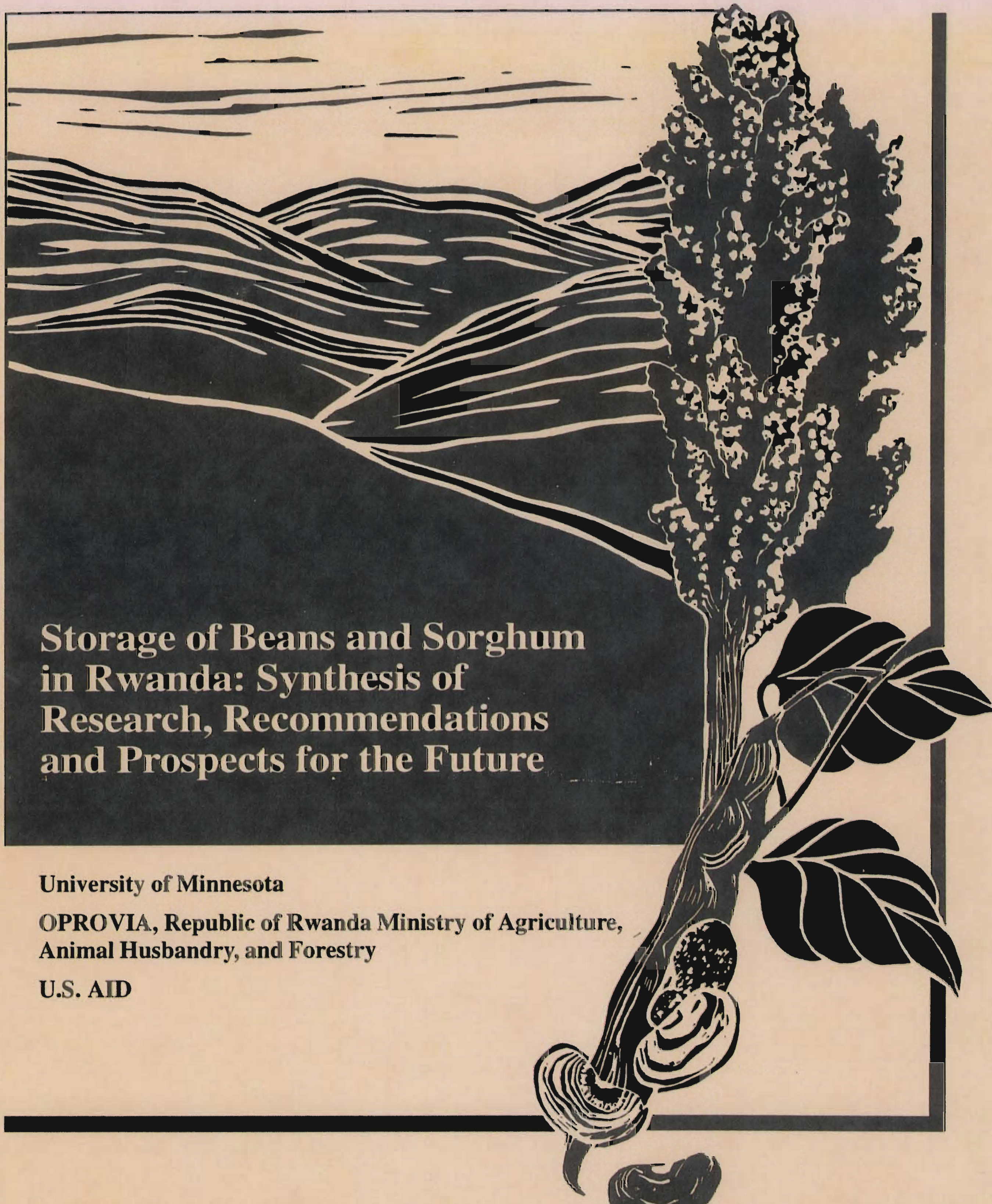

Storage of Beans and Sorghum in Rwanda: Synthesis of Research, Recommendations and Prospects for the Future

University of Minnesota

OPROVIA, Republic of Rwanda Ministry of Agriculture, Animal Husbandry, and Forestry

U.S. AID

Miscellaneous Publication 51–1988
Minnesota Agricultural Experiment Station, University of Minnesota

Local Crop Storage of Beans and Sorghum in Rwanda: Synthesis of Research Project Findings and Recommendations

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Preface

" KUBAKA IBIGEGA DUHUNIKAMO NI BYIZA. OPROVIA IBIFITIYE PROGRAMU.... NIDUSUBIRANE N'IBIGEGA BYACU, N'IMITIBA, N'IMIGULI. DUHUNIKEMO IBIZATUNGA IMILYANGO YACU." ("It is good that we have infrastructures available for storage. OPROVIA possesses a program to this effect.... Let us return to using our traditional granaries (ibigega, imitiba, and imiguli). Let us conserve our harvest so as to nourish our families.")

* *

Excerpt from the speech of Major General HABIYARIMANA Juvénal, President of the Rwandan Republic and President-Founder of the M.R.N.D., July 5, 1985 (pp. 21 and 22).

* *

Population growth, the limited possibilities to obtain productive employment, and the absence of elasticity in land resources define the essential problems for the future of Rwanda. The Rwandan Government has exerted considerable effort to achieve equilibrium between the growth of its population and growth of production. But in terms of agricultural research, these efforts have been devoted mostly to increases in production. However, there is now a realization of the need for research in the post-harvest area in order to safeguard, enhance value, and distribute the production obtained. It was in response to this preoccupation that the "GRENARWA II-Research Project" was created in 1982 thanks to the excellent cooperation between Rwanda and the United States of America. The research activities themselves began in early 1984 at OPROVIA with technical assistance from the University of Minnesota (USA).

Research centered on beans and sorghum because of the importance of these two commodities to food supplies in Rwanda, as well as the information accumulated on the problems encountered with their storage. Nevertheless, the majority of the results obtained are applicable to other food grains. OPROVIA, cooperatives, food industries, agricultural projects, merchants, and producers encounter storage problems of various kinds, and thus the results obtained by the GRENARWA II-Research Project will have a broad impact on the development of Rwandan agriculture.

The research program of this Project consists of seven separate but interdependent components. These components involved indispensable surveys on the post-harvest system in Rwanda, identification of storage problems, improvement of existing structures, design of new storage methods, problems of hardening and color change of beans as a function of storage period, studies of resistance of beans to insects, and finally development of quality standards and norms for beans and sorghum.

Several extension activities were also carried out across the country; and the "Food Quality Laboratory" created at OPROVIA by the Project continues to render various services to interested parties. It is indeed fortunate to have such a laboratory which is, practically speaking, the first of its kind in the country.

The research conducted, the results obtained, and the specific recommendations for each research component are developed in detail in seven different volumes which will be sent to the official Rwandan departments and other organizations directly concerned by the subject treated.

It is therefore in a spirit of synthesis of the work accomplished that this document was prepared for government officials and planners in order to facilitate an appreciation of the efforts already undertaken, and yet to be made, in the improvement of post-harvest systems in Rwanda. Beyond the synthesis of objectives, results, and recommendations by specific activity or component, the document discusses the prospects for the future of the Project, namely: the description of the second phase whose financing must still be sought; the order of priority for future activities; and the possible development of the structure created by the Project into a "National Center of Post-Harvest Techniques" which, in the long run, might itself evolve into an "Institute of Food Technology of Rwanda".

Closure of the first phase of the project comes at a particularly appropriate moment because the year 1988 has been dedicated by the Head of State, Major General HABIYARIMANA Juvénal, for the defense of farmer revenues. Nearly 95% of the Rwandan population is employed in agriculture; therefore most of the revenue is expected from this sector. The availability of results from the GRENARWA II-Research Project will contribute to increases in agricultural income by allowing Rwandans to better preserve, enhance value, and market the production obtained, but these benefits are only possible if application of these results occurs. It is for this reason that the Rwandan Government will make every effort to ensure their application without delay for the benefit of users. At the same time, efforts will be pursued so that the activities planned for the second phase of this Project can be funded in their entirety. This would provide for an adequate national resource of expertise for all problems arising in the post-harvest system of our country - an indispensable link for the success of food self-sufficiency.

The results of the GRENARWA II-Research Project, compiled in the various volumes mentioned above, are the fruit of a collective work. The different parties engaged in the Project, namely USAID, the University of Minnesota, and OPROVIA, were able to submit to the amiable authority and effective discipline imposed by the program and presentation of rather varied research, all of which aimed at an essentially practical goal.

The Project Director and his Rwandan counterpart were able to adapt the Workplans to the particularly difficult harvest conditions (1984) and to make the research scientists and technicians aware of their responsibilities to best accomplish the objectives by means of enhancing their knowledge and even increasing their efficacy. May the quality of these different publications be, for the entire team, a sign of success and render each member proud of the work accomplished. It seems to me that the research conducted by the GRENARWA II-Research Project provides an update, long awaited, which will increase awareness among Rwandan farmers as well as the public at large of the importance of mastering the techniques of post-harvest systems and of their influence on agricultural development.

Finally, I am grateful to all those who near and far have contributed to the realization of such a useful work, and one which will improve the lot of the farmers who have the noble task of feeding our people.

Kigali, June 20, 1988
The Minister of Agriculture,
Animal Husbandry, and
Forestry
Anastase NTEZILYAYO

ACKNOWLEDGEMENTS

This report summarizes post-harvest research on beans and sorghum conducted from November, 1983 to June, 1988 in Rwanda, East Central Africa, under the auspices of the GRENARWA II-Research Project. The work was performed collaboratively by the National Office for the Development and Marketing of Food and Livestock Products (OPROVIA), especially its Food Products Division (GRENARWA), in cooperation with the University of Minnesota and the Rwandan Institute of Agricultural Sciences (ISAR).

The editors wish to acknowledge the substantial contribution of human and material resources provided by the Government of Rwanda, especially the Ministry of Agriculture, Animal Husbandry, and Forestry (MINAGRI). Deep appreciation is extended to Mr. Anastase NTEZILYAYO and Dr. Dismas NSENGIYAREMYE, Minister and Secretary General respectively of MINAGRI for their support.

The editors gratefully recognize the facilities and assistance provided by OPROVIA where the Project was based. We are particularly grateful for the tireless efforts and forceful leadership provided throughout the Project by the Director of OPROVIA, Lt. Col. Bonaventure NTIBITURA, and his staff. The facilities provided at ISAR/Rubona and the support given by the Director of ISAR, Mr. Leopold GAHAMANYI, and his staff are also much appreciated.

Funding for this research was provided by the United States Agency for International Development (USAID), primarily through Contract No. AFR-0107-C-4001-00 to the University of Minnesota under the Local Crop Storage/Food Storage and Marketing Project, Phase II. This Project was part of a long-term commitment of USAID to food storage and marketing assistance in Rwanda. The editors gratefully acknowledge not only USAID's financial support, but also the excellent cooperation of the AID Representatives, initially Mr. Eugene Chiavaroli and later Mr. Emerson Melaven, as well as their staffs.

The editors also wish to acknowledge the key role played in this Project by the University of Minnesota in furnishing the necessary scientific expertise and supervision. Sincere appreciation is extended to Dr. Delane Welsch, Assistant Dean and Director of International Agricultural Programs, University of Minnesota, for his unwaivering support and personal involvement in guiding this international collaborative research project along a productive and successful path. Recognition is also given to Dr. Malcolm Purvis, former Director of International Agricultural Programs, for his foresight in initiating faculty interest and for his guidance during the early stages of the Project.

Finally, the editors are especially grateful for the dedication and substantial effort provided by those most closely associated with the research work:

- The Faculty Advisors of the University of Minnesota who helped design and supervise the research program,

- The Rwanda and Minnesota scientists responsible for conducting the field research in Rwanda and,

- The technical and administrative staffs in Rwanda and at Minnesota who provided indispensable support.

They are too numerous to be mentioned specifically by name here, but most are listed in the Appendices. Their many and significant contributions are hereby acknowledged with sincere appreciation.

The Editorial Committee:

Dr. Florence V. Dunkel, President
Mr. Phocas KAYINAMURA
Mr. Steven A. Clarke
Mr. Ronald Chastain

I. INTRODUCTION

1. Basic Information on Rwanda

1.1 Geographical Aspects

Rwanda is located in east-central Africa at a latitude of 1 to 3° south of the equator. It is bordered by Uganda, Tanzania, Burundi, and Zaire. Rwanda covers an area of 26,338 square kilometers. The topography is hilly to mountainous with altitudes ranging from 950 meters above sea level (masl) in the southern part of the country up to 2,500 masl (for arable land) and 4,500 masl (highest peaks) in the volcanic regions of the northwest. The native vegetation ranges from the savannah to the highland tropical forests which are already largely cleared and now devoted to farming. About 90% of the soils are basic pre-Cambrian type. Five percent are alluvial and are found in the marshy areas between the hills. The remaining 5% are rich volcanic soils which are found in regions characterized by high population densities. Streams, rivers and lakes are well distributed throughout the country. The rainfall pattern is bimodal, with the rainy seasons occurring between February and May and again between October and December. Total annual rainfall varies from 800 to 2,000 millimeters. Average temperatures range from 16° to 24°C depending on the altitude.

1.2 Demographic Aspects

The population of Rwanda was 5.5 million in 1983 with an annual growth rate of 3.5%, which is among the highest in all of Africa. The mean population density of the entire country is 200 inhabitants per square kilometer but rises to 400 inhabitants per square kilometer when calculated on the basis of arable land area. The population is still largely rural; only 5% of the people live in urban areas. Rural organization is characterized by small, scattered farmsteads rather than by organized villages. Continued population growth constitutes the greatest threat to the development of Rwanda.

1.3 Administrative Divisions

The Capitol of Rwanda is the City of Kigali. The country is divided into ten prefectures (Figure 1), each with a town designated as the center or seat of government. Prefectures are divided into sub-prefectures which are composed of communes whose number now totals 143. The communes are divided into sectors which in turn are divided into cells. It is these cells which constitute the smallest political and administrative units of the country.

1.4 Agriculture

A total of 1,229,600 hectares of arable land is available in Rwanda according to data collected in 1980 by the Agricultural Surveys and Statistics Service (SESA). Agriculture in Rwanda is predominantly one of subsistence. Farming is the principle occupation of 95% of the country's population. Each family has a farmstead which is on average 1 hectare in size (1980) and consists of small scattered plots. The country's

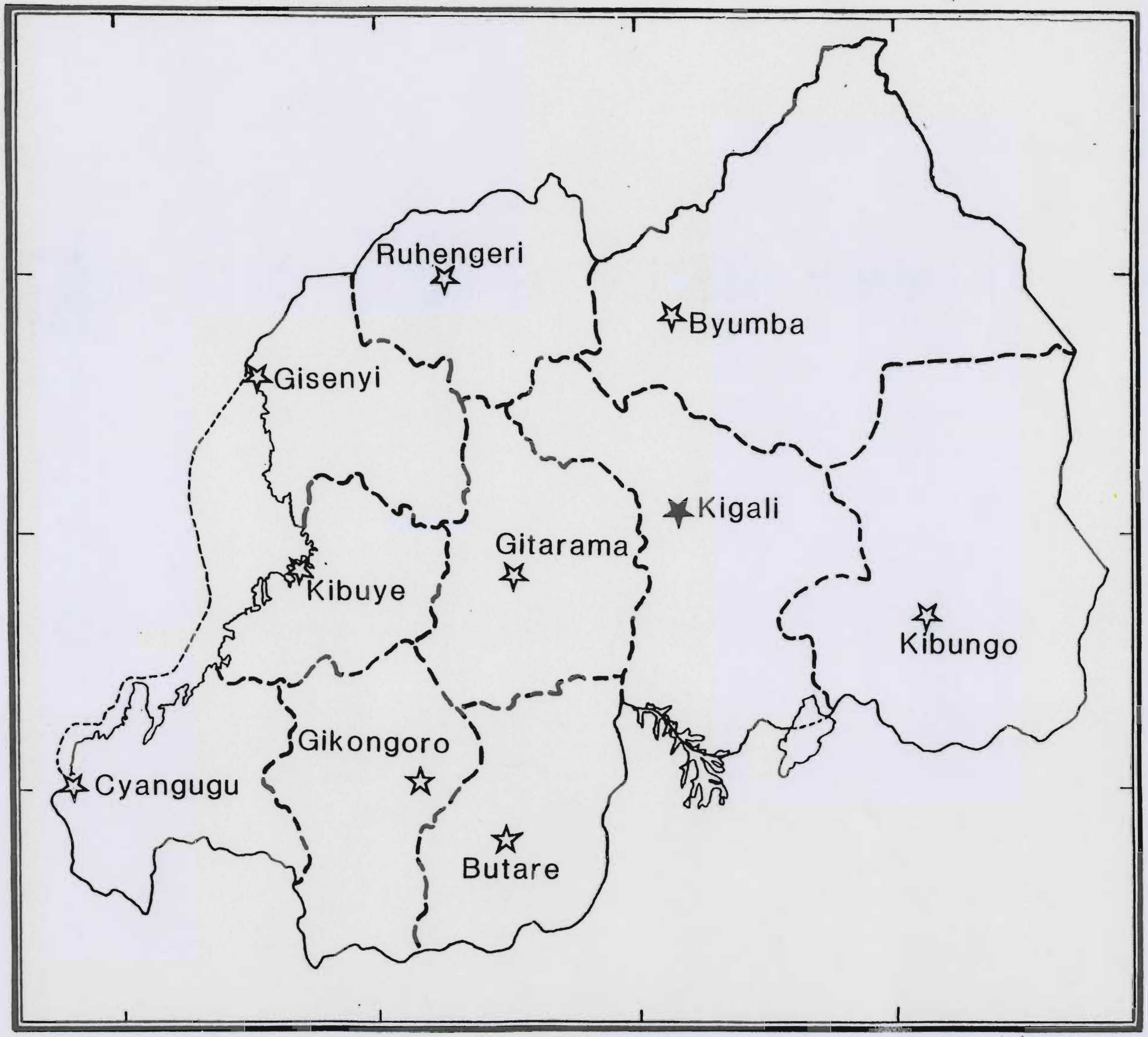


FIGURE 1. Map of the Prefectures of Rwanda and Location of Prefectoral Seats

agriculture is characterized by a lack of mechanization, intercropping, mixed crop and livestock farming, and the production of a diverse array of food crops. Food crops contribute more than 30% to the Gross National Product (GNP).

Crops are grown during two distinct growing seasons, but a third is possible in the lowland marshy areas between the hills. The most important crops in terms of the area harvested are beans (Phaseolus vulgaris), bananas, sorghum, sweet potatoes, maize, peas, cassava, and (Irish) potatoes. Other crops such as soybeans, groundnuts (peanuts), yams, coco yams (taro), and wheat are of a lesser importance. Vegetable crops found with some frequency include cabbage, eggplant, tomato, leeks, and onions. Fruits grown in Rwanda include avocados, papaya, pineapple, and custard apple. The main industrial crops, which provide important export revenues, are coffee, tea and pyrethrum. The livestock raised in the country include cattle, goats, sheep, pigs, chickens and rabbits. The country has been divided into twelve agroclimatic zones based on elevation, rainfall, soils and the types of agricultural production (Figure 2).

