BEAN NETWORK EVALUATION REPORT FOR INTERNATIONAL DEVELOPMENT RESEARCH CENTRE

IDRC Bean Network Contracts under Evaluation:

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Part I. ORGANIZATIONAL FEATURES OF THE BEAN NETWORK RESEARCH PROGRAM

A. OBJECTIVES OF INTERNATIONAL DEVELOPMENT RESEARCH CENTRE

The major objective of the Centre is to support research designed to adapt science and technology to the needs of developing countries.

The following elaboration of the Centre's objectives were presented in the Proceedings of the First Workshop of the Bean Network (IDRC-MR120e):

> "The International Development Research Centre is an organization that supports research designed to yield knowledge and information that can contribute to Third World development. Within the Centre, the Cooperative Program has been created to promote research collaboration between groups in Canada and those in the developing world, in the execution of projects that address a problem identified in the Third World. In addition to this thrust, the program has three other important objectives:
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> - To develop the scientific and technological research capacity of the participating Third World institutions or groups by improving their opportunities for collaboration with the Canadian part of the international scientific community;
>
> - To create channels of communication among scientists through which the results of successful research in Canada can be transferred to researchers in the Third World (the even more difficult transfer -- from scientist to user -- can then be addressed in the context of the developing country involved, as a separate step); and
>
> - To influence the direction of Canadian research toward Third World concerns."

It was apparent to the Evaluators that the following specific objectives, conforming to the major framework objectives of IDRC, were agreed to by the Bean Network participants and IDRC:

1. human resource development with respect to graduate education of international and Canadian students.

2. equipment procurement by the universities and INCAP for use in the IDRC-supported research project as well as in other research areas.

3. publication of research results in scientific journals and in bulletins.

4. dissemination of research information to target beneficiary groups.

It is the opinion of the Evaluators that the results from studies by researchers and graduate students can lead to strategies for solving, to some degree, the stated problem. The publication of research results and of strategies for problem solving is essential for effective distribution of information to target beneficiary groups and to the scientific community.

B. IMPORTANCE OF BEANS IN THE DIET OF CONSUMERS IN DEVELOPING COUNTRIES

Legumes are an important source of proteins and complex carbohydrates for many developing countries. Beans, in particular, have protein contents as high as 25% on a dry weight basis and have a high proportion of lysine compared to that for cereals. The sulfur-containing amino acid, methionine, is the first limiting amino acid in beans. The PER for cooked bean protein has been estimated to be about 0.8 to 1.4, but when 70% corn meal (tortilles) is incorporated with 30% cooked beans, the PER was raised to about 2.0 to 2.6. The digestibility of cooked bean protein is around 75 to 77%. The poor digestibility may be related to the tannin content of the beans. Toxic antinutrients such as antitrypsin inhibitors can contribute to poor protein digestibility in insufficiently cooked beans.

Beans are included in the meals of consumers in South and Central Americas, India and Africa. The amounts of beans consumed are dependent on the customs, availability, cost and flatulence tolerance. In Guatemala, cooked black beans are generally consumed by members of a farm family 3 times per day at meal time along with corn tortillas. Chileans prefer gray beans and consume them about twice per week. Compared to most high-protein foods, beans are usually reasonably priced, and are readily available year round. Increases in the consumption of beans may be limited by the poor quality of stored beans, and high energy costs for prolonged cooking of beans. The loss of the nutritional value of beans during the hardening period is of considerable concern to nutritionists in developing countries.

C. STATEMENT OF THE PROBLEM

After legume seeds are harvested, physical, chemical and biological changes may occur in a short time particularly when the commodities are stored under adverse conditions such as high humidity and high temperature or if the moisture content of freshly-harvested seeds is above about 12%. Post-harvest bean losses of 40% or more are frequently reported by developing countries (National Academy of Sciences, 1979).

Post-production losses of beans can result from:

1. mold growth on high-moisture beans
2. quality deterioration
   - color changes (natural pigment reduction, browning)
   - hardening (textural changes)
   - flavor changes
   - viscosity reduction of cooked-bean broth
3. nutritive value reduction
4. insect damage

Hardening of beans during storage is a major problem in Central American countries where the humidity and temperature are often high. According to Mejia (INCAP, 1979 Report), the economic loss of beans due to hardening was about U.S. $12 million in Central America during 1977.

The problem to be addressed was presented at the First Workshop of the Bean Network participants and was recorded in the Proceedings of the Workshop (IDRC-MR120):

"IDRC has supported research on legume quality in several countries including faba beans in Egypt, lentils in Lebanon and common beans in Guatemala. Researchers have tried to overcome the hardness and hard-to-cook properties which develop during storage and which cause economic loss through decreasing consumer acceptability and energy loss through increased fuel consumption.

Past work has sought correlations between mineral, protein or starch content, seed components (hull, cotyledon) and the degree of hardness after various conditions of storage. Various indices of hardness, usually of cooked beans, have been examined. Still required is a fundamental understanding of the mechanisms involved, standardization of bean samples, of handling and cooking procedures and of hardness testing both by physical instruments and human senses."

The aim of the research program was stated in the following sentence:

"The study of common beans (Phaseolus vulgaris) is being conducted by a network of specialized research activities aimed at increasing the consumption and nutritive quality of dried beans".

D. HISTORICAL PERSPECTIVE IN THE CREATION OF THE BEAN NETWORK RESEARCH PROGRAM

Dr. J.M. Aguilera of the Pontifical Catholic University of Chile and Dr. D. Stanley, University of Guelph, both having had research experience in the area of bean hardness, submitted to IDRC, a collaborative project proposal in 1983 to devise technologies for inhibiting the development of hard-to-cook defects in stored dried Phaseolus beans and to determine the mechanism of bean hardening. Optimum storage conditions for various varieties of dry beans were to be determined.

Since INCAP had carried out studies on hardened beans in the past under IDRC support, IDRC considered the possibility of broadening the proposed project base and of including more research groups. A workshop supported by IDRC was held in 1983 at the University of Manitoba to discuss research needs to solve the hard-to-cook bean problem. Research which could be pursued by researchers at the Catholic University (PUCC), University of Guelph (UG), University of Manitoba (UM) and INCAP were explored.

In January, 1984, the PUCC/UG Project A was approved by IDRC and the academic institutions for a duration of 3 years.

In March, 1984, researchers in the Department of Foods and Nutrition, University of Manitoba (UM) travelled to Guatemala to develop a project proposal on consumer evaluation studies on bean acceptability, objective texture measurement, and methods of overcoming hardness. The INCAP/UM Project B was recommended at the IDRC level, and was approved and initiated in February, 1985 for a duration of 2 years.

The specific objectives of Projects A and B are presented below:

PUCC/UG Project A

1A. to determine the biological changes that contribute to hardness during storage

2A. to develop simple and inexpensive post-harvest roasting technologies to arrest hardening of beans, improve their keeping quality and reduce cooking time

3A. to determine optimal storage conditions for different dry beans

INCAP/UM Project B

1B. to define specific characteristics of bean acceptability, using consumer survey techniques

2B. to establish a uniform, reliable laboratory methodology to quantify the physical, chemical, and sensory characteristics of bean quality as defined by Guatemalan consumers; correlate the laboratory methods with consumer panel data; and identify the number of tests needed to define consumer acceptability

3B. to evaluate hardness development in bulk storage and under farm conditions

4B. to develop procedures for the utilization of hard-to-cook beans in local foods

5B. to evaluate the effect of processing methods on protein digestibility and nutritive value.

Bean Utilization (UG/PUCC/UM/INCAP) II Project C

IDRC agreed to fund the bean program as a second phase (Phase Two) for 3 additional years. The grant was approved by IDRC on January 23, 1987 on the basis that considerable knowledge was acquired during the first phase of the projects. Specifically, it was noted that substantial progress was made in understanding biochemical mechanisms on bean hardening, in investigations on hardening under controlled storage conditions, in defining consumer requirements of bean quality and in possible processing approaches to the utilization of hardened beans. For Phase Two, IDRC funded one network project under which the four teams operated. The IDRC reason for the writer to the one network project concept was to bring about closer interaction and better research integration within multifaceted approaches. IDRC in Project Summary 3-p-86-1033 indicated that:

a. UG and INCAP will interact on biochemical issues which may effect nutritional value

b. PUCC and INCAP will work together on storage studies

c. UM and PUCC will interact on hardness development measurement

IDRC, referring to the one network project concept, stated: "This arrangement should provide for rapid solutions to identified problems by linking basic and applied research on the major Post-production Systems (PPS) components of bean handling, storage, processing and preparation."

