USE AND MANAGEMENT OF GRAIN PROTECTANTS IN CHINA AND AUSTRALIA

ACIAR Project PHT/1990/035

P.D. Chudleigh
Agtrans Research, Toowong, Brisbane
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The Manager
Impact Assessment Program
ACIAR
GPO Box 1571
Canberra ACT 2601
Australia.

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Contents

Tables

Abbreviations

ACIAR	Australian Centre for International Agricultural Research
AWB	Australian Wheat Board
CAL	computer aided learning
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
GEB	Grain Elevators Board (Victoria, Australia)
GMES	grain management expert system
GPIC	grain pest identification and control
GRDC	Grains Research and Development Corporation, Australia
MOC	Ministry of Commerce, People's Republic of China
MRL	maximum residue limit
Mt	million tonnes
NPV	net present value
QDPI	Queensland Department of Primary Industries
RMB	Renmimbi, monetary unit of the People's Republic of China
SAGR	State Administration of Grain Reserve, People's Republic of China

Executive Summary

Project PHT/1990/035, 'Integrating Grain Protectants into Storage Pest Management' was supported by ACIAR for nearly four years from 1992 to 1995. The project was based in China and Australia. Project activity within Australia included the further enhancement of an expert system that had been developed by CSIRO. Three main activities took place within the project in China:

- assessing the extent of resistance to the most commonly used grain protectant, malathion;
- determining the rates of fenitrothion and deltamethrin that might be used under Chinese storage conditions in order to improve the range of protectants available for Chinese grain storage; and
- adaptation for, and extension of, an Australian expert system in China.

Resistance to malathion was assessed to be serious, guidelines for the use of fenitrothion and deltamethrin were developed, and a start was made on adapting the expert system to Chinese conditions.

Most of the benefits from the project will accrue to China through the knowledge gained from the project on the management of the new protectants and the further development of the expert system. Potential benefits to Australia were limited by the change in market requirements in Australia from the mid 1990s, whereby grain was required to be both insect and chemical free, thereby ending the use of protectants here.

The investment analysis shows that the benefits from the project are significant, largely because of the very large amount of grain produced and stored in China. While protectants are not used on a high proportion of grain stored there, the new protectants are being used more rapidly and effectively than they would have been without the project. The net present value of the project at a 5% discount rate is estimated at $10.1 million, the benefit–cost ratio at 7 to 1 and the internal rate of return at 43%. The net present value is still positive ($3 million) even if only benefits up to 1999 are considered.

1. Introduction

This study provides an economic assessment of project PHT/1990/035, 'Integrating Grain Protectants into Storage Pest Management', which was supported by ACIAR from January 1992 to June 1995. The project aimed to promote integration of grain protectants into storage pest management in the People's Republic of China and Australia.

The objectives of the project were to:

- develop general conceptual models of pest management decision-making for stored grain and modify the general models for specific grains and storage systems;
- define relationships between control measures, particularly protectants and fumigants, physical components of the stored grain ecosystem, and pest population growth and commodity damage;
- use models to evaluate pest management strategies, particularly protectant use, in achieving required levels of pest control within the economic, social, environmental and management constraints imposed by a grain storage system; and
- develop decision support systems as components of expert systems integrating all components of pest management and storage systems.

Personnel from the Queensland Department of Primary Industries (QDPI), the CSIRO Division of Entomology (now simply CSIRO Entomology), the Bureau of Grain Storage and Transportation (China) and the Chengdu Grain Storage Research Institute (China) participated in the project. At the start of the project, the Bureau of Grain Storage was part of the Ministry of Commerce but in 1993 became the State Grain Reserve Bureau under the Ministry of Internal Trade. Another change took place in 1998 when the Bureau became the State Administration for Grain Reserves responsible for all matters concerning transport, storage and administration associated with grain reserves.

Control of insect pests is a key issue in preserving the quantity and quality of grain, from farm to the time and place of consumption of staple foodstuffs around the world. Grain exporting countries such as Australia must give particular attention to insect pest control because markets generally require grain that is free from insects and chemical contaminants.

The two main issues in the use of grain protectants are thus resistance (and therefore survival) of the insect pests with continued use of a chemical, and the occurrence of residues of protectants in grain that may persist in human or animal foodstuff. While there has been a worldwide consumer trend against the use of residual chemical materials in food production, processing and storage, it is also realised that, in some circumstances, the use of these compounds will continue to be necessary in the short term at least. Non-chemical methods of pest control are being developed for grain storage, but protectants still play an important role in many countries.

Section 2 of this report describes grain storage circumstances in Australia and China before the project. The outputs from the project and their translation into benefits for Australia and China are described in Sections 3 and 4.

The investment analysis for the project is presented in Section 5: first, project costs are described; then sets of assumptions used in the analysis are presented. These assumptions relate to the estimation of benefits from improvements to grain storage systems in Australia and China and the attribution of benefits to the ACIAR project. Third, results of the investment analyses, including those of sensitivity analyses, are reported. Section 6 concludes the study.

2. Pre-project Situation

2.1 Australia

At the time of the project, Australia was leading the world in the development and implementation of technology for reducing losses due to pests in stored grain, particularly technology based on grain protectants. The Australian Wheat Board (AWB) accorded grain protection, and the transfer of technology in this area, a high priority.

