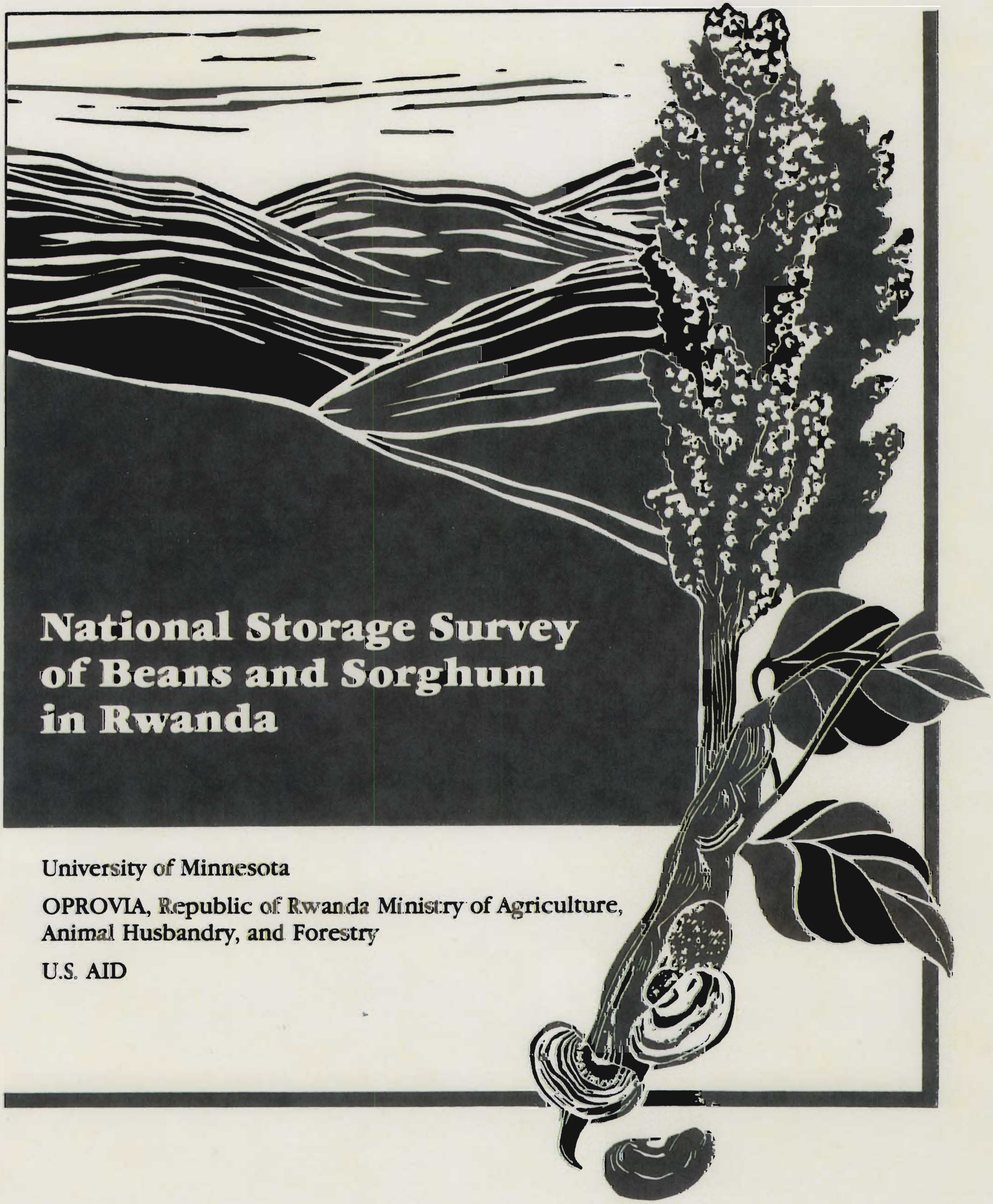

National Storage Survey of Beans and Sorghum in Rwanda

University of Minnesota

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

U.S. AID

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Minnesota Agricultural Experiment Station, University of Minnesota

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TABLE OF CONTENTS

PREFACE

This report describes the research conducted in Rwanda, East Central Africa, by the component entitled "Survey of the Methods and Conditions of Grain Storage in Rwanda" of the Local Crop Storage/Food Storage and Marketing-Phase II (FSM II) Project jointly financed by the Rwandan and American Governments (USAID).

The research work was carried out during 1984-1986 in cooperation with the National Office for the Development and Marketing of Food and Livestock Products (OPROVIA), a semi-autonomous agency of the Rwandan Ministry of Agriculture, Animal Husbandry, and Forestry (MINAGRI). Technical assistance was provided by the University of Minnesota (USA) through USAID contract No. AFR-0107-C-00-4001-00.

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Special thanks are also extended to Project technicians, Edouard Nizeyimana and Theodore Karekezi, for their assistance in data collection and laboratory quality testing. We are also grateful to the staff of OPROVIA, especially those in GRENARWA, who facilitated our task. We acknowledge the assistance provided by MIJEUCOOP and IWACU. We are indebted to all the managers of the OPROVIA warehouses and the cooperative silos and hangars who gave us their time and ideas. We are greatly appreciative of the assistance and expertise of Serge Rwasasirabo, Yvan Dejaegher, and other staff of the Agricultural Survey and Analysis Project, in helping organize and conduct the farm survey.

The authors wish also to express their appreciation to those people on the Minnesota side who assisted in designing and carrying out the survey and preparing this report: Dr. Larry Cutkomp and Dr. Bhadriraju Subramanyam, University of Minnesota, Department of Entomology; Jill Pokorny, University of Minnesota, Department of Plant Pathology, and Steve Clarke and Dr. Paul Hanegreefs, Chief of Party and Resident Scientist, respectively, of the USAID-Rwanda Local Crop Storage Cooperative Research Project. For typing this manuscript we gratefully acknowledge the work of Ruth Harter, Elvira Miranda, Lucy Shrader and Gretchen Wolfangel.

EXECUTIVE SUMMARY

The objective of this research was to determine the extent of storage losses at various levels in the Rwandan food system (farms, cooperative silos and hangars, private traders and OPROVIA warehouses) as well as the relative importance of the factors causing those losses. Forty-seven farms, twenty-one cooperatives and three OPROVIA warehouses were selected and intensively monitored for changes in stored bean and sorghum quality during a period of at least one year. For both bean harvests (June 1984 and January 1985) and sorghum harvests (1984) utilized in the survey, farmers experienced low yields due to unusual rainfall patterns.

Measurements of loss were obtained by developing a consumer index and a dry weight loss per unit volume. These loss figures were compared with levels of 10 categories of observable damage, population levels of insect species and percent incidence of seeds yielding storage fungi.

The most significant findings were that levels of total damage were almost twice as high in beans stored in the OPROVIA warehouses than in on-farm storages, with damage levels at the cooperatives falling between those of farms and warehouses. The poor quality beans received by the warehouses, however, did not change significantly except for a decline in ability to germinate (from 82% to 27%), during more than one year of storage. On the other hand, the percent beans classified as inedible increased during warehouse storage from 13% to 21% between reception of stocks at 5 months and 13 months after harvest. The highest mean consumer index of loss for inedible beans on farm was 12.4% ± 2.6 SE for June 1984 harvested beans after 5 months storage in the Kibungo area. For OPROVIA warehouses the highest mean loss index was 21.1% ± 0.8% SE for the same harvest in the same area after 13 months of storage. For the consumer index of not plantable the highest mean values were for the same crop year and the same location (21.5% ± 2.5 SE on-farm and 29.7% ± 1.2 SE in the Kibungo warehouse). Beans were placed into on-farm storage between 12.7% and 15.7% moisture content.

On the farm there was a large season-to-season difference in storage insect infestation which was passed on to the subsequent levels of storage. The main insect species in beans, <u>Acanthoscelides obtectus</u> Say, reached mean population levels of 131 per kg. in low altitude farms at the end of the storage period for 1984 June beans. The approach of the larger grain borer <u>Prostephanus truncatus</u> Horn into countries bordering Rwanda was reported during the survey period. Preliminary laboratory studies at the University of Minnesota indicated <u>P. truncatus</u> could be a serious threat to beans, especially if stored adjacent to maize and cassava. A national survey of maize stored on-farm and in cooperatives revealed no <u>P. truncatus</u>.

Sorghum was received into on-farm storage between 12% and 13% moisture content. The main insect problem was <u>Sitophilus</u> spp., primarily <u>Sitophilus oryzae</u>, which achieved population levels of 28.3 per kg. The weight loss experienced between the beginning and end of the storage period for the 1984 harvest was 2.6%.

Recommendations for alternative storage methods included the use of sealed underground pits with plastic liners and the evaluation of indigenous Rwandan plants and other materials used by the farmers for storage insect control. It was also recommended that an expanded study of merchant bean and grain quality, storage conditions and marketing patterns be conducted. An expanded on-farm storage survey instrument which was designed and pretested in the field utilizing Rwandan personnel in the Agricultural Survey (ENA) should be conducted. Plans for extension of this information to cooperative managers and suggestions for a system of bean and sorghum grade factors and grade levels have been recommended.