The General Objective and the Specific Objectives for research in Phase Two of the Bean Network are presented below:

General Objective

To improve the utilization of stored beans, by processors and consumers through control of hardening during storage and processing.

Specific Objectives

1C. To further clarify the biochemical and biophysical mechanisms involved in bean hardening;

2C. To translate hardening mechanism data into engineering models and identify handling and storage processes able to control hardening;

3C. To evaluate the economics of existing bean handling and storage procedures practiced by small producers and government storage agencies in Guatemala and Chile, test improvements with these groups and assess their potential economic impact;

4C. To develop rapid screening measures for quality characteristics associated with acceptability of raw and cooked beans and to determine the importance of hardness in bean acceptability;

5C. To develop processes for the utilization of hard beans in the Guatemalan food industry and evaluate their effects on nutritional value;

6C. To train researchers and strengthen institutional capability to undertake integrated research in solving postproduction problems; and,

7C. To disseminate research results and experiences through scientific publications, network communications and interaction with storage and extension agencies.

E. CREATION OF RESEARCH NETWORK

With IDRC approval of funding for Project A and Project B, the potential for a research network was realized. Since the inception of IDRC, a direct twinning of a research team in a developing-country institution with a counterpart in Canada has been encouraged (see Section A). Exchange of ideas, and the sharing of equipment and personnel was considered very beneficial in the pursuit of research goals of twinning teams.

As pointed above, Project A focussed on the mechanisms and inhibition of bean hardening. Project B was directed towards establishing bean acceptability criteria, objective methods for texture measurement, methods of overcoming bean hardness and utilization of hardened beans. It is apparent that the hardened bean research proposal grew into a two project network program which could be entitled "Bean Quality and Utilization". Quality must be regarded in the

broadest sense to include sensory attribute as well as nutritive value. Utilization must encompass bean storage, processing, packaging and preparation.

The first phase of the Bean Network research program consisted of two projects, with twinning research teams for each project. The four teams had separate research responsibilities and separate budgets. The PUCC and UG teams were twinned as a group (Group A) and INCAP and UM teams were twinned as another group (Group B). This model can be classed as a Duo Twinning Network with interactions between the twinning teams as well as between groups. The annual workshops were valuable in bringing about exchange of ideas and concepts, development of new research directions and solidification of research responsibilities of each team for the next year.

In the second phase of the Bean Network research program, all four teams were included in the same project to "allow closer interaction and integration of activities". However, each team had a separate budget. As pointed out in Section D of this report, interactive research areas were specified by IDRC. For example, UG and INCAP were to interact on biochemical issues which may affect nutritive value, PUCC and INCAP were to work together on storage studies and UM and PUCC were to interact on the development of methods for hardness measurement. This model can be classed as a interactive multiteam, multidisciplinary network. For this model to be workable, project leadership and effective communication between teams are essential.

F. BENEFICIARIES OF THE RESEARCH RESULTS

As pointed out in Section 6 of the Project Summary of Bean Utilization (Guelph/Chile/Manitoba/INCAP), the ultimate beneficiaries will be the farmers, bean consumers and storage agencies. The project design was developed with the beneficiaries in mind. The development of low-income consumer acceptability criteria in Guatemala and the development of objective instrumental analysis to predict acceptability were important objectives for targeted beneficiaries. Surveys of small farmers and storage organizations in Guatemala and Chile were considered necessary for improving handling and storage technologies.

Through the research activities of the four teams, results should lead to:

1. major savings to storage organizations in tropical countries by inhibiting bean hardening

2. economic benefits to bean farmers who will have the know-how on prevention of hardening of beans to be sold in the future.

3. benefits to consumer in terms of reduced cooking times, less loss of nutritive value and reduced fuel requirement.

Part II. EVALUATION OF THE BEAN NETWORK STRUCTURE AND ACTIVITIES

A. SPECIFIC OBJECTIVES AND RESEARCH DESIGNS

Phase One

The specific objectives and research designs for the Bean Network were formulated in a two-stage procedure. In the first stage, Dr. Stanley and Dr. Aguilera prepared, in 1983, a co-operative research proposal for submission to IDRC. This proposal had specific objectives of determining biological changes

that are involved in bean hardening, developing roasting technologies to arrest hardening and optimizing storage conditions for inhibiting hardening. A research design was constructed to satisfy the specific objectives.

In the second stage, INCAP and UM collaborated in 1984 at the suggestion of IDRC to develop a research proposal with specific objectives for research oriented to consumer acceptability and nutritive value of stored beans, and utilization of hard beans. Under the leadership of Dr. L. Elias and Professor M. Vaisey-Genser, a research design was proposed to satisfy the specific objectives.

Thus the Bean Network consisted of two projects with PUCC/UG Project A being initiated in January, 1984 and INCAP/UM Project B being initiated in February, 1985.

Ideally, the 4 teams should have jointly agreed upon specific objectives and developed a research design to satisfy the specific objectives. Without this ideal approach, some overlap of specific objectives occurred. In particular, research on the hardness development in stored beans and instrumental methodology for measuring bean hardness were overlapping areas. Apparently, confusion in the choice of a reproducible, highly-correlative method for measuring the degree of hardness has arisen at times because of the overlap objectives.

On the positive side, the research designs of the two research groups in the Bean Network were based on sound scientific knowledge, up-to-date methodology and available equipment. The flexibility of IDRC in allowing a team to redirect research emphasis is commendable. For example, the roasting of beans to reduce bean hardening was not successful and thus PUCC placed greater emphasis on computer modelling for the prediction of bean hardening and added a socio-economic research component to the list of specific objectives.

Phase Two

IDRC wisely required the Network teams to work together under one co-operative project. Such an arrangement was to increase interaction and integration of research activities, and to promote a rapid solution to bean hardening. Specific objectives for Phase 2 were based on the extensive results of Phase 1 experimentation and included further studies on the mechanisms involved in the hardening of beans, on processes to control the beans hardening and to improve consumer acceptability, and on utilization of hardened beans. IDRC designated specific team linkages for research activities to ensure effective utilization of talent and resources for the rapid solution to the bean hardening problem. Essentially the original research designs of the groups were retained for Phase 2 research activities.

It was apparent from discussions with the team leaders that communications between the teams had improved considerably with the unification of activities under one Phase 2 contract, and that co-operative research was initiated. For example, several bags of beans have been shipped from PUCC to INCAP to evaluate the effectiveness of plastic film bags to maintain the low moisture content of beans in a high humidity region (Guatemala). This joint research effort (PUCC/INCAP) should be of great value in the development of a procedure to inhibit hardening.

B. PROJECT PERSONNEL

The project leaders are highly-qualified research scientists who have expertise in the areas of food science, food engineering and nutrition. The multi-disciplinary approach in the research program of the Bean Network has resulted in an innovative and stimulating environment within which researchers have performed efficiently and effectively. The project leaders have demonstrated organizational and leadership abilities, and have been able to stay within their annual budgets.

It should be noted that a short course or workshop on contract research management would have been valuable for project leaders from the standpoint of personnel management skills and budget management. Such a course has been designed and offered by the Department of Agricultural Economics, University of Manitoba.

The Evaluators were impressed by the high-caliber of the research scientists in each team and their dedication to the projects. All of the full-time research scientists have university degrees at the Bachelor's and Master's levels.

About 27 students from Chile, Guatemala and Canada have participated in the research program of the Bean Network. The number of participating students at each institution is presented in Table 2. Two students have undertaken research at the Ph.D. level whereas 7 students have undertaken studies at the M.Sc. level. Many high-quality theses have resulted from these research findings of these students. The 6 participating undergraduate students at PUCC were in the Chemical Engineering program which has a requirement of an undergraduate thesis. Excellent research on bean hardening was conducted by these PUCC students. At INCAP, undergraduate students from local universities conducted research on bean hardening under the direction of the project leader, Dr. Elias, and his staff. The thesis topics are relevant to the project research being carried out at INCAP.