As a significant exporter of grain, Australia has to be extremely mindful of the sensitivity of its markets to insects found in grain shipments. The use of grain protectants, as well as fumigation, were the most common measures undertaken to control insect pests. Minor use was made of aeration, inert atmospheres, and thermal disinfestation. In using grain protectants, the grain handling authorities in each State, and ultimately the Australian Wheat Board, had to be extremely careful to adhere to maximum residue limits (MRLs) for protectants that applied in Australia and elsewhere.

Insect resistance to malathion, an organophosphorus compound and the first of the major grain protectants to be introduced, had been recognised and a range of other chemicals was being used in conjunction with malathion in order to maintain effective insect control. Two chemicals, fenitrothion (another organophosphorus compound) and deltamethrin (a synthetic pyrethroid), were cheaper than the alternatives and had proven effective against all insects when used in combination.

Grain storage management and the use of protectants is complex. Different types of protectants lose activity at different rates depending on factors such as their intrinsic chemistry, the grain and storage type, and ambient temperature and moisture. As regards the last-mentioned, higher temperatures and moistures generally lead to greater rates of decay of protectant efficacy. Hence, the amounts of protectants used, the type of storage, the length of storage, and the conditions experienced during storage (such as temperature and moisture) all had to be managed together to attain maximum protection. At the same time, it was essential to leave a minimum residue of protectant on the grain, and certainly below the MRL imposed by each importing country.

At the time the project was conceived, there was a need to further develop and use expert systems to develop optimal strategies for the various permutations of grain and storage type, length of storage, and ambient conditions. Some expert systems had been developed at the time. One prototype system, developed by CSIRO, was aimed at centralised storage management systems and was based on the operations of the Grain Elevators Board (GEB) in Victoria. It was particularly relevant to wheat and barley. Another system, developed by QDPI, targeted farm storage systems.

The ACIAR project aimed to further develop these expert systems so as to gain better control of insects in a cost-effective manner, while at the same time minimising pesticide residues. Specifically, it sought to enhance the GEB system and extend it to rice and maize storage. The Grains Research and Development Corporation (GRDC) was also involved in funding the further development of the GEB system so it could be used in other States.

It was also possible that the project could benefit Australia through the establishment of a technical relationship between the AWB and the Chinese authorities responsible for importing grain. The AWB saw the lack of agreed storage protocols in China as constraining Australian grain exports to that country.

2.2 China

China is one of the world's largest producers of grain. In 1990, when this project was being developed, China was producing about 400 million tonnes (Mt) of grain per year. This increased during the 1990s to around 500 Mt in 1999.

Growth in production had placed pressure on the traditional postharvest handling and storage sector. The imbalance led to reduced efficiency and capability in handling and storing grains safely. In turn, this resulted in an increase in quantitative and qualitative losses of grain. Problems in the handling and storage system also affected China's capacity to receive and store imported grain.

There was recognition before the project that China did not have the technical capacity to use some storage technologies effectively. China sought to improve its storage system and develop well-defined protocols for use of technologies such as grain protectants.

A constraint to the successful development of such technology and protocols was the immense size of China and its grain industry, and the impact this has on the level and rate of adoption of new technology. At the time the project was implemented, control of the grain industries in China was centralised in the Ministry of Commerce (MOC). It was expected the MOC would provide a basis for facilitating assessment of industry needs and identifying where and how assistance could be given in solving problems of national significance. The MOC could also be expected to ensure maximum adoption of appropriate technology. During the life of the project, the control of all policies concerning grain shifted to the State Administration of Grain Reserve (SAGR).

China's grain storage system has two main components: a centralised storage system (containing national reserves and regionally controlled stored grain), and storage on-farm by individual farmers. National storages are strategic; regional storages are the key operational entities (although they also maintain reserves). There are also local storages, but these simply receive from farmers and act mainly as a transfer station.

Fumigation (e.g. phosphine) had been the principal method of protecting centrally stored grain. Protectants, malathion in particular, had also been widely used. It was suspected that resistance to malathion was increasing. Increasing concentrations of malathion were being applied in some circumstances, increasing costs and, depending on the length of storage, potential residues. Use of other protectant chemicals was restricted because of a lack of knowledge about proper rates of application, residues after various storage periods, and their persistence and effectiveness against insects under Chinese conditions. The management of fumigation and the other technologies available to minimise grain losses during storage was becoming increasingly complex.

3. Project Outputs and Outcomes for Australia

3.1 Outputs for Australia

The research in Australia was restricted to further development of the expert system already established for the GEB in Victoria. While GRDC funded the development and extension of the model for other States, the ACIAR project concentrated on several other enhancements. Also, as the expert system overall accounted for only some 10% of the total budget for Project PHT/1990/035, progress with the development of the expert system was limited.

One of the objectives of the enhancements was to extend the system to rice and maize. While the existing expert system dealt with maize and rice pests in the component dealing with phosphine, it did not cover protectant use on rice and maize. However, Australian rice and maize-handlers had no involvement in the project, and in this respect the project did not meet its objectives.

The ACIAR project helped to refine the generic model in two ways:

- the phosphine module was extended to incorporate the interaction of fumigation with the use of grain protectants; and
- a barley germination component was added. The expert system examined the condition of grain for malting barley from the point of view of its germination percentage. Malting barley can be stored anywhere from one week to one year depending on temperature and moisture conditions.

Hence, protectant use was only part of the expert system developed. The type of grain and its end-use were also important inputs in order to assist improved decision making.