Demographic growth, the limited possibilities for productive employment, and the absence of land resource elasticity define the essential problems for the future of Rwanda. Despite the labor and discipline of its 1.2 million small farms, the development of new technologies is necessary to enable Rwanda to adequately feed its population in the future. This effort is directly related to the development of agricultural research institutions.

1.5 Agricultural Research

The Rwandan Institute of Agricultural Sciences (ISAR) has primary responsibility for all agricultural research conducted in Rwanda. Seven satellite or branch stations are located in various regions of the country (Figure 3). Currently ISAR is pursuing research on food and industrial crops, cropping and farming systems, forestry, and animal husbandry, but to date has placed little emphasis on the post-harvest area. ISAR's research stations contain laboratories and experimental fields for research on crop improvement, plant protection, soil and plant chemistry, and microbiology. In addition, research is carried out by faculty in the College of Agriculture of the National University of Rwanda (UNR). In general their research is enscribed within the training programs for students. In 1984 research on post-harvest problems was initiated at OPROVIA (National Office for the Development and Marketing of Food Crops and Animal Products) through the GRENARWA II-Research Project which was given the responsibility of conducting research on the storage of beans and sorghum.

2. Project Background

The original Food Storage and Marketing Project (FSM) began in December, 1974 through a grant agreement between the USA and Rwanda. As was the case with the National Office for the Development and Marketing of Food and Animal products (OPROVIA), it was created out of the poor agricultural years that the country experienced in 1973-1974.

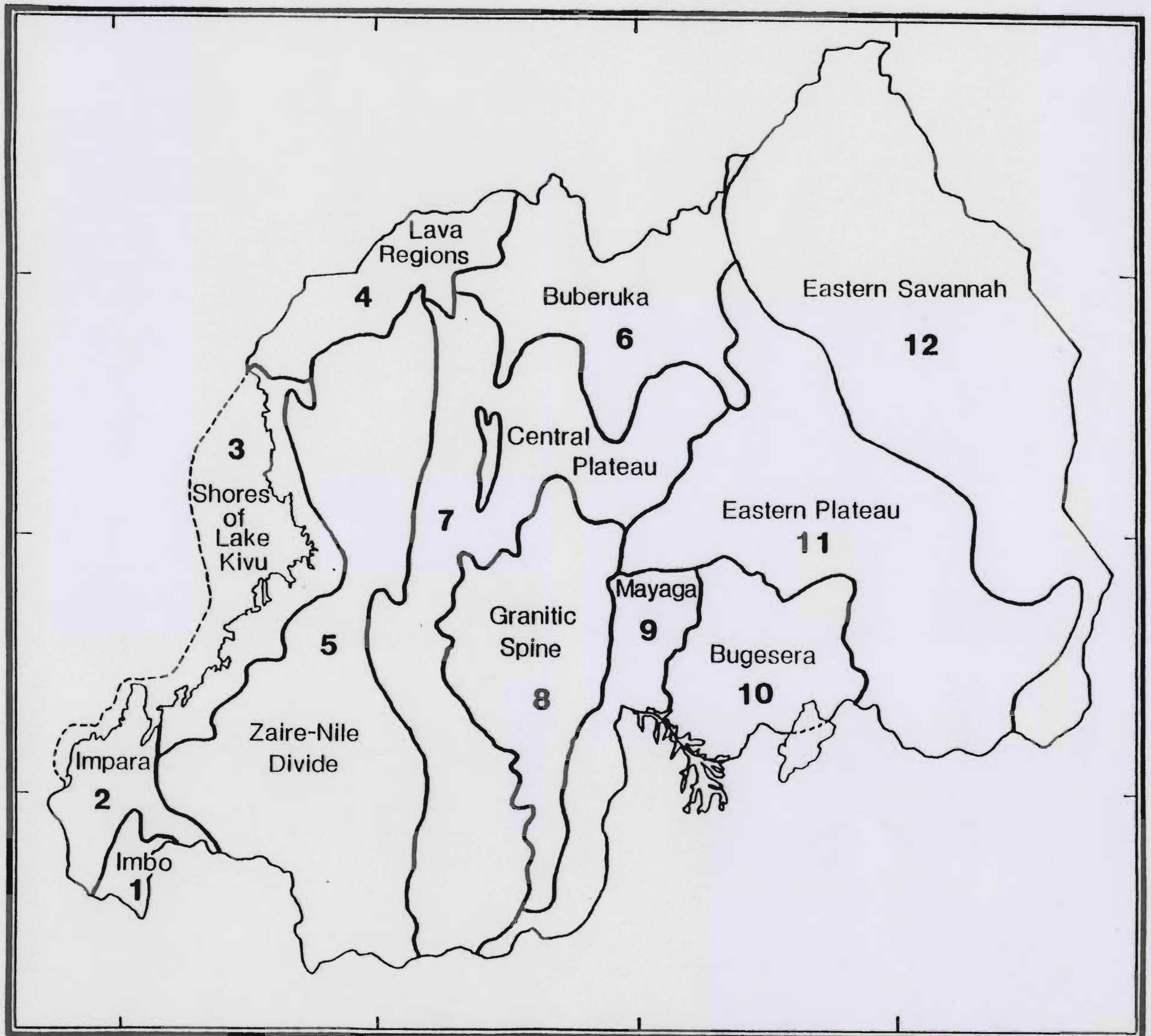


FIGURE 2. Map of the Agroclimatic Zones of Rwanda

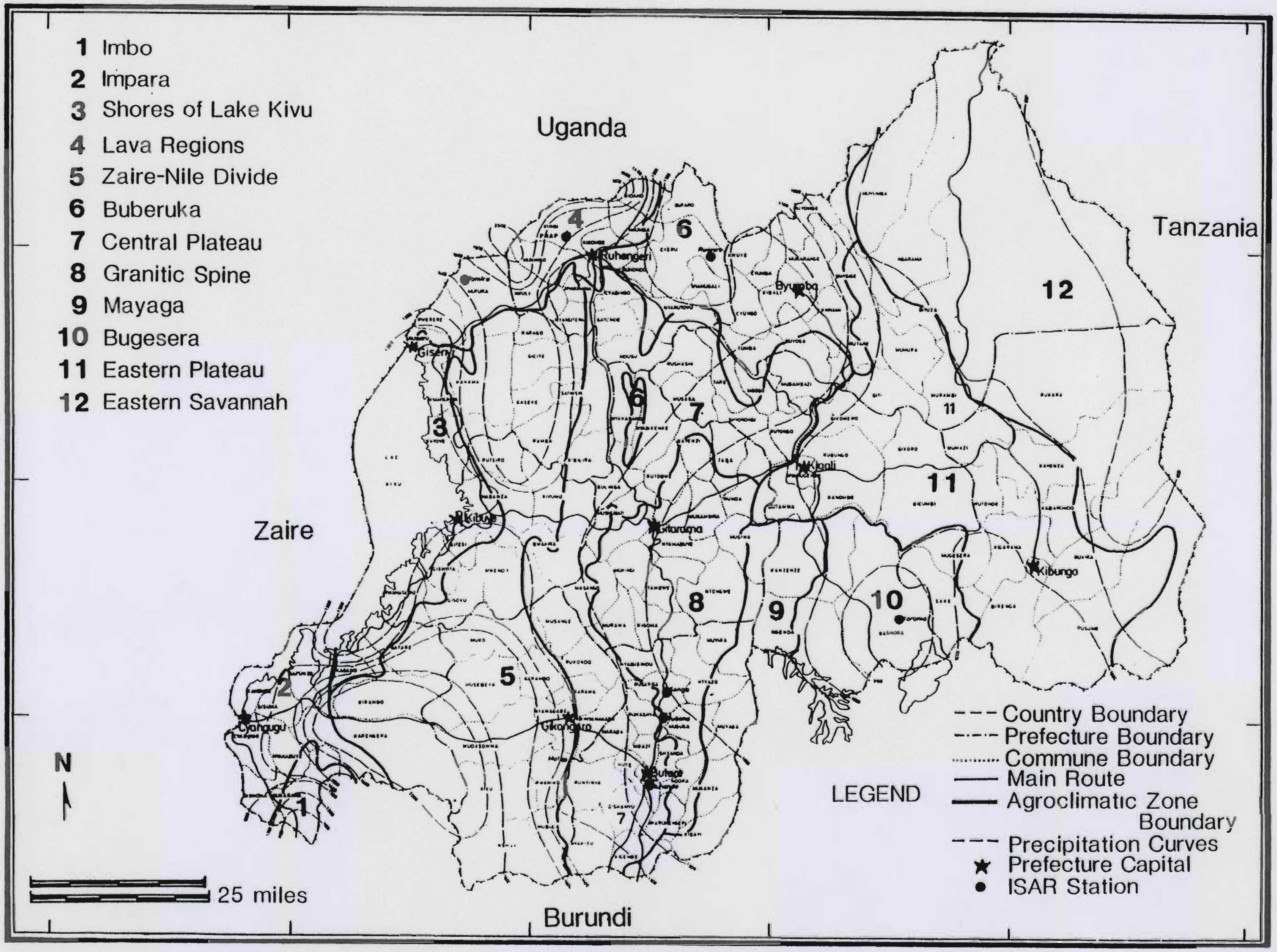


FIGURE 3. Map of the Agricultural Research Stations in Rwanda

Its three major objectives can be summarized as follows:

(1) promotion of production through the stabilization of prices of staple food products (beans, sorghum, etc.);

(2) reduction of storage losses caused by traditional methods through the improvement of storage techniques;

(3) equilibrium in time and in space of the availability of foodstuffs by insuring transfers from surplus to deficit regions.

In order to achieve these objectives, the Project, later named "National Grainery of Rwanda" (GRENARWA), established a network of storage facilities. It was endowed with the financial means (material and human) thanks to the contributions of the USA, the Rwandan Government, the Swiss Government and the World Food Program.

In January 1982, the GRENARWA Project was integrated into OPROVIA and has since constituted the Food Products Division of that organization. It continues to pursue, however, the same objectives as those that were established at the outset, but with an increased effort to extend its activities to foodstuffs other than beans and sorghum. In the course of its experience of seven years in the storage and marketing of beans and sorghum, the GRENARWA Project has encountered a number of problems which have significantly limited its effectiveness. Among these are the hardening and change of color of beans after a certain storage period, the lack of market outlets, and the lack of control of physical and biological parameters of storage. It is these problems which brought about the formulation of a second phase of the GRENARWA Project -- called GRENARWA II -- in order to support and improve the efforts of the new GRENARWA division within OPROVIA.

The GRENARWA II Project is governed by a new grant agreement between the USA and Rwanda which was signed June 7, 1982. The Project involves three primary activities, two of which are integrated into the GRENARWA Division and have become part of its daily activities. The third is a new and separate activity which is specifically intended to resolve the problems of bean and sorghum storage for GRENARWA in the near future.

These three activities are:

(1) improvement of the marketing capabilities of GRENARWA;

(2) improvement of accounting and management through the creation of an accounting department working effectively within the GRENARWA Division and;

(3) research on the conservation of beans and sorghum aimed at improving their storage and maintaining their commercial value. It is this research which, as a new activity within OPROVIA, has received the name of the GRENARWA II-Research Project.

The GRENARWA II Project is jointly financed by the Rwandan and American Governments. Its total cost is estimated at $4,750,000. The contribution of the Rwandan Government is approximately $1,850,000 while that of the USA amounts to $2,900,000. The research financed by the grant agreement signed June 7, 1982 between the Rwandan and American Governments was carried out under Contract No. AFR-0107-C-00-4001-00 of November 4, 1983 between the University of Minnesota and USAID. This research centered on activities arising from GRENARWA's experience and from the research component of the USAID-funded Local Crop Storage Project (LCS) which had been planned earlier but not yet conducted. An agreement was reached to transfer some funding from LCS to the GRENARWA II-Research Project to carry out the research desired by LCS.

3. General Objectives

The research under this Project was directed at resolving the problem of qualitative and quantitative losses of beans and sorghum during storage. Loss in quantity is the actual physical disappearance of dry matter (not moisture) of the product stored due primarily to biotic agents such as rodents, insects, and micro-organisms.

Quality factors can be quite complex, usually location or culture specific, changes which are often difficult to measure accurately or reliably. One aspect is overall visual appearance, reflecting the presence or absence of various kinds of visible damage compared to a standard of acceptability. In addition, bean quality is evaluated under this research according to the factors of sensory quality and cookability. In particular, the hard-to-cook factor in beans is a serious quality problem, and one accorded high priority by the Rwandan Government. The resolution of this problem is necessary to permit long-term storage and the establishment of a strategic food reserve. Germination capacity is an important factor in the evaluation of the quality of sorghum because the major part of the crop is used to make a local fermented beverage. Knowledge of the conditions and methods of storage currently used in Rwanda is also indispensable to the design of possible improvements.

The Project has these principal objectives:

(1) determine the extent of losses due to storage at different levels in the post-harvest system (individual, regional, and national level) as well as the relative importance of the factors which cause these losses;

(2) develop, test and demonstrate appropriate technologies at these different levels in order to reduce losses and increase the availability of beans and sorghum through the improvement of storage conditions in safe and economically acceptable ways, especially for storage periods exceeding 6 to 8 months;

(3) reduce the amount of caloric energy consumed in the cooking of hard beans by reducing the cooking time;

(4) alleviate the constraints on storage time which hinder the activities of OPROVIA/GRENARWA;

(5) facilitate the application of national marketing policies by improving the information base and taking into consideration among other factors: the quality and type of product, the distribution of crop varieties throughout the country, the preferences of consumers and producers as well as the flow of commodities within the production system;

(6) facilitate the establishment and management of the Emergency Food Reserve (strategic or security stock) planned by the government;

(7) develop an extension program and materials for disseminating research results.

The studies planned in this research program and presented in the following section were designed on the assumption that the major factors affecting storability of these two commodities (beans and sorghum) in Rwanda are:

(1) storage methods and structures;

(2) condition of the commodity going into storage, in particular moisture content, infestation by insects and molds, damaged grain as well as the presence of foreign matter;

(3) ambient air conditions, especially the levels and fluctuations of temperature and relative humidity prevailing during storage;

(4) length of storage;

(5) differences among the multitude of bean varieties grown in Rwanda, in particular the relative susceptibility or resistance of different bean varieties to attack by storage insects, as well as the relative sensory quality and cookability of these same varieties.

4. Research Program

The research conducted in the Project has been divided into seven different but interdependent components as described below:

A. Survey of the methods and conditions of grain storage in Rwanda. The objective is to inventory the methods and conditions of storage of cereals and grain legumes (especially sorghum and beans) at different storage levels, to evaluate losses and identify the important factors causing losses.

B. Inventory of bean varieties grown in Rwanda. The objective is to conduct a survey of the bean varieties grown in Rwanda, the system of regional distribution and the preferences of producer/consumers in order to facilitate the marketing of beans in Rwanda.

C. Study of the sensory qualities and cookability of beans in Rwanda. The objective is to study the effect of different storage conditions on hardening of beans as well as consumer preferences, and to study the possibilities of alternative conservation methods to avoid or minimize the problem of bean hardness.

D. Study of the differential resistance of bean varieties grown in Rwanda to storage insects. The purpose is to verify the differential resistance to bruchids of bean varieties found in the bean variety survey and to develop an on-going screening program of resistant bean varieties.

E. Study of alternative grain storage methods in Rwanda. The objective is to develop and test potential improvements in storage structures and management techniques in order to reduce the losses incurred during storage.

F. Development of a system of quality standards and norms for beans and sorghum in Rwanda. The objective is to develop a system of quality standards and testing procedures adapted to the specific conditions of Rwanda with the aim of improving both the storage and the marketing of these two commodities.

G. Development of a system for extending research results. The aim is to ensure the application and practical use of results obtained in the research program.

In addition, the GRENARWA II-Research Project has a certain number of more general and long-term objectives, namely:

(1) development of a department of applied research on post-harvest technology at OPROVIA in order to ensure the continuity of research and the application of results obtained after the conclusion of the Project.

(2) establishment of a complete laboratory at OPROVIA for testing, analyzing and controlling the physical and sensory quality of stored grain and other food products.

5. Organization of the Project

As shown in the Project's organizational chart (see Appendix VIII.2), the Project operates under the tutelage of the Ministry of Agriculture, Animal Husbandry and Forests (MINAGRI). OPROVIA, USAID and the University of Minnesota coordinate the Project in execution of the agreements signed between the Rwandan and American Governments. Through February 1987, the daily coordination of the different components of the research program was jointly managed by the project manager (University of Minnesota) and his Rwandan counterpart.

Research within each component has been supervised jointly by a research assistant from the University of Minnesota residing in Rwanda and a Rwandan counterpart in collaboration with one or several Rwandan Government agencies most closely involved with the component, and with the technical support of one or several experienced faculty advisors (Professors) of the University of Minnesota.

II. SUMMARY OF MAJOR RESEARCH FINDINGS AND RECOMMENDATIONS BY COMPONENT

1. Survey of the Methods and Conditions of Grain Storage in Rwanda

1.1. Objectives

1. Inventory the conditions and methods of storage of beans and sorghum at three levels, namely: producer, cooperative/communal, and national (OPROVIA) warehouses. For each level, the relationship between storage conditions and different agro-climatic regions based on altitude (low, middle, and high) will be assessed.

2. Evaluate losses resulting from the various methods and conditions during storage as well as the quality of the structures used at the different levels.

3. Identify the major factors which cause the losses observed.

4. Evaluate the quantities stored and the programs for managing and utilizing the commodities stored.

5. Conduct a survey to ascertain the presence or absence in maize stocks of the insect *Prostephanus truncatus*.

6. Formulate guidelines for research to be conducted by the component "Study of Alternative Storage Methods in Rwanda".

1.2. Research Findings

Forty-seven farms, 21 cooperatives and 3 OPROVIA warehouses were selected and intensively monitored for changes in stored bean and sorghum quality during a period of 12 to 18 months. In addition, maize was sampled in 77 storages, representing all levels from farm to OPROVIA warehouses located in 9 prefectures and 2 border towns of Zaire. Bean stocks monitored were from June 1984 and January 1985 harvests; sorghum from 1984 harvest and maize from 1985 and 1986 harvests. For the survey, a standard sampling plan and laboratory analysis were developed. The latter included the development of a 10-category damage analysis, a volumetric dry weight loss determination, and a consumer loss determination.

1.2.1. Farmer Level Storage Structures and Management Patterns

We found the following important features of farm-level storage:

1. Uncovered baskets were the predominant storage container, constituting two-thirds of those observed. In general, these were woven reed structures lined with cow dung and elevated by stones, straw or a platform. Few exterior granaries were used. A small number of sacks, earthen pots, barrels and gourds were found but of minor importance. A disposable container (imboho) made on-farm with grass and banana sheathes and leaves was found in use in one region of Kibungo.