The value of student participation in the team projects was many fold. In the first place, students investigated specific problems which otherwise could not have been addressed because of budget restrictions. Under the guidance of academicians, the students conducted research in a systematic, scientific manner, and thus produced reliable data to be used for solving problems of bean quality and utilization. Secondly, the undergraduates in Chile and Guatemala gained knowledge on how to design a research program and carryout effective experimentation. These students will be valuable human resources in their countries. Thirdly, the M.Sc. students from Guatemala and Chile gained a new perspective on research in Canadian universities and were able to use advanced instrumentation and to learn new techniques. These students, upon returning to their countries, will be highly qualified for research positions. Mr. Hohlberg, M.Sc. in Food Science at UG, has been employed by PUCC as a lecturer in Chemical Engineering. Hopefully, INCAP will be able to open 2 positions so that the Guatemalans at UM and UG will become employed after receiving their M.Sc. degrees.

C. ASSESSMENTS OF EXPERIMENTAL RESULTS

1. PUCC/UG Project A and Project C

The objectives of these projects were to determine the mechanisms involved in bean hardening during storage and to develop technologies to minimize the hardening.

a. PUCC

One of the specific objectives of the PUCC team was to determine the relationship of the hardening rate to storage temperature, bean moisture content and storage time. Although adverse storage conditions have long been known to enhance hardening, reliable, quantitative data was not available. Thus experimentation on the hardening of beans under highly controlled conditions was carried out by the PUCC teams. Such data was necessary to construct a mathematical model to predict the level of cooked hardness for stored beans. Polyethylene bags were used by the team for the packaging of beans to inhibit moisture loss. Storage temperatures of 8.5, 25 and 40°C were carefully controlled. The results pointed out clearly that low moisture beans (around 9%) held at 25°C could be stored for 9 months without appreciable hardening. Beans with a moisture content of 10.4% could be held at 40°C for 5 months and still be texturally acceptable. Thus adequate post-harvest drying of beans to bring the moisture content down to about 11% and the use of plastic bags with low moisture transmission for packaging should impede hardening of the beans stored in tropical countries for periods up to 9 months.

As a first step in assessing the value of polyethylene bags (50 kg) in the storage of low-moisture beans, the PUCC team shipped in June, 1989 several 50 kg polyethylene bags each with a weaved polypropylene overbag to INCAP. The beans will be evaluated under Guatemalan conditions.

The PUCC team used their data from the hardness/storage condition interrelationships to produce kinetic models to simulate hardening under a wide range of conditions. A computer program of the models have been constructed and will be valuable to bean storage agencies, farmers and shippers to predict bean hardness under specific conditions.

On the assumption that enzymic reactions are involved in the bean hardening phenomenon, the PUCC team evaluated the effect of dry heat treatment (roasting) of beans. Ceramic beads were used as the heat transfer medium. The results indicated that heating of beans to internal temperatures as high as 100°C did not inhibit the hardening of the stored beans compared to control beans with the same moisture content. Although the moisture content of beans was reduced by the dry heat treatment, the process is a relatively expensive drying procedure.

The PUCC team along with a M.Sc. student in Agricultural Economics designed a study to describe the production levels, post-harvest storage practices and marketing of beans grown in Southern Chile. About 52% of the beans grown are exported and these beans, grown mostly on large and medium-sized farms, are essentially black beans. The loss due to hardness has been estimated to be $2.6 million up to the 11th month of storage. This socio-economic study provides valuable data for decision-making strategies on bean production storage and marketing in Chile. The beneficiaries will be the bean farmers, storage agencies and marketers.

Highlights:
- reliable data on hardness/storage condition relationships has been acquired
- mathematical models have been prepared to simulate hardening process
- a computer program has been developed to predict storability of beans under various conditions
- a socio-economic study has been carried out on production patterns, post-harvest storage practices and methods of marketing beans
- potential use of plastic film bags for the transport and storage of beans.

b. U.G.

The UG team has concentrated mainly on the elucidation of the mechanisms involved in bean hardening. However, other avenues of research included 1. the hardening in 20 bean cultivars, 2. effect of seed coat on bean texture, 3. fluorescence intensity as an indicator of hardening, 4. effect of pH and ionic strength on water holding capacity of hard-to-cook beans, 5. cookability of black beans. Although many of these topics were not stated in the Project A or Project C proposals, the results from the research are important from the standpoint of the indicator methods for hardness to be used in quality control, of the possibility of breeding out the hardness phenomenon and of methods of measuring water inhibition and level of hardness of beans.

Many theories have been advanced by researchers on the mechanisms involved in bean hardening. The UG team along with most bean investigators agree that the strong adhesion of cells at the middle lamella level is responsible to a large degree for the hard-to-cook phenomena. Presumably calcium and magnesium pectates are the adhesive matter. Phytate a strong chelating agent, presumably binds in the bean cells a large amount of calcium and magnesium ions, which may be released by phytase (active in high moisture beans). The released ions may migrate to the middle lamellae of cells of beans held under adverse storage conditions and interact with low methoxy pectin which is known to be present naturally at relatively high levels. The failure of hard-to-cook bean cells to separate has been demonstrated by the UG team by microscopic examination.

The UG team has put forth the hypothesis that separation of cells in hard beans does not occur because of insufficient water entering the cells. It is presumed by the UG team that, in hard-to-cook beans, the cell walls have hardened and thus water transport to the cell contents is impeded. The UG team found that starch gelatinization and protein denaturation in hardened beans proceeds at a slower rate than that for unhardened beans. The UG team hypothesized that lignification in the cell walls was responsible in part at least for the hardening phenomenon, but they were unable to show conclusively the presence of lignin in the cell walls of hard-to-cook bean by microscopic means. Polymerization of phenolic and aromatic amino acid subunits was postulated as the reaction path for lignin production. The UG studies did not show high correlation between total extractable phenols and hardening of beans, and thus we suggest that the lignification theory may not be valid.

The UG team estimated the phytate loss during the storage of beans under various temperature and humidity conditions. The phytate content decreased progressively in all bean samples over a 10-month storage period, with the highest loss rate occurring with beans stored at high temperature (30°C) and high humidity (85%). With roasted beans (obtained from PUCC) held under adverse conditions, the phytate loss decreased at a fairly rapid rate but not as high

as that for the untreated raw beans under the same conditions. A signficant correlation between phytate loss and hardness development was obtained. Undoubtedly phytate is involved in the mechanism of hardening. Recently, Bhatty and Slinkard (J. Can. Food Sci. & Technol. J. 22,137,1989) suggested that phytic acid was largely, if not entirely, responsible for observed differences in the cooking quality of lentil. The Evaluators believe that the relationships between soil nutrient phosphorus, phytic acid and cooking quality should be investigated for beans.

Very interesting data was obtained from experiments on the water absorption during the soaking of black beans stored under various conditions. It is interesting that hardened beans absorb more water than beans held at low temperature and low humidity. The hardened black beans with a moisture content of about 18% developed hard-to-cook defect at the fourth month of storage whereas the beans stored at a low temperature of 15°C and with 9% moisture did not harden up to 10 month of storage. The UG team also showed that water accumulated under the seed coats and thus produced an overestimation of water absorption.

A standard shear method for measuring bean texture was devised by the UG team. This technique has been used by the UG and PUCC teams.

The UG team has found that the fluorescence intensity of microscopic areas of the cotyledon is related to the hardness level of beans. Such a microscopic method may be valuable in rapidly assessing the cooking quality of beans.

Highlights:

- microscopic evidence of strong adhesion in the middle lamellae of hard-to-cook beans.

- development of a shear method for measuring the hardness of beans
- evaluation of water absorbing properties of beans stored under various conditions
- confirmation that roasting of beans was not effective in preventing hardening of beans
- evaluation of phytate loss in stored beans and the conclusion that the loss of phytate is related to bean hardening
- the relationship of fluorescence intensity of stained cotyledons and the hardness of beans may be valuable in developing a quality control method
- evaluation of the seedcoat on the bean texture.

INCAP/UM Project B and Project C

This section includes the evaluation of research performed by both INCAP and UM teams because they co-operated extensively, particularly in defining characteristics of bean acceptability.

