THE IDRC BEAN RESEARCH NETWORK

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This series includes meeting documents, internal reports, and preliminary technical documents that may later form the basis of a formal publication. A Manuscript Report is given a small distribution to a highly specialized audience.

La présente série est réservée aux documents issus de colloques, aux rapports internes et aux documents techniques susceptibles d'être publiés plus tard dans une série de publications plus soignées. D'un tirage restreint, le rapport manuscrit est destiné à un public très spécialisé.

Esta serie incluye ponencias de reuniones, informes internos y documentos técnicos que pueden posteriormente conformar la base de una publicación formal. El informe recibe distribución limitada entre una audiencia altamente especializada.

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Evolution of a Network

Of the global annual production of 50 million tonnes of grain legumes, fully 20% is of the common bean (*Phaseolus vulgaris*). Grain legumes are important sources of proteins that provide essential amino acids to supplement cereal diets.

More than half of all grain legumes are produced in developing countries, and beans are included in the daily meals of people in South and Central America, India, and Africa.

Beans consumption depends on customs, availability, and cost. In Guatemala, cooked black beans are eaten up to three times per day, usually along with corn tortillas. Chileans prefer gray beans and consume them about twice per week.

Compared with most high-protein foods, beans are usually reasonably priced and available throughout the year. However, storage problems plague the bean industry. Postharvest losses in excess of 40% are occassionally reported in some countries. Poor postproduction practices can result in mould growth on high-moisture beans, quality deterioration due to colour and flavour changes, and insect damage. In addition, hardening of beans during storage reduces their quality and greatly increases cooking time.

Hardening of beans during storage is a particularly important problem in countries where beans are a staple. Hardness, brought about by elevated temperature and humidity during storage, extends the time necessary to cook the beans to acceptable tenderness and reduces palatability. These, in turn, lead to increased energy expenditures, loss of nutritional value, minimal consumer acceptance, economic losses to those who farm and store beans, and higher costs to consumers for good beans. In Central America, economic losses due to bean hardening amounted to USD 12 million in 1977. National storage authorities, consumers, and farmers are all affected directly.

The International Development Research Centre had, for several years, funded research on legume quality in Egypt, Lebanon, and Guatemala. These efforts sought correlations between mineral, protein, and starch content, seed components (hulls and cotyledons), and the degree of hardness. However, interpretation of the results of these projects was difficult because of a lack of standardization of the bean samples and storage conditions, the absence of physical procedures for hardness testing, and the unavailability of consumer acceptability criteria on which to develop laboratory tests.

Future research would have to address these shortcomings. As well, if the problem of bean hardening during storage was to be solved, it was believed that a fundamental understanding of the biochemical mechanisms that were taking place was necessary. Once these mechanisms were understood, appropriate postproduction treatments could be developed to prevent or control the phenomenon and input could be made into future breeding programs aimed at genetically reducing hardening.

Scientists in the Pontificia Universidad Catolica de Chile and the University of Guelph had, through previous work, gained experience in the engineering and biochemical aspects of bean hardness. Together they wished to tackle the task of determining the mechanism of bean hardening and ways to inhibit hardening. They approached IDRC to fund their research in 1982.

In response to this collaborative proposal, IDRC decided to fund a workshop in 1983 to review current knowledge of the bean hardening phenomenon and to identify areas of research needed to find a solution to the problem of hard-to-cook beans. Stimulated by these discussions, the University of Manitoba, the host for the meeting, and the Instituto de Nutricion de Centro América y Panama (INCAP) proposed a complementary study on consumers preferences.

Both these research projects were subsequently funded by IDRC. In 1983, food engineers from the Pontificia Universidad Catolica de Chile and food chemists from the University of Guelph started to investigate the biochemical mechanisms responsible for the hardening of stored black beans and to develop practical ways to stop the hardening. One year later, nutritional chemists and agronomists at the Instituto de Nutricion de Centro América y Panama and sensory specialists and food chemists at the University of Manitoba initiated work on identifying the characteristics that made beans acceptable to consumers, ways to measure the texture of processed beans, and possibilities for using hard beans.

These two projects reflected much of the underlying philosophy of IDRC research support. Institutions with similar interests but with different skills and expertise were linked to work on research that had a direct bearing on practical problems faced by poor people in developing countries. As well, as the projects progressed so did the skills of the young researchers in Canada and in Chile and Guatemala who were involved in various aspects of the research.

These projects were also historic because they marked the first time that food research institutions in Canada and Latin America had ever collaborated on a joint research project.

Sharing and learning among members of the research teams were extensive. The food scientists at Guelph shared techniques of biochemical laboratory analysis with their co-workers from Chile, who were engineers. The engineers brought quantitative techniques such as kinetic modelling to the project. From Manitoba came skills in consumer preference studies and sensory analysis that were new to the experience of the Guatemalans in nutritional analysis and product development.

The Canadians were enriched by the opportunity to work on real problems in the Third World and to learn from the practical field work undertaken by their partners. At the same time they were able to help with the development of approaches and techniques that had been unavailable to the scientists in Guatemala and Chile. The Latin Americans, too, were stimulated to move beyond their laboratories and to work more in their local context. They incorporated farmer surveys in their work and involved storage agencies, the food industry, and consumers in their activities.

This coming together and expansion of the various skills of the researchers was important to the success of these projects. It was only together that the scientists were able to muster the broad range of inputs needed to address the multifaceted research required to understand the hardening phenomenon, its implications, and its control.

By 1985, the pair of projects produced a considerable body of knowledge on bean hardening and on consumer preferences. However, although progress was significant, more work was still needed to solve the technical questions of why beans hardened when they were stored and the practical questions of how to minimize hardening under field conditions and how to use beans that harden.

Further IDRC funding for their research was forthcoming in 1987. In this phase of support, the institutions were formally linked in a four-member network, which it was hoped would make more rapid progress toward understanding bean hardening. With this knowledge, work would progress on controlling hardening during storage, accessing the economic impact of hardening, setting standards of consumer acceptability, and preparing acceptable foods using hardened beans. Beyond these research objectives, the network looked to strengthen methods for integrated research on postproduction problems, and to disseminate its findings to solve storage and handling problems of grain legumes.

The unification of the research at the four centres under one project improved communication among the partners and facilitated the exchange of bean samples and techniques between institutions. It also provided an innovative and stimulating environment for the researchers because of the multidisciplinary and multinational approach that was built into the network.