2. All storage structures of the 50 farmers surveyed were located inside houses, almost 50% of which had metal roofs, most without ceilings. Most building materials for floor and walls were earth. Over 60% of the homes had a separate room of the house for storage. Some used the cooking area for storage. Because storage was inside the house, the environment created by its design and construction materials influences storability.

3. Three-quarters of the farms treated their beans against insects. One-half used synthetic insecticides, the rest used ashes, kaolin (a local clay soil), laterite, powdered hot peppers and/or various local plants. Fewer farmers treated their sorghum stocks.

4. Post-harvest processing (handling) of beans involved a mean of 3 persons (generally one male and 2 females) for 3 work days. Threshing involved 1.6 persons, mainly male, for 1.7 days. On average, winnowing and sorting involved 1.4 persons, primarily women, for 1.8 days.

5. Post-harvest processing of sorghum involved approximately 11 days drying, equally divided between field and farmyard. Harvest required about 4 days; threshing less than one day; and winnowing plus sorting 2.5 days on average.

6. The mean quantity of beans harvested per household was 190 kg. Two months after harvest, the households surveyed had a mean of 83 kg. each in storage. The mean quantity of sorghum harvested per household was 202 kg. Two months after harvest, households stored a mean of 99 kg. each.

1.2.2. Cooperative Level Storage Structures and Management Patterns

In Rwanda, there exist two principal types of storage at the cooperative level: (1) silos (storage in enclosed bulk) and, (2) hangars (storage in sacks, though sometimes in open bulk).

For silos, the survey revealed the following:

1. In practice, these structures are not hermetic (air-tight) as intended.

2. Silo construction does, however, allow fumigation with phosphine gas, but the methods of application as well as their efficacy are quite variable and can be dangerous to personnel.

3. Damage due to fungi either because of the transfer of moisture through floors and walls or because of high grain moisture content is a problem, especially since there is no ventilation in the structure.

4. Little or no monitoring for quality occurs once the grain is stored because these silos were not designed for easy sampling, and because managers are neither trained nor equipped to conduct such monitoring. In short, grain is placed in the compartments of the silo and later, usually at the time of sale, one discovers the results which are sometimes disastrous and always a surprise.

For hangars, the following observations were recorded:

1. Risks of mold are much less than in the silos except when grain is stored in a pile directly on the floor (a practice due to lack of sacks and/or pallets).

2. Insect control is more difficult than in silos. Fumigation and insecticidal dusts are used very little.

3. Damage due to rodents is more serious than in silos because less natural protection against rodents exists in hangers.

1.2.3. Government Warehouse (OPROVIA) Storage Structures and Management Patterns

At this level, storage occurs in large warehouses in which grain is stored in sacks piled on wooden pallets. These piles are very large, often consisting of several hundred tons. The main features of this system are as follows:

1. Grain reception procedures currently require considerable time and space.

2. Monitoring of grain quality and storage conditions is minimal. No remote monitoring for temperature is used in Rwandan storages except for the experimental stacks used by the research team. Sampling is also not practiced routinely, and thorough sampling of large stacks of bags is difficult.

3. Heat is generated and accumulated at the peaks of the piles as a result of metal roofing and ineffective passive ventilation.

4. Insecticides (Actellic and Phostoxin) are in general correctly applied. There is, however, a rather strong dependence on the prophylactic use of only these two chemical insecticides for insect management, which can easily lead to resistant insect populations. Eventually, these insecticides may lose their effectiveness. This constitutes one of the most serious problems in OPROVIA warehouses.

5. The principles of sound management of stored grain are well known and understood by upper-level management in OPROVIA, but are not applied uniformly by warehouse managers and staff.

1.2.4. General Research Findings

1. The Project needed a standardized method of loss measurement for the Storage Survey Component as well as for the Quality Standards and Alternative Methods Components. The first method used defined loss as that dry matter portion of a product or commodity which has physically disappeared and is not available to be consumed. Losses were measured in the laboratory using a standardized volumetric analysis technique on grain samples taken at regular intervals from the stocks being monitored.

   Consumers indicated in interviews, however, that they completely discard beans which are not considered edible. Beans considered inedible included those with visible mold, rodent or insect damage, and germinated as well as severely shriveled beans. Beans considered unplantable included the above plus most of the broken beans as well as severely discolored beans. Dented or slightly shriveled or discolored beans, as well as those with a torn or wrinkled seedcoat, were considered acceptable by most consumers tested.

A second loss assessment method (no eat/no plant) was thus developed for beans based on severity of damage: beans were categorized as "too damaged to plant" or "too damaged to eat". Great care must be exercised when comparing the loss figures gathered in this study with those in other projects and other countries. Loss figures cannot be compared unless the method for determining them is the same, i.e., dry weight loss can only be compared with dry weight loss, perceived consumer loss for eating with perceived consumer loss for eating.

2. Storage losses of beans and sorghum found during the Project's survey at the farm, cooperative, and OPROVIA levels are summarized below. Because of the relatively small sample size imposed by staff and budget restrictions, and because of the somewhat atypical environmental conditions occurring during the sampling period, the results should not be considered conclusive. They require verification through additional surveys. All evidence suggests, however, that these data accurately reflect the proper order of magnitude and are thus useful from a policy and programmatic standpoint. By elucidating some of the complex methodological problems associated with loss assessment, the survey was also of great benefit for future postharvest studies in Rwanda.

(a) Weight loss measured in farm storage was less than 4% for beans and 3% for sorghum. These values are much lower than the 25% to 30% quoted by the FAO and others for Africa. The small quantity stored (100 kgs per farm) and short storage period (3-4 months) minimize the development of most causes of weight loss (e.g., insects and fungi). Losses did vary significantly between producers, however, as well as between regions and seasons. Certain farmers encounter storage problems and could benefit from assistance.

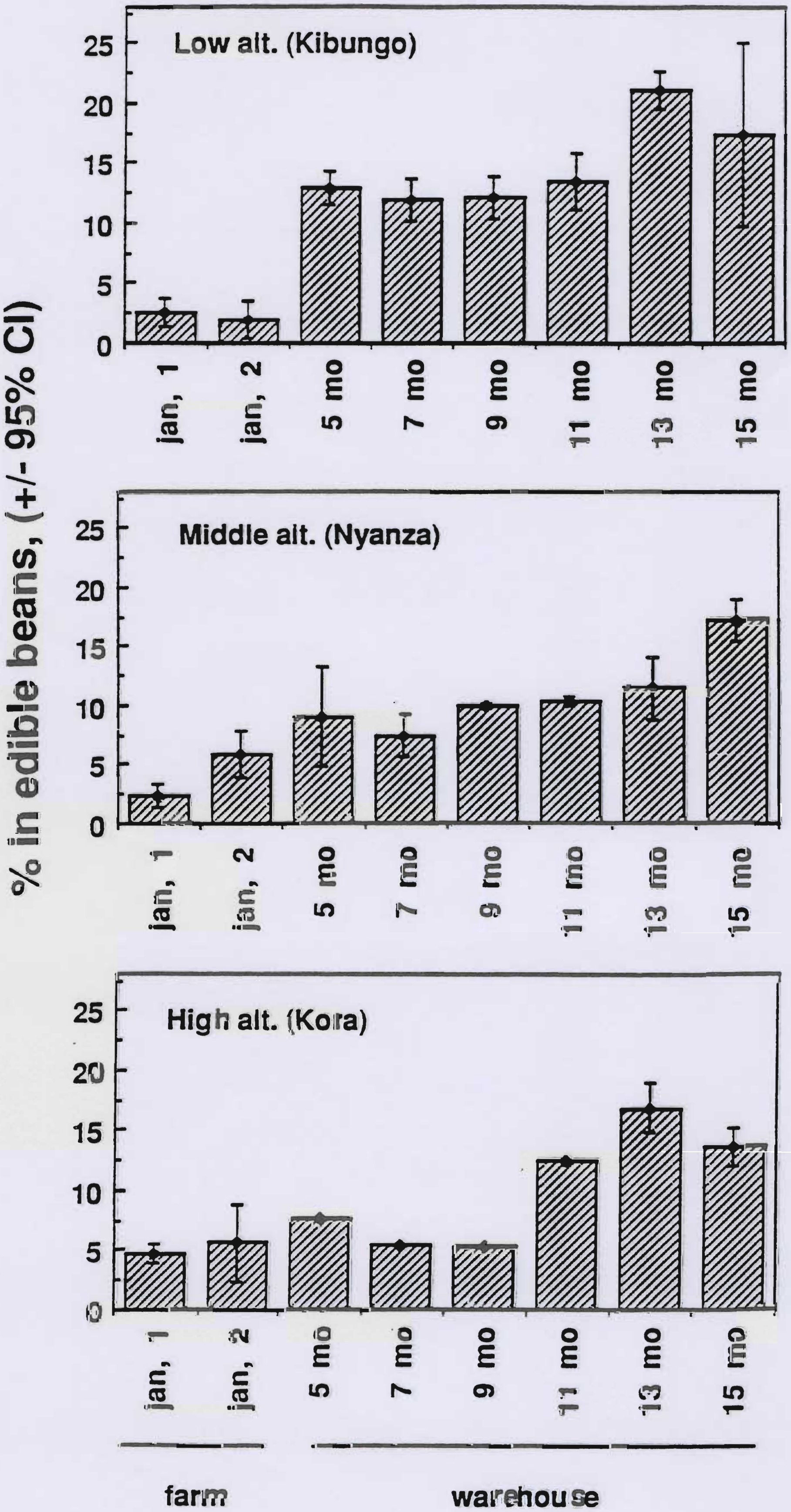
Weight loss of beans and sorghum in cooperatives from the beginning of storage (ca. 2 months after harvest) until the end (5 months after harvest) averaged 1% or less. However, a few storages showed higher amounts that warranted attention.

No measurable weight loss occurred in beans stored at OPROVIA warehouses between 5 and 13 months after harvest. For this same period, weight loss in sorghum at OPROVIA warehouses was 0.1% to 1.4%, with the higher weight loss at lower altitudes correlating with higher insect numbers.

(b) Losses were found to be higher when evaluated by using the consumer loss method described above. Of the beans sampled on-farm 3 months after harvest, 2 to 6% appeared to be unacceptable for eating (Figure 4). At cooperatives 5 months after harvest this value was 10 to 15%. Mean values of percent unacceptable for eating ranged from 8 to 13% when beans entered the warehouse (5 months after harvest), and ranged from 14 to 17% at 15 months after harvest following warehouse storage. The variability of these estimates is high, however, reflecting the variability of the beans sampled. It is difficult to say with certainty that there was a significant rise in this figure over the 10-month storage period in the warehouses (Figure 4).

3. One of the major causes of dry weight loss and perceived consumer loss is storage insects. High insect levels do occur in Rwanda, a fact reflected in the levels of insect damage. If insect populations develop that are resistant to the two primary insecticides currently used in cooperatives and at OPROVIA, serious losses could be produced in their stocks. Much information is available about the biology, management, and control of these insects. It is

Figure 4. Evolution over time of changes in consumer acceptability of beans (Phaseolus vulgaris) stored initially on farms and subsequently in OPROVIA warehouses in three different agro-climatic regions



important to note that, with the exception of Zabrotes, infestation can commence in the field prior to harvest and storage for the major species found. Fungi (molds) and rodents also cause losses in Rwanda stocks but are generally of lesser importance.

4. The main insect species found in beans was the bean bruchid Acanthoscelides obtectus Say. Although not appearing in any sampled material, Zabrotes subfasciatus Boheman was found locally abundant in warm regions of the country (e.g., Bugesera). Because these insects can occur in apparently clean beans and, in the case of Acanthoscelides even prior to harvesting, these species are called "hidden infestors". The weevils, Sitophilus spp., also hidden infestors, and the indian meal moth, Plodia interpunctella Huebner, were found in very small numbers in beans on farms, in cooperatives and at government warehouses (OPROVIA). Plodia is not at all hidden; its larvae often move from seed to seed consuming just the germ portion. It also produces webbing which causes grains/seeds to stick together and to adhere insects to seeds in transfer processes.

   On farms in low altitudes (June, 1984 harvest), the mean number of live and dead Acanthoscelides per kg. of beans rose from 25 to 131 during 0 to 3 months storage after harvest. In high altitude cooperatives this value rose from 8 to 63 during 2 to 5 months after harvest. At the Kibungo (low altitude) warehouse, this value (mean of 51) did not significantly change during the storage period 5 to 13 months following harvest, thus indicating no insect development.

5. For sorghum the main insect species found was the rice weevil, Sitophilus oryzae. Because S. oryzae is often difficult to distinguish from the maize weevil Sitophilus zeamais Motchlusky and is at times included in the same genus, we report these as Sitophilus spp. The lesser grain borer, Rhyzopertha dominica (also a hidden infestor that can enter grain prior to harvest) and P. interpunctella were found much less frequently.

   On farms only Sitophilus spp. was found and their levels rose from 0.8/kg. to 15/kg. during 0 to 3 months post-harvest. At coops 2 to 5 months after harvest, there was no significant change in levels of Sitophilus spp. (mean of 8/kg.) during storage. In set aside stacks treated with Actellic and Phostoxin in OPROVIA warehouses, (12 to 130/kg) and R. dominica (1 to 33/kg) during storage (5 to 13 months after harvest). This suggests that for some reason the treatments were less effective. Possible explanations for this could be application problems or a developing resistance in these species.

6. Although the growth of all storage fungi causes dry weight loss in grain and beans, the most important storage fungi are those which produce substances (mycotoxins) toxic to humans and domestic animals. Incidence of the fungus Aspergillus flavus, which can produce aflatoxins that are severely toxic to humans, was very low. On-farm, only 0.4% of the beans were infected with this fungus. The incidence was low (2.2% maximum) in beans and sorghum at all other levels and altitudes. Penicillium spp., which can also produce mycotoxins, generally had mean incidence levels of less than 5% in sorghum and beans.

   Of the 17 species of fungi found, Aspergillus glaucus had the highest incidence, increasing in beans from 1.3% (on-farm at start) to 58% (5 month post-harvest, at the time beans were entering warehouses). It was also common in sorghum, with incidence rates increasing from 10 to 53% one year after harvest. This species is not known to be harmful to vertebrates.

Fungi are prevalent in stored beans and sorghum in Rwanda, but according to damage analysis of samples, few beans showed visible mold. High incidence of fungi can be an important problem in certain situations, but the largest problem is that aflatoxins can occur at fungal levels that are not visible and are not detected by consumers or managers.

7. Laboratory analyses of grain samples indicated that losses due to rodents were generally quite low. Losses from rodents are difficult to determine with precision, however, because often entire seeds are consumed. Producers in certain regions consider them to be a major problem. Rodents were observed by research staff to be more of a problem in hangars and warehouses than in silos.

8. Maize production is increasing in Rwanda while a major maize storage insect problem has been developing in eastern and central Africa. The larger grain borer, *Prostephanus truncatus* Horn, became a national storage emergency after it arrived in Tanzania (ca 1970), since it had no natural parasites and predators, and probably was preadapted to the environment and management patterns there. Since 1983, reports show that it has spread to Kenya and to Rwanda's neighboring countries, Uganda and Burundi.

   No *Prostephanus* were found in maize, bean or sorghum surveys conducted by the Project in Rwanda. Surveys in maize included traps baited with the *Prostephanus* pheromone (Truncall). The insect's arrival or increase to detectable levels is probably imminent due to the lack of inspection for insects or damage at any borders, the practice of drying maize outside on the cob, and the proximity of most major maize producing areas of Rwanda to the border of countries already harboring this species. Other factors such as the use of much maize as a fresh vegetable (roasting ears), and not as grain, should deter the entry and/or spread of *Prostephanus* in Rwanda.

   Sitophilus spp. were the most frequently encountered maize storage insects. The lesser grain borer *R. dominica* was second in importance. The bamboo borer, *Dinoderus minutus* F. (Bostrichidae), was found to cause damage indistinguishable from *Prostephanus* in various locations including government seed multiplication units. However, its evolutionary center of origin is Africa, which means that natural mechanisms probably exist for curbing this borer's population explosions. Indeed, one-third of all insects encountered in the maize survey were parasites or predators of storage insects.

   Highest levels of non-beneficial maize insects per sample were found in project or school centers and cooperatives. Merchants with small warehouses and the OPROVIA warehouse receiving maize as food aid also had high levels of destructive insects. Farms and open-market merchants had younger maize and no serious insect infestation.

1.3. Recommendations

1. Based on the results of the storage survey and grain analyses, the following suggestions were made for research by other components of the Project:

   (a) Evaluate the factors that influence storage, particularly air temperature and relative humidity adjacent to the stored material.

(b) Study the efficacy of the different recipients of traditional on-farm storage (such as long baskets, round baskets, clay pots, gourds, sacks, and the imboho) as well as certain new containers (metal drums, plastic drums, plastic pails, and others).

(c) Develop and test instruments and techniques for inspecting and regular monitoring of stocks of GRENARWA and especially cooperative silos in order to detect possible problems (such as insects, fungi, hardness, germination) in a timely manner. It is necessary to resolve the problems of sampling large piles of bags in the GRENARWA warehouses.

(d) Assess the effectiveness of underground (hermetic) storage in controlling insects without chemical treatment and in maintaining the sensory qualities and cookability of beans.

(e) Examine the problem of migration, transfer and accumulation of moisture in cooperative silos.

(f) Evaluate the efficacy of natural products (various plants, ash, kaolin, laterite, etc.) used by producers to control storage insects.

2. Laboratory scientists and technicians should be trained in the concepts and techniques of detection of insect populations that are resistant to insecticides. The goal would be to develop a team of Rwandans that could write the protocols for performing these tests, run the bioassays and interpret the data using simple statistical methods. This team would then advise OPROVIA and other storage units on integrated chemical control as well as develop extension programs and materials to explain the problem of insect resistance.

3. The system of determining loss and damage should be clarified and refined. Specifically a series of line slides or photos and notecards should be developed which define visually and verbally the severity within each bean or grain damage category. These definitions should also be made for non-edible, non-plantable categories.

4. The causes of shriveled, dented, wrinkled and discolored beans and their relation to the cookability and sensory acceptability of beans should be determined. For example, it would be useful to know what proportion of severely shriveled beans in a mixture make the mixture considered hard-to-cook and at what level a decline in product quality is perceived by consumers.

5. The incidence of the Aspergillus flavus/Aspergillus parisiticus group in particular should be surveyed in maize, peanuts, cassava, and possibly other crops and processed foods. Samples of this species group should be tested for mycotoxin production. After an initial survey, these crops, including beans and sorghum surveyed in Phase I, should be monitored seasonally (once per crop per season) for these fungi and their mycotoxins. The mycology section of the Laboratory should be strengthened and a new section for the study of mycotoxins should be added to the existing facility.