During the first 2 years of Project B, the INCAP and UM teams spent considerable time and effort on the design and operation of the consumer survey with 600 Guatemalas. The goal of the study was to determine storage periods of beans in the homes, raw bean quality, cooking procedure and sensory characteristics of cooked beans. The results of the survey indicated that in general consumers regarded good quality raw beans as those being very dark (major characteristic), shiny, and easy to bite. Further, good quality cooked

beans were considered to have a smooth texture (no graininess), black appearance and soft seed coat. The broth must be viscous. Such information will be valuable for assessing the consumer acceptability of various bean cultivars and for guidance in developing objective laboratory methods for quality evaluation. This study was very well designed and the data was analyzed by factorial analysis of variance. The general conclusions of the consumer study are that an intense black appearance is essential for acceptable raw beans and that for cooked beans, the texture must neither be grainy nor hard, and the broth must have a high viscosity and be black. Stored beans were less acceptable in texture than fresh beans. It is apparent that hard-to-cook beans are not acceptable by Guatemalan consumers.

INCAP and UM teams co-operated in developing methods of sensory profile analyses for measuring bean quality attributes, and in investigating the usefulness of the Ottawa Texture Measuring System (OTMS) and the Mattson Bean Cooker (MBC). Descriptive terms and evaluation sheets were prepared and tested at UM, and used at INCAP for textural characteristics of various bean cultivars. These sensory analyses were conducted in the new INCAP sensory panel laboratory designed by the UM team. Trained panelists were able to distinguish significant quality differences among twenty samples of black beans. Since the panelists rated cotyledon texture as the most important quality factor, the hardening of stored beans is a significant problems which must be solved.

The UM team found that water absorption by cotyledons was highly correlated with MBC and Instron peak force values. The water absorption method could be useful for testing bean hardness. The values of the MBC method correlated well with the texture values of panelists.

The UM team found that soluble fiber levels decreased appreciably during the hardening of black beans and correlated negatively with MBC and Instron peak force values. Presumably soluble pectic substances (soluble fiber) became insoluble pectates during bean storage.

Phytate content of black beans decreased during storage and correlated highly with hardness values according to the report of the UM team. Similar results were found by the UG team. The relationship of the loss of phytate to the increase in insoluble fiber should be followed up.

The UM and INCAP teams have pursued the influence of storage time, cultivar and growing location on electrophoretic isoenzyme and storage protein patterns. This study should be finished in about one year.

The INCAP team investigated three bean-producing areas in Guatamala with different climatic conditions to assess postharvest handling of beans by small farmers and to measure losses during storage. About 90% of the total bean crop is grown on small farms. The moisture content of beans from San Luis was between 12 and 19%. The cooking time of these beans dropped at the second month of storage and then rose steadily with storage time. The hardening of beans stored on the farms was considered a serious problem. Within the next year, a model will be developed to measure the economic impact of post-harvest losses of beans.

A study of the effect of the type of container on the cooking time of stored beans was initiated. It was found that a metal container was best for inhibiting the hardening of beans during storage in comparison to a fiber bag.

The polyethylene bag suggested by the PUCC team for packaging of beans would be cheaper and presumably equally effective to prevent moisture increase at high relative humidities in Guatemala. Before packaging the beans, the moisture content should be low (12% or lower). The INCAP team has developed simple, reasonably-priced equipment for solar drying of beans on small farms, to bring the moisture content down to about 12% from around 20%.

By dehulling beans, the cooking time of hardened beans can be reduced by three-quarters, according to the INCAP team. Such an observation implies that seed coat changes which cause a reduction in water transport to the cotyledon may occur during adverse storage conditions. The dehulled cooked beans had a PER of about 1.3 to 1.6 whereas the beans with seed coats had a PER of about 0.65. It is presumed that the high content of polyphenols in the seed coats are responsible for low digestibility of the proteins. This area of research should be pursued in more detail since dehulling has the benefit of improving the nutritive value of beans.

Various cooking procedures were evaluated by the INCAP team to determine the influence on protein quality and bean texture. Of particular note is the observation that as the cooking time increased, the PER decreased progressively. Thus hardening of beans is undesirable from a nutritional standpoint. Beans, soaked in salt solutions (mono and divalent ions) and cooked in the solutions, had lower PER values than those cooked in water. It was also noted that solutions containing bicarbonate and carbonate markedly reduced the cooking time of hardened beans. Presumably the carbonate interacts with the divalent ions of the pectate to form insoluble carbonate complexes. According to the results of the PUCC team, EDTA was effective in reducing the cooking time of hardened beans.

A large number of processing techniques were explored to utilize hardened beans. The beans were milled, or dehulled and milled, and flour mixtures were extruded to produce dry products for incorporation into infant food (bean/soya/corn combination), pasta products, cookies, soups and sausage products. More details are to be reported within the next year.

Highlights:
- sensory characteristics and appearance have been defined for consumer acceptability of beans
- quality evaluation criteria were established for sensory panelist
- multivariant analysis was used to characterize sensory quality factors
- laboratory methodology was developed to quantify textural quality of beans
- insoluble fiber and phytate appear to be implicated in the hardening process
- cultural practices and post-harvest losses were assessed and bean hardening was found to be a major problem
- dehulling of beans improves the PER
- bicarbonate and carbonate solutions can lower the cooking time of hardened beans
- containers which have low moisture transmission rates inhibit hardening of beans
- some processing techniques may be useful in the utilization of hardened beans

D. DISCERNING RESEARCH ACHIEVEMENTS TOWARDS REACHING OBJECTIVES

IDRC Aim of the Bean Network

The IDRC aim of the Bean Network program was "The study of common beans by a network of specialized research activities aimed at increasing the consumption and nutritive quality of dried beans".

Certainly, this aim is very broad and encompasses all of the research carried out so far by the teams of the Bean Network. Although it does not identify the targeted populations, the small farmers, low income families and storage agencies in Guatemala and Chile are mentioned in the project proposals as the beneficiaries of the research results.

Framework of realisms for the development of meaningful objectives

In the opinion of the Evaluators, research objectives for the Bean Network program should have been constructed within a framework of stated realisms (practical tendencies) of the targeted beneficiaries. With these realisms, the team members would have had a clearer vision and reference points with respect to meaningful goals. Some of the following realisms are generally recognized:

a. Low-acreage, low-income (LA/LI) farmers are resistant to changing agronomic practices and increasing costs of production (e.g. fertilization) even though the crop yields may be improved.

b. Post-harvest practices of LA/LI farmers must be simple and inexpensive.

c. Low-income (LI) consumers have specific bean quality preferences. Bean hardness is recognized by LI consumers as a quality defect.

d. LI consumers regard beans as a low-cost food item and must remain so even if a value-added feature is introduced.

e. LI consumers are resistant to changing their cooking methods for beans and to altering their dietary habits (e.g. inclusion of greater amounts of corn in Guatemalan diets).

Fortunately, Bean Network leaders must have been aware of regional realisms and unconsciously referenced them during the development of the proposal objectives. These above-mentioned realisms have been known for years by government and research agencies but most of them could only be regarded in qualitative terms. With the data from INCAP/UG consumer survey studies on bean quality, consumption and cooking habits, some of the realisms have become more quantitative. From the farm survey studies by the PUCC team, some agronomic realisms have been validated in numerical terms.
Note: For future research studies on beans, these realisms must be addressed prior to the development of objectives.

The realism, that LI consumers regarded hard-to-cook beans as highly undesirable and not acceptable, could not be quantified at the time when the PUCC/UG proposal was approved. Further, the socio-economic impact of the hardening of beans in Chile and Guatemala was not known in quantitative terms. It was only when the PUCC and INCAP data from their survey studies was analyzed that rough estimates of losses due to bean hardening could be produced. In

retrospect, perhaps the socio-economic studies should have been carried out first to determine the importance and problems of bean hardening prior to the development of a program on the elucidation of the mechanism and the prevention of bean hardening. However, in light of the sequence of events on proposal submissions and of at least the qualitative realism that the hard-to-cook phenomenon is a problem, approval of the program by IDRC should be considered justifiable.