The expert system was thus enhanced and, with the GRDC funding, a system was at least partly developed for each State grain handling authority.

3.2 Outcomes for Australia

Because of increasing market pressure for residue-free grain, the expert systems developed in the project have not been implemented in Australia for the purposes for which they were originally designed. Changes in the requirements of some customers for grain not treated with chemicals evolved quickly in Australia from the early to mid 1990s. While this trend had been building during the project, it only became apparent in the mid 1990s and largely negated any impact the expert systems might have had. Customer perceptions of the effects of fumigants such as phosphine were not as strong and phosphine continues to be used. (Use of another important grain fumigant, methyl bromide, is being phased out because it is an ozone-layer depleter.)

The speed of the change was largely the result of policy changes by major importers of Australian grain (in particular Japan, China and Korea). This was so even though China continues to use protectants and is likely to expand their role in the next decade.

As a result of the reduction in the use of protectants, decision-making became much simpler, obviating the need for expert systems.

Another impediment to the adoption of expert systems, was that grain storage managers were disinclined to rely on a computerised model or a 'black box' over which they had no control. Nevertheless, they recognised that systems were required to help them make better decisions: the role of the expert system was changing from one of decision-making to decision support.

3.2.1 Computer Aided Learning

While the use of the expert system enhanced by the ACIAR project was very limited in Australia, an increasing interest emerged in computer aided learning (CAL) for the management of grain storage. For example, ACIAR supported projects in this area in Indonesia and the Philippines. The CAL package was also extended to Vietnam and Thailand. Much of the information in the package relied on parts of the expert system already developed, particularly the reference section.

3.2.2 *Enhanced Trade*

It was hoped that the cooperation between the Chinese authorities and Australian groups through the ACIAR project would help strengthen the AWB's trade relationship with China. The AWB's annual exports of wheat to China are highly variable, but may reach two million tonnes in some years. Nevertheless, unlike Canada and the USA, Australia is not one of China's major sources of grain. China looks to Australia as a residual supplier. It is likely that any tangible benefits to Australia (or to China) through enhanced trading operations due to the ACIAR project have been small or negligible.

In summary, the improved knowledge and data collection within the ACIAR project has resulted in few benefits for Australia, as grain protectants are no longer used here. Other benefits to Australia are likely to have been minimal.

4 Project Outputs and Outcomes for China

4.1 Project Outputs for China

As part of the ACIAR project, the most important insect pests in China were collected from storages and tested for resistance to malathion and phosphine. The project investigated, in both the laboratory and the field, combinations of protectants and their application rates, for both wheat and rice. Rates of breakdown of the newer protectants were measured under controlled conditions for wheat, rice and maize. Residue levels of protectants were measured after varying concentrations and combinations of protectants were used in varying conditions of storage (temperature and moisture) for different grains. Residue levels were determined on grain samples from field trials. All of these data were then used by the Chinese to develop a decision aid (expert system) based on the CSIRO expert system.

The expected outputs of this project were:

- data on major pest problems, the pesticide resistance status of individual pests, and the grain protectants most effective against them;

- definition of the constraints operating in pest management systems and the inputs necessary to achieve appropriate levels of pest control that were economically effective, socially acceptable and environmentally sustainable; and

- development of expert systems to optimise cost effectiveness and benefits of pest control, and to minimise pesticide residue loads.

All of these expected outputs were achieved. Of most significance initially was the survey of resistance levels. Significant resistance was found to both malathion (the principal grain protectant used) and phosphine (the principal fumigant used).

It was also determined that two combinations, malathion plus deltamethrin, and fenitrothion plus deltamethrin, gave effective control of grain pests for up to year's storage. Which of these two options to use would depend on the level of resistance to malathion in a particular region. Residues resulting from such treatments were below the MRLs set in China.

The project developed an expert system called 'Grain Storage Management Expert System' (GMES), based on the original Australian expert system.

4.2 Project Outcomes for China

4.2.1 Use of New Protectants

The ACIAR survey showed that there was considerable resistance to malathion in grain pest populations. This information was used by the State Grain Reserve Bureau in making decisions about the need to phase-in the use of alternative compounds.

As a result of greater knowledge of the efficacy of different application rates as well as degradation rates under various conditions of storage (predominantly temperature and moisture), the use of the new (new to China) protectants has increased. Both fenitrothion and deltamethrin were available in China at the time of the project but their use as grain protectants was minimal because little was known about application rates and residues. The detailed evaluation of fenitrothion and deltamethrin, and comparison with malathion, both in the laboratory and in the field, contributed to the understanding of Chinese scientists and has influenced decision-making about the use of these new chemicals.

Centralised storages

The new grain protectants are now being used in regional and national storages, as well as, in different forms, for on-farm storage. This result is partly an outcome the ACIAR project but other factors have contributed, such as the continuing efforts of the Chengdu Grain Research Institute.

The new protectants now make up a small but significant proportion of all protectants used in centralised storages. On farm, protectants are used to only a small extent and the new protectants make up just a small part of that use. However, as the amount of grain produced and stored on farms is very high, the amount of new protectant used on farms is quite significant, and possibly exceeds that used in centralised storages.

It is estimated that of all the grain stored in centralised storages, approximately 10% would be treated with protectant, and of this about one-sixth would be with the new protectants. It is estimated that about 10% of on-farm stored grain is treated with some form of protectant, and again with about one-tenth of this contributed by the new protectants.