6. Efforts should be undertaken to determine if resistant populations of storage insects are developing. An evaluation of present methods of applying synthetic insecticides should be conducted.

7. Applied research on the effectiveness of local insecticidal materials, rotation of insecticides, and new (backup) materials is urgently needed and should be initiated without delay. Because control of insects during storage is a major problem which requires the use of fumigants and insecticides under certain conditions, the use of these materials should be carefully managed. Applications should be made at proper rates and only when necessary. A variety of insecticidal materials (both natural and synthetic) should be available for rotation in an integrated management plan in order to reduce the potential for development of resistant strains of insects. In particular, insecticidal plants and other preparations presently used by Rwandan farmers should be evaluated for their toxicologic and behavioral properties. Other natural insecticides such as neem extracts should also be tested. Commercial insecticides not presently used in Rwanda should be evaluated for their cost and effectiveness.

8. To minimize dependence on insecticides, physical control methods such as low temperatures and underground storage should be further tested for their applicability to Rwandan conditions. In addition, parasite and predator relationships should be explored for their actual and potential role in managing storage insect populations.

9. Research should be continued to determine the levels of damage that constitute an economic loss. These data should then be used to determine the appropriate time to make insecticide applications.

10. Studies should be carried out to determine the percent of beans infested with Acanthoscelides in the field before harvest. The extent of exchange of genetic material between field and storage populations of this insect should also be ascertained. Because insecticides for controlling bean bruchids are applied during storage, insects with genotypes resistant to the insecticides will first develop in storage. Since Actellic is used routinely (prophylactically) in OPROVIA warehouses, resistant populations are most likely to develop there first, and this resistance may be transferred to the field populations by exchange of genetic material.

11. Extension programs should be developed for all storage levels on the correct use of insect management techniques such as rotation of insecticides, proper dosage, hygiene and modifications to the storage environment.

12. Laboratory scientists and technicians should be trained in the concepts and techniques of assessing rodent populations and quantifying rodent damage. Following training, a survey should be undertaken of rodent damage and activity within warehouses and other storage areas. Information should be collected on existing rodent control and rodent exclusion methods.

13. Because of the growing threat of Prostephanus truncatus, a modest surveillance program should be continued for this insect, including routine border inspections and monitoring of food aid shipments of maize. An extension program should also be developed to inform people about this insect. In particular, contacts should be maintained with neighboring countries so as to be kept informed of effective control and containment techniques. Names and location of authorities who can confirm identification of this species should be compiled. Because of its potential ability to cause loss, the presence of another typical quarantine insect, the khapra beetle (Trogoderma granarium Everts), should be monitored especially in warmer regions of Rwanda.

2. Inventory of Bean Varieties Grown in Rwanda

2.1. Objectives

1. Inventory the varieties (seed types) of beans produced in Rwanda.

2. Determine the regional distribution of bean varieties and varietal preferences of producer/consumers.

3. Prepare a reference collection and a catalogue containing photographs and detailed descriptions of the seed types collected.

2.2. Research Findings

During the course of the survey conducted in approximately one-half of the communes in Rwanda during 1984, nearly 600 samples of bean mixtures were collected on approximately 500 farms. At the same time, 180 samples were taken in 39 markets and from deliveries by producers to three warehouses of OPROVIA. Laboratory analysis followed by observations from seed increase plots at ISAR allowed the detailed description and differentiation of varieties contained in the samples collected. Responses from farmers during interviews conducted with a standard questionnaire provided information on production practices, names of seed types, and the bases for varietal preferences of producer/consumers.

Two reference collections of seed of these varieties were established: one at ISAR, the other at OPROVIA. They constitute a source of valuable information about bean varieties and can assist in the identification of bean mixtures. As an important source of germplasm, seed of these varieties has already been used in the national bean improvement program in Rwanda. In addition, certain varieties of this collection have been utilized by the Project to test their cookability and their resistance to storage insects.

Responses from producers and analyses of the mixtures collected show that:

1. The mixtures contained an average of 11 different bean types, but with a large range (1 to 27). An unexpectedly large number of distinct varieties (284) were identified in the mixtures collected.

2. Despite the predominance of mixtures in Rwanda, 12% of the samples consisted of one single bean type. Moreover, 31% of producers plant "pure" varieties to some extent, though not exclusively, on their farms. It was suggested that a small plot of a pure type may allow the farmer to test the variety before its incorporation into the mixture(s). However, fields of a single variety may give high yields but lack the "risk avoidance" of a mixture and therefore are planted on a limited basis only.

3. Among all the varieties found, only 15 were well distributed. The rest were limited in their distribution or present to a small extent throughout the country. Frequency of occurrence as well as relative proportion within individual mixtures are both necessary measures for determining the overall importance of a variety.

4. Thirty-six types were found in at least 10% of the samples. The range in color, color pattern, shape and size of these 36 types was quite wide, although nearly two-thirds were monochrome (one color). A small red, often called "Karolina", ranked at the top with a frequency of 39%. The second most common was a large "zebra" type (cream colored with black stripes) called "Kanyamanza". A large purple-seeded type with seven common names occupied third place. Four black-seeded types ranked in the top 20 despite their undesirable characteristic of causing cooking water to darken.

5. A problem of nomenclature exists because several names in Kinyarwanda are sometimes used for the same variety (e.g., Magaberi, Cyansoroso, and Mulisi in addition to Karolina for a small red variety), and sometimes a single name is used for several different varieties (Mutiki is one of the names used for 5 varieties among the 36 most important).

6. Fifty percent of the surveyed farmers sell a part of their production. Half of these sell up to 20% of their production while 5% sell more than 50% of their production.

7. More than half of the producers (56%) plant different mixtures for different field and cropping conditions (e.g., banana groves, poor soils, swampy areas). However, separate storage of these mixtures was practiced only on one-quarter of these farms. In most cases, the various seed mixtures are separated from bean stocks only at planting time, not prior to storage.

8. Climatic hazards, often expressed in terms of drought or excess rainfall, were considered by producers as the most important factor limiting yield.

9. Because of variations in elevation, temperature, and rainfall, beans are planted or harvested almost every month of the year in some area of the country. The greatest uniformity occurs with the planting time (September) for the first and most important season. First season harvesting and second season planting are subsequently delayed at the high altitudes because of cooler temperatures.

10. The vast majority (78%) of farmers produced their own seed for the following season. A large proportion of farmers (nearly 40%) do not separate beans to eat from beans for planting. Of those who do, practically all make this separation following harvest and prior to storage.

11. High yield and tolerance to low fertility soils and plant diseases were more associated with small rather than large seed types. Good taste, fast cooking time, and high market price seem to be related characteristics and were all highly associated with large seed size.

2.3. Recommendations

1. A varietal survey should be conducted in the remaining 76 communes of the country using methodologies similar to those used in the first survey. The purpose would be to collect information on important bean types and production practices which may have been missed in the initial survey which focused on intensive production areas. At the same time, the strategies

used by producers to guarantee an adequate supply of high quality seed of preferred varieties should be determined more precisely. Future surveys should be planned on a regular, recurring basis to ascertain changes in varietal use and management techniques.

2. A uniform system should be developed in Kinyarwanda for naming and describing the most important bean types (varieties) in Rwanda. Coupled with a standardized terminology for describing relevant quality characteristics, this should assist the grain and seed trade by improving information and communication about beans.

3. Information from the varietal collection and the survey should be used to improve the adaptability and acceptability of new varieties developed in the national bean breeding program. Storability and cookability should be incorporated into the selection criteria for the breeding and development of new bean varieties.

4. The methodologies developed by this component should be utilized in future bean research and extension activities.

3. Study of the Sensory Qualities and Cookability of Beans in Rwanda

3.1. Objectives

1. Study the effects of different storage conditions (e.g., moisture content, temperature, relative humidity, duration of storage) on cookability of beans as well as sensory preferences of consumers.

2. Study the possibilities of alternative preservation methods in order to avoid or minimize the problem of bean hardness.

To accomplish these objectives, the following nine experiments were designed and conducted:

(1) Development of standard laboratory sensory and cookability tests.

(2) Moisture meter (Motomco) calibration.

(3) Moisture sorption isotherms of Rwandan bean mixtures and individual varieties.

(4) Large-scale, long-term study of beans stored in plastic sacks.

(5) Laboratory studies of beans stored under different conditions.

(6) Alternative preservation of green beans and dry beans in Rwanda.

(7) Influence of drying on cookability, color, viability and germinability of Rwandan beans.

(8) Thin layer drying of Rwandan beans.

(9) Study of the sensory qualities and hardness of certain bean varieties after lab storage.

3.2. Research Findings

1. One of the major contributions of this component was to develop procedures and calibrated equipment for use with mixtures of dry bean seed types and varieties. Previous published studies have not described standardized procedures for mixtures.

   Standardized procedures for cooking beans and instrumentally measuring their hardness were developed. Sensory test procedures and test sites were established. Sensory testing of bean preferences included questions on subjects' willingness to eat the beans, the degree to which they liked the beans, and their perception of the current market value of those beans.

   Moisture meter calibration curves were developed for both pure Rwandan bean varieties and typical mixtures. Moisture sorption isotherms (desorption and absorption) were also obtained for both mixtures and pure varieties. These isotherms can now be used to predict the moisture content of stored beans when storage temperature and relative humidity are known and constant over time.

2. Hardening of beans during storage is central to the ongoing research and a major concern of the Rwandan Government. In order to determine the conditions which favor the development of hard-to-cook beans, this phenomenon was studied through a number of experiments, both in the laboratory and in warehouses. Laboratory studies showed that the storage moisture content of beans, storage temperature, storage relative humidity, and time all have an effect. Specifically:

(a) At 4°C (conditions of refrigeration), no change whatever was detected in hardness or color for 24 months of storage regardless of moisture content.

(b) At 23°C (typical ambient conditions in Rwanda between 1400m and 1900m altitudes), the storage moisture content greatly influenced the development of the hard-to-cook (htc) defect. For example, at 10% moisture content (mc), very little change in hardness occurred up to 24 months, and beans remained acceptable. At 12% mc, beans remained very acceptable for the first 16 months (24% htc), and were fairly acceptable even up to 24 months (40% htc). At 15% mc, they were fairly acceptable for the first 16 months, followed by a rather dramatic increase in hardness (80% htc at 20 months).

(c) At 30°C, the pattern was similar to that at 23°C, except that the beans become harder more rapidly.

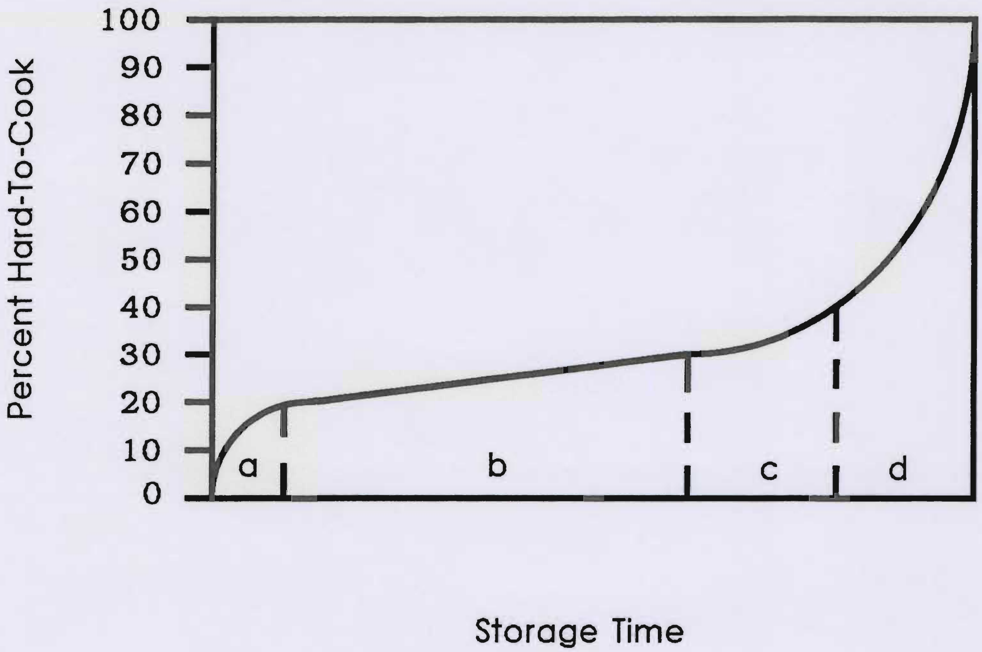
These data are confirmed by results of tests on bean piles of 15 and 30 tons which were followed during a 2-year period in the warehouses at Kibungo, Nyanza and Kora. The beans at Nyanza and Kora maintained cookability levels within acceptable limits for 18 months, and at Kibungo for 24 months. It should be noted that these beans were harvested during June-July and that moisture contents were low from the beginning (between 11 and 13%).

3. Only very newly harvested beans were as low as 0 - 1% htc. The percent htc rose rapidly after harvest to values between 20 and 30% (Figure 5). Eventually there was a rise in htc to 40% and then a steep rise after 40%. When a bean stock reaches 40% htc, it should be sold for processing or consumption.

4. The temperature at which beans are dried apparently did not influence hardness although the final moisture content of beans after drying did. Drying temperature, however, did affect other properties of the bean, such as integrity of the seedcoat. Above 40°C, drying temperatures promoted seed coat cracking which could lead to other quality problems, such as mold and insect invasion, and broken kernels.

5. Sensory preferences for the different varieties varied somewhat by region. These preferences may have been related to subjects' familiarity with the beans since people living in regions where large seeded varieties are commonly grown appeared to prefer the large seeded varieties, while people living in regions where small seeded varieties are commonly grown appeared to prefer the small seeded varieties. The small black variety, Ikinimba, may have been least liked because of its undesirable dark color. The anthocyanin pigments leach out of such dark colored beans during cooking and discolor other vegetables cooked together with the beans.

Figure 5. Generalized, hypothetical curve of post-harvest changes over time in the percentage of hard-to-cook (HTC) beans (*Phaseolus vulgaris*) based on interpretation of data collected in Rwanda by the GRENARWA II Research Project (1984-88).



a. Initial post-harvest period when beans are relatively cookable

b. Lag period when 20-30% of a given lot of beans is hard-to-cook (>450 g force as measured by Chatillon tester after 3 hour cook at 95° C. of non-presoaked dry beans). Length of this period depends on various factors, both inherent (e.g., variety, seed morphology) and environmental (e.g.,storage temperature, storage relative humidity, bean moisture content).

c. Transition period occurring from end of lag period (30% HTC) to threshold (40% HTC) of unacceptably high proportion of hard-to-cook beans.

d. "Hard Bean" period when a given lot of beans has developed an unacceptably high proportion of hard-to-cook beans (>40% HTC).

Preferences did not depend on cookability and did not decrease during the 12 months of storage. Varieties differed in cookability. Some varieties appear to be less susceptible to changes in cookability during storage than others.

6. A change in color (browning or darkening which develops over time) roughly parallels the development of hardness. However, the change in color may proceed more rapidly than hardening.

7. Soaking beans for 6 to 12 hours in salt solution (e.g., sodium bicarbonate and sel de pierre (rock salt)) reduced cooking time considerably. In Rwanda, rock salt (composed mainly of NaCl with a pH of 9.0 in aqueous solutions at concentrations normally used) is often added to the cooking water if beans are suspected to be hard. Generally Rwandans do not soak beans because it purportedly gives them a diminished flavor. In our acceptability tests, cooked, soaked beans were preferred to unsoaked controls. Although these results are contrary to current practice in Rwanda, they are significant because soaking might reduce cooking fuel consumption by 50% or more. Soaking in alkaline solutions such as sodium bicarbonate could, by increasing the pH, partially offset the loss of nutrients (e.g., thiamine and ascorbic acid).

8. Beans were pressure-cooked to an acceptable state of softness in only sixty to seventy minutes, regardless of whether they were old or freshly harvested. Therefore, this is a good technique for reducing cooking times and fuel consumption. Normal atmospheric cooking time is two to three hours, even for newly harvested beans; beans that had been stored for 5 years required 10 hours of atmospheric boiling to soften them to an acceptable level.

9. Several means of preserving beans in forms other than as dry whole beans were evaluated. Bean flour used as a thickener in a vegetable-pureed soup was well accepted even after 18 months of storage. The problem of hardness in cooking obviously does not exist in a finely divided flour product. Green beans and dry beans which had been thermally processed (canned) were also acceptable for up to 18 months of storage. Beans which were stored uncooked and dry (10-12% mc) under modified atmospheric conditions (well-sealed jars) maintained a good color and had not hardened by 18 months after harvest. It should be noted that the dry bean products for these studies were produced from recently harvested beans (10-12% moisture content).

3.3. Recommendations

1. The food science section of the laboratory needs a highly trained scientist. Funding should be sought to provide advanced training of that person. At the same time, efforts should be made to obtain short-term training for laboratory technicians.

2. In order to respond to its multiple obligations (training, extension, research, services to local food industries, and others), the Laboratory for the analysis of agricultural products created at OPROVIA by the Project should acquire certain supplementary equipment which will augment its present capabilities.

3. A full microbiological section should be added that will include the existing mycology and the proposed mycotoxin labs. This would include apparatus, media, and extra space for conducting qualitative and quantitative analyses of the microbial quality of raw and processed foods and preparation of fermentation cultures. It would also include the study of fungi which thrive in low O_2, high CO_2 environments. These laboratories should have separate and unshared facilities. This would probably require rearrangement of some of the existing facilities.

   The Cookability and Grain Quality sections of the laboratory perform many tests of a physical nature. These tests could be extended to include raw and processed fruit, vegetable, dairy, meat, and fish products. A microbiological section could perform certain tests on all food products.

4. The relationship between bean color, cookability, and germination, sensory preference of consumers, and various environmental factors (e.g., gas composition) should be investigated. Color should be monitored using the appropriate instrumentation (e.g., Hunter or Gardner color/color difference meter).

5. A laboratory study should be conducted to determine the O_2/CO_2 ratio x concentration that insures optimum retention of bean quality including color, cookability, sensory preference, germinability, insect and fungal control.

6. A supplementary study should be carried out on soaking of beans before cooking to determine in particular the effect of the salt used and resulting pH changes on the nutritional value of the beans, i.e., the changes in thiamine and ascorbic acid content. Nutritional Centers should actively participate in disseminating information in rural areas about the advantages of soaking.

7. Variability of bean mixtures and the effect of this variability on instrumental measures of bean hardness and moisture content should be studied. The variability of instrumental hardness measurements and measures of moisture content was quite large in this study and much of this variability might be accounted for by the variability in the composition of the bean mixtures.

8. Studies of the cookability and sensory preferences for different varieties of beans should be continued. The aim would be to create a large data base of information on the cookability and sensory preferences of all the bean varieties found at levels greater than 5% of a mixture. Continuation of these studies for 18 months or two years is advised since changes in either sensory preference or cookability were not observed after twelve months in this study.