LIST OF SELECTED ACRONYMS

AID..........................Agency for International Development

BGM..........................BUGESERA et GISAKA-MIGONGO

CRS..........................Catholic Relief Service

DERVAM.......................Developpement des Vallees du MUTARA

ENA..........................Enquete Nationale Agricole (National Agricultural Survey)

GOR..........................Government of Rwanda

GRENARWA.....................Grenier National du Rwanda (Food Products Division of OPROVIA)

ISAR.........................Institut des Sciences Agronomiques du Rwanda (Rwandan Institute of Agricultural Research)

MIJEUCOOP....................Ministere de la Jeunesse et du Mouvement Cooperatif (Ministry of Youth and Cooperatives)

OPROVIA......................Office National pour le Developpement et la Commercialisation des Produits Vivriers et des Productions Animales (National Office for the Development and Marketing of Food and Animal Products)

OVAPAM.......................Office pour la Vulgarisation Agropastorale du MUTARA (Office for Range Management Extension in the MUTARA)

SESA (=ENA)..................Service des Enquetes et Statistiques Agricoles (Bureau of Agricultural Statistics and Surveys)

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

A. BACKGROUND INFORMATION ON RWANDA

Geographical Aspects

Rwanda is located 1 to 3° south of the equator in east central Africa and is bordered by Uganda, Zaire, Burundi, and Tanzania. Rwanda covers an area of 26,388 km^2. The topography is hilly with elevations of 950 masl* in the southern region to 4,500 masl in the volcanic region of the northwest (Figure 1). The native vegetation ranges from savannah to highland tropical forest which has now been largely cleared for farmland. Ninety percent of the soils are basic pre-Cambrian. Five percent are alluvial and are found in the marshy areas between the hills. Areas with rich volcanic soils (5%) are characterized by high population densities. Streams, rivers and lakes are well distributed throughout the country. The rainfall is bimodal, with rainy seasons occurring between February and May and between October and December. Total annual precipitation is 800 to 2,000 mm. Average temperatures range from 16 to 24° C, varying with altitude.

Demographic Aspects

The population was 5.5 million in 1982 with an annual growth rate of 3.5 percent, one of the highest in Africa. The population density of the whole country is 200 inhabitants per square kilometer but rises to 400 inhabitants per square kilometer when it is calculated on the basis of arable land area. The population is still largely rural, with only 5 percent of the people living in cities. The rural organization is one of scattered homesteads rather than organized villages.

Political Division

The capitol of Rwanda is Kigali. The country is divided into 10 prefectures, each with a center of government. Prefectures are divided into communes, of which there are 143. Communes are divided into sectors which are further divided into cellules. These units constitute the smallest political unit.

Agriculture in Rwanda

A total of 1,229,600 ha of arable land is available (1980 data). Subsistence farming makes up the greatest part of agricultural effort in the country with each family having about one hectare of disjointed small plots to cultivate. Agriculture is characterized by a lack of mechanization, intercropping, mixed crop and livestock culture and the production of multiple food crops. The cropping seasons reflect the rainfall pattern although a third season is possible in the marshy areas.

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* Meters above sea level.

The most important crops, by harvested area (1978-1980), are beans (*Phaseolus vulgaris*), banana, sorghum, sweet potato, maize, pea, cassava and Irish potato. Maize, pea and Irish potato are most important at the higher elevations. Soybean, peanut, millet, wheat, rice, taro, and yams are also grown, as well as various vegetable crops including tomato, eggplant, cabbage, leek, and onion. Fruits grown include papaya, pineapple, avocado and custard apple. The principal industrial crops are coffee, tea and pyrethurm. Cattle, goats, sheep, pigs, chickens and rabbits are produced. The country has been divided into 12 agroclimatic zones, based on elevation, rainfall, soils and types of agricultural production (Figure 2).

Agricultural Research

ISAR* has primary responsibility for all agricultural research done in Rwanda. Seven branch stations are distributed in various regions of the country. Research is carried out on food and industrial crops, farming systems, forestry, and livestock production. Seldom are postharvest topics selected for research projects. At the headquarters in Rubona, laboratory and field space is available for plant breeding, plant protection, soil and plant chemistry and microbiology. Some research is carried out by the Faculty of Agronomy of the National University of Rwanda (UNR), generally in relation to the training of students.

Bean Production, Storage and Marketing

Beans (*Phaseolus vulgaris*) are the major source of vegetable protein in the Rwandan diet. The estimated consumption of dry beans is 40 kg per person per year. Yields ranged from 417 kg/ha to 975 kg/ha with a nationwide average of 662 kg/ha. The mean yield for the first and most important season, harvested in January, was 760 kg/ha dropping to 475 kg/ha for the second season. Based on national averages, each family plants 0.35 ha to beans, either as a pure crop or the primary component in a mixed crop. Only 10.4 percent of the area used for bean cultivation is devoted to pure crops. On 71 percent of the area, beans are the primary crop and on 18 percent of the area, the secondary crop. The total harvested area of beans is approximately 240,000 ha and the total production in 1984 was 256,306 metric tons.

Beans are stored for seed and food by farmers between harvests. Generally, they are stored in large baskets in the house. Storage cooperatives are organized where farmers may sell their beans with the possibility of purchasing beans at a later time. These cooperatives use hangar or silo-type storage structures. GRENARWA has a storage capacity of 16,000 metric tons of grain, mostly beans and sorghum. The most commonly encountered storage problems of beans are molds, insects, physical changes resulting in cookability problems, and rats.

Marketing is usually done at the local level. An estimated 30 percent of total production is marketed. Excess produce may be sold at harvest or at various times during the year when money is needed. Local merchants also buy and resell beans, generally buying when the prices are low and selling when beans are more scarce and more expensive. OPROVIA also buys beans from farmers and merchants and markets them through the OPROVIA stores.

Sorghum *

Sorghum is the traditional cereal crop of Rwanda. During the last decade the area devoted to this crop has been increased by about 10% and production has risen by 26%. Average yields have increased from 1 to 1.1 t/ha. This increase is the result of the crop being planted in regions only recently occupied by farmers (Bugasera and Mutara). Sorghum is one of the few cereals adapted to conditions in these semi-arid regions.

Sorghum is cultivated at altitudes of between 1,400 and over 2,000 m, i.e., at altitudes exceptionally high for this crop. Many hardy varieties exist, selected for their organoleptic qualities. Sorghum is grown on such a large scale that bird attacks, percentage-wise, do negligible damage except to the very late- and the very early-maturing varieties.

During the last 20 years, ISAR has been working intensively on improving sorghum through mass selection and the development of pure lines from local varieties. Many introductions are the result of joint efforts with ICRISAT, IDRC, CIMMYT, and the Ford Foundation in Lebanon. Results clearly indicate that varieties of Rwandan origin give good yields and that most of the imported material had to be rejected because it was poorly adapted to local conditions. Selections from local varieties have a yield potential of up to 6 t/ha, a satisfactory height, a good-quality panicle and a good level of disease resistance, especially in the high-altitude areas.

Maize *

Maize has not become very popular in the traditional agricultural regions of the central plateau, nor around Lake Kivu. On the other hand, it is becoming increasingly important in the high-altitude regions (above 1900 m) and in the lower regions (below 1500 m). Except for a few farmers (Mutara) which produce and sell a surplus, maize is still grown as a subsistence crop. During the last 10 years, the maize-growing area has been increased by 40% and the production has risen by 56%. The average yields have improved slightly to reach a level of about 1.1 t/ha.

In the Ruhengeri prefecture, a project is now taking shape which could have substantial impact, because in this high-altitude region it may become necessary to find a replacement crop for pyrethrum. The project seeks to produce maize as a cash crop for human and animal consumption.

B. IMPORTANCE OF SURVEY INFORMATION IN DEVELOPMENT OF EXTENSION MATERIALS AND VIABLE MANAGEMENT ALTERNATIVES

Useful applied research comes from a clear understanding of the existing situation, the problems and constraints inherent to that existing system. Successful extension brings applicable research to actual problems as they occur in practice. Successful extension is actually the marriage of a well-done survey of the situation and applied research which solves the problems discovered in a survey. A survey is an essential link between research and extension. It provides direction for both.

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* From: International Service for National Agricultural Research (ISNAR). 1983. "The National Agricultural Research System of Rwanda."

This Storage Survey along with the Bean Varietal Survey form the foundation of AID project No. AFR-0107-C-00-4001-00. Together, they establish the baseline on which the five other components of this project will plan their experimental protocol and interpret the results of the research. Future recommendations in extension programs to improve management at all levels of storage will refer to data contained in these two reports.

In this survey we have obtained information on conditions in which locally grown beans and sorghum from all organizational levels are stored. Storage practices for the June 1984 and January 1985 harvests were followed. Sorghum harvested in July 1984 was also followed. We estimated 2 types of loss and 10 types of damage. We also looked at quality changes over time and pattern of utilization. Because the original Request for a Technical Proposal (RFTP) and contract did not mention the merchant, this portion of the survey is least developed. Future surveys will hopefully include the merchant as well as larger total numbers of storages. Increasing the total number of storages will enable us to make statistically sound inferences between agroclimatic areas.

C. REVIEW OF LITERATURE PERTAINING TO OTHER STORED BEAN AND GRAIN SURVEYS

Stored commodity surveys during the past 10 years (1976-1986) have experienced three distinct trends. These are: a) the increase in the reporting of data which quantify postharvest loss, b) the use of a rapid reconnaisance or farmer dialogue survey to determine storage problems and c) the quantification of time and estimated monetary costs of certain procedures.

First, a much needed change has occurred in the accurate quantification of postharvest loss. The details of the new methods which evolved are discussed in the section of the introduction which follows. With two exceptions, results of these new quantitative methods have been reported only in on-farm situations. On-farm studies are numerous and this review will be confined to those in sub-Saharan Africa, namely Malawi, Burundi, Zambia, Kenya, Central African Republic, Tanzania and Rwanda. On the other hand scant attention appears to have been paid to the primary trading level. This level may be responsible for a high proportion of overall losses especially where price varies by supply and demand, where prolonged trader storage is practiced, and where commodities change hands several times.