Grain losses in the centralised storage system are likely to be lower in only a small number of situations with the introduction of the new chemicals. Grain stored for long periods is often fumigated repeatedly. This is because the value of losses is considerably higher value than the cost of treatment methods, especially fumigation.

The target criterion and official standard for losses of grain in national storages is 0.2%. It is understood that at times in some locations this criterion is exceeded. Actual losses are likely to vary across storage types, temperatures, the state of the grain taken in, and storage management. Losses are variable by region and different climatic conditions.

One of the major benefits from the use of the new protectants is that it will relieve the pressure on malathion, particularly where resistance is already present. As well, use of the new protectants could delay the onset of resistance to malathion in other areas. Phosphine resistance is also manifest and there are few other fumigants available for use.

The hypothesis of the delay of the onset of resistance through use of alternative chemicals is still somewhat controversial. But even if the effect is limited, it could still prove to be an important benefit that might emerge from the project, because of the high costs of developing new chemicals, which must ultimately be borne by grain storers. Unfortunately, because of a lack of resources the Institute is no longer monitoring resistance.

Another benefit is that the new protectants, when applied at the appropriate rates, will provide protection for longer periods than fumigation or use of malathion.

While the new protectants have a higher cost per unit of active ingredient than malathion, the quantities applied are less. Overall, however, they usually cost more to apply than a single fumigation or the use of malathion at low rates, though in some cases the application rates for malathion were becoming so high that the cost was becoming quite significant. Also, the flexibility in managing grain releases for consumption is reduced with high rates of malathion application as the end residue levels are higher for a given period of storage time than if a lower rate were used. At times the new protectants may be lower cost than the next best option, which may entail installing additional equipment and facility conversion for such technologies as aeration.

On-farm storages

Most farmers store grain and some use various means of protecting the grain in storage. There has been no comprehensive survey of farmers' grain storage practices, but they do vary significantly throughout the regions. Fumigation with phosphine is practised by a few farmers who have appropriate physical facilities, and various forms of protectants are also used.

After the ACIAR project was completed, and management guidelines for the new protectants devised, techniques and products have been developed incorporating fenitrothion and deltamethrin in powder form. The most commonly used method of applying the new protectants for farm storage is to mix a powder of fenitrothion and deltamethrin with rice hulls and then mix the rice hulls with the grain.

Commercial products packaged in convenient packs to treat specific quantities of grain (e.g. 1.5 tonnes) are available in different forms in various regions, although it is understood that there is no product sold nationally. One product, called Bao Liang Lin, is produced by the Institute. It uses talcum powder as a carrier. Another commercial product is a mixture of a Chinese herb and deltamethrin.

Health

The data on insecticide concentrations and residue levels produced by the ACIAR project were critical in validating the field trials. The data on rate of breakdown of individual compounds and the residue levels on grain in the field trials helped assure the health authorities in China that recommended treatments produce residue levels acceptable to international authorities.

The introduction of the new chemicals has probably had little effect on the environment or the health of consumers, depot workers, or farmers. Presumably, MRLs would not have been exceeded without the ACIAR research. However, because of the use of the new protectants, overall residue levels are now likely to be far below the MRLs. For example, the MRL for deltamethrin is 0.5 ppm; the same as the application rate. This may or may not translate into a health benefit.

Use of appropriate application technology for the new protectants is important, because they have a high mammalian toxicity in concentrated form. On the other hand, a number of deaths on farms have been reported in the past due to misuse of phosphine and some of the new protectant products are much safer than phosphine where they are pre-mixed and packaged.

Future use of protectants in China

It is likely that the use of protectants worldwide will decrease in the future but in China this may take quite some time. Alternative, non-chemical control methods are generally higher cost when capital requirements are considered. China has a significant amount of new storage being constructed at present, which will lift the capacity to store national reserves in an improved manner. It is likely that government policy will encourage more stocks to be held on-farm but with a strategic national reserve of quality grain still in place. Grain protectants are likely to continue to be used for a considerable period into the future in China.

Distribution of benefits

Overall, both grain producers and consumers should benefit from the use of the new protectants through reduced advent of malathion resistance, lower cost of treatment for some stored grain, lower losses on farm, and lower residue levels in grain consumed.

4.2.2 Use of Expert Systems

The final report for the project and the subsequent project review indicated that development of this system was successful, with plans for extensive trials and adoption in China following the project completion in 1995. In its development, it used part of the GMES system (Grain Management Expert System) that was translated from the original expert system supplied by the ACIAR project. The system is called ‘Grain Protection

Insect Control' (GPIC) and operates in a Windows (Chinese version) environment.

Testing and adoption has been significant, with 120 users now running GPIC; about 110 storages and 10 training and research institutions. The expert system is being used as a decision aid as well as an educational tool for managers and other depot employees.

GPIC has had an impact at most of the storages where it has been used. Cost savings are being made in these depots largely through instilling greater confidence in the decisions being made and managers being more innovative in treatment strategies. Most cost savings are attributable to reductions in protectant and labour use.

4.3 Project Outputs and Outcomes for the Rest of the World

Benefits accruing to countries other than China would most likely be concentrated in Southeast Asia, because of other, related projects implemented in that region.