9. The data from the large-scale bag study should be analyzed thoroughly. This very large data base will be useful for answering a variety of questions regarding the relationship of sensory quality to bean hardness and storage conditions.

10. The Food Quality Laboratory should develop and maintain a relationship with local food processing industries. These activities may include assistance in development of new products, support of quality control programs, calibration of equipment, sensory testing and problem solving. In order for the Laboratory to eventually become self-sufficient, an appropriate fee should be charged for laboratory services.

4. Studies of the Differential Resistance of Bean Varieties Grown in Rwanda to Storage Insects

4.1. Objectives

1. Verify that differential resistance to the storage insects (bruchids), *Acanthoscelides obtectus* (Say) and *Zabrotes subfasciatus* (Boh), exists in local varieties of beans.

2. Develop a method of screening local and introduced varieties for resistance to bruchids, to be continued with the cooperation of the National Legume Improvement Program at ISAR.

3. Develop a program of training and extension which demonstrates the importance of plant resistance in the management of bruchids in the storage of dry beans.

To fulfill these objectives, the following hypotheses were developed and tested:

(1) Varietal resistance to both species can be identified and measured in dry bean seed.

(2) Varietal resistance to *A. obtectus* can be identified and measured in ripe pods.

(3) The relative level of resistance in a set of bean varieties is not affected by different environments typical of storage conditions in Rwanda.

(4) The development of a population of either bruchid species is restricted on resistant varieties compared to susceptible varieties.

(5) The presence of a resistant variety in a mixture of bean varieties reduces the damage sustained by the mixture as a whole.

(6) Varietal resistance to bruchid damage can be broken down by a continuous infestation of insects on a resistant variety.

The experiments were carried out in a laboratory at ISAR/Rubona specially equipped for research on storage insects. The bean varieties were provided by the Varietal Survey component. The insects were reared in the laboratory from insects collected in several areas of the country. An incubator was designed and built from locally available materials for insect rearing and experiments requiring controlled temperature.

The personnel of this component worked in cooperation with the Alternative Storage Methods component of the Project, the Entomology section at ISAR, and the International Center of Tropical Agriculture (CIAT), Colombia, for several studies. The Rwandan laboratory staff members were trained in the design and implementation of scientific experiments and in the techniques for identifying and working with bruchid species. In addition, a second-year Agronomy student at the National University of Rwanda spent three months working with this component of the Project. The researcher in charge of this component at ISAR was trained in techniques and methods used in the experiments.

4.2. Research Findings

1. Hypothesis 1. A rapid method for screening bean varieties for plant resistance for bruchids was developed and tested. Over one hundred local varieties were tested for the level of resistance to each insect species. The results showed that few local varieties have resistance to bruchids, particularly to Z. subfasciatus. In those varieties showing measurable resistance, the level was too low to be used as the sole factor in avoiding/reducing insect damage. Plant resistance to one bruchids species was not always associated with resistance to the other.

2. Hypothesis 2. Ripe pods of five bean varieties showed differences in attractiveness for oviposition (egg laying) and in number of eggs laid per pod by A. obtectus. These differences were not strongly associated with the level of resistance to seed damage in a variety.

3. Hypothesis 3. Environment, in terms of temperature and relative humidity, affected the expression of resistance differently in different varieties. In a set of eight varieties tested at three OPROVIA warehouses, the relative resistance level of some varieties changed with location.

4. Hypothesis 4. Varietal resistance of bean varieties to bruchids can be measured by the change in number of insects or rate of population growth over time. Using the results of a five month test of ten varieties, a resistant, intermediate and susceptible group could be distinguished for each insect species.

5. Hypothesis 5. The presence of a resistant variety in an artificial mixture of two varieties reduced the amount of damage in the mixture as a whole. As the proportion of the resistant variety in the mixture increased, the amount of damage decreased.

6. Hypothesis 6. An examination of the stability of varietal resistance to Z. subfasciatus over three months suggests that resistance is not easily broken down.

7. Specific information was also obtained on weight loss resulting from bruchid feeding. In 6 months at 28°C, a dry weight loss of 40% occurred in beans incubated with 40 adult Acanthoscelides per kg. Of these beans, 87% had one or more emergence holes (81% had multiple holes). Other studies in the Project showed that these 81% would be considered a total loss for both consumption and planting. Mean daily temperature, of course, will directly affect (lessen or accelerate) rate of loss.

8. The potential for damage to stored beans caused by the bruchids A. obtectus and Z. subfasciatus is greater than is indicated by the reported losses. The actual amount of damage is related to environmental conditions, the resistance level of the varieties in the mixture, and the intensity of the initial infestation. In large-scale, long-term storage, it is possible that near optimum environmental conditions and high initial infestation levels could result in heavy losses.

4.3. Recommendations

1. Screening for resistance to storage insects in national bean improvement programs should be continued. This should be used both for evaluation of existing and newly released varieties and for the breeding and selection of new varieties. The identification and breeding of beans resistant to storage insects is another type of non-insecticidal insect management which ought to be considered. This kind of management offers the advantage of not needing to be repurchased or reapplied each season as an insecticide does.

2. The screening methodology should be refined to reduce variability. Possible factors to change include the use of eggs rather than larvae of *A. obtectus*, a method of accurately counting the eggs of *Z subfasciatus*, the use of smaller containers or a larger number of seeds to fill the containers, and increased numbers of replicates of each variety tested. Varieties should be tested in long-term (at least six months) screening tests to better evaluate resistance under actual storage conditions. These tests should be carried out under optimum and actual environments. The correlation of long-term and rapid screening tests should be evaluated.

3. For those varieties which are found to be resistant, the factors conferring resistance should be identified so as to allow more efficient screening. Attention should always be paid to the association of the factors conferring resistance with undesirable characteristics, e.g., unliked sensory properties.

4. In order to decide if studies on resistance in pods should be continued with *A. obtectus*, a basic study should first be carried out on the percent of beans in the field which are infested with *A. obtectus* in comparison with the percent of beans infested from poorly maintained storage areas. Pod resistance should not be developed in lieu of varietal seed resistance since pods only deter the initial infestation and not the infestation occurring after threshing or during storage.

5. In order to reduce the likelihood of insects developing resistance to the insecticides used, chemicals should be used only when necessary to reduce populations below the economic injury level. In a storage management system, temperatures, insect numbers and expected storage period should be determined in order to appropriately time the application of insecticides. Research should be conducted to determine the level of damage which constitutes an economic loss (i.e., discarding of damaged seeds or a lower selling price) and the level of damage at which insect control is appropriate.

6. The effect of low temperatures, as commonly occur in regions such as Kora, on the development of life stages and populations of bruchids should be studied. Important factors to be considered are the length of time for emergence and the survival rate for each generation. A determination should be made on how level of damage changes with time of storage under cool conditions. Naturally occurring low temperature is an effective method of increasing the development time of bruchids and may offer an inexpensive alternative to chemical insect control.

7. Local mixtures should be tested with the addition of an increasing proportion of a variety resistant to insect damage. The mixtures should be standardized for number of seeds of each type and data collected for damage to each of those seed types. Resistance should be tested in mixtures in long-term as well as short-term tests.

   The use of a resistant variety in a mixture to reduce the damage in the mixture as a whole suggests that not all varieties need have resistance to bruchids to control losses due to insects. However, the proportion of a resistant variety necessary to result in adequate control may be high. Including several varieties with resistance in the mixture may be more acceptable to consumers.

8. The use of resistant varieties in an integrated system of bruchid control in storage should be explored and encouraged.

5. Studies of Alternative Grain Storage Methods in Rwanda

5.1. Objectives

1. Evaluate the characteristics of the storage methods and conditions identified during previous storage surveys conducted at the producer, cooperative, and GRENARWA levels.

2. Develop appropriate storage alternatives for each level based on the preceding evaluation.

3. Test and evaluate these new methods in order to make recommendations.

4. Develop a system of rapid detection of storage problems, especially for cooperatives and OPROVIA/GRENARWA.

5. Train Rwandan technicians in storage methods, technical operation of storage centers, and maintenance of storage and research equipment.

5.2. Research Findings

5.2.1. General

1. Management is the single most important aspect to improving storage at all levels. It includes: a) assessing quality going into storage, b) monitoring quality throughout storage, and c) taking corrective action where necessary.

2. Storage structures in most cases are adequate for good storage if properly managed. In some cases, modifications can be made to make monitoring easier and to improve storage conditions.

3. The long-term storage of beans requires low moisture contents and temperatures to maintain cookability. This places additional demands on storage design and management.

5.2.2. OPROVIA/GRENARWA Level

1. Aeration has been used in many parts of the world to lower and equalize temperatures of stored grain and thus improve storage conditions. In Rwanda, beans in government storages are contained in jute bags. The bags are stacked preventing uniform aeration. Methods to improve uniform airflow were considered and rejected. The decision was made to direct efforts to lowering interior temperature by reducing heat load on the warehouse and improving ventilation.

2. Temperature measurements in a non-aerated pile indicated temperature gradients in the pile. Temperatures were higher at the top of the pile than at the bottom. This is likely a result of heat load on the roof of the building during the daytime hours. Results of an experiment to evaluate the potential effect of insulation suggest that including a layer of insulation under the roof along with improved roof ventilation would significantly lower roof temperatures and, therefore, heat transfer to the warehouse interior during daytime hours. Lower interior temperatures can potentially reduce the rate of insect development and the rate at which beans become hard-to-cook.

3. The experiment involving monitoring of non-aerated and aerated bag piles showed that storage related damage was already high for beans going into storage. These results suggest that procedures to evaluate bean quality as beans are received with the option of cleaning and/or segregating beans by various quality levels could improve overall quality. Adopting a system of quality standards would facilitate this effort.

4. In an experiment to evaluate different bag materials, both polyethylene sheeting and woven plastic provided a more effective barrier to insect (bruchid) penetration than jute. This is important because reinfestations from outside after fumigation as well as proliferation of insects within a pile may be slowed down in piles constructed with bags providing an effective physical barrier to insect penetration.

5. Supplementary drying will likely be necessary for beans destined for long-term storage. Results from cookability studies indicate that decreasing moisture content to 11-12% wet basis (w.b.) significantly reduces development of the hard-to-cook problem. Because the petroleum-based fuels required for heated air drying are expensive in Rwanda while electrical energy is relatively inexpensive, ambient air drying is attractive. This method relies on drying capacity in the ambient air and on electrical energy to power drying fans.

   Relative humidity data suggest that a procedure which runs the drying fan for 12 hours per day (900-2100 hrs.) would result in beans reaching 14-15% moisture content (mc) during the February to April period. This would reduce spoilage potential and the rate at which the hard-to-cook condition develops. Once the 14-15% mc range is reached, the system could be shut off and beans held until the June-July period when lower humidity conditions allow drying to about 11% mc moisture by operating the fan for 12 hours per day. To test this two-stage approach, a drying bin has been designed, built and installed, and experiments are now in progress.

6. Bulk storage of grain with aeration may be a useful alternative for OPROVIA in the future. Although beans and sorghum are currently stored in sacks in large warehouses, potential inclusion of drying and cleaning operations as well as increased flexibility for storage and handling may provide impetus for bulk storage. Although aeration was not effective in the bag storage experiment, it is a useful and often necessary aid in management of bulk storage, particularly for large quantities (greater than 100 MT). Aeration helps to maintain uniform temperatures throughout the grain mass and equalize areas of non-uniform moisture content. Two experimental cylindrical silos have been designed and built, and aeration experiments are planned.

7. The warehouse design is adequate for storage of beans and sorghum in bags. The structures provide good protection from rain, runoff and drainage water. They provide only limited protection from rodents and birds. Ventilation is adequate although some improvements could be made to reduce heat gain and therefore interior temperatures during the day.

   Bottlenecks in receiving, treating and rebagging exist at many warehouses. Inspection of grain quality at reception and during storage is minimal. The only cleaning performed is sorghum to be milled at Kicukiro. Improved procedures for drying, handling and storage have been developed.

5.2.3. Cooperative Level

1. Well-constructed, well-managed cooperative silos provide good storage conditions. The problems observed have been associated with poor construction including poor site selection which ignored proper drainage. Moisture migration through floors or walls has caused severe cases of spoilage. Poor management resulting from the rapid turnover and inadequate training of silo managers was also observed to be a problem.

2. Experiments involving monitoring of temperatures in non-aerated and aerated silos showed that the silos provide good thermal protection for stored products. The results indicated that aeration provides little advantage in these relatively small compartments.

3. Monitoring of storage conditions and grain quality during storage is almost non-existent. The design of the silo compartments, however, makes it difficult to monitor. Modifications in silo compartments to facilitate monitoring are currently under evaluation. One system consists of incorporating four sampling ports into the compartment ceiling. These modifications along with improved procedures for monitoring developed by the Project as a whole should lead to improvements in management of beans and sorghum during storage.

4. Unloading of the silos has been a problem (slow and inefficient). A manually operated auger system currently being tested shows promise for improving unloading of silo compartments.

5. Hangars (small warehouses) are suitable for storage in bags stacked on pallets. Hangars are not suitable for storage in bulk, however, due to poor vapor barriers in floors and walls.

   Although hangars are less expensive than silos and offer more flexibility in use, they provide less natural protection against rodents and greater risks with fumigation for insect control. Monitoring grain quality is critical as with other structures. If storage size is kept relatively small (less than 20 MT), satisfactory representative sampling is feasible with some ingenuity and effort.

5.2.4. Producer Level

1. Bean storage experiments involving traditional containers (small, medium, large and very large baskets, clay pots, imbohos and exterior granaries) were carried out. A high degree of variability was found in the results with no obvious storage advantage exhibited for any one of the traditional containers over another. Moisture contents moved toward equilibrium with the surrounding air since these structures do not provide vapor barriers. Despite insecticidal treatments (Actellic), live insects were found at relatively high levels in several large baskets and one exterior granary. These results show that control failures (incomplete kill and/or reinfestation) can occur. Mold and insect damage was highly variable but instances of high insect numbers corresponded with high levels of insect damage.

2. Bean storage experiments were also conducted with two alternative containers: metal and plastic drums. These structures proved to be impermeable to vapor movement as bean moisture contents remained essentially constant during one year of storage. Live insects were found in several of these structures, but only at low levels. Control failures did not occur to the degree that they did in several traditional containers in which beans were treated with an insecticide. Though insect control was not perfect or complete in all cases, control was probably sufficient given the length of the storage period. No differences in instrumental hardness were found between traditional and alternative containers. Particularly low germination was observed for higher moisture (16.5% mc) beans stored in the metal and plastic containers, but decreases in germinability of beans stored at 13% mc or less were roughly similar for all containers.

3. Because of the importance of insect problems in stored grain, the potential long-term risks (human health, insect resistance) of continual dependence on synthetic chemical insecticides, and the expressed need for more durable farm-level storage structures, two prototype 'airtight' metal containers were designed and built in early 1987. They were developed in an effort to improve on the used oil drum. Though more expensive, they were built with locally available materials and are intended to be sturdier, longer lasting (10-20 years), more airtight and easier to empty than the oil drum. They were also designed for easy fumigation and for use in conserving seed stocks. This kind of structure is less suitable for short-term storage and situations where the container must be opened frequently to meet family food needs. It is more applicable for longer-term storage of crop surpluses and late season food supplies.

5.2.5. Underground Storage

1. Two underground storage experiments have been undertaken with small amounts (less than one MT) of beans stored in bags and covered with polyethylene sheeting. Results of a one-year experiment starting with good quality beans are available. No live insects were observed in any of the beans stored underground. No damage by rodents occurred. Moisture content remained essentially constant. Bean hardness rose gradually but remained within acceptable limits. Bean germination was still high after one year. No off-odors were observed. Seedcoat brightness (new crop appearance) was relatively well maintained. In addition to insect control without chemicals, maintaining natural color in beans constitutes an important potential benefit of underground storage.

2. Results of a two-year experiment using poor quality, insect-infested beans are also available. Again, no live insects were found, which suggests that oxygen levels were sufficiently reduced because of the airtight storage conditions to completely kill all insect stages.

3. Both experiments have been technically successful. However, special management is needed in building the pits and sealing the bags. Grain monitoring is difficult or impractical. The level at which underground storage is applicable is a major question. The experiments conducted involve storages of a size that could fit a cooperative or a group of producers. However, underground storage's primary technical application is to long-term (strategic) storage which is envisioned to be administered at the government or OPROVIA level.

5.3. Recommendations

5.3.1. General

1. Extension as well as research efforts should be directed towards improving storage management expertise at all levels. The development of regular, ongoing technical training programs for managers of warehouses, cooperatives, and other large units should be an important part of this effort.

2. The expertise of the GRENARWA II-Research team in monitoring, sampling, laboratory analysis and diagnosis of problems should be utilized to improve storage management at all levels including grain merchants.

3. Improvements in monitoring techniques, an essential component of storage management, should be implemented as developed and wherever possible. Modifications should be made to storage structures and methods to facilitate monitoring. In particular, because insect control failures can occur in any system for many reasons, insect pests must always be closely monitored so timely corrective action may be taken.

4. A system of quality standards which could aid in describing quality and provide incentives to improve quality should be instituted. This could significantly improve storage management.

5. Use of insecticides should be carefully managed including application at proper rates and only when necessary. It is important that a variety of insecticidal materials (both natural and synthetic) be available for use to reduce the potential for development of resistant strains of insects. Applied research on the effectiveness of local insecticidal materials, insecticidal mixtures, rotation of insecticides, and new (back-up) materials is urgently needed and should be initiated without delay.

6. Future work in the alternative management area should include activities in cleaning, handling and drying.

7. The possibilities offered by underground storage should be further explored. Emphasis should be placed on resolving practical handling and management problems associated with large-scale applications, confirming effective insect control without insecticides, and determining the ability to maintain bright bean color (new crop appearance) during extended storage.

8. Additional engineering expertise related to storage, cleaning, handling and drying is needed in Rwanda. A pool of well trained professionals is the key to the long-term success of improved storage management. Since the pool of Rwandans with the needed expertise is extremely small and educational, programs are not available in Rwanda, a program to send promising students to other countries (preferably African) to obtain B.S. degrees in agricultural engineering or a related engineering field with emphasis on crop storage, handling and processing should be started immediately. In the short-term, expatriate expertise is essential to insure that the existing program moves forward.

5.3.2. OPROVIA/GRENARWA Level

1. Efforts should be directed at reducing heat load on warehouses through the use of roof insulation and improving ventilation of the interior space. This appears to be the most effective means of reducing pile temperatures and creating the most favorable storage conditions possible. This could be especially beneficial for long-term storage of beans since higher temperatures accelerate the development of the hard-to-cook problem.

2. The ambient air drying experiments planned with the drying bins should be carried out and evaluated because low moisture content (11-12%) is essential for beans going into long-term storage. For most of the year, natural drying conditions in Rwanda do not allow reduction in moisture content to this level.