A second trend in stored commodity surveys documented during the past 10 years (1976-1986) has been the rapid reconnaisance or farmer dialogue type survey of storage problems. The interview technique has been discussed in Farming System literature for the farm system in general (Shaner et al., 1981) and specifically related to postharvest systems (Harris and Lindblad 1978). A pilot project was sponsored by the Community Development Trust Fund of Tanzania (1977) in which a series of 20 formal meetings in 8 weeks led to improved designs and management methods for a village in the Morogoro District. This resulted in the farmers collectively building and evaluating modifications. Training materials developed during the process then formed a resource for review and teaching of others. Apparently objective analyses of quality were not made. Only rice, sorghum and maize were discussed, not beans. A study of losses during handling and storage of millet in Mali concluded that weight losses alone are of limited value (Rowley 1984). It is only when they are combined with manager interviews that attitudes toward loss can be obtained. These attitudes combined with quantitative loss data are essential for the successful introduction of loss reduction measures.

A third trend that appeared in survey reports during the 1976-1986 period is the quantification of time and estimated monetary costs of certain procedures in postharvest management. In the 13 month on-farm Zambia study (Adams 1977b) it was determined that the likely cost-benefit ratio was 1:1.6 for a farmer storing maize in husks and 1:2.4 for a farmer storing untreated shelled maize. One previous survey of Rwandan storages has been reported (Durnez and DeJaegher 1980). Its scope was small (one commune in Butare Prefecture), but it formed an important preliminary picture used to develop the project identification document which planned the present survey. Among numerous other survey data and laboratory analyses, this study compared the cost/benefit of various local insecticidal preparations, such as ashes or kaolinic soil, with that of malathion.

D. REVIEW OF LITERATURE PERTAINING TO LOSS ASSESSMENT AND SAMPLE PROCEDURES

The reduction of food losses by 50 percent in 1985 was set as a target by the seventh special session of the United Nations General Assembly in 1975. This has generated much work on loss and its assessment. In 1978 the available information on losses in cereals and pulses was summarized by the U.S. National Academy of Sciences.

Calculations of actual weight loss from samples of a stored commodity follow one of two basic formulae. The first is simply the percent dry weight loss. This requires the moisture content and weight of a standard volume of a reference sample without damage or just after harvest and the same from a sample of the same stock at some point in the future (Adams 1977b)

$$\% \text{ dry weight loss} = \frac{a-b}{a} \times 100$$

where a = dry weight of a standard volume of the reference sample and b = dry weight of the standard volume of the field sample.

The second type of dry weight loss involves the separation of the sample into damaged and undamaged kernels or grains and the weighing of each of these groups. Time costs per sample analyses are greater with this method as compared with first. This formula is based on (Adams 1977b):

$$\% \text{ weight loss} = \frac{(UNu) - (DNd)}{U(Nu+Nd)} \times 100$$

in which U = weight of undamaged grains
D = weight of damaged grains
Nu = number of undamaged grains
Nd = number of damaged grains

An intrinsic problem of this method is missing the kernels damaged by insect larvae of internal infestors. Dissection is therefore recommended to overcome this problem (Hamilton 1975). A synthesis of these 2 basic methods has been proposed (Proctor and Rowley 1983). This method calculates dry matter in a sample of varying size which is then adjusted to have 1000 kernels. The same rules hold for using a representative sample as do for the other methods. Because damaged and undamaged grains are not separated at any stage, it is not clear how this differs from a dry weight loss per unit volume in 2 samples taken from the same lot at the beginning and end of a time period.

The references prior to 1977 which describe postharvest loss in tropical and subtropical countries have been summarized and rated by type of quantification method (Adams 1977a). In another summary of the literature regarding estimation of losses (Adams 1977c), pulses appear almost as popular as cereals for experimental investigations but 70% of the total work (field and laboratory) had been done with cereals. When the numbers of loss estimation references from field work is compared by geographical area, a very small proportion (12%) of the studies that have been done in central and east Africa have been done on beans or other pulses. In a Zambian study (Adams 1977b) the second formula was found to be unreliable at high damage levels and the first formula described was used in their loss estimates. The Rwandan pilot storage study (Durnez and Dejaegher 1980) included 20 farmers in a single colline (equivalent to a neighborhood). Weight loss was determined during the storage period for both beans and sorghum. Mean percent weight loss recorded for sorghum was 1.8% with a range from 0. to 11.5%. For first season beans (harvested in January) this figure was only 0.07%. For beans harvested in June this figure was 0.25% after 4 months storage. Many figures for many countries for percent loss are available in the literature. Often these are percent seeds attacked and not actual loss, either by weight or by a consumer index. Ongoing studies which include weight loss during storage are being conducted in Kenya and the Central African Republic. Here again these will include on-farm levels only and are confined to one region of the country.

Several other characteristics of labor intensive grain storage systems are important to summarize. In an analysis of general quality which includes the percent weight of dockage and damaged kernels, labor intensive agricultural systems typical of developing countries often have an order of magnitude lower level of mechanical damage and dockage than similar categories of stored grain in developed countries (Dunkel et al., 1985). Also due to the value of labor and the relatively high cost of mechanical moving equipment, large grain storage facilities are usually set up with the grain or beans in bags. Obtaining a representative sample from bags for quality analysis is very difficult either as they are received at the facility or during long-term storage. Because of the clumped distribution of insects (due to behavioral characteristics) and the high proportions of the insect populations on the bottom of the bag (due to gravity), the only accurate way to sample a bag is to empty the entire contents over a sieve or series of sieves. Two examples have been used successfully for this, the produce flow sampler and the sack sieve (Golob 1976). Selection of which sack in a lot is to receive this analysis is also a sampling problem. Without this thorough look inside the bag selected, however, even the most adequate sampling pattern would give misleading results.

Weight loss data based on damaged kernels using values for kernels determined to be damaged or undamaged by an investigator have the disadvantage of not accounting for what the consumers actually consider as loss in practice and what is actually discounted in the marketplace. Therefore, there is a third type of loss estimation of dry unprocessed cereal or bean products: a consumer rating of the severity of various damage types. Although this has been suggested in the literature (Adams 1976), data utilizing such an index of perceived consumer loss has not been reported. The present survey represents the first report which combines a consumer index with statements of loss.

E. DEVELOPMENT OF WORKPLAN FOR THE PRESENT SURVEY

The University of Minnesota proposal to AID gave two objectives for this component:

1.) To conduct a survey of the methods and conditions of indigenous storage of food grains and pulses in all areas of Rwanda.

2.) To estimate the quantity stored and the losses from the different methods over time.

The proposal, submitted May 5, 1983, suggested monthly sampling at the farm level following an entire crop year storage which for beans would begin in January and for sorghum in July. The workplan proposed included a detailed review of other surveys (particularly in the Great Lakes Region of Africa) and of a pilot study in Rwanda. Careful attention would be placed on a 6-week preharvest fact-finding survey. Grain and bean quality as well as storage structure data and storage environment data would be obtained. Specific quality tested would be % moisture content, % dockage, number and species of insects sieved and obtained after incubation, mold damage, insect damage and test weight. Test weight and % moisture content were to be used for determination of dry matter weight loss. The proposed workplan also included making suggestions of alternate methods and structures where losses were a serious consideration. Finally, the outcome proposed was to include recommendations for development of a program of extension to farmers.

The contract signed November 5, 1983 added "cooperative and private trader and GRENARWA warehouse storage" to the levels to be surveyed and receive extension recommendations. It was also added that the "quantity marketed" would be estimated.

The final workplan was written after a presurvey was completed in April 1984, and was approved May 1984 by the Government of Rwanda and AID. The workplan included all of the aforementioned survey categories as well as an analysis of correlations between the 3 altitudinal regions. In addition to the quantity marketed, the workplan included quantity "consumed and utilized." It was also added that maize stocks should be surveyed for the presence of Prostephanus truncatus, an insect which had become in the year following the proposal a local threat to seed corn and to stored unfermented cassava and possibly also to beans in Rwanda. The workplan specified that 18 farmers, 10 cooperatives and one GRENARWA warehouse in each of the agroclimatic zones would be sampled. During a reconnaisance visit to Rwanda immediately after the contract was signed, it was determined that farmers chosen could be a subset of the national agricultural survey (ENA) presently underway. At the government warehouses set-aside piles of bags representing one-fourth the normal stack of the warehouse would be constructed. (These were completed September 1984). For the commercial level, 10 merchants would be sampled for each commodity as they sold them to the warehouse. For farmers the frequency of sampling described in the proposal was reduced to once every two months, with similar sampling intervals at other levels. For the laboratory analysis of quality, 8 additional damage categories were added to those proposed in 1983. An analysis by seed type was developed for beans in a presurvey and included in the workplan to obtain information on consumer-preferred loss for planting and eating.

Due to recent reports of aflatoxin problems in neighboring countries, it was also added to the workplan to analyze a subsample from each level of incidence of beans and sorghum yielding certain species of storage fungi, including *Aspergillus flavus* which produces aflatoxin.

After the first months of the survey several revisions had to be made in sampling intensity due to the time required to traverse roads to farms and cooperatives and due to the low yields from the June 1984 bean harvest. The major changes were 21 rather than 30 cooperatives, and on many farms no second sampling was possible for that crop.

II. MATERIALS AND METHODS

A. SELECTION OF SITES SURVEYED

Rwanda can be divided into three major agroclimatic zones (Figure 1). These zones are based in large part on altitudinal variation. One of the original intents of the survey as requested by AID and GOR was to make comparative statements on storage conditions between the three regions here defined.

Low altitude (less than 1500m) covers the entire eastern portion of Rwanda.
Medium altitude (1500-1900m) is characterized by the central plateau which extends from the Burundi border through the midsection of the country into Byumba Prefecture.
High altitude (greater than 1900m) is distinguished by the Congo-Nile Crest and the high plateau of the north (Figure 1).