Greater efficiency of grain storage in China may have a number of potential impacts on the rest of the world through both supply and demand impacts within China. The overall outcome of greater efficiency in grain storage is that the welfare of the population will be increased. Relative impacts on consumers and producers are difficult to predict as there are a number of scenarios that could eventuate. Also, any impacts on the rest of the world through greater efficiency in grain storage in China are likely to be minor compared with the changes that might be made to Chinese Government policy on grain prices paid to local grain producers, future strategies on stockholding, and trade policy. If and when China enters the World Trade Organization, such policies will come under increasing scrutiny.

5. Investment Analysis

5.1 Project Costs

The funds provided by ACIAR for project PHT/1990/035 are detailed in Table 1.

Table 1. ACIAR expenditure on project PHT/1990/035 (nominal A$)

Year ending 30 June	ACIAR expenditure
1992	179,150
1993	136,950
1994	125,650
1995	66,550
Total	508,300

In addition to these costs, other resources were provided by CSIRO, the Chinese Grain Research Institute at Chengdu, and by QDPI. Estimates of these costs are given in Table 2.

Table 2. Expenditure by other organisations on project PHT/1990/035

Year ending 30 June	Grain Research Institute, Chengdu (RMB)	CSIRO Entomology (A$)	QDPI (A$)
1992	600,000	37,500	37,500
1993	750,000	75,000	75,000
1994	750,000	75,000	75,000
1995	700,000	37,500	37,500
1996	100,000	0	0
1997	100,000	0	0
1998	0	0	0
1999	0	0	0
Total	3,000,000	225,000	225,000

5.2 Estimation of Benefits to China

5.2.1 Benefits from Use of New Protectants

Quantities of grain to which protectant is applied

It is estimated that some 500 Mt of grain were produced in China in 1999. It is further estimated that about 90% of this was of types that are stored (e.g. wheat, barley, maize, rice etc).Of the 450 Mt of annual production that is stored, it is estimated that 78% is held for longer than 3 months, thus becoming vulnerable to insect infestation. Of this 351 Mt, approximately 25% is stored in national and regional storages, and the remainder on-farm. The storage interval can be from 3 months to 2–3 years, with the longer periods usually applying to grain within the strategic national storages.

Of the estimated 88 Mt stored centrally in 1999, it is reckoned that 10% was protected using chemicals, with fumigation the most common treatment. Of the estimated 8.8 Mt to which chemicals are applied, the 'new' protectants of fenitrothion and deltamethrin are used in about one-sixth of grain treated. Hence, the use of the new protectants by central storages is estimated to be associated with about 1.5 Mt of grain produced in 1999.

Of the 263 Mt stored on farms for more than 3 months, it is estimated that only about 10% of it is treated with any type of protectant. Hence, about 26 Mt is treated with some form of protectant. It is estimated that the new protectants contribute about one tenth of this, that is, about 2.6 Mt.

Benefits to central storages from use of protectants

Potential benefits that might be gained from the use of the new protectants by central storages include:

- saved grain losses that might have occurred due to failure of previous methods used where resistance levels were high;
- lowered costs of protecting grain but with similar losses as before; and
- reduced amounts of chemicals used with consequent reduced residues on consumed grain.

Because of the need to reach the maximum loss target of 0.2% stipulated by the Chinese Government and the low cost of treating grain by various methods in relation to its value, it is unlikely that losses would have risen much above the maximum loss target, except in exceptional circumstances. The benefits of the new protectants have therefore been quantified mainly through overall reductions in the costs of treatment relative to what they would have been if the new protectants were not available, as detailed below.

In general the new protectants are higher cost than the traditional treatments of fumigation with phosphine and use of malathion as grain protectant. The relative costs of the chemicals are shown in Table 3. Table 3 also shows for central storages the approximate application cost. Estimates of the on-farm storage chemical and application costs are also included.

Table 3. Approximate costs of grain treatment methods

Treatment method	Cost (RMB per tonne treated)
Central storages	
Fumigation with phosphine (one fumigation)	0.24
Malathion @15 ppm	0.38
Malathion @ 30 ppm	0.76
Aeration (variable costs only)	0.60
Aeration (variable plus capital recovery costs with new facilities)	4.00
Fenitrothion 10 ppm	0.70
Malathion plus deltamethrin	0.65
Fenitrothion 5 ppm plus deltamethrin 0.1 ppm	0.78
Application costs per treatment with chemicals	0.16
On-farm	
Rice hulls incorporating new chemicals	2.0
Packaged products incorporating new chemicals	4.5

The savings arising from use of the new protectants have been estimated in the following way:

1 Saved grain losses: It is assumed that losses would be reduced when quite severe resistance to malathion is evident and where fumigation is not possible. It is assumed that this saved loss would apply to only 2.5% of centrally stored grain using the new protectants. It is assumed that the losses may have increased from 0.2% to 1.0%, a loss avoided of 0.8% over 37,500 tonnes, valued at 1500 RMB per tonne. This saved loss is equivalent to 450,000 RMB per year. The cost of the new protectants would be 0.78 plus 0.16 RMB per tonne, about 0.94 RMB

per tonne treated. If the saved cost is assumed to be 0.38 RMB per tonne, the net additional cost is 0.56 RMB per tonne, or only about 21,000 RMB per year.