3. Procedures to evaluate the quality of beans and sorghum as they are received with the option of segregating by levels of quality or of cleaning to improve quality should be implemented.

4. The planning that has already occurred related to improved handling at the central warehouse of OPROVIA in Kicukiro should be pursued and finalized. Improved facilities and equipment for cleaning, treating and handling are needed to upgrade service to customers and the quality of the product.

5. A program should be initiated to regularly monitor stocks to promote improved storage management. This program should include sampling, laboratory analysis, and written reports to upper-level personnel once a month.

5.3.3. Cooperative Level

1. Regular monitoring based on procedures developed by the Project should be implemented to improve storage management. The relatively inexpensive modifications in silo structures developed to facilitate monitoring should undergo intensive field testing.

2. Relatively simple equipment modifications to facilitate unloading silos should be widely tested in cooperation with managers.

3. Storage in bags on pallets is recommended for hangars. Bulk storage should be strongly discouraged in hangars because floor and wall areas do not appear to be designed with adequate moisture barriers.

4. Programs to train managers such as the recently initiated efforts involving the GRENARWA II-Research team, Ministry of Youth and Cooperatives (MIJEUCOOP), and IWACU are essential and should be pursued. Poor management resulting from the rapid turnover and inadequate training of silo and hangar managers is a critical problem and partially responsible for losses incurred.

5.3.4. Producer Level

1. Alternative airtight storage containers, such as the metal and plastic drums under test, seem promising and should be further studied. Significant

improvement in design of traditional baskets, the predominant storage container, is unlikely though means of rodent-proofing structures should be further explored. The alternative containers are more durable than baskets, rodent proof, and have the potential for controlling insects without insecticides. Their ability to maintain quality attributes such as germinability, bean cookability, and bean coloration should be determined. Though more costly, these containers may be economical when considered as a long-term investment.

2. Extension programs for the safe, effective, and selective use of low-cost insecticides (traditional and synthetic) should be developed. Because control of insect infestation is a key factor in storage management, investigation of non-insecticidal alternatives such as airtight storage should be continued.

3. Efforts to improve storage management at the producer level should be continued. They are justified to improve not only on-farm food supplies but also the quality of beans and grain entering market channels. This could have significant impact on storage at the cooperative, merchant, and OPROVIA levels.

5.3.5. Underground Storage

1. Further work on practical management problems should be undertaken before this technology is considered for application on a major scale. This is particularly true if it is decided to pursue the use of larger size underground units for long-term storage. One management problem which needs to be addressed is a cost-effective method for monitoring product quality and/or storage environment in underground pits. Locally available and less expensive materials must also be identified and assessed for use in constructing underground pits. In addition, effects of different soil types and climatic regimes on the important design features should be evaluated before diffusion of this technology.

2. A series of experiments should be conducted to answer questions related to bean discoloration due to age in both airtight and non-airtight environments. Though not yet confirmed, an important potential advantage of underground storage resulting from the airtight environment is the ability to maintain bright bean color (new crop appearance) during extended storage. If confirmed, this could lead to economic benefit for marketing beans removed from the long-term storage.

6. Development of a System of Quality Standards and Norms for Beans and Sorghum in Rwanda

6.1. Objectives

1. Develop and test a system of quality standards and norms adapted to the specific classification system in Rwanda to improve storage and the commercialization of beans and sorghum.

2. Study the feasibility of implementing the proposed system of quality standards.

6.2. Research Findings

A workshop/conference at the University of Minnesota in May, 1986, drafted the initial workplan for this component and prepared a set of proposed quality standards for Rwandan beans and sorghum. The standards under study are a series of grades, each with maximum limits for specific quality factors, such as foreign material and damaged grain. The standards developed have been used for testing the quality of 45 bean samples taken from merchant stocks and of about 100 sorghum samples purchased by OPROVIA primarily from producers and cooperatives during the 1986 buying campaign. This allowed observation of the difficulties encountered, including the time and skills required. As a result, a revised set of quality standards and procedures has been drafted.

At the same time, four surveys were conducted to study:

(1) the perception of current grain quality and the importance of different quality factors for the different groups operating in commercial grain channels.

(2) the presence of different prices for different qualities of the same commodity.

(3) the prevalence of rejection practices when grain quality is low.

(4) the reaction to the possible installation of a system of quality standards.

Four groups involved in the grain trade were interviewed:

(1) 164 producers who delivered sorghum to OPROVIA during the most recent buying campaign.

(2) 30 cooperatives, many of which have done business with OPROVIA in the past.

(3) 30 private merchants.

(4) various institutional clients, especially the public "market" such as military camps and prisons, and the World Food Program.

6.2.1. Results of Initial Quality Testing

1. The quality of beans and sorghum is quite variable in the Rwandan grain market, and tends to deteriorate as grain moves up through the system, from producers through cooperatives and merchants to OPROVIA.

2. The quality of beans sampled from 45 different merchant stocks in 1986 was relatively poor, especially with respect to damage levels. Total damage averaged nearly 6% by weight, most (over 90%) of which was due to insects and molds. Damage due to rodents, germination, and abnormal maturation (shrunken, shriveled seeds) was minimal. Only 7% of the samples met the proposed damage standard for Grade No. 1 (1.0%). Most graded No. 3 or Substandard. Foreign material in beans averaged slightly over 1.0%; 60% of the samples met the proposed standard for Grade No. 1 (1.0%). Stones are of special concern but accounted for less than one quarter of total foreign material. The lots tested contained insignificant amounts of broken beans (mean less than 0.3%), probably reflecting the non-mechanical methods used in Rwanda for harvesting, threshing, and handling beans.

3. The quality of sorghum delivered primarily by producers to OPROVIA warehouses in 1986 was generally quite good. Moisture contents were low (mean of 11%, maximum of 13%) and thus excellent for storage. Damage levels averaged only slightly more than 1.0%; two-thirds of the samples contained less than 1.0% and thus met proposed Grade No. 1. The mean value of total foreign material ranged from 1.1 to 1.5% for the three groups of samples. One third contained less than 1%; the most found in any sample was 3.0%. As with beans, stones amounted to less than 0.3%.

6.2.2. Results of the Surveys Presented by Organizational Level

6.2.2.1 Producer Level

1. The vast majority (90%) of producers correctly identified quality problems, and most perceived differences in levels of two important quality factors (damaged grain and foreign material).

2. Most producers stated that they would perform additional cleaning of grain to receive a premium price for high quality. This indicates that many would respond to adequate economic incentives to improve the quality of the grain they market.

3. Grain cleaning practices, essentially non-mechanical winnowing and hand-picking operations, are most rigorous for beans reserved for planting (seed). Standards are somewhat less stringent for beans intended for home consumption (food), and significantly less strict for beans destined for sale or for storage.

4. Producers reported the existence of price differentials and rejections in the grain market. However, these practices are rather infrequent. Only 1% of the producers indicated that they ever had grain refused at OPROVIA; about 5% have been offered higher prices by merchants for higher quality and about the same numbers have had grain refused by merchants because of poor quality.

6.2.2.2. Cooperative Level

1. Most cooperative managers correctly identified quality problems and perceived differences in varying levels of quality defects.

2. Insect attack was perceived as the most important cause of storage losses. Weight loss due to reduction in moisture content was also considered important. Three-quarters of the cooperatives indicated they had storage problems of some kind; 30% of these indicated that they had numerous problems.

3. Many managers reported that they base and thus vary purchase price on the amount of damaged grain and foreign material, though age and varietal composition are also important factors.

4. In general, cooperatives do not clean grain to improve quality. Most feel that responsibility for cleaning lies with the producer. Some (25%) segregate stocks according to quality, but only based on age.

5. All cooperatives stated they refuse grain if quality is not good. Foreign material and damaged grain are considered the two most important quality factors on which rejections are based. Moisture content, age, variety and the presence of live insects are of lesser importance. Frequency, uniformity, and standards of rejection are not known but are likely quite variable. Many managers believe quality can be improved by tougher standards and increased rejections.

6.2.2.3. Merchant Level

1. The vast majority of merchants correctly identified quality problems and perceived differences in varying levels of quality defects.

2. The majority of merchants stated that they refuse beans of poor quality but rejections are infrequent. Damaged grain and foreign material were the principal factors on which rejections are based. Moisture content, age (color), and varietal composition are considered but to a lesser degree.

3. Some merchants base their purchase price on quality. Like cooperatives, three-quarters are in favor of price differentials.

4. A few merchants segregate stocks according to quality, but usually the segregation is based on age, though not exclusively.

5. The vast majority do not clean grain after purchase. Unlike cooperatives, almost half of the merchants indicated they would undertake some cleaning given satisfactory premiums.

6. Many merchants (70%) reported frequent problems with insects in storage. More than a third associated storage problems with humidity or moisture content. About 25% stated that they encounter no problems at all in preserving the grain they purchase.

6.2.2.4. OPROVIA Level

1. Prior to 1985, OPROVIA procured grain primarily in large lots from merchants. Starting in 1986, purchases of small lots directly from producers accounted for well over half of the total. This change impacts significantly not only on logistical arrangements for receiving grain but on the possible quality testing procedures that can be implemented.

2. OPROVIA's procedures for buying, storing, and selling grain take quality into consideration on a limited basis. Basic standards have been set, but quality testing is quick, subjective, and non-uniform. OPROVIA has a policy to not accept low quality grain but rejections are not strictly applied and infrequent.

3. Segregation of stocks according to quality is practiced in only a few warehouses, and in those cases is based only on variety and age.

4. No warehouse undertakes drying or cleaning of grain after purchase, except at Kicukiro where sorghum to be sold as flour is mechanically cleaned prior to milling. Only one warehouse (Cyangugu) is sometimes authorized to price beans according to quality where large size beans are purchased at a small premium (1-2 FRW/kg) to satisfy local consumer preferences.

6.2.2.5. Institutional Clients of OPROVIA

1. In general, the quality of beans and sorghum flour furnished by OPROVIA is considered acceptable to its principal institutional clients. Quality was found to be generally comparable to that available from other sources (marketplace, private merchants), and sometimes the quality of OPROVIA's products was considered slightly superior. However, some complaints and even some rejections have occurred in past years.

2. For beans, the quality problems which were specifically mentioned by these institutions are damage due to insects, molds, age (cooking time), and undesirable varieties (e.g., small black beans which are deemed inferior). For sorghum, insects represent the major quality problem.

3. Cleaning of beans by hand is carried out at most of these institutions just prior to cooking rather than before storage. The mean length of storage for beans and sorghum flour was three and four months respectively at the institutions surveyed.

4. Although it is not a client of OPROVIA at the present time, the BRALIRWA brewery has begun to incorporate local sorghum into its recipe for making beer. As a result, it has developed a program of contract production, quality specifications, price discounts, rejection policies, and mechanical cleaning. The model of quality control which this program provides, as well as the demand for grain which will likely be generated, could be useful for OPROVIA and other participants in the commercial grain market.

5. Survey results indicate that an increase in overall grain quality will be necessary for OPROVIA and other suppliers in order to maintain current institutional customers as well as to attract new clients.

6.3. Recommendations

1. After further testing and refinement during 1987, an improved system of grain quality standards and testing procedures should be implemented at OPROVIA for large grain purchases, and especially for beans going into long-term storage (e.g., security stocks). The need for grain of high initial quality is greatest for these long-term stocks, because the potential for storage problems is highest. This system could substantially increase knowledge of the kind and range of quality received, and provide improved information for making important management decisions such as segregation of stocks according to storability, scheduling of stock rotations, and the timing as well as types of insecticide treatments. It would, of course, be the initial link in an effective quality monitoring program operating throughout the storage period. Furthermore, this system would serve as a precursor for the eventual creation of an official government-sponsored grain inspection system. In short, OPROVIA would be the testing ground for a quality system which could gradually evolve into one of national stature.

2. A rapid (5 minute) but more objective and precise quality testing procedure for small producer lots received by OPROVIA should be developed and tested. The small size and large number of producer lots received by OPROVIA make highly objective, time-consuming inspection and testing procedures difficult if not impossible.

3. For grain cooperatives and merchants, practical methods for more objective testing of quality should be investigated to improve storability of grain received and to reduce losses during storage. OPROVIA can assist in this effort because the methods used would likely be similar to those developed by OPROVIA to handle the large number of small lots it receives from producers. At the same time, OPROVIA would be helping these groups to effectively and economically meet new standards if implemented by the government through OPROVIA or otherwise. The ultimate benefit for all parties may be improved commercial relationships.

4. In combination with the installation of improved quality testing procedures, OPROVIA should institute with government approval a pricing system based on quality. In view of the current market situation and high government-fixed producer prices, the "fixed" price ought to be considered the price for premium quality grain, with discounts (penalties) imposed on grain whose quality is below a specified level. The discount schedule presented in the report, based on each quality factor and not on overall grade, should be a useful starting point. Initially, discounts should be based on amounts of damaged grain and foreign material for both beans and sorghum. Moisture content (mc) should be measured in both crops but weight adjustments as well as price discounts for excess moisture (13% mc basis) should be applied initially only to beans.

5. Coupled with price differentials, OPROVIA should institute a more severe rejection policy, which should be strictly respected and uniformly applied. Only grain which grades No. 1 or No. 2 should be considered acceptable under normal circumstances. Grain grading No. 3 or Substandard would therefore be rejected. However, flexibility should be maintained since conditions of refusal or acceptability are subject to change as a function of market conditions. Differences in supply or demand and seasonal differences in product quality may require these changes in order to obtain the desired quantities and qualities of a particular product.

6. A study should be conducted to evaluate consumer demand for quality designations (grades) of beans at the retail level. This should involve actual sale to consumers of beans priced at different levels according to quality, and could be carried out at several OPROVIA outlets over a period of several months. The relative demand for different grades and appropriate price differentials between grades would then be assessed.

7. In the future, based on OPROVIA's experience, the Government of Rwanda (GOR) should consider establishing an official system of grain quality standards and testing procedures for beans and sorghum. This would be the logical outcome of a gradual, evolutionary process. The grade designations selected should be the sole ones legally and officially recognized in Rwanda, and no grain should be in any way considered or labelled a particular grade without an officially approved inspection. This will discourage the development of separate grades by private traders and others.

   The GOR should consider a mandatory system for all international transactions (imports and exports) and all government purchases (OPROVIA, military camps, prisons, public schools, etc.). The system should have a strong service orientation and be fee-based (revenue generating). The purpose would not be to regulate every single transaction but to provide services to those operating in the market with respect to describing and communicating about product quality.

8. Given the importance of the growing agro-processing industry, as experience is gained and success achieved, quality standards and procedures should be developed and tested for other grain crops, giving priority to those for which marketing and processing are important (e.g., wheat, maize, rice).

9. The goal of all these activities should be to improve overall quality of the grain OPROVIA buys and sells, to enhance storability of grain purchased, and to reduce storage losses at all levels in the food supply system. For OPROVIA, these efforts should help improve its reputation as a supplier of high quality food products, establish its place as a national leader and advocate for quality in the Rwandan marketplace, and increase demand for its products and services and hence its revenues. It is expected that these efforts will produce similar benefits throughout the food marketing system.

III. SYNTHESIS OF RECOMMENDATIONS BY STORAGE LEVEL

1. Producers

Most of the beans and sorghum produced in Rwanda are stored and consumed on the farm. Thus the effectiveness of storage methods at the producer level is important to Rwanda's overall production and food supply.

A Project survey of farms throughout Rwanda conducted in 1984-85 found that weight losses during storage were less than 5% for beans and only 2% for sorghum. Bean losses were greater in the lower altitudes where higher temperatures prevail and more rapid build-up of insects occur. The principal factors contributing to these comparatively low levels of loss are (1) the small quantities stored, (2) the short storage period, and (3) the frequent withdrawal of small amounts of the commodity which gradually reduces the quantity in storage and causes regular observation of grain quality and storage conditions, which in turn allows early detection of storage problems. Certain quality problems (losses other than dry matter) such as germinability, bean cookability and color change are generally not important because of the short storage periods.

These loss data are only averages, however, and obscure the fact that certain farmers do experience storage problems and need assistance. It should be noted too that even a 2% loss of total annual bean production in Rwanda (250,000 MT) constitutes a large amount of food (5,000 MT).

The key recommendations at the farm level include:

(1) Developing and disseminating information on safe, effective, and selective use of low-cost, locally available insecticides (both natural and synthetic). The primary management factor for farm-level storage is the control of insects. The ability of farmers to monitor grain in storage, especially to identify insects and detect incipient infestations, will also aid in reducing losses. This activity should be part of an extension program that explains the basic principles of sound storage.

(2) Investigating further the effectiveness of small air-tight containers (e.g., metal and plastic drums) for controlling insects without insecticides. They should also be evaluated for their durability and prevention of rodent damage. In addition, their ability to maintain quality attributes such as germinability, bean cookability, and bean coloration should be determined. Though more costly than traditional structures, these containers may be economical when considered as a long-term investment.

(3) Developing and testing modifications for rodent-proofing traditional containers. Structures are not a major deficiency in the system; management is of greater importance than the structures themselves. All traditional storage containers tested can safely store grain for long periods if properly managed. In any case, significant improvement in design of traditional baskets, the predominant storage container, is unlikely. However, these containers can and should be modified in ways that will more effectively prevent entry by rodents into stored grain.

(4) Determining more precisely losses due to rodents. This will enable the design of appropriate rodent control programs. As with insects, an integrated pest management approach is recommended.

(5) Conducting additional surveys on storage problems and losses by region (or agro-ecological zone). This can be conducted through SESA or through local extension agents and development projects. The latter method has the advantage of involving extension staff in diagnosing problems, which will enable them later to explain recommended solutions to farmers more effectively.

Continued efforts to improve storage management at the producer level are justified to improve not only on-farm food supplies but also the quality of beans and grain entering market channels. Such efforts could have significant impact on storage at the cooperative, merchant and OPROVIA levels.

2. Cooperatives

In Rwanda two basic types of storage structures are used at the cooperative level: silos and hangars. The former is used for bulk storage, the latter for bag storage. More than 100 units have been built throughout the country during the last 10-15 years. In the earlier stages, silos were much preferred. Although silos are still the predominant type, hangars have received more attention lately, mainly because this type of structure lends itself better to uses other than long-term storage (e.g., meeting hall or short-term storage of coffee), and thus makes it an attractive alternative in rural communities.

Well-constructed, well-managed silos and hangars provide satisfactory storage conditions. Problems observed in silos have been associated with poor construction including poor site selection which ignored proper drainage. The design of the silos provides good thermal protection of the storages, and thus aeration does not appear to be necessary. The average storage periods are quite variable but generally do not exceed six months for beans and one year for sorghum.

Major recommendations at this storage level include:

(1) Encouraging regular monitoring of stocks and storage conditions based on procedures developed by the GRENARWA II-Research Project in order to improve storage management. The relatively inexpensive modifications in silo structures developed by the Project to facilitate monitoring should undergo intensive field testing. Methods should also be developed to monitor rodent activity in hangars.