For several agricultural studies and surveys that have been conducted and that are presently underway in Rwanda, these 3 regions have been further divided into 12 agroclimatic regions (Figure 2) (Delepierre 1975). These 12 regions define soil type within altitude. The 3 main areas covered by this survey correspond to the following agroclimatic areas (Figure 3):

High Altitude	=	Lava Soil (4)
		Congo-Nile Crest Highlands (5)
		Buberuka Highlands (6)
Middle Altitude	=	Central Plateau (7) and Granitic Dorsal (8)
Low Altitude	=	East Plateau (11)
		East Savannah (populated portion) (12)
		Mayaga (9) and Bugesera (10)

Regions number 1 and 2, Imbo and Impara were not included in the survey because of logistical problems in reaching those areas.

The specific geographic work areas for the farm storage, cooperative storage and GRENARWA surveys were defined as follows. Kibungo Prefecture in the south-west was chosen to represent the low altitude. Butare and Gitarama Prefectures were chosen to represent the mid-altitude. Ruhengeri, Byumba and Gisenyi Prefectures were chosen as the high-altitude research area. The GRENARWA storages (warehouses) used for this study had been selected by OPROVIA/GRENARWA prior to the commencement of research. These three warehouses are situated within the three altitudinal zones at the following altitudes:

Kibungo	low	1675m
Nyanza	medium	1740m
Kora	high	2415m

(Note that the Kibungo warehouse is above 1500m but this warehouse is located in a low area and receives beans and grain from low altitude farms).

The Kibungo and Nyanza warehouses are located about two hours drive from Kigali. Kora warehouse presented logistical problems for most of the sampling period due to road construction between Kora and Kigali. Now that the road is finished, it can be reached in a 2.5 hour drive from Kigali.

Site selection for the farm level storage survey was seriously impaired by two consecutive bad harvests for beans and a poor sorghum crop. The sites represented a subsample of the farm families used by the National Agricultural Survey (Enquete Nationale d'Agriculture or ENA). The Agricultural Survey (ENA) is now a Rwandan Government bureau (SESA) which originated as a USAID project and still receives AID funding. Families within the Ag Survey network were preferred because they had been visited by interviewers in the past and it was presumed that they understood the importance of providing accurate information. They were also more likely to allow an interviewer to enter the house for the purpose of taking samples and observing storage conditions.

The ENA Survey had been following farm families in 1489 sectors throughout the country since 1983. Sectors for this study were chosen with the use of a random number table. Three sectors were chosen from a list of ENA Survey sectors in Kibungo Prefecture (low altitude) and of these 12 farms were selected. Likewise, three sectors were chosen from combined ENA Survey lists from Butare and Gitarama Prefectures and 37 farms were selected for medium altitude. Three sectors were chosen from combined lists of Ruhengeri and Gisenyi Prefectures and from these 30 farms were selected for the high altitude (Table 2a, Figures 3, 4, 5).

The three sectors in the medium altitude were first visited in April 1984 just prior to the advent of the bean harvest.[1] It was evident by mid-May that all Rwanda was experiencing a poor harvest. A GOR field loss estimate for beans in Gisenyi Prefecture was 60-70%. In this area the average precipitation for April is 182mm. During April of 1984, however, the total was 12mm. Visits to the randomly chosen sectors showed that farmers had harvested and were storing very small quantities. The survey design intended that repeated samplings be taken over time from the same stocks. It was obvious during the first on-farm visits that most farms in the original randomly chosen sectors did not have sufficient stocks to allow repeated sampling. The grain would be consumed before the second visit. Additional sectors were chosen and when visited, revealed the same situation. Random sampling was not possible and much time was lost in repeated visits to unproductive sectors. Farms were selected on the basis of size of stocks in storage, the minimum being set arbitrarily at 100 kgs. The greatest difficulties in site selection were encountered in the low altitude and high altitude regions. Sites had to be chosen outside the predefined prefectures. Additional sites were finally found in low altitude Kigali prefecture to augment those from Kibungo and farms in high altitude Byumba prefecture were added to those chosen in Ruhengeri and Gisenyi Prefectures.

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1 Bean harvest times vary greatly throughout Rwanda. Generally, the first beans are harvested in the lowlands or marsh. The next harvest is in the low altitudes and the last harvest is in the high altitude areas.

For sorghum and the main harvest of beans (December/January) the same farms were used with a few substitutions (Table 2a, Figure 5). The December bean harvest is generally the major harvest of the year but stocks in 1985 were unusually low. As previously stated sorghum is harvested once a year. Even though sorghum is a somewhat drought resistant crop, the harvest was very low. In order to facilitate a survey which covered 2 bean harvests as well as sorghum, farms were chosen which held stocks of both crops whenever possible.

Sorghum site selection as well as site selection for beans was difficult because of small quantities harvested and placed in storage. Even though farms with the largest quantities in storage were chosen, the attrition rate by the time of second sampling was high. Attrition rates of the selected sites (i.e., no stocks by the time of second sampling) were as follows:

Sorghum 1984	59%
January 1985 Beans	52%
June 1984 Beans	62%

An estimate of farm level losses over time is therefore difficult to make. The analysis presented here is based on not just one but three poor harvests.

Site selection of cooperative silos and hangers was more difficult than the farm level. The Local Crop Storage office of MIJEUCOOP (Ministere de la Jeunesse et Du Mouvement Cooperatif) and the CRS (Catholic Relief Services) provided lists of their cooperative storage units. The Inspector of Cooperatives was visited in each of the 5 prefectures. Due to the gravity of the poor harvest most cooperatives received little or no stocks of beans and sorghum during most of the survey period. A total of 21 cooperatives (12 silo type and 9 hangar type) were selected (Table 2.b. and Figure 6) but stocks of local beans and sorghum remained low. The reception of tons of food aid given to Rwanda by donor countries further complicated the survey. These foodstuffs (American sorghum and maize, Canadian beans and peas, and European wheat) were mostly distributed through the coops. The surveyed stocks of local beans and sorghum were frequently displaced. To compensate for these setbacks the cooperative survey continued until January 1986.

B. SAMPLING PROCEDURES

Farm Level

Since in all cases beans were stored in the house, it was necessary to gain admittance into the house - family dwelling so that the stock could be sampled and storage conditions observed. Some individuals were apprehensive about allowing strangers (especially a foreigner) into the house. This problem was encountered particularly in cases where the storage container was held in a sleeping room. Careful explanations of our intent were necessary. This coupled with the fact that all respondents were part of the National Agricultural Survey and had some experience with interviewers somewhat facilitated the storage survey.

Once the storage container was identified, a sample was taken from just below the surface with a metal cup and placed in a plastic (whirlpac[R]) sack. If beans were held in more than one container, a composite sample was obtained.

Temperature readings were taken in each stock with a Dehlmhorst temperature probe (Model TM-2) type electronic thermometer. The stock temperature was obtained by inserting the probe into the bulk until the tip of the probe was in the center of the bulk. Ambient temperatures were taken with the same device in the area adjacent to the container. Frequent equipment problems were encountered and in many instances it was impossible to obtain relevant temperature data.

Observations of beans/sorghum were made and the overall storage conditions were recorded on the survey form (Figure 7). The observer would note any visible insects and fungal growth, any adjacent storages of other commodities (maize, cassava, coffee, etc.) and the general storage hygiene and practices.

Cooperative Level

Cooperative storage consisted mainly of three forms; bulk in silos, bagged in hangars, and bulk in hangars. The latter form was not the intended mode for a hangar but was frequently encountered due to a nationwide shortage of jute and plastic fiber sacks. Therefore, cooperative hangar managers were sometimes obliged to pile large quantities of beans and sorghum on the floors.

In those hangars that did have sacks, the bagged commodities were often piled haphazardly making random sampling difficult. Composite samples were taken from five to seven different bags with the use of a trocar (spear trier).

Hangars with bulk piles were samples with a tin cup providing the bulk was not very deep (over 50 cm). Five samples were taken in such a bulk, one from the center and four from each extremity. In deeper bulks, a deep cup probe was used and composites were formed from the top, bottom and middle of the bulk. Some hangars were encountered with bagged produce mixed into the bulk. Care was taken to obtain relevant sub-samples from the bags. This was dependent on the overall volume or number of haphazard bags encountered in or adjacent to the bulk. In general, random sampling in hangars was difficult.

In silos, the deep cut probe was used to take samples from the center surface, middle and bottom of a compartment (in sorghum) whenever possible. This was not feasible when the silo was full due to the position of access hatch (loading port). The Rwandan cooperative silos are cubes with the access hatch and ladder invariable placed at a corner rather than in the middle. In such cases as when the compartment was full, a surface sub-sample was taken at the hatch and the subsequent sub-samples were taken with the probe angled as much towards the center as possible.

In the case of beans, the deep cup probe could not penetrate more than 50cm into the bulk beans. Therefore, a composite sample was formed from the subsurface and from the empty spout which could be opened from the exterior of the compartment.

Temperature readings were taken, but as with the farm level survey frequent equipment problems were encountered. Whenever possible temperature readings were taken with the probe thermometer from the middle of the bulk and ambient was taken equidistant from the area between the bulk surface and the ceiling. In bagged storage, one bag was selected and the probe inserted to the middle of the bag.

Merchant Level

Two procedures were planned for obtaining samples from merchants. The first was to collect samples from merchants bringing beans and sorghum to GRENARWA warehouses. The second was to visit trading centers and collect samples.