2 Lowered cost of protecting grain with same losses:

(a) Fumigation with phosphine may have to be carried out three times for some grain stored over long periods. This would be equivalent to 1.20 RMB per tonne of treated grain (3×0.24 plus 3×0.16). The new protectants would incur slightly lower costs at 0.94 RMB per tonne treated (0.78 plus 0.16) for a saving of 0.26 RMB per tonne. It is assumed that 20% of the new protectants are used in this situation. Thus, 300,000 tonnes will incur a saving of 0.26 RMB per tonne, equivalent to net benefits of 78,000 RMB per annum.

(b) Where fumigation is not possible, it may be necessary to use the next most promising method (e.g. low temperature control or aeration in regions where the climate is suitable). The cost of aeration is estimated at 4 RMB per tonne and includes a capital recovery cost as few storages currently have the capacity for aeration. It is assumed that 20% of stored grain using the new protectants would be subject to this situation. Savings would be about 3 RMB for 300,000 tonnes, yielding benefits of about 900,000 RMB per year.

3 Reduced residues on consumed grain: This has not been quantified due to inadequate information on the linkages between residue levels and the health of consumers, or information on the satisfaction of knowing there are lower residues on the grain from use of new protectants.

Likewise, benefits arising from the likely reduced advance of malathion resistance due to the introduction of the new protectants have not been quantified. It is likely that increasing levels of malathion would have had to be used, which might not only have become more costly than the use of the new protectants, but also might have reduced flexibility in the timing of grain use, because of the longer periods taken for the residues to degrade to acceptable levels.

Benefits to farmers from use of new protectants

A range of estimates of on-farm losses during storage has been made for various regions of China but there is no estimate for China as a whole. The best estimate available from personnel at the Grain Storage Research Institute is that the average loss due to insect damage is 3 to 5%, with some farms experiencing far higher losses. The loss after the new protectants are used is probably about 0.5% or lower.

The use of the new protectants on-farm is usually more costly than other storage measures taken on-farm. As there has been no resistance to malathion detected on farms to date, the reasons why farmers may be moving to the new protectants include:

- they do not have access to malathion;
- they cannot use fumigation because their storages are not suitable;
- they are being advised not to use phosphine by the authorities due to the risks of its use; or
- promotion of the new protectant mixes by the local manufacturers and the Grain Storage Research Institute.

In general, the new protectants are being used on farms largely in areas where they are being manufactured and promoted. It is likely that many of those using the new protectants are at the forefront in overall postharvest management and in grain storage technology. It is estimated conservatively therefore that the losses on farms before adopting the new protectants were quite low at 1%, far lower than the overall farm average of 3 to 5%. After the adoption of the new protectants it is assumed losses fall from 1 to 0.5%. The likely saving in grain therefore attributable to the new protectants is 0.5% of 2.6 Mt or 13,000 tonnes per annum. If grain is valued at 1500 RMB per tonne then the gross saving is 19.5 million RMB per annum.

It is likely that there are additional costs of using the new protectants. These additional costs will depend on what measures have been replaced by the new protectants. As the cost of the new protectants applied on-farm varies between 2 and 4.5 RMB per tonne treated, it is assumed that the net additional cost is 3 RMB, totalling some 7.8 million RMB per annum.

This indicates a net saving to farmers of around 11.7 million RMB per annum from the use of the new protectants.

5.2.2 Benefits from Use of the Expert System

It is assumed that the cost saving of grain stored is 0.12 RMB per tonne due to GPIC. This estimate is based on examples of cost savings that are currently being experienced in central storage depots. One storage of 100,000-tonne capacity was making savings of 12,000 RMB per annum because of the GPIC. Another storage of 60,000-tonne capacity was making savings of 50,000 RMB per annum. This would be equivalent to 0.83 RMB per tonne of grain stored. The lower benefit of 0.12 RMB per tonne has been used in the analysis.

GPIC is currently being used in 110 central handling storages throughout China. This represents about 10% of the total grain stored centrally. It is likely that benefits are currently accruing to many of the 110 storage depots.

It is assumed that GPIC will continue to be used throughout China and that the maximum amount of grain stored centrally that will eventually gain from this technology is 50%. It is anticipated that there will be a gradual and linear increase in the current proportion using GPIC (10%) to a maximum of 50% by the year 2005.

5.2.3 Framework for Attribution

As the new protectant chemicals were available in China before the ACIAR project, it can be assumed that the information produced by the project might have eventually become available to the Chinese even without the project, albeit at a much later time. Hence, the actual benefits ascribed to ACIAR project PHT/1990/035 have been estimated through the benefits being brought forward in time. Staff at the Chengdu Grain Storage Research Institute estimated that the benefits have been brought forward by about five years as a result of the project and this assumption has been used to estimate the difference due to the investment and hence the investment criteria associated with the project.

5.2.4 Summary of Key Assumptions

Tables 4 and 5 summarise the key assumptions made to estimate benefits from the ACIAR project in relation to central and on-farm storages.

5.3 Estimation of Benefits to Australia

As discussed earlier, the benefits to Australia are minimal and have been derived mainly from the computer assisted learning initiative that built on the existing expert system and on which it relied to some extent. It is unlikely that the AWB made trading gains as a result of the project.

5.4 Results

Using the key assumptions in Tables 4 and 5, a discounted cash flow analysis was used to estimate investment criteria for project PHT/1990/035. The analysis was carried out for a 30-years time span, with the first year of the analysis as the first year of funding for the project (year ended 30 June 1992). A discount rate of 5% was used. NPVs are reported in 1997 dollar terms as of the year ended 30 June 1997. Results are reported in Table 6.