At four network meetings, project leaders and research staff discussed their efforts, shared ideas about future activities and directions, and clarified the research responsibilities of each team. These meetings also provided a venue for discussions with other bean researchers from cooperating agencies in Colombia, Brazil, Costa Rica, and Mexico.

Almost thirty students in Chile, Guatemala, and Canada were active in the research. Some worked on graduate theses, while others fulfilled undergraduate requirements (Fig. 1). Student participation allowed the investigation of specific problems that otherwise could not have been addressed because of budget restrictions.

These young scientists gained valuable experience in the design and conduct of research in a systematic and scientific manner on an international scale. It was also rewarding to see the data they helped produce be used to solve practical problems faced by the bean industry and to provide better quality food products for people in Latin America.

Over 6 years, 40 staff and students participated in a diverse and complex set of activities aimed at a common objective. This booklet describes the activities of the network and the products of its research. The description of the work carried out by the network is

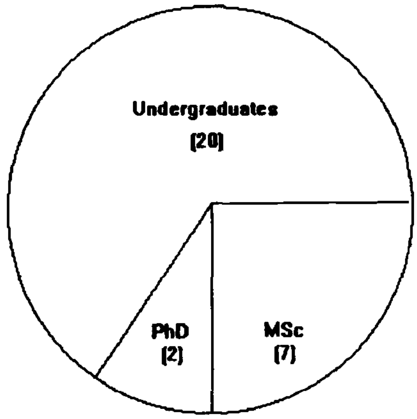

Fig. 1. Student participation in IDRC bean network.

brief. This is because the major findings of the research network have been reported in various journal articles and other publications. The original sources, which are listed in the bibliography, should be consulted for specific details on the methods used and the detailed observations and resulting conclusions. Finally, the booklet assesses the ups and downs of managing a network, and makes recommendations for others who may be managing or participating in a similar cooperative activity.

Achievements

Much new knowledge was gained during the years of collaboration among the four research institutions. The ways in which farmers and storage agencies store and handle beans were documented and economic losses due to hardening were quantified. The complex underlying physical reasons why beans harden when they are stored were clarified and, based on this, new ways were developed to store beans so as to minimize hardening. Consumer studies identified the features that make raw and cooked beans acceptable. Finally, ways to use hard beans in food products were developed and tested.

The researchers in this network did not work in isolation of either their fellow researchers or those who could potentially use the results of their research. They involved farmers, storage agencies, and consumers in their research so they could understand existing practices and their economic implications. These same groups were also involved in the introduction and testing of the new methods of handling and storage and the assessment of new food products that were developed.

Each partner in the network contributed on their own and as part of a multidisciplinary team. The network tackled a very diverse range of topics associated with the hardening of stored beans. This made the project both challenging and complex. It allowed the researchers great flexibility in their research pursuits, but made coordination more difficult. Without the sharing of expertise and results and the mutual encouragement among the four members of the team, much of what is reported here might have taken much longer to produce.

In an effort to provide a clearer overview of the elements of the research matrix, the results have been grouped by research objective. Table 1 and Figure 2 summarize the range of problems addressed by the network and research interventions that were made.

Existing Practices

Work was conducted in both Chile and Guatemala to understand the existing system for processing and storing beans and to obtain information necessary to estimate the losses attributable to hardening during storage. Data were compiled on how the beans were being harvested and stored and where losses and problems existed in the system.

In Guatemala it was found that as much as 30% of the stored beans were damaged and could not be used. In Chile, more than half of the postharvest loss was attributable to physical losses, 30% to nutritional losses, and the remainder to extra energy cost to soften the beans.

Understanding the steps involved in getting the beans from harvest to storage as well as the storage conditions themselves was critical. Once established, the results were used to

Table 1. Research areas investigated by the members of the IDRC bean network.

Research area	INCAP	Manitoba	Guelph	Chile
Existing practice	x			x
Storage conditions	x			x
Laboratory tests/methods		x		
Mechanism of hardening		x	x	
Nutritional changes	x		x	
Consumer acceptance	x	x		
Rapid hardening		x		
Driers/containers	x			x
Roasting				x
Sensory/consumer tests	x	x		
Use of hard beans	x		x	
Tests with farmers	x			x
Computer models (economic losses)	x			x

determine the economic impact of bean hardening during storage and to develop computer models to predict hardening and economic losses under various conditions.

Economic Implications of Hardening

Economic losses due to hardening were estimated with both consumers and producers. Surveys in Guatemala showed that many small farmers sell their bean crop immediately after harvest because they lack adequate storage facilities. This means the farmers lose potential income because they do not benefit from the increased price of beans later in the year. The most obvious problem for consumers is the cost of the extra energy that is needed to cook hard beans for the longer time needed to soften them.

The time it took to cook beans stored in the various experimental containers was compared with the time needed to cook beans stored in the traditional way. The difference in cooking times were then translated into savings in energy costs. The beans stored in the experimental containers were not as hard, and consumers could cut their energy costs in half because of the reduction in cooking time. These energy savings are significant in the cost savings to consumers and producers and have an ecological benefit as well because a large percentage of the energy used to cook food comes from wood in many developing countries.

Changes also occur in the nutritional quality of the beans when they are stored, and these changes have economic implications. In Guatemala, significant decreases in protein quality and