Specific Projects

a. PUCC/UG Project A and Project C

The objectives IA and IC of determining the physical and chemical changes that contribute to bean hardness during storage have been accomplished to some degree by the UG team. The supposition that lignification in the cell walls plays a role in bean hardening was explored but could not be validated. The DSC study indicated that differences in starch gelatinization were not related to bean hardness. The extractable phenolic content in beans could not be directly related to hardness. The level of peroxidase activity was not found to be correlated with the degree of hardness. Although all of this data are negative from the standpoint of elucidating the hardness mechanism, it enters into the process of elimination. The UG team obtained some positive data which will be valuable in piecing together the hardness mechanism. In the first place, the water absorption of hard beans is greater than that for soft beans. Further, large amounts of soluble solids including calcium and magnesium ions are lost during the soaking of hard beans. Such a phenomenon could be attributed to phytate and protein hydrolysis (observed in studies by UG team) during storage of beans at a high temperature and high humidity. It is of interest that when the UG team applied high pressure to the soaked beans, the hard-to-cook beans were found to hold less water after soaking than the control beans. The low water binding capacity of soaked hard beans carried through to the cooked beans. This observation is the basis of the supposition that restricted imbibition of water by cotyledon cells of hard beans is an important factor in the hardening process. The presumed low water availability in hard beans has been attributed to cross-linking between proteins and/or carbohydrates and tannins (lignification). Since cotyledon cells in cooked hard beans and cooked soft beans have similar dimensions, the low water availability theory does not seem to be valid.

Now greater emphasis should be placed on the properties of the middle lamellae of hard beans. The microscopic studies by the UG team found that hard-to-cook beans had cells which were strongly adhering to each other in the middle lamella vicinity. The importance of divalant (perhaps trivalent) ions in the middle lamella was established when results indicated that carbonate and bicarbonate (INCAP) and EDTA (PUCC) in the soaking water of beans can reduce the cooked bean hardness. These compounds can form complexes with calcium and magnesium ions and may bring about the solubilization of pectic substances in the middle lamellae with the consequence of reduced intercellular adhesion.

The Evaluators propose that some of the UG results fit into the following hypothetical mechanism of bean hardening:

During the storage of beans at high temperatures and high humidities, a sufficient amount of water is absorbed by cotyledons to bring about mobilization of calcium and magnesium ions. During the induction period of bean hardening, the divalent ions diffuse into the middle lamellae and interact with the

carboxyl groups of naturally-occurring low methoxy pectic substances to form divalent bridges between pectin molecules. The extensive network of water-insoluble pectin polymers acts as an adhesive material for strongly binding cotelydon cells together. Phytate may restrict divalent ion movement to the middle lamellae and thus inhibit bean hardening. The UG team has shown a strong correlation between phytate loss and hardness development. Presumably the high moisture beans possess a sufficient amount of free water to mobilize phytate to phytase sites to catalyze the hydrolysis of phytate. Calcium ions may be lost easily from hydrolyzed phytate to migrate to the middle lamellae.

The objective 2A of developing post-harvest roasting technologies to arrest hardening of beans could not be achieved by the PUCC team since roasting of beans did not have a beneficial influence. In fact, the roasting process has the disadvantages of high energy expenditure, increasing the rate of hardness of beans, enhancing seed coat cracking and reduction of nutrients. The Evaluators cannot understand why further studies on roasted beans are being carried out at INCAP and UM.

Objectives 3A and 2C to determine optimal storage conditions for different dry beans to control hardening and to develop engineering models to predict bean hardening have been essentially achieved by the PUCC team. The hardness values of black beans with various moisture contents and held a various storage temperatures were obtained. Kinetic models to simulate the hardening process and to predict the storability of beans under various environmental conditions have been developed. A computer program with the mathematical equations of the model is being perfected for black beans. Further, preliminary experimentation on the storage of low-moisture black beans in polyethylene bags indicated that hardening of the beans could be impeded by maintaining the beans at a low moisture level within plastic film containers. Indeed, polyethylene bags may be suitable for the storage of moderately high moisture beans if moisture loss in beans occurs during high temperature storage (studies at INCAP indicated that black beans in polyethylene bags lost moisture during long term storage). It is of interest to note that the PUCC team found that beans with a moisture content of about 9% did not harden significantly over extended storage period at a high temperature. Solar drying, investigated by the PUCC team, should be considered as a low cost process for moisture removal from beans to about 9 to 10% moisture levels.

The objective 3C to evaluate the economics of existing bean handling and storage procedures practiced by small producers and distribution agencies in Chile has been accomplished to a large degree. Mr. R. Diaz, a graduate student in Agricultural Economics (PUCC), conducted survey research on the post-harvest losses of beans in Central Chile and the socio-economic impact on the farmers and the distribution agencies. The losses were expressed in terms of extended fuel consumption, decrease in nutritional value and waste. The thesis of Mr. Diaz was being written during our visit and thus detailed evaluation of economic models could not to be carried out. However, an economic model for hardened beans predicted that up to US $2.6 million per year loss due to extra fuel consumption and waste due to uncookability of beans.

b. INCAP/UM Project B and C

The objective of 1B to define specific characteristics of bean acceptability for Guatemalans, using consumer survey techniques has been

achieved. The results of the survey have been presented in a scientific publication (Ecol. Food Nut. 22, 183, 1989). This survey data will serve as a basis for studies on bean quality requirements in other bean consuming countries.

Objective 2B was to establish a uniform, reliable laboratory methodology to quantify the physical, chemical and sensory characteristics of bean quality as defined by Guatemalan consumers, and correlate, laboratory methods with consumer panel data. This objective has been satisfied. The UG and INCAP teams have co-operated in developing standardized methods for objectively assessing the texture of cooked black beans. The OTMS was used by INCAP and the Instron by UG along with a special extrusion-type sample cell. Correlation between the instrumental texture measurements and sensory texture values was significantly high. The instrumental texture analysis is presented in the manual entitled "Laboratory Methods of Bean Quality Evaluation" by Watts and Ylimaki (1989). This manual also contains other methods for laboratory texture analysis, chemical composition determinations and physical property assessments of beans. Further, a manual entitled "Basic Sensory Methods of Food Evaluation" has been prepared as a guide for reliable sensory analysis of beans as well as for other food commodities.

Objective 4C was to develop rapid screening measures for quality characteristics associated with acceptability of raw and cooked beans and to determine the importance of hardness in bean acceptability. Sensory analysis of beans was carried out by trained panelists at UM to determine the differences in the quality of beans with various degrees of hardness. UM sensory analysis methodology was used by an untrained panel at INCAP for rapid screening of beans for quality characteristics. The UM team has shown that both the Mattson Bean Cooker test and a cotyledon water absorption test are reliable for rapid prediction of cooked bean hardness. Thus the rapid screening methodology part of the Objective 4C has been fulfilled. The relationship of soluble fiber in beans and bean hardness is being investigated. Fiber analysis, which involves complex laboratory manipulations, would not be valuable as a rapid screening test. However data from this study will be valuable in the development of a mechanism for hardness. The ongoing electrophoretic study of isoenzymes in beans with various degrees of hardness may provide a basis of a moderately-rapid, simple test for hardness. The second part of Objective 4C, the determination of the importance of hardness in bean acceptability, has been addressed by the study of sensory characteristics of cooked beans by sensory panels at UM and at INCAP and by the survey study conducted in Guatemala by the INCAP/UM teams. The INCAP sensory study indicated that 90% to 100% of the cooked beans from 6 cultivars had to be soft to be scored as acceptable. These results strengthen the concept that the tenderness of cooked beans is an essential quality characteristic for acceptability.

Objective 3B was undertaken by the INCAP team to evaluate hardness development in bulk storage and under farm conditions. It should be noted that all beans in Guatamala are stored in woven bags, not in bulk storage. The INCAP team have conducted studies on the hardening of beans stored in several warehouses and stored on small farms. A preliminary study of beans stored in one warehouse (temperature and relative humidity data were recorded) indicated that over a 11-month period the cooking times rose from 65 to 100 minutes. With such a low cooking time for beans held for 11 months, storage conditions at this warehouse can be considered to be acceptable. The location of the warehouse was not given in the report. Note: More warehouses should be included in this

study to provide reliable data for estimation of economic losses. Data for the hardening of beans stored in small farms has been presented in Bean Network reports. Economic losses were estimated as extra expenditure of energy required to cook beans held in traditional bags as well as in paper, metal, vegetable fiber and polypropylene containers for 6 months. Beans were purchased from farmers in Juliapa and Peten for the hardness studies. Note: The data is scattered in various reports and should be brought together, analyzed and presented in a systematic manner. The Network Newsletter (July, 1988) indicated that physical, nutritional and quality losses would be measured for every sample from warehouses and farms. Objective 3B has not been satisfied as yet.