Table 4. Key assumptions in estimating benefits to central storage operations

Benefit	Assumption
Benefits from new protectants	
Amount of grain to which new protectants were applied	1.5 million tonnes in year ended 30 June 1999
Benefit A: Saved grain losses due to use of new protectants	Applies to 2.5% of new protectant use on centrally stored grain where loss is reduced from 1% to 0.2%
Benefit B: Cost savings where multiple fumigations were an alternative to new protectants	Applies to 20% of new protectant use where cost is reduced from 1.20 RMB to 0.94 RMB per tonne
Benefit C: Cost savings where the only alternative is to build or incorporate facilities for aeration	Applies to 20% of new protectant use where cost is reduced from about 4 RMB to 1 about RMB per tonne.
Value of grain	1500 RMB per tonne
Period which above benefits brought forward due to the ACIAR project	5 years
Benefits from GPIC	
Cost savings from use of GPIC in storage depots	0.12 RMB per tonne of grain stored
Percentage of grain centrally stored to which benefit applied in 1999	10%
Maximum percentage of grain centrally stored for which GPIC benefits will accrue	50%
Year in which maximum benefits will accrue	2005
Period which above benefits brought forward due to the ACIAR project	5 years

Table 5. Key assumptions in estimating benefits to on-farm storage operations

Benefit	Assumption
Amount of grain to which new protectants were applied	2.6 million tonnes in year ended 30 June 1999
Saved losses due to new protectants	0.5%
Value of grain	1500 RMB per tonne
Additional cost of using new protectants	3 RMB per tonne of grain treated
Period which above benefits brought forward due to the ACIAR project	5 years

Table 6. Investment criteria for ACIAR project PHT/1990/035

Net present value (A$m)	Benefit–cost ratio	Internal rate of return (%)
10.1	7 to 1	43

When benefits were considered only up to 1999, the NPV was still positive at $3 million, the benefit–cost ratio was 2.8 to 1, and the internal rate of return was 31%.

5.5 Sensitivity analysis

5.5.1 Extent of Losses Avoided on Farm

A high proportion of the benefits to China appear to be derived from the use of the new protectants on-farm. While there is no dispute about the extent of the on-farm use of the new protectants, there is very little information on the degree of loss reduction on-farm and hence the extent of the benefits that are accruing from that source. A sensitivity analysis was therefore made around the assumption that without the new protectants the loss would have been 1%. The assumed loss before the new protectants were used was varied at 0.75%, 1% (base) and 3% to ascertain the NPV with each of those assumptions. Results shown in Table 7 suggest that even small levels of losses avoided on-farm provide a positive return to the ACIAR investment.

Table 7. Sensitivity of investment criteria to changes in assumptions about on-farm losses

Assumption of loss without protectants (%)	Net present value ($)	Benefit–cost ratio	Internal rate of return (%)
0.75	3.5	3 to 1	22
1 (base)	10.1	7 to 1	43
3	62.7	39 to 1	102

5.5.2 Extent of Use of Expert System

The base analysis assumed that the expert system would eventually provide the identified benefits to 50% of the centrally stored grain. Analyses were carried out assuming this was only 10% or 25% of centrally stored grain. Results in Table 8 show that the investment criteria are not particularly sensitive to the extent of use of the GPIC system.

Table 8. Sensitivity of investment criteria to extent of adoption of GPIC

Assumption for adoption of GPIC (%)	Net present value ($)	Benefit–cost ratio	Internal rate of return (%)
50 (base)	10.1	7 to 1	43
25	8.7	6 to 1	42
10	7.8	6 to 1	41

Sensitivities were also carried out for different discount rates (0, 5 (base) and 10%). Results showed that the investment criteria are not particularly sensitive to the discount rate across this range (Table 9).

Table 9. Sensitivity of investment criteria to discount rate

Discount rate (%)	Net present value ($)	Benefit–cost ratio
0	12.6	10 to 1
5 (base)	10.1	7 to 1
10	8.1	5 to 1

6 Conclusion

The NPV of $10.1 million demonstrates that the investment in ACIAR project PHT/1990/035 appears to have been sound, with all quantified benefits accruing to China. Benefits to grain storages have accrued to both central storage systems and farm storage, with the latter being larger than the former. Central storage systems have benefited from some small savings in losses but with significant benefits derived from saved costs through the use of the new protectants and GPIC. On-farm storages have benefited mainly through reduced losses of grain that otherwise would have occurred.

Assumptions have been conservative. No allowance has been made for the likelihood that the use of the new protectants will increase in future, although it is expected that this will be the case for both central and farm storage.

Benefits to Australia have been negligible due to the phasing out of the use of grain protectants. However, project work to refine and extend the Australian expert systems has not been wasted since much of the information contained has been utilised in computer aided learning programs in both Australia and overseas.