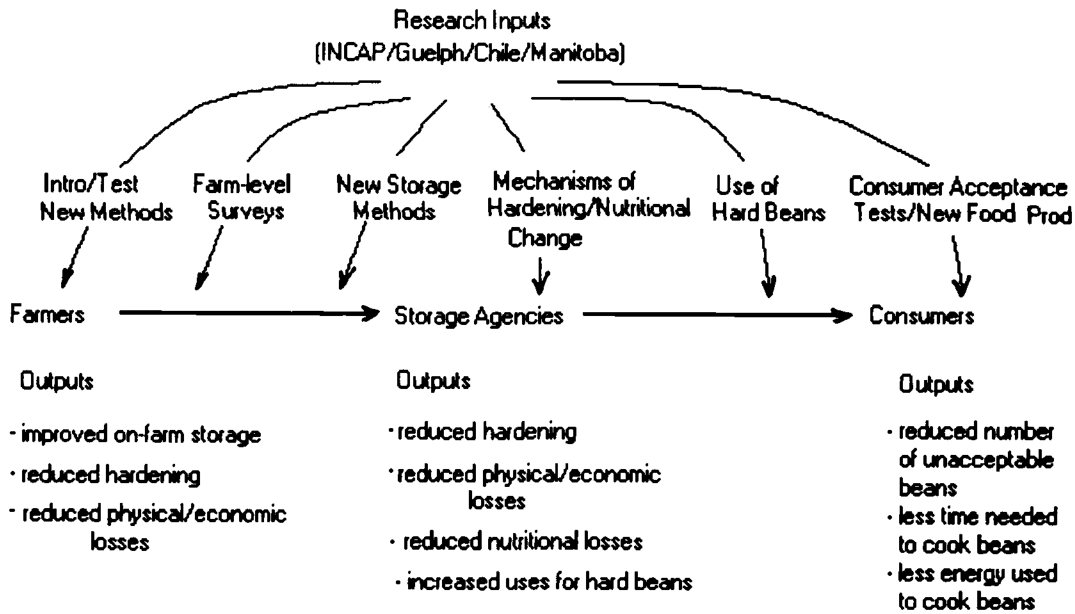

Fig. 2. The inputs and outputs made by the bean network on the range of problems related to bean hardening.

digestibility were observed after 6 months of storage. This decrease in utilizable protein, was also used as a measure of economic loss.

In Chile, a computer software package called MacBean was developed to predict hardening and economic losses under different storage conditions and to estimate physical losses due to handling practices in the market channels. This software has four functions. It can plot hardness versus storage time when moisture and ambient temperature are specified; it can produce contour plots of different types, for example, with constant temperature and variable storage time and moisture content, it will draw contours of different hardness values; it can produce a dynamic simulation of bean hardening under variable storage conditions; and, though a game-format, it can assess economic losses induced by hardness and physical losses through different market channels. Work is continuing in Guatemala to adapt this model to predict the losses that are occurring in the various steps of the local postharvest system.

Storage Conditions

To store beans successfully, and with minimal hardening, the beans must be dried to a low moisture content before they are stored and this moisture level must be maintained for as long as the beans are stored.

Field studies in Guatemala in three areas with different climatic conditions looked at postharvest handling of beans by small farmers, who produce about 90% of the crop, to evaluate losses during storage. Metal boxes, vegetable-fibre sacks, paper bags, and plastic bags were used

A

B

C

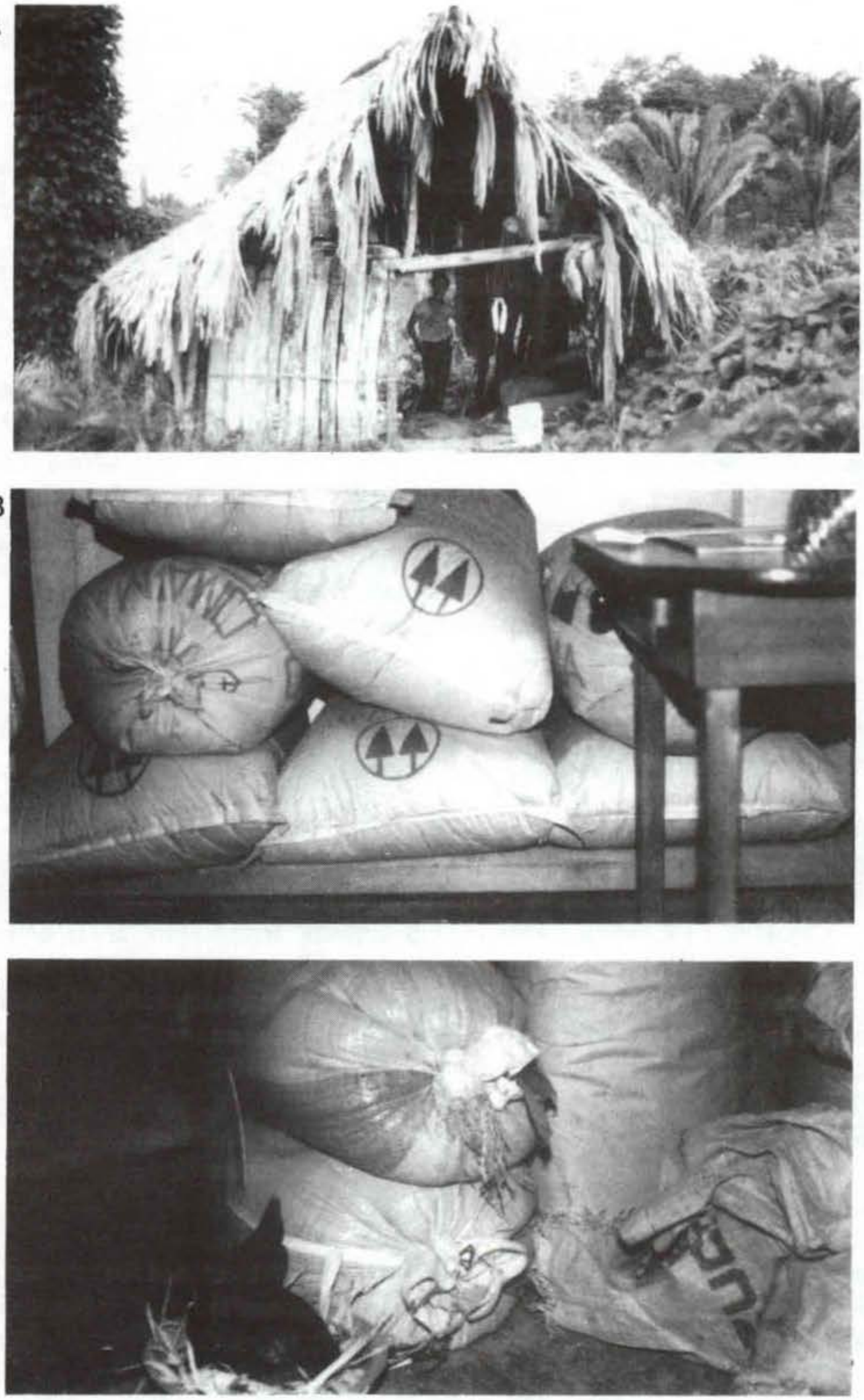

Fig. 3. A. Typical storage structure in Guatemala; B. Beans stored in paper bags; C. Beans stored in polyethylene bags.

as storage containers (see Figure 3). Containers with low moisture transmission rates inhibited bean hardening. As well, the INCAP group used a simple solar drier that could reduce the moisture of the beans to 12% for storage.