For the sampling of merchants as they sold stock to GRENARWA, each warehouse manager was instructed to fill 1.5 plastic sample bags with beans and sorghum from 10 merchants within a given period of time (10 days). When the tenth merchant was sampled they were to radio OPROVIA headquarters and our team would dispatch someone to pick them up.

The second plan was to be implemented if the first did not work. For this, GRENARWA files would be used to obtain names of traders who frequently traded with them. These persons would be visited and samples purchased.

OPROVIA Warehouses

Piles of bagged (jute sacks with 90 kg. each) and palletized beans and sorghum were constructed in three GRENARWA warehouses situated within the three agro-climatic or agro-altitudinal regions from September 1984 to December 1985 (Table 3)[1]. These piles represented approximately one-quarter of the size of a normal pile for that particular warehouse:

Kibungo	Low Altitude	=15 MT Beans =15 MT Sorghum
Nyanza	Medium Altitude	=30 MT Beans =30 MT Sorghum
Kora	High Altitude	=15 MT Beans =30 MT Sorghum

These stocks were purchased by GRENARWA from several sources especially for this survey. After construction of the piles, they were set aside and were not subject to the normal commercial activities of GRENARWA.

1/ At the time of final revision of this document, (May 1986) these stacks were still in place and the routine monitoring for quality changes continued.

These piles were monitored every two months. In situ temperatures were recorded. Ambient temperatures (Table 67) were taken for most of the sample period[2/]. Twelve samples of beans were taken from the outside of the pile (3 from each of the 4 faces) and three from the interior (center) of the pile. Each sample (350g) was a combination of three subsamples taken from a single bag. Each of these single bag samples were analyzed separately for moisture content and insect numbers. Then the 3 samples from each side or the center were pooled forming 5 composite samples of 1 kg each. These 5 samples were then analyzed for test weight and percent damage.

Individual samples were obtained by spear sampling from the bottom 1/3 of the three selected bags as they lay horizontally in the pile. For the samples taken from the face, one bag was chosen from the top one-third of the face; one bag from the middle one third of the face; and one bag from the lower one-third of the face. Samples taken from the face were obtained in situ from the same bag at each sampling. For the samples taken from the center, bags were removed from the center of the pile beginning on top and proceeding conically toward the dead center of the pile. Slightly above the center 3 bags were chosen for sampling. To sample, the bag was lifted up on one end and 3 samples were taken from the side of the bag that lay facing the floor as it would lay in the pile. After sampling, these bags were then returned to the same location and orientation within the pile and the other bags were replaced as before. All bags were marked and the same bags were sampled on each sampling date.

Continuous recordings of ambient temperature and relative humidity inside each warehouse during the sample period were obtained with a Cole Palmer hygrothermograph. Due to equipment malfunction some periods were omitted.

The piles were periodically fumigated by GRENARWA along with all other stocks in the building (Table 3b). During the warehouse survey, set-aside piles were fumigated as follows: Kora warehouse on 6 June 1985; Kibungo warehouse on 16 November 1984 and 15 May 1985; and the Nyanza warehouses on 10 November 1984 and 26 April 1985.

C. DEVELOPMENT OF QUESTIONNAIRES

The questionnaire (Figure 7) was finalized by the team following a pretest in April-May 1984. It was translated into French and prior to presenting it to farmers, the Rwandans (J. Kayumba, E. Munyarushoka, or E. Nizeyimana) were given practice sessions with the University team as they verbally translated the questionnaire into Kinyarwandan. A major drawback of the data collection process was never to have had a draft in Kinyarwandan which could be carried to the field and used by the Rwandan asking the questions. This required the interviewer to on the spot translate from French to Kinyarwandan and then translate the farmer's response into French and write it down. We suggest the focus in the interview should be information gathering, not translation. Future surveys should not neglect this step.

[2/] Temperatures from late 1984 and early 1985 were missing due to manager turn over in Kora and Kibungo and equipment problems.

Prior to the first day of the survey and sampling, most farms were visited to explain and introduce the project. At the first visit, planned as soon after harvest as possible, basic information was obtained on house construction and arrangement as well as on postharvest, prestorage treatments and division of labor. At each successive visit (approximately every two months until the stock was used up) questions on treatment during storage were asked as well as questions on use of the beans and sorghum. An attempt was made to determine a quantitive use pattern. Asking the farmers to remember quantity was not sufficiently accurate, although we did obtain some information on usage. Ideally, the farmer would have been instructed to use a certain premeasured cup for withdrawal of beans and sorghum from the stock. The farmer would then need a booklet and pencil to record how many measures of what commodity were used for what purpose.

At each visit the Rwandan team member interviewed the farmer and following the interview the samples and temperatures were taken, usually by T. Wittenberger.

Two questionnaires were later developed to (a) obtain information on management patterns and background of cooperative managers (to test the hypothesis that there was a correlation between training and management performance) and (b) to obtain information on the storage of maize which might harbor Prostephanus truncatus.

D. ANALYSIS PROCEDURES

Most samples were analyzed in the main lab in Kigali. In some cases, such as in the Ruhengeri-Gisenyi area, sample moisture contents and test weights were analyzed at a satellite lab set up by the project in the Kora warehouses.

The first characteristic of the sample analyzed was test weight. The entire sample, ca. 1 kg., was placed in the funnel of the test weight apparatus and then allowed to fall into the receptacle, a Winchester bushel (= 0.909 liters) (Figure 8). Of this, 250g were used for a determination of moisture content using a Motomco meter (model 919). The entire content of the Winchester was then separated using a sieve (Figure 8) and 30 strokes. Material which fell through the sieve and insects and foreign material (stones, etc.) which were picked out of the material in the sieve were combined and weighed to determine percent dockage and foreign material.

To calculate % dry weight loss in our survey data:

1. $\left(1 - \frac{\%MC_a}{100}\right) \times TW_a = DW_a$

2. $\left(1 - \frac{\%MC_b}{100}\right) \times TW_b = DW_b$

3. $\frac{DW_a - DW_b}{DW_a} \times 100 = \%$ dry weight loss

Where % MC_a = % moisture content of first sample
% MC_b = % moisture content of second sample
TW_a = test weight of first sample
TW_b = dry weight of second sample
DW_a = dry weight of first sample
DW_b = dry weight of second sample

The material which fell through the sieve (dockage) was combined with foreign material (stones, etc.) picked out of the material above in the sieve, and weighed. This combined weight and the weight of the beans/sorghum in the test weight bucket were used to calculate the % wt/wt dockage (impurities) in the sample. The material below the sieve was checked for insects prior to weighing. Numbers of live and dead insects were recorded and identified. For beans, the following subsamples were taken from the clean beans combined with dockage and foreign material: 300 beans for the damage determination by variety and perceived loss determinations; 200g. for a 42 day incubation after which the number of live and dead insects and their species were recorded; 100g. for fungal determination; and 300g. for a cookability test. The remainder was reserved. The sieve weight subsamples were used except for % damage, which was analyzed using 100g. For sorghum, damage was based on U.S. standards listed in "Grading Standards for U.S. Sorghum". The sorghum damage analysis was not done by variety and did not include consumer perceived loss determination. No cookability tests were done on sorghum.

The damage determination was accomplished as follows. For beans, the first 100 beans of the 300 bean subsample were separated by variety and then characterized according to the standard descriptors used for the bean varietal survey component of this project. Then, within each variety, the number of beans with each of the 10 damage categories was determined. Also the more subjective or holistic diagnosis of "would not be planted" and "would not be eaten" was performed by the Rwandan technician. (His distinctions have been verified by an on-farm survey, Appendix E). The remaining 200 beans were then searched for evidence of each of the 10 damage categories. Then from these, the "would not be planted" and "would not be eaten" distinction was performed.

For all incubation of beans and sorghum for determination of immature stages of internal insect infestation, 200g. of the sample were placed in glass jars with screen covers on the laboratory shelf. Temperature and relative humidity was 23±1°C. and 65±5% respectively. Numbers of adult insects (both live and dead) were recorded after 8 weeks.

A total of 198 samples, 100 dried bean and 98 sorghum, were examined for the presence of fungi. Forty bean and sixty sorghum seeds were selected at random from each sample. Seeds were surface disinfected with 2.5% NaOCl for 1 minute, rinsed three times with sterile distilled water, and plated on acid potato dextrose agar (PDA) and tomato juice agar (TGA) with 6% NaCl. All plates were incubated at room temperature and examined after 7 and 14 days. Species of Aspergillius were identified according to Raper and Fellel (1965). A limited number of fungi were identified to species.

III. RESULTS AND DISCUSSION

A. RESULTS AT THE FARM LEVEL FOR BEANS HARVESTED JUNE 1984

Storage Structures

The most striking features of storage structures used for beans at the farm level is that after threshing all beans were stored inside the homes. The outside granary within the farm compound existed in various regions[1/], but in 100% of the cases, all visits considered, it was not being used for beans (Table 4). The significant part of this observation is that the reason for this location of the stored beans is security. Theft is possibly one of the largest causes of actual loss. There were 8 main types of "inside the house" storage containers:

long basket	jute sac
round basket	plastic or paper sack
earthen pot	metal drum
gourd	imboho

Of these, the baskets were the most frequently encountered. Collectively, they were the main container for freshly threshed beans in 77% of the 47 farms visited with equal numbers of farms preferring the long and round types (Table 4). The basket, whether long or round, was also always uncovered and lined with cow dung. Cow dung has, at this point in our investigation, an uncertain usage. It is possible that this material has rodent repellent and/or insect repellent properties. It should be considered, therefore, as one of the most frequently encountered structural treatments for pest management.

Although the basket is the most universally preferred structure in which to store beans on-farm, there are altitudinal differences in the preference for round versus long. The round basket was more frequently encountered in low altitudes and the long basket was more frequently encountered in the high altitude farms (Table 4). The latter is about one half the size of the round, so this preference may simply reflect number of kilograms harvested.