(2) Developing improved methods of detection and control of insects. The silos have not proven to be sufficiently hermetic to control insects without insecticides. Managers need to be better trained in the safe, effective, and selective use of insecticides. The efficacy of currently used materials and application techniques needs to be continually monitored.

(3) Field testing simple equipment modifications developed by the Project to facilitate unloading silos. Current methods are laborious and time-consuming.

(4) Strongly discouraging bulk storage in hangars because floor and wall areas do not appear to be designed with adequate moisture barriers. Only storage in bags stacked on pallets is recommended.

(5) Developing rapid, practical methods for more objective testing of quality in order to improve storability of grain received at cooperatives and to reduce losses during storage. This is the first step in an effective quality control program that continues throughout storage.

(6) Providing regular training programs and technical backstopping for cooperative managers in storage technology. Poor management resulting from the rapid turnover and inadequate training of silo and hangar managers is a critical problem. Programs to train managers such as the recently initiated efforts involving the GRENARWA II-Research team, MIJEUCOOP, and IWACU are essential and should be pursued. On-site follow-up visits comprise an important part of such programs.

3. <u>Merchants</u>

Private merchants constitute an important element in commercial grain channels in Rwanda. Historically, they have been a major supplier of beans and sorghum to OPROVIA. Compared to other storage levels (producers, cooperatives, OPROVIA), little precise information is available about storage methods, conditions, and problems at the merchant level. Merchants were not part of the original storage survey conducted by the Project. Observations during occasional visits and analysis of various grain samples over the past three years, coupled with a recent survey of some 30 merchants during work on grain quality standards, have provided some preliminary information. The evidence indicates that storage conditions are less than ideal, that storage problems are common, and that substantial losses have occurred in some cases.

Major recommendations for this group include:

(1) Finalizing the analysis and preparing the report of the merchant survey mentioned above. This should serve as a basis for formulating extension, and if necessary, applied research recommendations for this group. A supplementary survey, with repeat visits and collection of samples, may be necessary to estimate losses and determine more precisely the factors causing losses. The ultimate goal is to develop and disseminate a package of sound storage practices tailored specifically to merchants. Already, it is apparent that most merchant-level storage resembles that found at cooperative hangars and small OPROVIA warehouses. Thus much of this management package including quality assessment, regular monitoring, and insect and rodent control, is already well developed. In addition, as with

cooperative hangars, bulk storage in merchant buildings should be strongly discouraged because floor and wall areas have usually not been designed with adequate moisture barriers. Only storage in bags on pallets should therefore be recommended.

(2) Developing rapid, practical methods for more objective testing of quality in order to improve the storability of grain that merchants receive and to reduce losses during storage. The GRENARWA II-Research team and OPROVIA can assist in this effort because the methods used would likely be similar to those developed by OPROVIA to handle the large number of small lots it receives from producers. Since merchants are major suppliers for the Rwandan market, improvement of grain quality at this level will be beneficial to consumers as well as to OPROVIA and the growing food processing industry.

(3) Maintaining a post-harvest facility such as the GRENARWA II-Research Project where merchants can obtain information and advice on storage problems and submit grain samples for quality analysis. Some of these services can be provided on a fee-basis. Regular short courses on storage technology could also be provided given sufficient interest.

4. <u>OPROVIA</u>

OPROVIA operates a network of about 25 warehouses throughout the country, including those that are constructed for the storage of food aid and the strategic food reserve. Total storage capacity of this network exceeds 25,000 MT. The layout and design are quite similar for most of these buildings, though the storage capacity ranges from 200 to 3,750 MT. The main storage center is located at OPROVIA's headquarters near Kigali, and consists of three large warehouses of similar design: OPROVIA (3,750 MT), GRENARWA (2,500 MT) and World Food Program (2,500 MT). A 3,000 MT addition to the GRENARWA warehouse has recently been completed for storing the strategic food reserve. OPROVIA stores grain exclusively in bags which are stacked in large piles on wooden pallets. It has no bulk storage facilities. Major suppliers include producers, cooperatives, and merchants.

Key recommendations for OPROVIA include:

(1) Reducing heat load on warehouses through the use of roof insulation and improved ventilation of the interior space so as to reduce pile temperatures and create more favorable storage conditions. Low temperatures help maintain grain quality and slow the development of insects and fungi which cause losses. Aeration of bag piles for this purpose is difficult because of air distribution problems.

(2) Improving facilities for cleaning, treating and handling grain in order to upgrade service to customers and the quality of the products marketed. The planning that has already occurred related to improved handling equipment at the central warehouse in Kicukiro should be pursued and finalized.

(3) Initiating a program to regularly monitor stocks including sampling, laboratory analysis, and written reports to upper-level personnel once a month. Monitoring is essential for improved storage management.

(4) Developing a program for the use of insecticides which insures the protection of stocks and the reduction of losses due to insects but seeks at the same time to avoid the development of resistance to insecticides by insects and to minimize the dangers to employees' health.

(5) Implementing an improved system of grain quality standards and testing procedures for large grain purchases. Development of this system is well advanced. In addition, a rapid (5 minute) but more objective and precise quality testing procedure for small producer lots received by OPROVIA should be developed and tested. This system could substantially increase knowledge of the kind and range of quality received, and provide improved information for making important management decisions such as segregation of stocks according to storability, scheduling of stock rotations, and the timing of insecticide treatments. It would also be the initial link in an effective quality monitoring program operating throughout the storage period. Furthermore, this system could serve as a precursor for the eventual creation of a government-sponsored grain inspection system. In short, OPROVIA would be the testing ground for a grain quality system which could gradually evolve into one of national stature.

(6) Instituting, with government approval, a pricing system based on quality (i.e., price discounts for low quality) and a more severe rejection policy. These are natural concomitants of improved quality standards and testing procedures.

The goal of all these activities would be to improve overall quality of the grain OPROVIA buys and sells, to enhance storability of grain purchased, and to reduce storage losses at all levels in the food supply system. For OPROVIA, these efforts should help improve its reputation as a supplier of high quality food products, establish its place as a national leader and advocate for quality in the Rwandan marketplace, and increase demand for its products and hence its revenues. It is expected that these efforts will produce similar benefits throughout the food marketing system.

5. <u>Long-term Storage</u>

The Rwandan Government has planned the establishment of a food reserve stock. The management of this stock has been entrusted to OPROVIA and the first warehouse designated for this stock was built in 1986 at Kicukiro. The two commodities planned initially for the reserve are beans and sorghum. A reserve stock implies long-term storage (1-3 years).

The key recommendations to enable safe long-term storage include:

(1) Installing a system of standards and objective inspection of quality in order to have precise information on the quality of products to be stored and to assure a very high initial quality of the commodities destined for long-term storage.

(2) Modifying the storage structures used so as to reduce and stabilize storage temperatures as much as possible. Low temperatures assist in slowing down the development of insects and fungi as well as the hardening of beans.

(3) Studying the feasibility of drying beans, initially by selective use of unheated ambient air, in order to be able to store beans at moisture contents between 11-13%. Low moisture contents serve also to slow the development of beans which are hard to cook. The possibilities of purchasing beans from the second season, which are normally drier, should also be studied. Laboratory hardness tests developed by the Project will be an important tool for predicting high levels of hardness and therefore indicating the opportune time for stock rotations.

(4) Following the recommendations proposed above for OPROVIA concerning improvements to storage management techniques.

6. Local Food Processing Industries

A growing number of agricultural industries, which make and sell processed food products, are emerging in Rwanda. These include among others a brewery, flour mills, and factories for tomato paste, jams and fruit juices. In fact there exists in Rwanda a rather large range of potential food processing projects which seem to offer promising opportunities. The commodities which offer possibilities for such projects include sorghum (malt), oats, cassava, certain dried vegetables, and spices.

Many analyses conducted in routine fashion in the Project's laboratory at OPROVIA will be useful in quality control programs of processing plants which already exist as well as in the development of new enterprises. In addition, the experience of the Project in the evaluation of sensory qualities of products, the development of standards and methods of quality analysis, and the monitoring of physical and biological conditions during storage could certainly serve this emerging industry. It is therefore recommended that the postharvest laboratory/center introduce its testing and extension services to the Rwanda agro-food industry and indicate its willingness to collaborate with these groups in the area of research and development on new products. A good first step would be to make preliminary visits to contact these different industries and to determine their needs and possible problems. To help the laboratory/center attain a certain financial independence, it is entirely normal that the services be rendered on a fee-paying basis.

IV. EXTENSION OF RESULTS

Besides the six research components described in Section II of this report, a seventh component was established by the Project team in Rwanda to provide a framework for a program to extend and disseminate results generated by the research program. By making this activity an explicit and integral part of the Project it was also intended to focus the attention of the staff on the ultimate goal and measure of success of their research.

This seventh component did not exist in the contract of the University of Minnesota nor in the initial Project documents. It was eventually added by Project management to insure the application and practical utilization of information collected within the research program.

No specific personnel were assigned nor funds reserved for this component. All staff and all six research components were expected to contribute to the effort. However, as a result the Project has furnished various technical, advisory, and extension services to third parties. To illustrate, a number of examples are given below.

(1) Consultative visits have been requested by the Farming Systems Project (FSRP/ISAR) at Rewerere for producers in the communes covered by the Project with the aim of studying existing storage problems and recommending actions and solutions to be undertaken.

(2) An appraisal was made at the National Center for Small Animal Husbandry (CNPE) Kabuye (near Kigali) of the management of large-scale storage of grain and other raw products used in the manufacture of animal feed.

(3) The Project collaborated in the conduct of thesis research work for two Masters-level students from the National University of Rwanda (UNR). The subjects of the research were the evaluation of insecticidal properties of local plants and the varietal resistance of beans to bruchids (storage insects).

(4) OPROVIA and the IWACU Center (Cooperative Training and Research Center) are jointly implementing the Project called "Post-Harvest Management in Rwandan Cooperatives", which provides training in storage and marketing of agricultural commodities. The GRENARWA II-Research Project is responsible for the organization, monitoring and evaluation of the training in grain storage management of 120 managers and board members of some 30 producer cooperatives. Substantial funding for this activity has been provided by a private American food industry group called FICAH (Food Industry Crusade Against Hunger).

(5) An agreement has been signed between OPROVIA and the Global Development Project (PDG) of Butare which provides for the GRENARWA II-Research Project to make appraisals of storage problems prevailing in the zone covered by the Project and to organize training on storage practices for managers of cooperatives and commune-level agricultural extension agents in the Butare prefecture. This training has already been provided, and the follow-up and evaluation phase is currently under way.

(6) An agreement similar to the PDG above is currently under negotiation and calls for the GRENARWA II-Research Project to supply technical assistance to the North Kivu Agricultural Cooperatives Union (UCOOPANOKI) in Zaire. The UCOOPANOKI presented a formal request in April, 1988.

(7) In April 1988, FAO/Uganda sent to the Project a request for technical assistance to their program involving on-farm storage of dry beans which was recently launched by the Ugandan Government with support from FAO.

(8) The Project has provided services for the benefit of OPROVIA, private merchants, cooperatives, and other agricultural projects on various commodities (beans, sorghum, rice, and food aid products among others). On numerous occasions, the Project laboratory has conducted quality analyses of samples submitted by these groups.

(9) For the "Grain Legumes Workshop" (Journeés d'Etude) organized by ISAR in December 1985, the Project presented two papers, one on the results of the component "Study on Sensory Qualities and Cookability of Beans" and the other on the results of the component "Inventory of Bean Varieties Grown in Rwanda".

(10) During the regional seminar on the production and improvement of beans in the Great Lakes Region held in Kigali in November 1987, Project team members presented three papers on different aspects of the research that has been conducted.

(11) Several radio broadcasts on RADIO RWANDA have been written and presented by Project Staff. Topics have included various aspects of the research program underway and project results which are of benefit to Rwandan farmers.

V. SECOND PHASE OF THE GRENARWA II RESEARCH PROJECT

The application of the results obtained during the course of the first phase and implementation of the recommendations derived from initial and on-going research are key program thrusts designed within the second phase of the GRENARWA II-Research Project. A second phase is strongly recommended by the three parties involved in the first phase, but funding must be sought within a brief period of time in order to avoid a discontinuity in activities due to a rupture in financial support.

1. Program Emphasis

1.1. Services

One of the principal activities will be to provide services in the area of storage and quality analyses of food grains not only to OPROVIA but to interested third parties (producers, cooperatives, private merchants, agricultural development projects, the agro-food industry, and others). To enhance the capacity of the Laboratory and to foster its development into a self-supporting unit, many of these services will be provided on a fee-paying, revenue-generating basis.

Specifically, some of the service activities envisioned are as follows:

(1) monitoring and control of quality of products marketed by OPROVIA,

(2) physical and/or sensory analyses of samples as well as establishment of quality standards of food products received from various sources,

(3) technical advice on the storage of food products in general (agricultural engineering, entomology, mycology and others),

(4) certification of the quality of food products (domestic production, imports and exports).

1.2. Extension

The objective of this activity is not to replace the administrative and technical services of The Ministry of Agriculture's Division of Agricultural Extension, but rather to disseminate information (research results) on a continuing basis and to facilitate the task of the official extension agencies involved by providing:

(1) training programs for managers and technical staff of storage centers (national, cooperative/communal, merchants and private industry) and other interested parties;

(2) consulting visits throughout the country to storage centers, food industry groups, and agricultural development projects upon request; and

(3) continuous diffusion of storage techniques and research results on post-harvest technology through the publication of articles, technical fact sheets, radio broadcasts, and other appropriate communication methods.

1.3. Research

Although service and extension are considered the activities of highest priority, the second phase will include a coherent program of applied research on post-harvest techniques based on the results of the first phase and with effort given to extend these activities to products other than beans and sorghum. Continued research is essential in order to support the efforts of the Rwandan Government to promote rapid development of the agro-food industries in the country, to generate and test the new technology which will be needed as the entire food supply system evolves and new problems inevitably arise, and to utilize as effectively as possible the food quality analysis laboratory already created at OPROVIA within the GRENARWA II-Research Project. Based on the recommendations resulting from the first phase, the research activities of the second phase should emphasize the following studies:

(1) Study of the methods of receiving, drying, cleaning and handling of beans and sorghum in the large storage centers.

(2) Study of underground storage (pit silos) of beans and other commodities as well as the value in using the Ruhengeri caves for the storage of foodstuffs.

(3) Studies of processing techniques, value enhancement of local agricultural products, and the preservation of processed products (flours and others). The aim of this research would be to develop food products through new and diverse uses of local food crops. It would be useful to develop new foods from composite flours (flour of beans whether hard-to-cook or not, cassava, wheat, sorghum, maize, soybeans, sweet potatoes, and potatoes). Such research would increase the value of hard-to-cook beans and enhance tubers from a nutritional standpoint. Studies will also emphasize the storage and preservation of processed products such as flours where difficulties of quality maintenance continue to persist in many organizations which are involved. This research will examine in more depth the effects of soaking of beans in salt water (rock salt) on their nutritional value (thiamine, ascorbic acid, pH, etc.).

(4) Study on long-term storage (3 to 4 years) of bean varieties grown in Rwanda, including:

(a) the effect of variability of bean mixtures on instrumental measures of hardening and moisture content;

(b) variability between hardening and varieties; and

(c) the effect of concentrated atmospheres of carbon dioxide on the preservation of the quality of stored beans.

(5) Identification of fungi and analysis of mycotoxins. This will involve adding to the current Project laboratory a section for the identification of fungi in food products and for the isolation and determination of mycotoxins. This is important because fungi which produce highly toxic substances called mycotoxins (such as aflatoxin produced by A. flavus) were identified in grain samples during the survey on conditions and methods of grain storage in Rwanda conducted by the Project.

(6) Studies on insecticides and the resistance of insects to these materials, specifically:

  (a) study of the possibilities of using local plants and other natural products as insecticides in the storage of food products in Rwanda; and

  (b) study of the resistance which insects apparently develop to the insecticides currently used in Rwanda (Actellic, Malathion, and others) and the development of appropriate alternatives.

(7) Study on quality standards and norms of food products:

  (a) perfecting the quality standards for beans and sorghum; and

  (b) developing quality standards for other food grains judged of high priority in order to facilitate their marketing and sustain the growing food industry in Rwanda.

1.4. Training of Staff

Given the mission entrusted and the activities planned for the second phase, staff training and development should be continued and even more strongly emphasized. Training content and scheduling will have to be worked out by Project management, and are not discussed in this report.

2. Current Status of Funding for the Second Phase

As USAID is unable to fund the second phase of this Project because of financial difficulties encountered by the American Government, it is important to approach other donors for funding future activities. OPROVIA and the University of Minnesota began this effort more than a year ago in order to avoid a discontinuity of activities. The current status of these efforts are described below.

2.1. Funding Already Approved

(1) Concerning extension activities, the Food Industry Crusade Against Hunger/USA (FICAH) has provided financing since early 1987 for the training of cooperative managers through the Project called "Post-Harvest Management in Rwandan Cooperatives" jointly implemented by OPROVIA/GRENARWA II-Research and the IWACU Center. Annual funding is approximately $100,000 on a renewable basis for a maximum of five years.

(2) The USAID Science Advisory Council has just approved funding for research on the possibilities of utilizing local plants and other natural products for insect control purposes in the storage of foodstuffs in Rwanda. This study is to be jointly carried out by OPROVIA/GRENARWA II-Research, ISAR, and the University of Wisconsin (USA). Total funds available amount to $150,000 for a period of three years. The start-up of this research is planned for September, 1988.

(3) The USAID/Washington Office for Historically Black Colleges and Universities (HBCU) has recently given their agreement in principle for funding research on the resistance of insects to the insecticides presently used in Rwanda and the development of alternatives. This study will be jointly implemented by OPROVIA/GRENARWA II-Research and the University of Selma (Alabama, USA). Annual funding for this study is estimated at $100,000 with a possibility of renewing for a period up to 5 years. Start-up for this study is also planned for September, 1988.

2.2. Sources of Anticipated Funding

(1) The Adventist Development and Relief Agency (ADRA) of Sweden has expressed interest in financing an in-depth study on underground storage of beans as well as the feasibility of this technique in certain storage situations for producer groups. The technical dossier supporting the request for the funding of this study has already been finalized by the Project team in Rwanda.

(2) The United Nations Development Program (UNDP) has shown interest in funding a feasibility study (including a pilot trial of 18 months) of storage of foodstuffs in flexible silos for use at cooperatives, OPROVIA, and for emergency food aid agencies. The technical dossier supporting this funding request has been finalized by the Project team in Rwanda, and the official request was introduced in January, 1988.

(3) The official funding request to create within the current Project laboratory a section for the identification of storage fungi and mycotoxin analyses was submitted to the Food and Agricultural Organization (FAO) of the United Nations by the Rwandan Government in June, 1987. A formal response has not yet been received.