In Chile, beans dried to 10% moisture were stored in different packaging materials under simulated tropical conditions. Due to improved moisture control, beans stored in impermeable packages were found to harden more slowly than beans stored in conventional woven polypropylene bags. Beans stored underground (and thus at lower temperatures) hardened even less. However, the use of modified atmospheres, which has been suggested to improve storage, had no major effect on the hardening of roasted or untreated beans.

The information from these studies was used to develop the computer model of hardening, which was able to predict how beans would fare under a variety of storage conditions. Network results suggest that a moisture content of 10-14% is sufficient to delay hardening even under tropical conditions and to minimize damage due to handling.

Effect of Roasting

An important working hypothesis at the beginning of the project was that dry roasting would inactivate the enzyme system responsible for hardening. Black beans were therefore studied in Chile to characterize the activity of the enzyme peroxidase and to determine the effect of heat treatment and storage conditions on hardening and enzyme action. Heating the beans to inactivate the peroxidase was ineffective in arresting hardening.

However, the hot sand roaster was very effective in drying the beans and reducing insect infestation. When the moisture content of the beans was reduced from 13 to 9% (by roasting at 120°C for 2 minutes), the beans hardened more slowly when they were stored at 32°C. Infestation by insect pests was significantly reduced in beans roasted at 120°C for 2 minutes and stored for 10 months at 12% moisture.

Consumer Preferences

The network sought to develop a way to rapidly measure the quality characteristics of raw and cooked beans and to find out how important bean hardness was to consumers.

Focus groups were used for the first time with indigenous women to identify important quality parameters and the importance of hardness. This led to a more specific consumer survey developed through collaboration between INCAP and the University of Manitoba. Information was sought on how long Guatemalans stored beans in their homes, what characteristics they use to select raw beans, their methods of assessing hardness, how they cook the beans, and the qualities they looked for in cooked beans. This input was valuable for assessing consumer acceptability of various bean cultivars and for developing objective laboratory methods to evaluate quality.

Guatemalans, it was found, prefer raw beans that are black, shiny, and soft. In assessing cooked beans, consumers place importance on texture and related characteristics such as cooking time to achieve the desired texture, the thickness and colour of the broth, and the ease with which the beans can be spread.

Laboratory Methods

Colour and texture were the most important features that made beans acceptable to consumers. Therefore, techniques were developed through collaboration between INCAP and Manitoba to use chemical, physical, and sensory measurements made in the laboratory to select beans varieties that would be acceptable to consumers. Establishment and standardization of these methods were important as they allowed comparability of results between laboratories. At Manitoba, manuals of standard methods for laboratory tests and sensory evaluations were prepared and distributed. Table 2 lists the tests for which standardized laboratory methods were developed.

To be able to conduct these quality studies, a reliable supply of hardened beans was needed. Ideally, beans should be hardened quickly in the laboratory so that they have the same hardness and biochemical characteristics as beans hardened under field conditions. In the Manitoba laboratories, beans were exposed to severe storage conditions of high moisture and temperature to induce hardening. Measurements of changes in cooking time and physical characteristics demonstrated that red and black beans hardened to the same degree when they were treated under accelerated storage conditions for 4 weeks or were stored for 24 weeks under field conditions.

The team at Guelph developed a shear method to measure bean texture, which was used in Chile, Manitoba, and INCAP as a standardized index of hardness. Instron and Ottawa Texture Measuring Systems were used to shear beans across a standard grid. At Guelph and in Chile results were expressed as relative hardness compared with initial hardness. Manitoba and INCAP expressed their results as newtons per gram. Consumer panels indicated that indices beyond 400 N/g corresponded to unacceptable beans.

Mechanism of Hardening

A review of the literature at the start of the project indicated that hardening was considered to be two separate problems: hard shell beans that did not soften because they did not imbibe water when they were soaked; and hard-to-cook beans that, although soaked, required extended cooking times to soften or did not become tender when they were cooked.

Bean hardening was commonly thought to result from the crosslinking of pectates in the middle lamella of the bean. Once linked, these pectates were unaffected by cooking and thus the beans remained hard. In soft beans, a chelating agent (phytate) was thought to eliminate this crosslinking; whereas, in hard beans, the phytate was hydrolysed and could not prevent the crosslinking. Storage at high temperature and humidity was thought to lead to increased

Table 2. Tests for which standardized laboratory methods were developed.

Instron (OTMS) Peak Force Measurement of Cooked Beans
OTMS (Instron) Peak Force Measurement of Raw Beans
Mattson Bean Cooker Relative Cooking Time Method
Moisture Content of Beans
Whole Bean and Cotyledon Water Absorption
Proximate Composition of Beans Fat content of beans Protein content of beans Ash determination of beans
Phytic Acid
Seed Weight
Seed Size Distribution
Percentage Seedcoat
Seedcoat Thickness
Percentage Hardshell

hydrolysis of the phytate and thus to bean hardening. However, research by the network teams indicated that several other mechanisms contributed to hardening.

A study at Guelph on the role of phenolic compounds in bean hardening was conducted because it was suspected that lignification of phenolic compounds could add strength and decrease water uptake. This work focused on the area of the cell wall and the middle lamella because the hard-to-cook problem is actually a failure of the cotyledon cells to separate during cooking (see Figure 4). Cell wall materials from soft and hard beans were isolated and examined microscopically. Some evidence was found for lignification in hard-to-cook beans, and autoflorescence, which is characteristic of phenols such as lignin, was highly correlated to hardness.

When the cell walls in the cotyledons were extracted and quantified at Manitoba using dietary fibre fractionation techniques changes in the fractions were highly correlated with hardening. Insoluble fibre was positively correlated with hardness in both red and black beans (see Figure 5). This work suggested that additional research was warranted on the non-lignin fibre components (cell wall materials) and on fibre-protein interactions.