The second most frequently encountered storage container is the clay pot and the jute sack, each found in 17% of the storages sampled (Table 4). The clay pot, however, was absent in the high altitude farms sampled. In one farm a controlled atmosphere storage had been created with dung by covering the top and sealing the edge with the material. The farmer indicated this was for rat control, but some insect avoidance as well as mortality was no doubt achieved because of the beneficial effect of CO_2 build up with this technique.

1/ Outside granaries are used for storage of sorghum on the panicle and maize on the cob. These storages are frequently encountered in the Ruhengeri and Gisengyi areas and in some parts of Kibungo Prefecture.

Least frequently encountered storage structures for this harvest, 1-2 months after harvest were the gourd (calabash), the plastic or paper sack, (Table 4). The imboho is an exceedingly interesting and unique 'disposable' storage structure made of banana plant sheaths. The details regarding this structure are located in Appendix A.

Because the long basket is the largest <u>and</u> the most frequently encountered Rwandan on-farm bean storage container, it is not surprising that almost half of the total 1362 kg. sampled was stored in this structures (Table 5). Each of the remaining quarters were maintained in the round basket and sacks, with very small amounts in the other structures. Between altitudes the distribution of weight reflects the usage preference for round versus long baskets.

Storage structures can have a profound effect on moisture, temperature and pest control of the stored commodity. For the 3 altitudinal zones sampled, we now know the preferred storage structures for beans and various peculiarities of the structure. This information is necessary before improvements in on-farm storage can be developed and the extension process begun.

<u>Storage Environment</u>

The storage structure has a profound effect on conditions which increase post-harvest loss. In Rwanda, however, beans are stored on-farm in a structure within a structure. The environment that building materials create within the house, therefore, and placement within the home also affect the microenvironment of the beans. This, in turn, affects the rate at which the beans harvested become a loss. Construction materials used for the farmhouse, such as walls, roof, the presence or absence of a ceiling create various barriers for heat and moisture transfer in a commodity inside the home. Such elements of the storage environment include placement within the house and the use of elevation for the actual storage structure.

In the regions sampled, the metal roof was most frequently encountered (40.5% of sample). Tile (33%) and thatch (26%) were slightly less frequently encountered (Table 6). Strong regional preferences appeared, however, when frequency was subdivided by altitude. Two-thirds of the sampled homes had earthen walls with the remainder being primarily cement or stucco. Although bricks are produced in virtually all regions in Rwanda, and bricks are used for homes in some areas, no homes in our sample had fired brick walls (Table 6). Earthen floors were the most frequently encountered with only 15.2% of the homes having cement floors. Ceilings were found in 43% of the total homes sampled but for the high altitude farms this was 80%.

Choice of storage location within the house can have several important ramifications:

1.) If storage is in an area where it can be reached by fumes from the cooking process, this will produce a fumigative effect.

2.) If storage of the beans is under the farmer's bed, this may indicate that security for this commodity is of paramount importance.

3.) If storage of beans is primarily next to or in same container as maize, this will mean that Prostephanus truncatus is an even greater threat to beans during storage.

4.) If storage of beans is primarily in an area set aside specifically for storage, extension efforts will have more options for improvement.

Of all the beans surveyed, most (66.7%) were placed in a separate storage area within the house (Table 7). The sleeping area (under the bed) was the next most frequently used area (19%) and a foyer area was used by 12% of the respondents. Of these locations 34% were close enough to cooking fumes to obtain a measure of insecticidal effect from it. Only 4.8% of all stocks were stored with or adjacent to maize. It should be remembered, however, that over one-third of our cases did not occur in maize production areas (Table 6). Furthermore, the 2nd crop bean harvest does not correspond with any significant maize harvest.

Elevation of the bean container provides another important effect on the microenvironment of the beans. The main benefit is passive airflow to the bottom of the container. With the largest container which is also the most frequently encountered, this would certainly be advisable. Seventy two % of all respondents elevated their bean stocks (Table 7) and of these 42% used a set of 3 or more stones (radius = approximately 9 cm.). Other elevating devices were the flat single stone which would provide a negligible aeration effect and the ingata or traditional woven ring which is used for either stabilizing a basket on the floor or on an individual's head.

Storage and Post-Harvest Handling Practices

Preparation for storage and additional manipulations during storage can have a profound effect on the rate at which loss occurs. In this study, we have obtained information on 3 types of practices: a) the number of days and time of drying provided, b) the source and application of insecticidal preparations, and c) the suspected removal of broken and severely damaged beans and foreign material during storage.

As data on bean quality and bean damage indicate, insects and rodents are important contributors to the total loss. Assisting the farmer in decreasing these losses, requires knowing what is presently in use and what is locally available.

We found that 81% of farmers sampled used some type of insecticidal treatment (Table 8). There were 52% who mentioned some type of commercial product in combined altitude data, but within altitudinal groupings, there were strong differences in the % which used commercial insecticides.

Five different types of natural materials were mentioned:

> kaolin, laterite, ash (wood ash, banana leaf ash, mixtures), pili pili (type of hot red pepper Capsicum sp. used mainly for cooking), leaves of Ocimum kilimandsharicum Guerke, a plant in the same genus as sweet basil.

Of these, the use of kaolin and ash was mentioned in 11 and 13.6% of the total cases, respectively. Kaolin use was mentioned only in middle altitudes, whereas ash was primarily used in low altitude farms visited. Laterite and pili-pili were each only encountered in 2.2% of the farms and both of these only at low altitudes. The use of natural insecticides was primarily at the low and middle altitudes (34, 33%, respectively). Only 10% of high altitude farmers used natural insecticide preparations. The mean % of farmers using natural insecticides irregardless of altitude was 28%. Of course, this would be higher would we incorporate into the total the use of cooking fumes and the use of a cow dung lining for baskets,both of which probably have insecticidal properties. An encouraging note is that 3 of the 47 farmers took an integrated management approach and used a combination of commercial and natural insecticides. One of these created the combination of a commercial insecticide, ashes, laterite and pili pili.

Changes in Bean Quality and Damage During Storage

Tables 9 through 18 show the changes in quality and % damage during storage. Clearly there were significant differences between first and last samples and between first samples in different agroclimatic areas. Even though the first sample after harvest revealed a highly significant (less than .01) lower % moisture content at low altitudes than in other regions, the mean % insect (specifically bruchid) damage was significantly higher (less than 0.01) than in the high altitudes. This was supported by the increase in actual numbers of bruchids obtained between first and last samples in the low and middle altitudes. In the middle altitudes, the mean number of insects obtained per kg. increased from 0.16 to 4.13 but in the low altitude this increased from 24.8 to 131.0. Clearly bruchids, namely Acanthoscelides obtectus, are a serious problem in low altitude bean storage.

A very important number in assessing bean and grain quality is total damage (mean %). Because the attrition rate was so great in high altitude farms, the following comparison will include only low and middle altitude. Damage was assessed in 10 categories that were visible by examination. The sum of damage in these categories was highly significantly increased (0.01) in the sample obtained just prior to total utilization (37.1%) compared with the level of damage visible just after harvest (17.3%) (Table 10). Both the % of dented kernels and the % of discolored kernels highly significantly increased at the close of the normal storage period. Rodent damaged and wrinkled kernels were both significantly increased in the last samples prior to total utilization. When analyzed separately (low and middle altitudes (Tables 9 and 13)) rodent damage was not significantly increased during the storage period. What the relationship of wrinkled, dented, and discolored conditions of the bean are to Rwandan preference and sensory hardness is not at this point known. It is strongly recommended that such a relationship be investigated. If these visible changes are related to unacceptable nutritional or sensory conditions, then storage conditions of the beans in low and middle altitude farms need to be improved.

There is a difference between damage observed and actual loss to the consumer. Loss to the consumer may take the form of dry weight loss; loss through consumption by rodents, insects or birds; nutritional loss due to chemical changes in kernel or seed or selective feeding by one of the organisms just mentioned; human theft; contamination by fungi and their mycotoxins; or loss due to decreased germinability or cookability or sensory preference by consumers.

Three types of loss were measured in addition to rodent and insect feeding described earlier; one of these is actually dry weight loss, the other 2 are consumer perceived losses. Weight per unit volume was not significantly different between the first and last samples. In fact, it increased in all cases (low, middle and low plus middle altitude). We also submitted damaged seeds to scrutiny by our Rwandan lab technicians who developed "no eat" and "no plant" categories (Tables 16 and 17). This loss perceived by consumers increased between the beginning and end of the storage period in all cases except for beans stored in the high altitudes. In low altitudes 12.4 ± 2.6 S.E. % of the beans were classified as a total loss to the farmer. This represents 9.5 Kg for the harvest or 475 Rwandan francs per farmer per harvest.

In summary, storage losses caused by conditions and storage management on the farm in at least low altitudes is high enough to warrant assistance in improved postharvest pest management for beans.

B. RESULTS AT THE FARM LEVEL FOR BEANS HARVESTED JANUARY 1985

Storage Structures

Similar to the storage of beans harvested in June 1984, no exterior containers were used for beans sampled in the January 1985 harvest (Table 19). Once again the most frequently encountered structures were baskets lined with cow dung (65%). Like the June harvest, sacks (both jute and plastic) were the second most frequently encountered storage container (25%). The clay pot represented 8.3% of the storage containers sampled, and the imboho accounted for 2.1%.

In contrast to the June 1984 harvest no gourds or metal drums were used to store beans harvested in January 1985. Also in contrast to the previous harvest, some farmers were using baskets without the cow dung application (6.3%).