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Appendix

Detailed cash flows from the economic assessment of ACIAR-supported project PHT/1990/035

Year ended 30 June	Annual Chinese benefits (1999 RMB)	Annual Chinese benefits (A$ nom.)	Research cost in A$m	Inflation Index	Real discount factor	Discounted Chinese annual benefits (1997 A$)	Discounted research costs (1997 $A)
1992	0	0	346763	107.3	1.2763	0	434257
1993	0	0	402716	109.3	1.2155	0	480313
1994	0	0	391416	111.2	1.1576	0	444605
1995	0	0	249598	116.2	1.1025	0	270015
1996	2625413	405244	15435	119.8	1.05	417517	15903
1997	5912301	912589	15435	120.2	1	895455	15146
1998	9564771	1476364	0	121.0	0.9524	1379661	0
1999	14288653	2205516	0	122.5	0.907	1962908	0
2000	14815153	2286783	0	122.5	0.8638	1938320	0
2001	15341653	2368051	0	122.5	0.8227	1911623	0
2002	16394653	2530586	0	122.5	0.7835	1945552	0
2003	17447653	2693121	0	122.5	0.7462	1971916	0
2004	17974153	2774388	0	122.5	0.7107	1934686	0
2005	18500653	2855656	0	122.5	0.6768	1896531	0
2006	18500653	2855656	0	122.5	0.6446	1806220	0
2007	18500653	2855656	0	122.5	0.6139	1720209	0
2008	18500653	2855656	0	122.5	0.5847	1638295	0
2009	18500653	2855656	0	122.5	0.5568	1560280	0
2010	18500653	2855656	0	122.5	0.5303	1485981	0
2011	18500653	2855656	0	122.5	0.5051	1415220	0
2012	18500653	2855656	0	122.5	0.481	1347829	0
2013	18500653	2855656	0	122.5	0.4581	1283647	0
2014	18500653	2855656	0	122.5	0.4363	1222521	0
2015	18500653	2855656	0	122.5	0.4155	1164305	0
2016	18500653	2855656	0	122.5	0.3957	1108862	0
2017	18500653	2855656	0	122.5	0.3769	1056059	0
2018	18500653	2855656	0	122.5	0.3589	1005771	0
2019	18500653	2855656	0	122.5	0.3418	957877	0
2020	18500653	2855656	0	122.5	0.3256	912264	0
2021	18500653	2855656	0	122.5	0.3101	868823	0
Total						36808332	1660239
Total up to and including 1999						4655541	1660239

IMPACT ASSESSMENT SERIES

No.	Author and year of publication	Title	ACIAR project numbers
1	Centre for International Economics (1998)	Control of Newcastle disease in village chickens	8334, 8717 and 93/222
2	George, P.S. (1998)	Increased efficiency of straw utilisation by cattle and buffalo	8203, 8601 and 8817
3	Centre for International Economics (1998)	Establishment of a protected area in Vanuatu	9020
4	Watson, A.S. (1998)	Raw wool production and marketing in China	8811
5	Collins, D.J. and Collins, B.A (1998)	Fruit fly in Malaysia and Thailand 1985–1993	8343 and 8919
6	Ryan, J.G. (1998)	Pigeon pea improvement	8201 and 8567
7	Centre for International Economics (1998)	Reducing fish losses due to epizootic ulcerative syndrome — an ex ante evaluation	9130
8	McKenney, D.W. (1998)	Australian tree species selection in China	8457 and 8848
9	ACIL Consulting (1998)	Sulfur test KCL–40 and growth of the Australian canola industry	8328 and 8804
10	AACM International (1998)	Conservation tillage and controlled traffic	9209
11	Chudleigh, P. (1998)	Post-harvest R&D concerning tropical fruits	8356 and 8844
12	Centre for International Economics (1998)	Biological control of the banana skipper in Papua New Guinea	8802-C
13	Chudleigh, P. (1999)	Breeding and quality analysis of rapeseed	CS1/1984/069 and CS1/1988/039
14	McLeod, R., Isvilanonda, S. and Wattanutchariya, S. (1999)	Improved drying of high moisture grains	PHT/1983/008, PHT/1986/008 and PHT/1990/008

ECONOMIC ASSESSMENT SERIES (DISCONTINUED)

No.	Author and year of publication	Title	ACIAR project numbers
1	Doeleman, J.A. (1990a)	Biological Control of Salvinia	8340
2	Tobin, J. (1990)	Fruit Fly Control	8343
3	Fleming, E. (1991)	Improving the Feed Value of Straw Fed to Cattle and Buffalo	8203 and 8601
4	Doeleman, J.A.,(1990b)	Benefits and Costs of Entomopathogenic Nematodes: Two Biological Control Applications in China	8451 and 8929
5	Chudleigh, P.D. (1991a)	Tick-borne Disease Control in Cattle	8321
6	Chudleigh, P.D. (1991b)	Breeding and Quality Analysis of Canola (Rapeseed)	8469 and 8839
7	Johnston, J. and Cummings, R. (1991)	Control of Newcastle Disease in Village Chickens with Oral V4 Vaccine	8334 and 8717
8	Ryland, G.J. (1991)	Long Term Storage of Grain Under Plastic Covers	8307
9	Chudleigh, P.D. (1991c)	Integrated Use of Insecticides in Grain Storage in the Humid Tropics	8309, 8609 and 8311
10	Chamala, S., Karan, V., Raman, K.V and Gadewar, A.U. (1991)	An Evaluation of the Use and Impact of the ACIAR Book *Nutritional Disorders of Grain Sorghum*	8207
11	Tisdell, C. (1991)	Culture of Giant Clams for Food and for Restocking Tropical Reefs	8332 and 8733
12	McKenney, D.W., Davis, J.S., Turnbull, J.W. and Searle, S.D. (1991)	The Impact of Australian Tree Species Research in China	8457 and 8848
	Menz, K.M. (1991)	Overview of Economic Assessments 1–12	