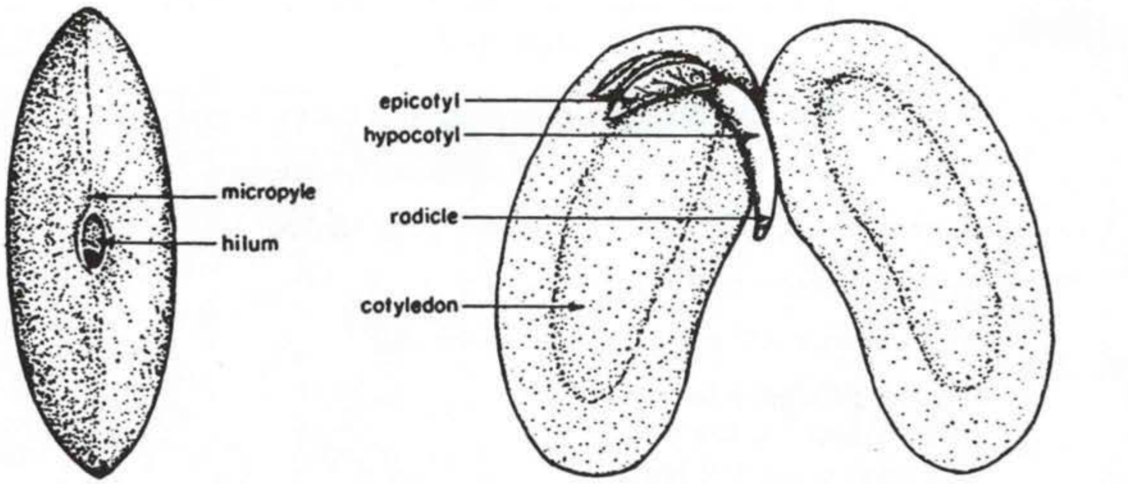

Fig. 4. Structure of typical legume seed. Left: external view; right: internal view (from Stanley and Aguilera 1985).

Guelph also studied the relationship of condensed tannins (polyphenols) to hardness because of complaints from bean processors in Canada that beans darken when stored and that this darkening parallels hardening. The total soluble condensed tannins in beans decreases as hardening develops. Therefore, it was proposed that under tropical storage conditions, condensed tannins migrate from the testa to the cotyledons, where they bind with macromolecule in the cell wall and middle lamella. This binding enhances cell wall strength, reduces water penetration and swelling, inhibits cell separation, and prevents softening during cooking.

In these experiments, no changes were noted in total fibre. This is consistent with the theory that lignification is responsible for hardening. This lignification hypothesis is difficult to prove; however, a corollary would be that beans without seed coats would harden less rapidly because intact beans would accumulate higher tannins levels as the tannins diffuse from the seed coat to the cotyledons. This was in fact reported in parallel work conducted by network members in both Guatemala and Chile. Thus, the metabolism of phenolic compounds appears to be a significant factor in bean hardening.

These observations suggested that bean hardening proceeds by a multiple mechanism that includes loss of phytate, lignification, and breakdown of the membrane fraction (see Table 3 and Figure 6). The dominance of one pathway over another seems to depend on storage time and conditions. However, the lignification of phenolic compounds seems to play a key role in hardening. This suggestion of a multiple reaction was confirmed by kinetics studies in Chile.

Table 3. Possible enzymatic mechanisms involved in bean hardening.

Enzyme	Action	Consequence
Phytase	Hydrolyses phytate to inositol and orthophosphate	Loss of ability to chelate divalent cations
Pectin esterase	Removes methyl groups of pectin, exposes carboxyl groups	Crossbridging of pectin carboxyl groups by divalent cations
Lipoxygenase	Conversion of lipids to polar, oxygenated polymers	Degradation of membranes, solute leakage
Proteases	Hydrolysis of storage proteins	Production of lower molecular weight, more reactive proteins capable of interacting
Peroxidase	Crosslinking of polyphenols to proteins of cell wall	"Lignification-like" reaction leading to hardness and restricted water absorption

Identification of Beans with the Hard-to-Cook Defect

Research was conducted at Manitoba to try to identify hard-to-cook beans by electrophoresis. Seedling tissues and beans from six cultivars of black beans grown in three locations over two harvest periods were analyzed for isoenzymes. Two of the cultivars that had longer cooking times had a unique esterase band and the cultivar that had the greatest tendency to harden had a different leaf acid phosphatase pattern. These characteristics were present regardless of where the beans were grown or when they were harvested. None of the other cultivars had the same patterns.

Storage proteins extracted from the bean tissues using various solvents were also analyzed. It was found that all cultivars could be identified on the basis of two extract patterns, however no relationship could be identified between these patterns and the cooking times or hardening rates.

Work at Guelph found that the genetic part of the hardening could be influenced by environmental factors, but effects were low. This dimmed initial prospects that improvements could be made in texture through traditional breeding programs.