With respect to the first part of Objective 3C on the economic evaluation of bean handling and storage procedures practiced by small producers and government storage agencies in Guatemala, some information on agronomic practices has been tabulated as well as on losses due to mold growth and insect infestation (up to 20% losses). A model of a post-harvest system for beans was proposed by the INCAP team but this has not been presented as yet. More details on bean handling from harvest to consumer are required to fulfill the first part of Objective 3C. The second part of Objective 3C involves the testing of proposed improvements. INCAP have conducted studies on solar drying and on the use of various bean containers for maintaining low moisture contents. Other improvements in the post-harvest system may be forthcoming. To fulfill the second part of Objective 3C, the INCAP team should provide details on solar drying, properties of bean containers and methods for preventing mold and insect damage.

Objectives 4B and 5C were to develop procedures for the utilization of hard-to-cook beans in local foods and evaluate their effects on nutritive value. Three research approaches were undertaken by the INCAP team; a study of the effectiveness of salt solutions to reduce cooking time, an investigation of the effect of dehulling beans on reducing the cooking time and a study on the use of flour from hardened beans. Major strides have been made in these studies and thus Objectives 4B and 5C should be fulfilled by the termination date of the program. A variety of salts were used for soaking solutions to determine their influence on the cooking time of hard beans. The combination of sodium bicarbonate and potassium carbonate was found to be effective in the form of a soaking solution to reduce the cooking time of hard beans from over 360 minutes to 105 minutes. The PER of the salt-treated cooked beans was about 0.86 compared to about 1.01 for the water soaked, untreated cooked beans. Digestibility values of all treated and untreated beans were about the same (about 76%). Savings on electrical energy with the use of salt solutions were determined. Sensory analysis of the fried salt-treated cooked beans indicated high acceptability. The studies on dehulling of hard beans showed that the process decreased the cooking time significantly and improved the PER value. Investigations by the INCAP team on the use of whole and dehulled bean flour from hard beans have been extensive. Bean and soybean flours have been combined to improve the nutritional value. Extrusion cooking of flour mixtures has been used successfully to produce products for infant food, pastas, soup bases, meat products and cookies. INCAP has co-operated with a local food company in producing some of these food products on a commercial scale.

Objective 6C to train researchers and strengthen institutional capability to undertake integrated research in solving post-production problems have been accomplished. See Part II B and II F for details.

Objective 7C to disseminate research results and experiences through scientific publications, network communications and interest with storage and extension agencies has been achieved. See Part II G for publication details. PUCC has co-operated with a bean storage company on assessing the value of bean drying and the covering of bean bags with polyethylene film to impede moisture pick up and bean hardening. INCAP has collaborated with DIGESA on the study of hardening of beans in storage facilities and on the small farms, and on the economics of existing bean handling and storage procedures. INCAP also co-operated with INDECA (National Centre for Grain Storage) on quantifying bean losses, ICTA (National Institute of Research in Agriculture) on storage effects of beans, ICAITI (Central American Research Institute for Industry) on appropriate drying technology and University of San Carlos on student training on post-production problems. CIAT and INCAP co-operated in the assessment of the Mattson Bean Cooker for bean hardness.

E. CIAT VISITATION

During our visit to CIAT, we discussed the IDRC Bean Network program with Dr. Douglas Laing, Deputy Director of CIAT and Mr. Leonardo Lareo, Head of the Nutrition and Bean Testing Laboratory. They felt that CIAT should have been included in the IDRC Bean Network since 1. a wide variety of bean cultivars, which have been bred at CIAT over many years, would have been available at the start of the program 2. an ongoing interchange of information on cooked bean texture testing and cookability of beans could have occurred between Mr. Lareo and the other research team members.

Dr. Laing stressed that the diffuse nature of the Bean Network was a weakness of the program and that a co-ordinator/director of the program would have provided more focus on the problem solving of bean hardening.

Dr. Laing pointed out that post-harvest research at CIAT must be strengthened. In the near future, a senior food technologist should be employed by CIAT to develop an expanded post-harvest research program. The program would include studies on consumer acceptability, nutritional value and flatulence of bean cultivars from their breeding program.

Dr. Laing provided an example of the failure of a CIAT bean cultivar to be accepted by consumers. CIAT breeders developed a cultivar with excellent agronomic features for Colombian production. The color of the bean was a major consumer deterrent. Thus CIAT was further convinced that post-production research must be an essential component for the Centre.

CIAT would be pleased to provide leadership for a new bean network after the IDRC Bean Network program expires. Dr. Laing emphasized that only operational funds should be needed for network participants, some of which may be in the IDRC Bean Network. Objectives of any new bean network must be defined clearly and in detail prior to program initiation.

The major emphasis of CIAT is on applied research which provides solutions to problems in a direct, expeditious manner. Low-income urban consumers and small farmers are the major beneficiaries of the CIAT research. CIAT have developed effective methods for transferring the technology to targeted developing countries so that expertise can be transplanted to their home

research organizations. The above-mentioned strengths of CIAT indicate that CIAT leadership for a new bean network would be appropriate.

The research results generated in the IDRC Bean Network will be invaluable as basic foundation information for an expanded post-harvest bean research program at CIAT and as technology to be transferred to appropriate agencies and distribution companies through the CIAT system. Again, with the expertise in technology transfer throughout the world, CIAT should have no difficulty in disseminating the IDRC Bean Network results to targeted beneficiaries.

F. IMPACT OF PROGRAM ACTIVITIES ON RESEARCH INSTITUTIONS

INCAP

- Extended the research areas of the Division of Agricultural and Food Science to other aspects of food availability (e.g. bean flour utilization).

- Increased the number of research professionals in the Division with the view of retaining them for other research projects.

- Provided fund to acquire Ottawa Texture Measuring System and spectrophotometer.

- Provided funding to develop a sensory analysis laboratory for food evaluation.

UM

- Improved awareness of faculty members and staff on developing country problems and methods of problem solving at appropriate levels.

- Developed new techniques in texture measurement and electrophoresis.

- Introduced graduate and undergraduate students to food and nutrition problems in Central America.

- Assisted in obtaining other contracts for IDRC-sponsored projects in Latin America.

- Provided impetus to seek advice from other UM departments and Federal government laboratories on experimental design, methodology and statistical analysis (e.g. Statistical Service Group and Food Science).

- Provided funds to acquire Mattson Bean Cooker, texture cell and electrophoresis unit as well as to support graduate students.

PUCC

- Provided funding for the first long-term research project in the Department of Chemical Engineering with the implementation of research planning, budget control, management procedures and equipment purchasing.

- provided funding for research technicians and graduate students (at UG), and establishment of a food research laboratory.

- Increased confidence in research capabilities of faculty members and provided an avenue for research publication and professional advancement.

- Provided funding for equipment such as a GC centrifuge, balance, water activity meter, temperature-controlled chambers and a balance.

UG

- Provided funds for graduate students
- Provided funds for 2 temperature controlled chambers
- Improved awareness of food problems in developing countries.

G. PUBLICATIONS AND PRESENTATIONS

The number of publications and presentations are presented in Table 2. The UG and PUCC teams have published many papers and several review articles in scientific journals. Stanley and Aguilera have gained international recognition from their reviews on textural quality of beans. Hopefully, INCAP and UM will write up some of their experimental data for submission to scientific journals. Such publications are of value from the standpoint of peer review of the data and world-wide exposure of information.

Many undergraduate students participated in the bean research projects at PUCC and INCAP. These developing-country students have not only gained valuable knowledge of research design, experimentation and data analysis, but have also provided valuable data for the Bean Network.

Bulletins and books are important communication vehicles for general knowledge on a topic. In particular, the in-press publication entitled, "Basic Sensory Methods for Food Evaluation" prepared by the INCAP and UM teams and published by IDRC will be the most up-to-date book on reliable sensory testing methodology. Another in-press book which has resulted from the Bean Network program is entitled, "Microstructural Principles of Food Processing and Engineering" by Aguilera and Stanley. The bulletin entitled, "Laboratory Methods for Bean Quality Evaluation" was prepared by the UM team to document their standardized procedures for physical and chemical analysis of beans. This should be of great assistance to the Bean Network members.

Presentations at conferences and workshops is important from the viewpoint of introducing new ideas and concepts and of exchanging information with interested scientists.

