develops.

Collaborative Activities

Participation in GASGA

ACIAR is the nominated Australian participant in the Group for Assistance on Systems Relating to Grain After-Harvest (GASGA). The Program Co-ordinator attended annual Executive Meetings held in Cairo from 20-24 June 1983, and in Montpellier on 12-13 June 1984. Opportunity was taken during these visits to have discussions with FAO in Rome and various research establishments in England and France.

ASEAN Food Handling Sub-Committee, Grains Working Group

The Program Co-ordinator continued as consultant and ACIAR representative to the Grains Working Group and attended the 12th Meeting of the Group in Manila from 15-19 March 1983, the 13th Meeting in Kuala Lumpur from 11-13 October 1983, and the 14th Meeting in Denpasar from 10-12 April 1984.

Attendance at International Conferences and Workshops

The South East Asian Co-operative Research and Development Programme 1983 Grains Post-Harvest Workshop, held from 3-6 May at Puncak Pass, Indonesia, was attended by the Newsletter Editior, Mr E. Highley, and by the Program Co-ordinator who presented a paper on "Storage of grain under plastic covers". The attendance of Dr P. Williams of the Department of Agriculture, Victoria was supported to enable presentation of an invited paper on "Advances in grain insect control in Australia".

The Commonwealth Workshop on Post Harvest Losses, South Pacific at Apia, Western Samoa was attended from 25-29

May 1983 by the Program Co-ordinator. On behalf of Professor J.R. McWilliam, Director of ACIAR, Dr Champ delivered the keynote address of the Workshop entitled "Post harvest losses in the South Pacific, an overview". He also chaired a Technical Session on Indigenous Systems of Storage, and presented a paper on "Short term storage of durable commodities".

In line with ACIAR's interest in facilitating the transition from bag to bulk handling in the grain industries of South East Asia, the Malaysian National Paddy and Rice Authority's Brainstorming Session on Padi Bulk Handling from 7–9 June 1983 at Alor Setar, Kedah was attended by Dr R.G. Bowrey (Project 8308A), Mr M. Goldring (Project 8308B), Dr M. Bengston (Project 8309), and the Program Co-ordinator.

The 3rd International Working Conference on Stored Product Entomology was held in Manhattan, Kansas from 23–27 October 1983. The Program Co-ordinator attended and presented a paper on "Storage of grain in earth-covered bunkers". He also attended meetings of the Permanent Committee of the International Working Conferences, of which he is a member.

Mr H. Baird, Deputy General Manager of Ricegrowers' Co-operative Mills Ltd was nominated to attend the ASEAN-EEC Technical Consultation Workshop on Research, Training, and Extension in the Philippines from 10–12 January 1984 to present an invited paper "Recent developments in paddy drying, milling, and bulk handling in the Far East." The Workshop considered methodologies to be used in research and extension in the ASEAN-EEC Programme.

Dr R.G. Bowrey (Project 8308A) attended the ASEAN Crops Post-Harvest Programme Workshop on Wet Grain Handling which was held in Manila during the week of 23–27 January 1984 as part of the ACPHP's 1983 Exchange Programme.

The CHOGRM Consultative Group held a workshop on energy in agriculture in Sri Lanka in April 1983. It was attended by Dr R.G. Bowrey (Project 8308A) and Dr G.R. Thorpe (Project 8310) as Australian representatives. Interest was expressed in drying of paddy in-store.

Within Australia, ACIAR was represented by the Program Co-ordinator at the following meetings:

- International Symposium on the Practical Aspects of Controlled Atmosphere and Fumigation in Grain Storages, Perth 11–13 April 1983;
- Seminar on Pyrethroids—The Safe Pest Managers, Canberra, 8 August 1983;
- Australian Bulk Grain Handling Authorities Stored Grain Protection Conference, Melbourne, 12–14 September 1983;
- National Symposium on Ionizing Energy Treatment of Foods, Sydney, 5–6 October 1983.

Mr G. Pym of the Ricegrowers' Co-operative Mills Ltd attended the Solar World Congress in Perth, in August 1983.

Dr Tuan Nguyen (Project 8310) attended the DSIR/CSIRO Seminar on Convective Flows in Porous Media in New Zealand on 3–4 May 1984.

Other Aspects of Collaboration

ACIAR was represented by the Program Co-ordinator as an invitee at the 8th Policy Advisory Board Meeting of the South-East Asia Post-Harvest Research and Development Programme in Singapore on 19–20 April 1983.

The Program Co-ordinator continues as Regional Editor for Australia and Asia of the *Journal of Stored Product Research*.

Program Seminars and Publications

Two seminars are planned for 1985.

The first, on 'Pesticides and Humid Tropical Grain Storage Systems', is scheduled for the first half of 1985. Provisionally it will be held in the Philippines and will be conducted jointly with the Philippines National Post Harvest Institute for Research and Extension and the ASEAN Food Handling Bureau. The seminar is designed to identify the role that pesticides should play in protecting stored grain and to detail the current state of knowledge of the principles and practices of their use in the humid tropics. In so doing, it will also provide a forum for open discussion on the many issues and attitudes that must be taken into account when considering introduction of pesticides to the humid tropics and particularly into developing countries.

The second seminar, on 'Preservation of Grain Quality by Aeration and In-store Drying', is planned for late 1985. It is anticipated that it will be held in Malaysia and will be conducted jointly with GASGA and the ASEAN Food Handling Bureau. The seminar is designed to present the current state of knowledge under broad headings of objectives, basic principles, and design systems, followed by a discussion of individual case studies. Particular emphasis will be given to simulation of the processes involved and the extension of the models so developed into practical application.

Preparation of three publications covering the following topics is under way:—

(i) The identification of insects associated with stored products, including domestic species.
(ii) World distribution of stored product insects.
(iii) Grain storage research and its application in Australia.

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