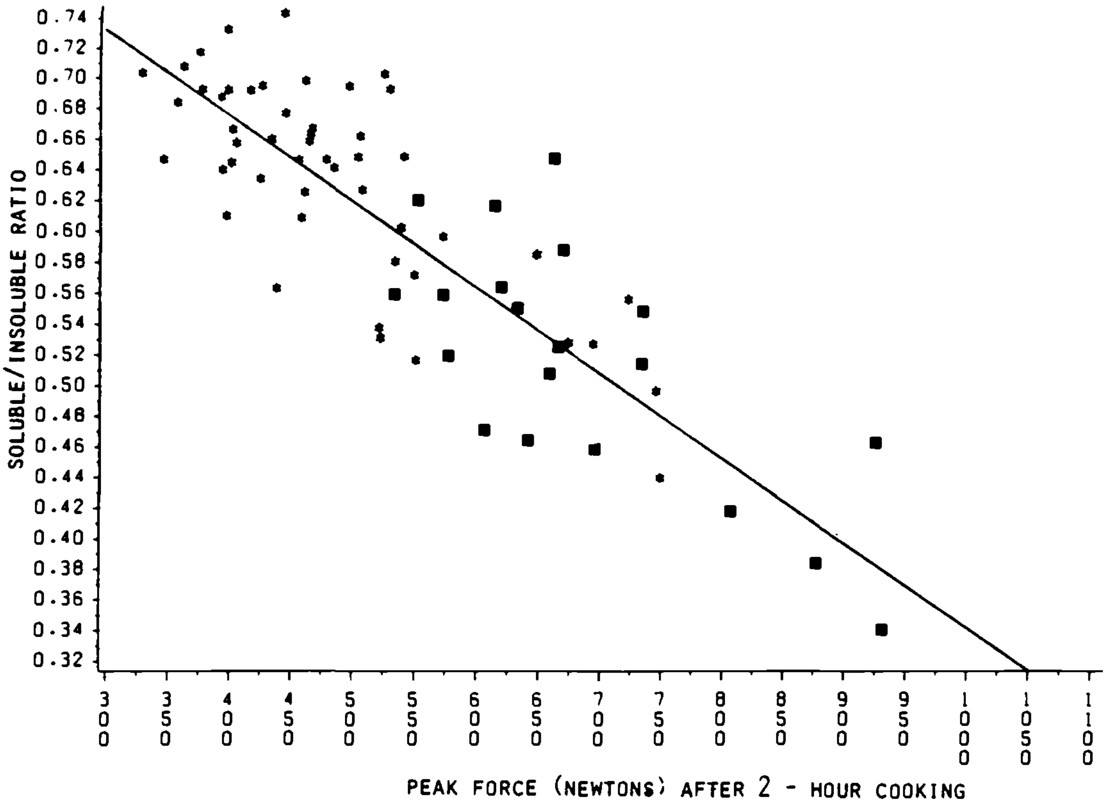

Fig. 5. The relationship of the soluble/insoluble fibre ratio to Instron peak force values (hardness) after black and red bean samples had been cooked for 2 hours: * Tamazulapa; ■ Dor.
(From de Godinez, C.M., 1990, MSc Thesis, University of Manitoba.)

Physical Consequences of Hardening

One consequence of bean hardening is an increased loss of electrolytes and solids from bean cells during soaking. Losses of solids from hard beans have been reported to be more than five times the losses from comparable soft beans after 18 hours of soaking. Membrane breakdown may account for this loss, which would support the idea that membrane breakdown is an important event in hardening. This breakdown would allow the physical loss of electrolytes and solids and also mean that enzymes, such as phytase, peroxidase, lipoxygenase, and polyphenolase, could mix and react with previously unavailable substrates.

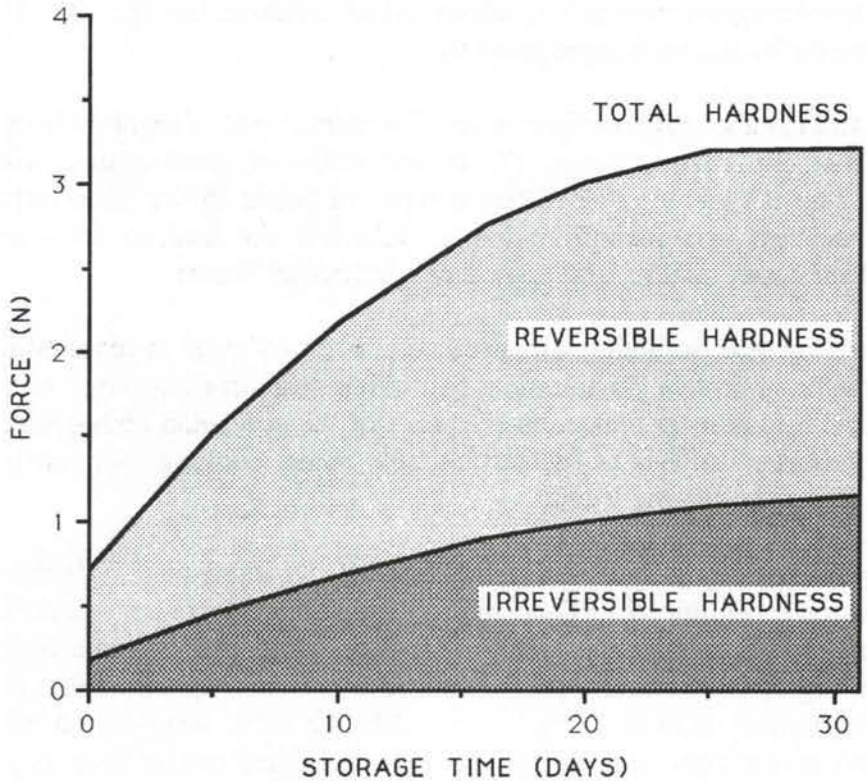

Fig. 6. Time course of bean hardening showing reversible and irreversible components of total hardness.

Sensory and Physicochemical Properties

An important achievement of the network was the creation of a sensory analysis laboratory at INCAP. As well, a book was published in English, French, and Spanish on sensory methods, which has already found widespread use among food technologists and researchers working on commodity improvement, storage and processing techniques, and product development in developing countries.

Studies were conducted to determine the sensory and physicochemical properties of Chilean black beans. Beans were roasted and then stored along with untreated beans at low temperature and humidity and at high temperature and humidity for 6 and 12 months. The beans were then tested to determine their cooking times, sensory qualities, and water absorption characteristics.

Beans roasted at higher temperatures generally took the longest time to cook and the development of graininess was highly correlated with quality deterioration. Roasting at lower temperatures was found to produce beans of better quality. High temperature roasting also reduced the water absorption rates of cotyledons, which indicates that the high temperature likely damaged the cotyledon structure more severely.

Instrumental and sensory methods were also used to try to determine the optimum cooking times for different Guatemalan beans. The critical effect of cooking time was confirmed by comparing the time it took to cook different types of beans to the same degree of softness. However, no one test was identified that could alone be used to set cooking times for comparisons of the taste, texture, and appearance of cooked beans.

However, for bean softening, an adequate amount of water is required in the cotyledon cells to allow swelling, protein denaturation, and starch gelatinization. Water must not only pass the seed coat, it must enter the intercellular spaces of the cotyledon and diffuse across the cell walls. If this does not happen, as in hard-to-cook beans, cooking will not produce the cell separation required to soften the beans.

A second experiment looked at the sensory characteristics of beans from different locations and storage conditions in Guatemala. Results from laboratory analysis and in-house consumer panels were combined to identify the most important characteristics for consumer acceptance (see Figure 7). Further work developed regression equations that could be used to predict the acceptability of different varieties. Although there were significant differences in appearance, taste, and texture, acceptability could be predicted on the bases of just two or three variables.

The seed coat is also important to the sensory properties of beans. Although only 10% of the entire bean, it is composed of cellulose, hemicellulose, and lignin and likely influences texture and water uptake. Sensory and instrument measurements of bean texture were halved when seed coats were removed from soft and hard beans. The physical properties of the seed coat (hardness, deformation, and thickness) were not related to cooked bean hardness, but harder seed coats were associated with a reduced ability to absorb water. Therefore, the harder seed coat can act as a barrier to water penetration during soaking and cooking.