H. IMPACT OF RESEARCH

Many avenues of research have been followed in the Bean Network by project leaders, seasoned scientists, graduate students and undergraduate students. The teams have provided scientific information which will be helpful in the elucidation of the hardening mechanism, in the reduction of the hardening rate of stored beans, in the decrease in the cooking time of hardening beans and in the utilization of hardened beans. Since survey studies in Chile and Guatemala have indicated that hardening is a serious economic problem, this scientific

information must be used to develop a practical strategy to solve the hardening problem. This strategy should be formulated within the next year and should include the areas of 1. solar drying of beans on the farm, 2. container suitability for bean storage, 3. cultivar assessment for reduced hardening and 4. suitable cooking procedures for nutrient retention. Once the strategy is in place, then extension agencies must be brought in for the dissemination of the information and demonstration of the practices. CIAT could become involved in activities and could provide leadership for further studies (see Part II E).

The benefits of such a strategy will be of great value to the farmers and the storage agencies, all of whom strive for good quality beans year round. Certainly from the consumer viewpoint, energy saving by the rapid cooking of beans would be highly advantageous and further, with short-time cooking, the PER for beans is maintained.

I. EVALUATION OF THE BEAN NETWORK APPROACH

The description of the structural features of the Bean Network program has been presented in Part I. Briefly, the structural network model for Phase One of the program was duo-twinning whereas in Phase Two, a unified multi-disciplinary multiteam network model was instituted.

Since the duo-twinning network evolved from a single co-operative proposal from PUCC and UG, a problem of effective communications arose when Project B was approved in 1985, one year later than the PUCC/UG Project A approval. This problem was pointed out by Dr. Aguilera at the First Workshop of the Bean Network in June 1985 (page 38 of the Manuscript Report, IDRC-MR120e). He indicated, "a lack of inter-network communication and collaboration", and emphasized that "each group within the network must however be kept informed of the latest approaches taken and data generated by researchers". He suggested that "trip reports should serve the needs of the network rather than merely fulfilling the administrative requirements of IDRC". Attention should be directed to Dr. Aguilera's statement that "no one is specifically responsible for the entire collaborative effort".

With respect to co-ordination of the network, a suggestion was made at this First Workshop that IDRC should be responsible. However, it was pointed out by Dr. Edwardson that IDRC Program Officers are unable to undertake such a time-consuming task. The possibility of employing someone on a part-of-a man-year basis to co-ordinate the program was discussed. Unfortunately funds were not allocated in the projects for a co-ordinator. This topic was to be included on the 1986 annual meeting agenda. For the interim, the group agreed that network co-operation would be improved by quarterly progress reports produced by each group in September, December, March and June. It was agreed that Dr. Edwardson would act a distributor of research results, progress reports and travel reports to network groups.

Through Phase One and Phase Two periods, excellent communication and co-operation occurred between the PUCC/UG group and the INCAP/UM group. Even with the exchange of reports and the annual workshop meetings, the two groups did not communicate and collaborate as substantially as would be expected in a ideal network system. However, without a co-ordinator, an ideal situation was not possible.

According to the project leaders, the annual workshops were invaluable for up-dating each other on research findings, for presenting ideas for further research and for initiating the exchange of samples and information. The publication of the Proceedings of each workshop by IDRC is commendable since the team members of each project could review the presentations at the meetings which they were unable to attend because of financial restrictions. The attendance of workshops by invited scientists started with the First Workshop. At the 1985 Workshop, the Bean Network team leaders examined the advantages and disadvantages of the inviting scientists from outside of the network. The large number of advantages listed on page 40 of the 1985 Bean Network Proceedings outweighed the one disadvantage of inhibition of frank discussion amongst participants. This disadvantage could be circumvented by holding a network particpants meeting prior to the Workshop.

Over the duration of Phase One and Phase Two programs, some specific objectives were discontinued or deemphasized and some others were added. Some overlap of research areas had occurred with the addition and extension of specific objectives. Fortunately, the overlap created a comparative attitude amongst the teams and new improved ideas evolved. However, with a co-ordinator, a more efficient interweaving of new research directions within a framework could have occurred. Certainly the elasticity of IDRC to accommodate new research approaches in a project is commendable and such a policy should be continued.

It is the opinion of the Evaluators that IDRC should have allocated sufficient additional funds for employing a technical co-ordinator when the possibility of in effective communication, collaboration and co-ordination arose at the first workshop meeting in 1985.

Mr. Hohlberg was appointed a communicator in 1988 to disseminate research results through Newsletters. The Newsletters were well received by the Teams. However, a communicator was no substitute for a co-ordinator.

The ideal network for the bean research project would have been a unified, multi-disciplinary, multi-team network (as instituted for the Phase Two research program) with general objectives and specific objectives fully accepted by the research leaders. Under the guidance of an outside (not involved as a project researcher) co-ordinator, participants would agree to undertake definite avenues of research. The co-ordinator (a senior, research scientist with experience in research and research management) should have the authority to make decisions (on an ongoing basis) on the most effective and efficient research approaches in concert with the research leaders and the IDRC Program Officer. The co-ordinator would be responsible to the IDRC Program Officer of the project. The co-ordinator and the research leaders should attend a course on research management prior to the initiation of the research activities to gain an insight into practical management concepts, budgeting, time-saving techniques and government report writing. Such a course is offered by the Department of Agricultural Economics, University of Manitoba.

J. COST EFFECTIVENESS OF THE BEAN NETWORK SYSTEM

As shown in Table 2, the total IDRC contribution amounts to almost $1.4 million and the recipient contribution has been estimated to be about $740,000.

From the standpoint of the high value research results, publication of results, equipment purchases by developing country institutions and the education of graduate and undergraduate students from Chile, Guatemala and Canada, the money has been well spent. Certainly the IDRC Bean Network program has gained world-wide respect and notoriety, and has contributed excellent scientific knowledge on bean quality and utilization which is open to outside scrutiny and usefulness. The total amount of money (about $2.1 million) spent on the bean program is a small fraction of the annual cost of bean losses in Chile (about U.S. $2.6 million) and in Guatemala (about U.S. $19 million for 1987). The dollar value on the research experiences gained by the project leaders and members of the teams cannot be measured quantitively, but the impact will be felt in other developing country research projects. UM team have recently received approval of a project by IDRC for research on improved methods of food processing). The Bean Network program has been a training-ground for future project leaders.

IDRC proposed that a research program be aimed at increasing the consumption and nutritive value of dried beans in developing countries. Such a broad aim embodies numerous complex problems to be solved. Problems dealing with agronomic production, post-production deterioration of beans and processing for increasing bean functionality and acceptability should be addressed. If these problems are to be solved through research, experts from several disciplines must be recruited as team leaders. The simplest organizational approach to the above-mentioned research program would be the allocation of specific funds on a contract basis to each team leader of a research group which has expertise in the specific problem-area and which has excellent facilities and equipment to conduct straight forward step-by-step research. Each research group in an institution would work independently and would report directly to IDRC. No travel expenses or equipment purchases would be necessary. However, an overhead charge of at least 65% would be required and perhaps a part-time salary for the team leader might be a requirement. Recipient Institutional funding for the project would be exceptional.

The individual team approach to research would be cost-efficient in that expenditures would be limited to direct research costs for straightforward problem-solving. There are several disadvantages to the individual team approach including: 1. the inability of many Third World research institutions to compete for contracts because of lack of suitable equipment and expertise 2. high overhead charges by institutions 3. no recipient institutional financial contribution 4. research personnel would lack awareness of on-site problems in targeted developing countries 5. inspired, dedicated, appropriate research effort may be missing because of no interaction with Third World researchers 6. student exchange for increasing scientific resource personnel in Third World countries would not be possible 7. review articles on a broad problem would not be prepared. In summary, the individual team approach as outlined above would be cost-efficient for solving a simple, straightforward problem area without regard to information transfer, solution testing in targeted Third World countries and human resource development.

Now let us focus our attention on the IDRC aim on the bean research program for increasing the consumption and nutritive value of dried beans in the light of IDRC ideas that Third World research institutions must be involved, human resource development must be instituted and research information must be transferred to targeted beneficiaries. Thus an <u>effective</u> research program for

achieving these stated goals must include interactive linkages of all research teams in the Third World and Canada. The linking model should be cost-effective, which means that adequate funds must be determined and made available to bring about the desired effects or results. Adequate funding implies that the program would be cost-efficient in that money would be spent only on activities proposed in the contracts.

A network is a vehicle to link research teams together for on-going exchange of ideas, equipment, materials, personnel and documents. The network model provides a dynamic environment for bringing forth creative approaches for problem solving and for discarding fruitless research avenues. With a network, targeted beneficiaries can play a role in the solving of some problems in concert with some research teams. The cost of a network system for a research program may be higher than the individual team system in that travel, equipment purchases, student exchange expenses and communication expenditures are necessary. However, the disadvantages of the individual team system as listed above could be eliminated with the adoption of a network system for a research program.