For this harvest 48 farms were visited with a more equal distribution between altitudes than in the previous harvest. Of the 48 farms 41 had been used for monitoring storage of the June 1984 beans. The main difference in the farmers which composed these two sets were those located in the high altitudes. The total amount of beans sampled from the January 1985 harvest was 2578 kg. (Table 20). Of this, 69.4% was stored in the long baskets and only 9.6% of it was stored in the round baskets. Although 58 - 68% of the beans sampled from this harvest were stored in the long basket in low and middle altitudes, over 90% of the beans stored in high altitudes were placed in the long basket.

Beans harvested January 1985 were totally utilized (eaten, discarded, sold, given away) an average of 95 days after the first visit which means 3.5 to 4.0 months after harvest (Table 21). Most of these beans were consumed on the farm where they were produced. None were used for livestock feed. Approximately equal amounts were used for seed as were sold in the market. The mean selling price was 35 to 50 Rwandan francs. A small portion of the beans surveyed were given as gifts. Actual amounts in each of these utilization categories cannot be quoted with certainty. This type of information would require more frequent visits (weekly or bi-monthly), and a larger survey team (this team in the field consisted of usually only 2 persons with 1 technician in the laboratory). Also farmers could be given a standard sized receptacle so that each time beans are used, the number of standard receptacles filled could be noted.

Storage Environment

Because all bean storages sampled were located inside the farm house, the structure of the house is a very important factor in defining the actual storage conditions to which the beans were exposed. Analyses presently being conducted will correlate quality changes observed with both structural properties of the house and of the storage container itself.

The farmer sample used for June 1984 beans is slightly different than that of the January 1985 bean harvest. Structural materials of the house, therefore, are summarized again (Table 22). The most important structural analysis will be the correlation with quality. Values obtained for the harvest varied slightly from that of the June 1984 harvest. Of the three roof types encountered, metal was again the most frequent (47.7%). Tile was the next most common (31.8%) and thatch was the least frequently encountered (20.5%). Wall materials were also predominantly earth (70.3%). A clay plaster was placed over some walls (27.0%) of the homes. Floors were also predominantly earth (85.7%) as opposed to cement (14.3%).

The major change in storage environment was the location of the storage structure within the house. One-third of the farmers sampled with June 1984 beans stored the beans in a cooking area whereas only 4.3% of the farmers with January 1985 beans stored their beans in the cooking area (Table 23). Over half of the farmers stored the January 1985 beans in a separate storage area within the house. The next most common location was the foyer or guest greeting area (30.4%), a value almost 3 times greater than that of the previous bean harvest. Only 13% of the farmers kept beans in the sleeping area. A major change was also noted in the percentage of storages which were elevated. This percent decreased from 68.0 to 25.0 and of these, it was primarily the storages that were elevated on stones and straw which decreased.

Storage and Post-Harvest Handling Practices

For this bean harvest as well as for the June 1984 harvest information was obtained on several storage practices (Tables 24 and 25 and Figure 9): (a) the number and days of drying time, (b) threshing, (c) sieving and winnowing, (d) triage, and (e) application of insecticidal treatments.

Drying requires more person time than any of the other major post bean maturity tasks such as threshing, winnowing, triage and other processing activities. More time is spent in middle altitude households on the post-mature bean crop than in the other altitudinal areas.

The total percent of farmers which used any postharvest insecticidal treatment was 70.9, compared to 80.6 with the previous harvest. The useage of commercial insecticides by the farmers remained at 50%. The use of natural insecticides decreased, however, from 28.4% in June to 20.9% in January. The two main types of natural insecticidal treatment continued to be the soil type kaolin and ash preparations.

Changes in Bean Quality and Damage During Storage

Insects appeared to be the major concern for beans harvested January 1985 (Tables 26-36). If data from all altitudes are combined, the only damage category which was significantly increased between the first (just after harvest) and the last sample (just prior to total utilization) was that of insect damage (Table 35). Indeed, the number of total insects obtained from these samples rose from 0.09 to 7.45 per kilogram, which is a significant difference at P less than 0.001 (Table 36).

Note that insect damage values (Table 35) reflected an excellent internal check on level of insects detected (Table 36). For all altitudes combined a mean of 7.5 insects/kg. were found. This is roughly equivalent to 7.5 insects/2000 kernels. If each insect (all were internal feeders) emerged from a different bean, 0.38% of the beans would be insect damaged. Actual values showed a mean of 0.37% insect damaged kernels. The main insects obtained were Acanthoscelides obtectus, Plodia interpunctella, and Sitophilus spp. Of these it was only the bruchid, A. obtectus that increased significantly (P less than 0.01). In the previous harvest (June 1984) the actual numbers of insects (primarily A. obtectus) obtained in beans stored on low altitude farms just prior to total utilization was seriously high (131.0 insects/kg. beans). Due to a large between-sample variation however, this increase was not significant at 0.05.

For the January 1985 harvest, it is the low altitude farms that experienced the greatest increase (highly significant, P less than 0.01) in insect numbers. This time a 57.6 fold increase occurred in stocks sampled in low altitudes (Table 28).

Mean values combining all altitudes indicated no difference between beginning and ending mean % moisture content, i.e., 14.7% (Table 36). At the onset of storage, however, mean % MC of bean stocks was significantly different between altitude groupings (Table 26). Considering each altitude group separately, % MC in low altitude stocks decreased between emplacement and total utilization (Table 28). Middle altitude % MC remained the same, but high altitude mean % MC rose 1.0% (Tables 30 and 32).

Mean test weight decreased highly significantly during storage when all altitudes are combined (Table 36). The only reason for this decrease apparent from these data is the highly significant increase in insect damage (Table 35). Development of insect populations from incubated samples (Table 39) also indicated a steady increase in insect activity during the 1985 storage period. Dry weight loss (%) was highest in beans grown and stored in high altitudes. The percent mean weight loss was 1.80, 2.09, and 3.34 for low, middle and high altitude farms, respectively. Besides insect damage and a significant increase in broken beans, none of the damage categories showed a significant increase between first and last samples.

In summary, insects again in this harvest emerged as a problem. The January 1985 harvest beans were placed in storage at 14.95% MC, significantly higher (P less than 0.001) than the previous harvest (Table 38). Percent kernels with visible mold growth (1.26) were also significantly higher (P = 0.001) than the 84 June harvest at the onset of storage (Table 37). Moisture content of the January 1985 stock just prior to utilization was also higher than the previous harvest, but kernels with visible mold were significantly less numerous than the previous harvest. One explanation could be the triage or early selling of the mold-infested beans by the farmers. Shriveled kernels were also significantly (P less than 0.001) more frequent in the January 1985 harvest at the beginning of the storage period but not at the end. Perhaps the same explanation holds here also. Total mean % dry weight loss was greater (2.26) for the January 1985 harvest than for the highly infested June 1984 harvest (0.49) (Table 38). Other factors indicated these beans experienced a better maintenance of quality than those of the previous harvest (Tables 37 and 38).

C. RESULTS AT THE FARM LEVEL FOR SORGHUM HARVESTED JUNE 1984

Storage Structures

Similar to beans, no exterior containers were used for the storage of sorghum sampled after the 1984 harvest. Exterior granaries do exist in Rwanda but are mainly found in higher altitude areas in the north where sorghum is stored on the panicle. Also similar to beans was the predominant storage structure, the long basket (60%) (Table 41). Once again the round basket (20.5%) was the second most frequently encountered receptacle. No baskets were encountered without the cow dung lining. Sacks (18%) and metal drums (12.8%) were encountered to a lesser extent. No cases were found of gourds or imbohos being used for sorghum.

For this harvest 39 farms were visited and 3870 kg. were sampled (Table 42). Most of the sorghum stored at high (94.8%) and middle (86.8%) altitudes were stored in the long basket. Low altitude farmers sampled, however, stored most of their sorghum (89.4%) in jute sacks. In contrast to beans, more sorghum was sold (2400 kg.) than was used for food and seed on the farm where it was produced (Table 43). Similar to beans, none was used for cattle feed. All sorghum in farms sampled was completely used or sold within four months after harvest.

Storage Environment

As with beans, all sorghum was stored in the home. The house structure, then, becomes an important feature affecting the environment of sorghum in storage. One-third of the farmers sampled for sorghum were different individuals from those in the bean survey. These included 3 farmers at the medium altitude and all farmers at high altitudes.

Of the 3 roof types, metal was again the most frequently encountered (52%) (Table 44). Thatch, however, was twice as common (32%) as tile (16%) in this set of farmers. Wall materials were also again predominantly earth (82.6%) with the only other type being a plaster of locally available kaolin (17.4%). Floors were again predominantly earth (87.5%) as opposed to cement. Only 15% of the homes had ceilings.

Over one-third of the farmers stored their sorghum in a separate storage area within the house (Table 45), but most of them kept the sorghum container(s) in the foyer of their house. Several farmers stored sorghum in the sleeping area (5.1%) and the cooking area (7.7%). Similar to beans harvested in the same season (June 1984), most of the sorghum was in elevated containers (74.4%) (Table 45). The best type of elevation device observed in use was the stones. Generally 3 large stones were used to support the basket. This provided more opportunity for passive air exchange than other elevating devices observed.

Storage and Post-Harvest Handling Practices

Preparations for storage and additional manipulations during storage can have a profound effect on both the rate at which loss occurs and the net profit (minus labor and materials) of the product. In the on-farm sorghum study, we have obtained information on 2 types of practices: (a) the number of days and time of drying provided and (b) the source and application of insecticidal preparations.