Use of Hard Beans

Hard beans have few uses. They cannot even be used for animal feeds. Therefore, processes to use hard beans in the food industry were studied. Three different approaches were used: salt solutions to decrease cooking time; dehulling of the hardened beans; and extrusion cooking.

When the beans were soaked in various salt solutions prior to cooking, cooking time was reduced. Changes in protein quality depended on the soaking time. Further work was conducted in collaboration with the food industry to refine soaking methods.

Canned fried beans produced from salt-treated hard beans were processed using common industrial methods. The processed beans were stored for 15 days and found to be acceptable by

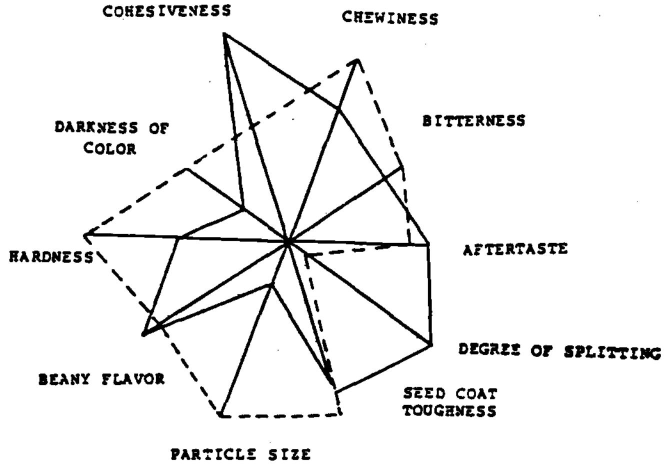

Fig. 7. Web diagram showing relative intensities of sensory attributes (length of vectors) for well-liked (------) and disliked (- - - -) bean samples (from Rios, B.L., 1988, MSc Thesis, University of Manitoba).

the industry and by consumer panels. The use of these beans meant energy savings for processing and reduced costs for raw materials.

This work in Guatemala, and elsewhere, confirmed that soaking in a salt solution prior to cooking decreased hardness. Sensory analysis of the hardened beans processed using these techniques showed that soaking the beans prior to cooking had no negative effects on consumer acceptability. In addition, nutritional evaluations showed that salt treatment produced an product of acceptable nutritional quality. An accompanying cost analysis indicated that this method saved money when used to process hard-to-cook beans at the industrial level.

Beans were also dehulled to see what effect this would have on cooking time and protein quality. Dry and wet dehulling methods gave similar yields, but the wet dehulled beans took a much shorter time to cook. Because dehulling reduced the tannin content and increased protein quality and digestibility, further work was done to incorporate dehulled hardened beans in different food products.

One attractive possibility was the use of precooked bean flour in various foods. Extrusion cooking, atmospheric cooking, drum-drying, and toasting were used to prepare precooked bean flour and each of the flours was analyzed for its nutritional and functional properties. Extrusion cooking produced the best flour.

The precooked flour was then further processed to produce several different food products. A high-protein infant food was developed using a mixture of bean flour with corn and soyabean flour. A wheat and bean cookie was developed as was a soup-based product. And, bean flour was incorporated successfully with wheat in pasta products and into sausage products with corn.

It was concluded that hard-to-cook beans, processed by extrusion cooking, could be incorporated successfully into in a wide range of food products for the local food industry in Guatemala as well as in other parts of Latin America.

Development of Models

An important objective of this network was to be able to develop improved methods for the storage and handling of beans to reduce their tendency to harden over time. Mathematical equations for the influence of temperature and humidity on hardening were developed in Chile. These equations were part of an engineering kinetic model developed to predict the hardness of beans in different storage conditions. Models such as this are important for understanding the hardening mechanism and also useful for demonstrating the differences that changes in storage conditions at the farm and processor level can make.

Other models and computer software were developed in Chile to assess the economic impact of reducing losses due to bean handling. These models are useful to demonstrate the potential benefits of introducing beans that are less susceptible to hardening and storage methods that reduce hardening rates. Extension of the marketing period, energy savings, and increased availability of good quality beans mean economic benefits to consumers and producers alike.

Sharing of Results

Throughout the period of these studies there was considerable sharing between all centres. Students and researchers benefited from working visits to their partner institution, and new techniques and equipment were introduced and used. In addition, manuals were written, papers were presented at seminars and workshops, journal articles were published, and visits and links were made with other institutions working on aspects of bean research (see Figure 8).

As a result of the activities in Guatemala during the project, the National Centre for Grain Storage (INDECA) helped quantify bean losses, the Extension Service of the Mininstry of Agriculture (DIGESTA) participated in the study with farmers, the National Institute for Research in Agriculture (ICTA) has started studies on the effects of storage in different rdegions of the country, ICAITI (Central American Research Institute for Industry) is using appropriate drying technologies in their programs, and the University of San Carlos is participating in training programs on postproduction problems.

In Chile, efforts have been directed toward keeping in close contact with the actual storage and commercialization problems of small farmers. To help ensure that recommendations for better packaging and storage reach these people, the industry, news media, and exporters were contacted to advise them of project findings.

The work at Guelph led to contact in Canada with the Ontario White Bean Marketing Board to look at the mechanisms involved in the darkening of beans during storage. Manitoba forged links in Canada with other laboratories at the Freshwater Institute, the Canadian Grain

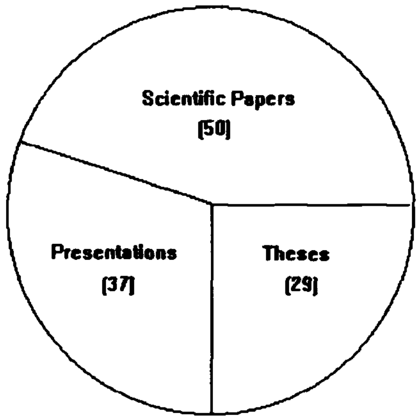

Fig. 8. Outputs of the IDRC bean network expressed as books and articles, presentations, and theses (details are given in bibliography).

Commission, and the Agricultural Research Station in Winnipeg. Internationally, contact was made with researchers in Mexico, Brazil, and Colombia who are interested in bean utilization and quality assessment, and discussions have been held with the International Centre for Tropical Agriculture (CIAT) concerning quality and consumer assessment methods.

Efforts were also made in the network to directly involve consumers, who were consulted to determine what made beans acceptable to them, farmers, who were involved in the storage trials under different conditions, and food processors, who were part of the studies to develop new processing techniques and foods. Involvement such as this should improve the likelihood that these groups will adopt the recommendations and improvements suggested by the research.