(4) The technical dossier for a study to identify and evaluate damage caused by rodents to agriculture crops (both in the field and in storage) and to develop appropriate control methods has been finalized by the Project team in Rwanda. The official request of the Rwandan Government was introduced in March, 1988 to the Belgian Government.

The remaining activities do not yet have funding sources identified, but efforts should be pursued so these activities may be undertaken. The Project team continues to prepare technical dossiers on an ad hoc basis in order to support and assist steps taken by the Rwandan Government to seek the necessary funding.

VI. PRIORITIES FOR FUTURE ACTIVITIES

The first priority for the future should be the solution of current post-harvest problems in Rwanda and the extension of improved storage techniques to all individuals and institutions involved in the conservation of food products. The key to these efforts is the continuation of the Post-Harvest Center/Laboratory (currently located at OPROVIA in Kicukiro) as a national resource of expertise. This center should maintain and strengthen its scientific activities by means of additional training for all personnel, exchange visits with other centers or post-harvest projects, participation of staff in national and international meetings, and the publication of results in scientific journals. In the future, this center should begin to establish itself as a regional resource in East and Central Africa.

Based on the last four years of research, this center is now able to initiate a well-founded program of training and extension on the reduction of post-harvest losses. Special programs should be developed for on-going training in integrated storage management, especially monitoring techniques for managers of cooperatives and warehouses as well as merchants. The center's staff is capable of conducting a repertoire of basic quality analyses, which should be offered on a fee basis to storage units and, in particular, to the new agro-food industry in Rwanda. For this latter group, other forms of collaboration and of technical services should be explored. The service and extension functions including training should receive priority in these future activities, whatever the level of available funding.

Nevertheless, research is the foundation for Rwanda's future capacity to reduce post-harvest losses. It is an essential investment for the future. But the research must have an applied orientation and concentrate on specific problems encountered in Rwanda. The center's strength will reside in the resolution of problems and the conduct of applied research on post-harvest systems in Rwanda.

Therefore, if funds are limited, at least the current levels of staffing should be maintained, and the activities of extension, training and service should be emphasized. The Rwandan and American Governments have made a large initial investment. This investment will only provide returns if this nucleus of staff and infrastructure is retained and supported. This ensemble is well placed at present to provide an array of services in the area of food technology, and thus have an impact in the immediate future on the improvement of grain quality and on the reduction of storage losses.

New funds are already available for continuation of certain research and certain service and extension activities. When additional funds are available, a larger range of services will be possible as other staff and equipment are added. First and foremost, however, the expertise which exists now must be mobilized and utilized to the maximum in order to resolve the country's post-harvest problems.

First priority must also be accorded to resolving the problems of storing beans and sorghum. Because of the importance of the production of these two crops, the dependence of the population on them, and the information base already accumulated on these two compared to other crops, it is likely that working on beans and sorghum will ensure the greatest immediate impact. Work should be pursued on other food products if additional funding is obtained.

A summary of what are considered the general priorities is as follows:

(1) Service and extension activities (training included) over research;

(2) Beans and sorghum over other commodities; and

(3) Problems of storage over those of the food processing industry (one must identify the problems and their importance in order to evaluate the expected benefits and therefore determine the financial resources to allocate to specific areas).

With respect to research, priority should be given to the following problems or topics:

(1) Insect control at all levels of storage;

(2) Hermetic storage (including underground storage);

(3) Detection and control of rodents;

(4) Quality standards and norms for food products;

(5) Techniques for monitoring stocks; and

(6) Food technology.

VII. DEVELOPMENT OF ORGANIZATIONAL STRUCTURE AND RELATIONSHIPS

To date the GRENARWA II-Research Project has been "housed" and attached to OPROVIA as an integral part of the second phase of GRENARWA which was itself integrated into the administrative structure of OPROVIA as its Food Product Division.

The three parties (OPROVIA, University of Minnesota, and USAID) are satisfied with the logistical and administrative support that OPROVIA has provided the GRENARWA II-Research Project since the very beginning. Thanks to this support, the Project has not only been a success but has grown and established its structures. The three parties believe that the current level of the Project's evolution within OPROVIA is an incontestable guarantee of a promising post-project future. For reasons of continuity, experience and logistics, the partners therefore recommend that the Project continue to be attached to OPROVIA and remain within its physical facilities.

Furthermore, the partners consider that not only must OPROVIA maintain a quality analysis laboratory within its walls given its own objectives, but at the same time this laboratory must be the preponderant tool in the accomplishment of the objectives of the second phase of this Project. In addition, it is advantageous to place these activities in an organization which has a direct interest in the results. The Project is thus best housed and retains closer attention within OPROVIA, which of course has accepted and helped shape it since its inception. This evolution has also been expected in the planning of OPROVIA's activities for the next five years and in the Performance Improvement Plan of OPROVIA prepared by the "Centrale Comptable et Organisation" under the auspices of the Office of the President of the Republic.

Because the Project continues to have external financial support, for reasons of efficacy, the Project must continue to be autonomous in its management, and its accounting must be separate from that of OPROVIA.

The goal for the mid-term is that this Project, which is now evolving within OPROVIA, will become a "National Center for Post-Harvest Technology" with diverse activities (service, extension, and research) focused on the technology of post-harvest systems. In the long-term, this Center could gradually evolve into an "Institute of Food Technology of Rwanda (ITAR)". An autonomous institute of this kind specializing in post-harvest technologies would find its place downstream from ISAR which has specialized in pre-harvest research, and would thus complement current agricultural research in the country by its specific contributions towards enhancing the value of food products.

Project management of the first phase of the GRENARWA II-Research Project fostered collaboration with national and international institutions and organizations interested not only in research but also the application of research results (ISAR, UNR, MIJEUCOOP, Agricultural Development projects, military camps, nutritional centers, universities and foreign research organizations, etc.). The three parties are satisfied with this collaboration, which has been a distinctive characteristic of the Project, and expects that these linkages will be further strengthened in the next phase.

A P P E N D I C E S

APPENDIX VIII.1

LIST OF THE PRINCIPAL OFFICIAL DOCUMENTS OF THE GRENARWA II-RESEARCH PROJECT

1. Grant Agreement between the Government of Rwanda and the United States Agency for International Development (USAID), signed June 7, 1982.

2. Project Paper, GRENARWA (Food Storage and Marketing-FSM) II, USAID, 1983.

3. Project Paper Supplement approved by USAID June 20, 1985.

4. Plan de Travail Budgetisé (Work Plan and Budget-Revised). Exercices 1983-1986, GRENARWA-Deuxième Phase, Projet GRENARWA II (696-0116), June 1983.

5. Plan de Travail Rebudgetisé (Work Plan and Budget-Revised, Exercices 1983-1986, GRENARWA-Deuxième Phase, Projet GRENARWA II (696-0116), October 1983.

6. Request for Technical Proposal - RFTP No. ROD/LAC-83-004, prepared by USAID. Local Crop Storage (Research Component) in Rwanda. 1983.

7. Response to a Request for Technical Proposal - RFTP No. ROD/LAC-83-004. Local Crop Storage (Research Component) in Rwanda. Submitted by the University of Minnesota to USAID, May 5, 1983.

8. Contract between USAID and the University of Minnesota, signed November 3, 1983. Local Crop Storage. Cost Reimbursement Contract No. AFR-0107-C-00-4001-00.

9. Contract between USAID and the University of Minnesota, amended in 1985. PIO/T 696-0116-3-30042.

10. Project Implementation Letters (PIL) Nos. 1 to 13, USAID, GRENARWA (FSM) II-Research Project, various dates.

11. Programme de Recherche (Research Program), Projet GRENARWA II-Recherches, May 1985.

12. Quarterly Progress Reports, GRENARWA II-Research Project, January 1984 to December 1986 (12 reports).

13. Rwanda Trip Reports, Technical Advisors (Faculty) and Administrators of the University of Minnesota, various dates between November 1983 and April 1988 (see Appendix VIII.4 for the list and dates of these trips).

14. Evaluation Interne de la Mi-Projet/Mid-Project Internal Evaluation (January 1984-December 1985), GRENARWA II-Research Project, June 1986.

15. Final Technical Reports of the Research Components (6 reports and a catalog of bean varieties), GRENARWA II-Research Project, various dates.

16. Synthesis of Research, Recommendations, and Prospects for the Future. Final Technical Document of the Project. GRENARWA II-Research (LCS/FSM) Project, June, 1988.

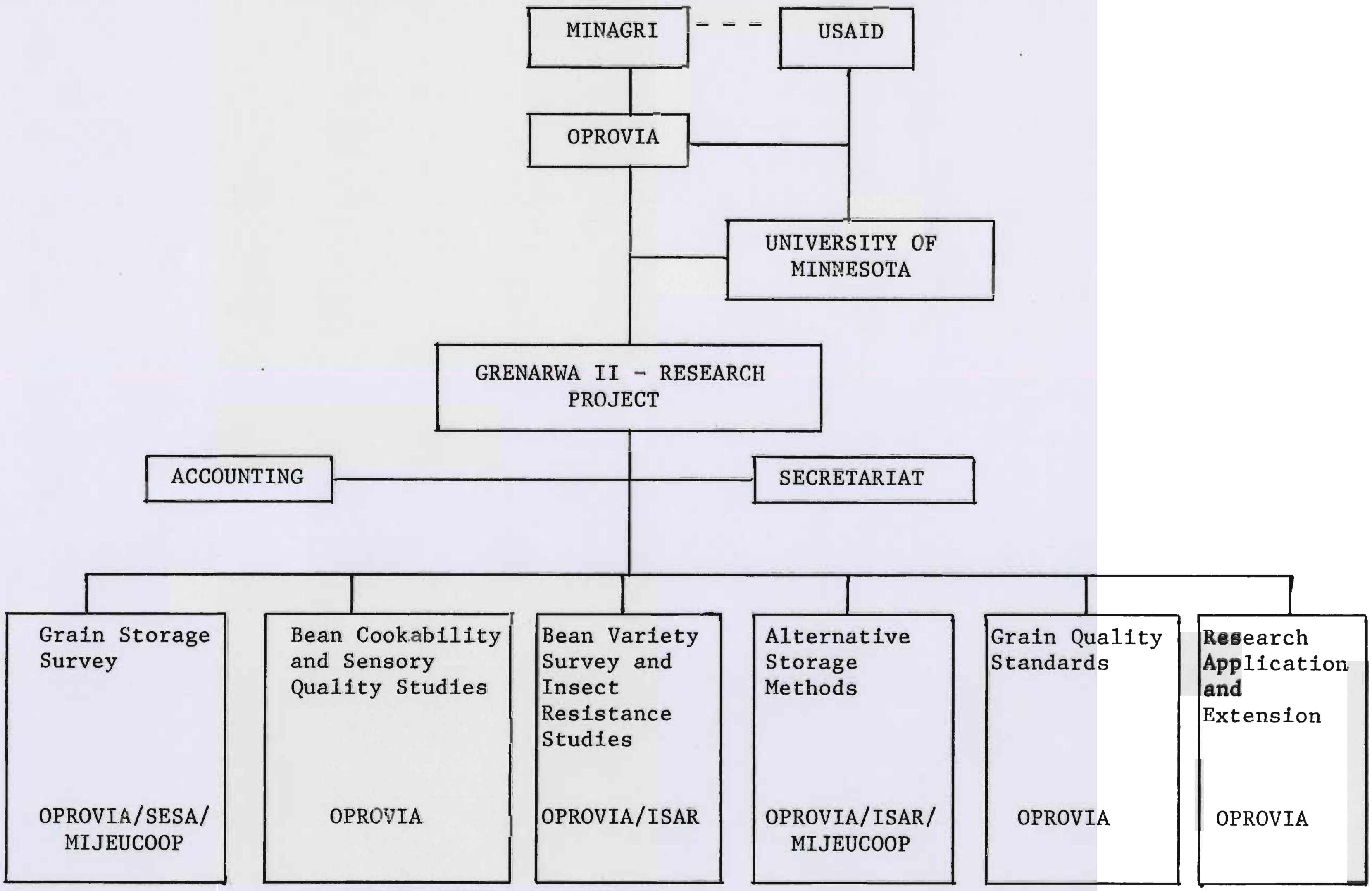
17. Official Project Communiqués:

- Final Joint Report on the Modalities of Implementation of the GRENARWA II-Research Project, prepared in Kigali, November 22, 1985.

- Final Joint Communiqué on the GRENARWA II-Research Project, prepared in Kigali, November 4, 1986.

- Final Joint Communiqué on the Synthesis of Research of the GRENARWA II-Research Project, prepared in Minnesota, May 18, 1987.

ORGANIZATIONAL CHART OF THE GRENARWA II-RESEARCH PROJECT



(Administrative and Technical)
OF THE
GRENARWA II-RESEARCH PROJECT

Component	Date Started	Name	Title	Training	Date hired	Admin. entity	Date departed
Coordination	2/83	NTIBITURA Bonaventure	Directeur de l'OPROVIA	Sciences Militaires et Sociales		GOR	
Direction/ Administration (Project Management)	2/83	CLARKE Steven	Chef de Projet	Agronomie (Masters)	2/84	UM	2/87
		KAYINAMURA Phocas	Homologue du Chef de Projet	Génie Rural (Ing.Ag.)	2/83	GOR	
		MWISENEZA Beatrice	Secrétaire-Comptable	Secrétariat-Com. (D7)	5/84	Projet	
		MUREKEYISONI Domithille	Secrétaire-Dactylo	Secrétaire-Adm. (D5)	7/84	Projet	
Enquête sur les Conditions et les Méthodes de Stockage des Grains au Rwanda (Grain Storage Survey)	1/84	WITTENBERGER Ted	Responsable du Volet	Education Agricole (BS)	1/84	UM	7/85
		MUNYARUSHOKA Evariste	Homologue du Resp. du Volet	Agronomie (Ing.Ag.)	8/84	GOR	
		NIZEYMANA Edouard	Technicien de labo	Agronomie (A2)	5/84	GOR	
		KAREKEZI Théodore	Technicien de labo	Humanités Scient.	3/86	GOR	
Inventaire des Variétés de Haricots Cultivées au Rwanda (ISAR) (Bean Variety Survey)	1/84	LAMB Elizabeth	Responsable du Volet	Horticulture Entomologie (Masters)	1/84	UM	12/85
		HARELIMANA, Germain	Technicien	Agronomie (A2)	2/84	GOR	9/85
		UWIMANA, J. Damascène	Aide Laborantin	Etudes Artis. (CERAR)	6/84	Projet	7/87
Etude sur les Qualités Sensorielles et l'Aptitude des Haricots à la Cuisson (Bean Cookability Studies)	2/84	EDMISTER Judith	Responsable du Volet	Sciences Alimentaires (Masters)	2/84	UM	6/86
		UMUGWANEZA, J. de Chan.	Homologue du Resp. du Volet	Nutrition (A1)	8/84	GOR	9/85
		SERUGENDO Assumani	Homologue du Resp. du Volet	Nutrition (A1)	10/85	GOR	
		MUREBWAYIRE Vénéranda	Technicienne de labo	Hum. Techn. Fém. Péd. (D7)	3/84	GOR	8/86
		BIZIMANA Augustin	Technicien de labo	Hum. Pédagogiques (D6)	3/86	GOR	
		MUKAKUNZI Julienne	Technicien de labo	Infirmière (A2)	3/86	GOR	

LIST OF PERSONNEL
(Administrative and Technical)
OF THE
GRENARWA II-RESEARCH PROJECT

Component	Date Started	Name	Title	Training	Date hired	Admin. entity	Date departed
Etude de la Résistance Différentielle des Variétés de Haricots Cultivées aux Insectes de Stockage (ISAR) (Insect Resistance Studies)	1/84	LAMB Elizabeth	Responsable du Volet	Horticulture/ Entomologie (Masters)	1/84	UM	12/85
		HARELIMANA Germain	Technicien	Agronomie (A2)	2/84	GOR	9/85
		UWIMANA J. Damascène	Aide laborantin	Etudes Artis. (CERAR)	6/84	Projet	7/87
		KAYITARE Joseph	Homologue du Resp. du Volet	Entomologie (Masters)	12/85 (Mi-t)*	GOR	
Etudes des Méthodes Alternatives de Stockage des Grains (Alternative Storage Methods)	3/85	HANEGREEFS Paul	Responsable du Volet	Génie Rural (PhD)	3/85	UM	11/87
		SEKANABANGA Claudien	Technicien principal	Agronomie Trop. (A1)	3/86	GOR	9/87§
		KARENZI Seleman	Technicien	Electro-mécan. (A2)	4/85	GOR	
Développement d'un Système de Standards et de Normes de Qualité du Haricot et du Sorgho au Rwanda (Grain Quality Standards)	5/86	BYLENGA Sharon	Responsable du Volet	Agro-écon-omie (Masters)	9/86 (Mi-t)*	UM	2/87

* Mi-t: Mi-temps (part-time)
§ décédé en septembre 1987
(deceased in September 1987)

APPENDIX VIII.4

LIST OF TECHNICAL ADVISORS (FACULTY) AND ADMINISTRATORS OF THE UNIVERSITY OF MINNESOTA ASSOCIATED WITH THE GRENARWA II-RESEARCH (FSM) PROJECT AND THE DATES OF THEIR TRIPS TO RWANDA

Component	Technical Advisor	Department or Discipline	Date of Trip
Administration and Coordination	Dr. Delane Welsch	Assistant Dean and Director of International Agricultural Programs	Oct 1985 Oct 1986
	Dr. Florence Dunkel*	Project Coordinator	Nov 1983 Apr 1984 Nov 1984 Apr 1985 Nov 1985 Nov 1986
Storage Survey	Dr. Florence Dunkel*	Entomology	Apr 1984 Nov 1984 Apr 1985 Nov 1985
	Dr. Richard Meronuck	Plant Pathology	May 1984
	Ms. Nancy Read	Entomology	Jun 1984
Bean Variety Survey	Dr. Leland Hardman	Agronomy	Mar 1984 Jan 1985
Bean Cookability	Dr. William Breene	Food Science	Feb 1984 Jan 1987 Apr 1988
	Dr. David Thompson	Ag Engineering/ Food Science	Nov 1983 Jan 1985
	Dr. Zata Vickers	Food Science	Apr 1984 Jul 1985
Insect Resistance	Dr. Florence Dunkel*	Entomology	Nov 1984 Apr 1985 Nov 1985

Component	Technical Advisor	Department or Discipline	Date of Trip
Alternative Storage Methods	Dr. Vance Morey	Ag Engineering	Sep 1985 Sep 1986
	Dr. Harold Cloud	Ag Engineering	Dec 1984
	Dr. Florence Dunkel*	Entomology	Apr 1985 Nov 1985 Nov 1986
Quality Standards	Dr. Jerome Hammond	Ag Economics	Jul 1984 Sep 1986
	Dr. Jean Kinsey	Ag Economics	Jul 1984

* All the visits of Dr. Dunkel usually combined her functions as Project Coordinator and Technical Advisor for certain research components.