The Evaluators agree that the most productive, cost-effective research model for a program with complex problems to be studied by Third World and Canadian research institutions would be the network system. The Evaluators strongly recommend that IDRC should promote networking for future research programs in food areas.

Details on network approach in the bean research program are presented in Part II I.

The cost-efficiencies of the Bean Network program can be noted in Table 4. In particular, the stipends for graduate students were low cost, research leaders contributed their time at no cost to IDRC, undergraduates involved in research were not paid, overhead costs were a modest 13% and secretarial services were not charged to the projects except for INCAP.

K. PROGRAM SUPPORT BY IDRC

The IDRC administration has been strongly supportive of the Bean Network program by providing funds for travel to workshops and team institutions, and for publication costs and publication of Workshop Proceedings. The leadership and ongoing assistance of Dr. W. Edwardson was greatly appreciated by the project leaders. Without his guiding influence on research directions and without his valuable advice on project management, the network would have lacked cohesiveness and definitiveness. His insistence of quarterly reports by project leaders was valuable in that teams were forced to analyze data on an ongoing basis and draw conclusions quarterly.

L. RECOMMENDATIONS FOR FURTHER RESEARCH

During the interviews with the research teams and at the annual workship in Winnipeg in July, 1989, the Evaluators gained an insight into the Network research activities and results. As Dr. Edwardson pointed out clearly at the meeting, the major purpose of the bean program is to solve or work towards

solving the bean hardening problem. Certainly many spin-off objectives are inherent in the program and must be acknowledged as most valuable. As mentioned in Section H, a strategy must be developed in the remaining months of the program to utilize the accumulated knowledge to help solve the bean hardening problem. To this extent, the Evaluators have documented in Table 5 recommended further (wrap-up) research towards achieving goals of the Bean Network program.

Table 1. Student participation in research

	PUCC	UG	INCAP	UM
Graduate Students				
Ph.D.	---	2	---	---
M.Sc.	---	3	---	4
Undergraduate Students	6	---	12	---

Table 2. Publications and presentations of research results.

Type Group	PUCC	UG	INCAP	UM
Scientific publication	6	17	1	2
Review articles	2	2	0	0
Theses	6	3	12	2
Bulletins	-	-	1	1
Books and monographs	1	1	1	1
Reports	5	7	5	8
Presentations	9	11	18	10

Table 3. Budget distribution.

Recipient	IDRC Contribution	Recipient Contribution (Estimated)
UG	218,500	61,600
PUCC	316,700	65,700
INCAP	537,400	274,632
UM	312,200	336,500
TOTAL	$1,384,800	$738,400

Table 4. Cost efficiencies of the Bean Network

Research Services and Activities	Cost to IDCR	No Cost to IDRC
Research personnel	Technicians, graduate students	project leaders, undergraduates
Research facilities	Overhead 13% INCAP 13% UM 13% UG	no overhead (PUCC)
Equipment, rental	new equipment purchases INCAP, UM, UG, PUCC)	existing equipment
Supplies	beans, chemicals, glassware, paper	----
Travel	airline tickets, lodging meals	----
Computer, statistical analysis	time basis	----
Publications, communications	scientific papers, news letters, Bean Network reports, telephone	----
Secretarial services	part-time INCAP	typing, office services (PUCC, UG, UM)
Co-ordinator	part-time	----

Table 5. Recommended further (wrap-up) research towards achieving goals of the Bean Network program.

Priority	Recommended further research	Teams to be involved
First	-Detailed studies on suitability of plastic film bags for beans storage; study on the loss of moisture from high moisture beans in plastic bags at tropical temperatures (up to 37°C).	PUCC/INCAP
	-Further studies on effectiveness and suitability of the low cost solar dryer for farm use.	INCAP/PUCC
	-Completion of the computer program for predicting hardness and evaluation of program with beans stored in Guatamala.	PUCC/INCAP
	-Optimization of soaking salt mixture formulations on the basis of low cost, nutritional value, ease-of-use, high acceptability; assessment of the acceptance of the mixture by target population.	INCAP/UG
	-Standardization of methodology for cooked bean texture measurements and for rapid testing of bean acceptability.	UM/UG
	-Cell size distribution study on cooked freshly-harvested and cooked hard beans; study of pectic substances in cotyledons of fresh and stored beans.	UG
	-Study of the browning (Maillard?) of cotyledons during bean storage and relation to hardening, nutritive value and flavour; role of raffinose and related sugars in browning (See Figure 1).	UG/INCAP
Second	-Further studies on the importance of phytate in the prevention of hardening; role of high phosphorus fertilizer on increase of phytate in beans with potential benefit of reduced hardening.	UM/UG/CIAT
	-Further studies on the potential of breeding-in factors (phytate?) which will impede bean hardening.	UG/CIAT
	-Study of the relationship of cooked bean broth viscosity and cooked bean hardness; determination of components (pectins, gums) responsible for broth viscosity.	UM/INCAP
	-Study the acceptability of dry dehulled beans by the targeted population in Guatemala; further study of nutritional and quality advantages of dry dehulled beans.	INCAP/UM

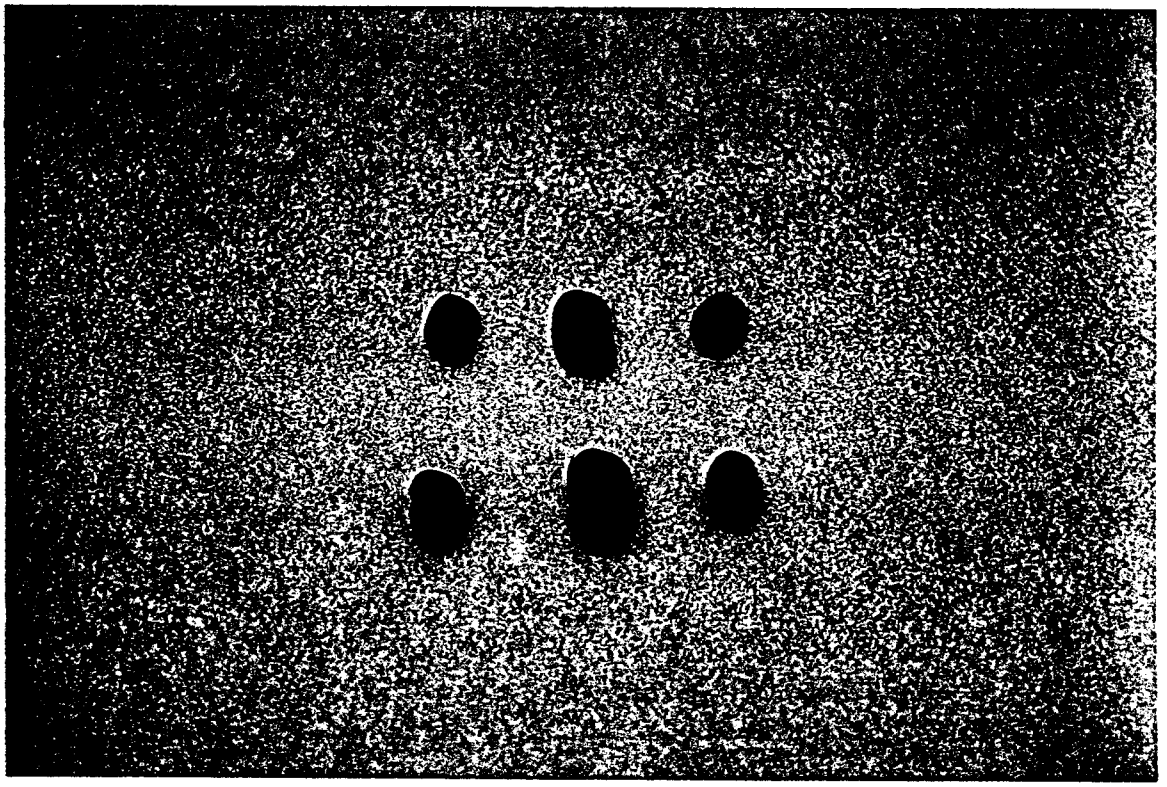

Figure 1. Brown-coloured cotyledons of stored black beans and navy white bean