INCAP demonstrated the importance of sensory analysis techniques for quality control in the food industry and at universities through courses that were given in Guatemala and Costa Rica.

In the final stages of the research in Chile, the findings were tested with a group of small farmers in southern part of the country. Storage of beans in improved packages was demonstrated to result in lower hardening rates. It was also shown that woven polypropylene bags alone were ineffective in protecting the beans against increases in moisture during storage.

The computer program developed to predict hardness under different storage conditions and the computer game, which assesses economic losses when different storage and marketing alternatives are selected, are useful tools for demonstrating the benefits of applying the research findings. This software is now being prepared for broader use and possible commercial application.

Farmers and government storage agencies could well benefit from the results of the research conducted by the network, as could consumers throughout a large part of Latin America.

The publications and computer programs that have been developed will be useful, but they in themselves may not be sufficient. To reach technology transfer groups, farm leaders, and the popular media extra efforts will be needed to ensure that the outputs of the projects go beyond the publication of scientific papers.

What Lies Ahead

Efforts will continue to develop further applications for this research and to clarify the scientific basis for the hardening process and its effects and economic impact. Equally important, work will continue in Chile and Guatemala to explain the results of the science to farmers, processors, and consumers and recommend procedures that can improve storage and handling methods and produce new food products.

Research will be undertaken to help fill the remaining gaps in understanding the underlying processes and to answer questions that remain to be answered for processors, farmers, and consumers. Throughout this work, efforts will continue to involve farmers, consumers, and storage agencies in Guatemala and Chile in the research and to validate the results with these groups.

Processors

1. Efforts should be made to develop salt formulations for soaking that will consider cost, nutritional value, ease of use, and consumer acceptance of the final product.

2. Assistance should be made available to small food enterprises in Central and South America to assist them to set quality standards and establish quality testing procedures.

3. The computer program developed in Chile should be adapted for use in Guatemala to predict the economic losses resulting from the handling and storage practices currently used by the industry.

Farmers

1. Additional farmers should be contacted to demonstrate the effectiveness of plastic-film bags for the storage of beans in tropical countries.

2. Studies should be completed of the effectiveness and suitability of low-cost driers for farm use.

3. Farmers should be contacted to determine the applicability and feasibility of implementing changes in handling and storage practices.

Consumers

1. Studies should be undertaken on the acceptability of dry dehulled beans and on their nutritional and quality advantages.

2. Further work should be undertaken on the development of acceptable food using processed hard beans.

Scientists

1. Further standardization should be done on the methods for the measurement of the texture of cooked beans and for rapid testing of bean acceptability.

2. Studies on changes in cell size of freshly harvested beans and cooked hard beans should be completed to complement work already done on the role of water in the hardness phenomenon.

3. The browning of cotyledons during bean storage should be investigated along with its relation to hardening, nutritive value, and flavour, and the role of raffinose and related sugars in browning.

4. The importance of phytate in the prevention of hardening, and the role of high phosphorus fertilizer in increasing phytate levels in beans to potentially reduce hardening should be studied.

5. The potential for breeding programs to increase phytate levels and so impede bean hardening deserves investigation.

6. Studies should be completed on the relationship between cooked bean broth viscosity and cooked bean hardness as well as the components (pectins, gums) responsible for broth viscosity.

7. Further work on membrane breakdown (especially the time course of membrane breakdown) would be useful.

8. The concept of total quality should be broadened to include acceptability, technological characteristics, and nutritional quality factors that can be measured in a standardized way to identify bean varieties that will be both beneficial and acceptable according to local definitions of "total quality."

Lessons and Recommendations

1. The choice of partners and of the research to be conducted is critical to the success of any collaborative activity. The partners should have similar research interests and complementary skills, so that they can learn from each other and share information and resources. As well, for development research, the objectives should lend themselves to joint action (for example, have both field and laboratory components), be oriented to practical problems with application in the Third World, and call for inputs or experiences not available to one or the other of the partners so that learning and experience can be gained.

   Sharing is skills and of research experience in different settings occurs. Special techniques (statistical methods, sensory and consumer survey techniques) and the use of sophisticated equipment can be transferred, as can the special challenges of working in different research environments. Partners must be chosen carefully because there is potential for professional jealousy among partners with similar research interests who wish recognition for their own institutions and for the work they do.

2. It is important that there are research and non-research objectives in development projects. Projects, therefore, should be viewed and evaluated not just in terms of research objectives but also in terms of institution building (skills of researchers, access to new equipment and techniques, exposure to different research methods/management, training of students both in Canada and developing country). These objectives should be clear to all partners from the beginning of the project because it is possible one of the partners may feel purely scientific research is being compromised due to communications delays and the need to wait for samples and to travel overseas. However, on balance more relevant work that is linked to identified and defined field problems is undertaken. Ideally, the research should also have a reasonable likelihood of completion in 3-6 years. However, in some situations considerable lag time is incurred in initially understanding the context, building relationships, and perhaps training young staff.

3. A greater number of resources can be focused on a single problem by bringing four institutions together. This is particulary useful for complex research, where several teams are able to look at a research continuum, rather than simply small pieces of the puzzle. This helps ensure progress toward solving research objectives and may lead to a greater liklihood of collaboration among the partners and the other instituions they interact with during the life of the project. However, this requires strong direction and integration. The use of a network coordinator, possibly a nonresearcher who is outside the network, is recommended. But, it must be clear whether this person is to funnel information or actually direct and coordinate the research. Regular annual meetings are useful to help clarify roles and future directions for network activities, as is the publication of summaries of these annual reviews.

4. Cooperative projects provide incentive for Canadian researchers to tackle practical problems and to seek ways to apply their skills so that others may use their results. At the same time they assist developing country institutions with access to new resources and information. The cooperative project mode is therefore of benefit to both the Canadian and Third World partner.

5. The inclusion of students in research projects is very beneficial not only to extend the range of activities that can be undertaken, but to provide valuable research experience and opportunities to complete thesis requirements for graduate and undergraduate degrees. During this project, nearly 30 students in Canada, Chile, and Guatemala benefitted from such involvement.

6. Beyond the research phase, it is essential to consider further efforts to ensure that the results of the research are extended to those that can use then in day to day situations. This may mean a further phase of support with a different set of institutions that would pay more attention to promotion than to research.

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