There are 4 main activities which farmers do with sorghum after it has matured. These are: drying, harvesting, threshing and winnowing (Figure 10). Triage, or sorting of the useable (plantable or edible) kernels, according to the response during interviews was done at the same time as winnowing by the farmers sampled. Thus, the time cost of winnowing is shown here (Figure 10) combined with triage. This information implies that no triage occurs during storage. There is some evidence from damage analysis during the storage period that triage may occur during storage, e.g., the worst beans are eaten first or sold first. Certain categories of damage, e.g., wrinkled, decreased significantly (p less than 0.01) between the onset and the end of storage (Table 51).

Of the total time spent by farmers in the 4 main post-harvest activities with sorghum, over twice as much (12 days) was spent drying. From this data one could conclude that there is a difficulty with high moisture sorghum and it needs a heavy time investment, and/or moisture content is a very important aspect of good quality sorghum and it deserves a large commitment of time. Since the mean % moisture content varied from 12.06 to 13.18 between altitude groupings at the onset of storage (Table 47) whichever the case, the moisture content was brought under good control before storage. Another labor intensive period of care by the farmer of post-maturity sorghum is when the sorghum is processed for consumption. Data of this type was not part of the survey. Similarly, application of and, in the case of natural insecticides, collection and preparation of insecticides also involves a time cost.

Fewer farmers used insecticides on stored sorghum than on stored beans (Table 46). About half (56.4%) of the farmers used insecticides and of these, one-half (28.2%) used a commercial or synthetic type and the other half (28.2%) used a natural preparation. The former was not further specified because they are usually purchased without labels. Actellic, and malathion are the possibilities. The latter were primarily ash, wood ash and ash of other origin. No soil preparation, kaolin or laterite was found used for sorghum by any farmers surveyed. The mode of insecticidal action of ash can be as a barrier to O_2, CO_2 exchange with ambient air and as a respiratory pollutant for the insects.

Changes in Sorghum Quality and Damage During Storage

Sorghum grown and stored in high and middle altitude farms were found to have four-fifths (6.0%) to two-thirds (10%) less damaged kernels than that of the beans at the same altitude (Tables 29, 31, 48, 51). Low altitude sorghum contained over 30% damaged kernels at the end of its storage period (Table 53). Although % germinated kernels increased significantly (p less than 0.05), it was primarily the category of discolored (p less than 0.01), which accounted for this difference in the low altitude sorghum. Whereas visible mold was an important damage category in Rwandan beans during storage, in sorghum it was not. The highest rodent damage levels (1.0%) were recorded in the high altitudes. Insect damage, so important in beans, did not increase significantly in any agroclimatic areas sampled. The highest mean level recorded (1.0%) was also, however, in high altitudes (p less than 0.10).

Most insects encountered were Sitophilus spp. Most of these were the rice weevil, Sitophilus oryzae L. Although not reflected in insect damage levels, sorghum from the middle altitudes had very high levels of insects (28.3/kg.) (Table 50). Other species obtained were the lesser grain borer, Rhyzopertha dominica F., also an obligate internal feeder as a larva, and the indian mealmoth, Plodia interpunctella Huebner. The danger with the first 2 species is that their infestations are quite hidden. Only the adult stage which lasts 2 of the 8 weeks of the life cycle is readily visible to the farmer or the buyer. Plodia is serious because of its mobility, the preference of larvae for feeding on the germ, and the resistance of many of its populations to malathion. Incubation of sorghum (Table 5b) did not indicate higher internal infestation levels than adults obtained.

Impurities were low in all samples with a mean of 1.1, 0.8, and 0.9% w/w for low, middle, and high altitudes (Tables 49, 50, 52) at the end of the storage period. This represented no significant change (p less than 0.05). Test weight showed a significant change only at the low altitudes (from 716 to 700.2) (p less than 0.05) (Table 48).

D. RESULTS AT THE COOPERATIVE LEVEL

Observations of General Management Conditions

The cooperative system was set up as a place where farmers could sell their raw commodities, generally beans and grain and then later in the season buy back the same quantity of beans or grain lower than market price. Some silos were built by AID funds and some by CRS (the Catholic Relief Service) and some by other funding. Often a general store is associated with the cooperative. The purchaser of the raw commodities could be farmers themselves, merchants and OPROVIA. OPROVIA can be a customer, provided the cooperative is on a road accessible by OPROVIA trucks.

The management of cooperatives is under the auspices of the Ministry of Youth and Cooperatives (MINEJUCOOP). USAID also employs a fulltime technical assistant to advise on management and/or building issues for the cooperatives. The following general observations were made during more than a year of bimonthly visits to 21 of the over 100 cooperatives.

1. Managers do not observe their stocks once in storage, consequently they do not know when a problem arises. Without a system of monitoring or detection, damage to grain is often only discovered at the end of the storage period.

2. Managers are often difficult to find even on the days when they are supposed (scheduled) to be present at the silo or hangar.

3. Insecticides especially Phostoxin, but also Malathion and Actellic, are not always used properly. There is evidence of incorrect dosages and application methods which has resulted in incomplete control of insect infestations.

4. Managers do not use moisture meters. The value of the moisture meter is debatable since managers do examine incoming stocks and determine, using tactile methods, whether grain is dry enough for storage. The managers' success is evidenced by the fact that very few samples analyzed by our laboratory have had moisture levels higher than 15%. Also the meters presently available at cooperatives are not maintained nor regularly recalibrated and lack conversion tables for Rwandan beans.

5. Incoming stocks are seldom segregated according to quality factors and storability.

6. Stocks seldom receive any triage, cleaning or conditioning prior storage in order to improve quality and storability.

7. Sanitation/hygiene: (a) often compartments are not thoroughly cleaned out from one stock to another (especially ceilings and walls) which may lead to insect infestations of new stocks; (b) often trash and old sacks are piled in corners, providing good rodent habitat.

8. Lack of general maintenance of structures (screens, roofs, walls, floors, and ladders) is especially evident in older silos and hangars.

Observations of Structural Conditions

In Rwanda there are two basic types of structures for cooperatives, hangers and silos. The hanger type is a one story brick or cement building usually with a cement floor. Often there are separate rooms for different commodities. Beans, grain and flour are stored in bags with or without pallets. Raw commodities have also been observed laid directly on the floor. Silos are 2 story compartments with an open area above covered by just a roof. The top story is usually accessible only by a ladder. Each silo holds 4, 6, or 8 cement, rectangular compartments (12 to 15 metric tons each). The overall outside dimensions are that of a rectangular building, the inner dimensions are square. The silo is filled from the top through a rectangular hatch set to the side of the actual silo. Unloading occurs by gravity at the bottom on the outside wall through an approximate 15 cm aperture which can be locked. The following specific observations of construction and conditions were noted:

1. Silo compartments are not airtight as devised in the original plans. Unloading spouts are probably satisfactory but loading hatches on the top do not seal completely. In addition, frequent opening of the loading hatches during an extended filling period and the presence of a large air space when silos are incompletely filled mean that conditions are rarely airtight enough to prevent development of molds and insects. Samples have often contained live insects. However, compartments do seem sufficiently airtight enough for at least partial fumigation.

2. Screens are often in disrepair or the wrong size.

3. Hangars frequently lack sacks and pallets which result in flat (bulk) storage.

4. Generally, silo capacity appeared underutilized. Possible reasons are the poor harvests of 1984 and the lack of funds to purchase grain, lack of marketing expertise of managers, and overall pricing policy.

5. Silos are not easily unloaded, particularly if high moisture conditions have created aggregated chunks of grain.

6. Building plans called for the placing of a plastic moisture barrier in each compartment during construction. Behavior of some grain bulks during storage indicate perhaps these moisture barriers were omitted in construction.

Pros and Cons of Silos versus Hangars

Both types of construction have advantages and disadvantages. The following are pros and cons of each type.

1. Protection vs. insects: silos can be more easily and effectively fumigated for insect control than hangars.

2. Protection vs. mold damage: hangars are perhaps less susceptible to mold problems than silos where mold damage can be encouraged by increase in grain moisture content due to internal moisture migration or absorption of moisture through floors and walls. This advantage is negated when hangars are used for flat storage directly on the floor instead of bag storage on pallets.

3. Protection vs. rodents: rodents can easily be excluded from silos; they are attracted to bag storage where they are difficult to control.

4. Protection vs. theft: silos are easier to protect against theft.

5. Maintenance costs: hangars require a regular supply of bags and pallets in good condition.

6. Monitoring: bulk storage is easier to sample and monitor.

7. Building costs: Hangars are less expensive than silos.

8. Alternative use: Hangar space is easily converted to other uses when no grain is being stored.

Summary of Bean Quality Data in Cooperative Storage

One question we raised with cooperative silo/hangar data was: will the level of insect infestation seen at the farms be reflected and augmented at this cooperative level? Very few coops had the same stock of beans after our first sample hence our numbers of continuously sampled stocks are small. Data from all 3 altitudes were combined and the first and second samplings were compared (using paired t-tests). Overall, the mean number of bruchids increased from zero at the first sampling to 3.7 at the second (n=9, p=0.093). All other insect counts or measures of damage did not vary significantly over time. Interestingly there were more bruchids/kg in high altitude beans (63 *A. obtectus*/kg. at the last sample) than at low altitudes (Table 58). This was not clearly reflected in damage levels (Table 59). Although damage in low altitude coop beans began higher than in the other areas, none of the same stocks were available to sample on a return visit. For both middle and high altitude coops, insect damage was one of the most important of the typical post harvest damage categories.

Summary of Sorghum Quality Data in Cooperative Storage

The general condition of sorghum stored 5 months or less was good and did not change much between the first and second samplings. The % of kernels with visible mold increased significantly (p less than .05) in medium altitude storages (Table 61), as did the % moisture content and the temperature differential between inside the storage and ambient (Table 60). Visible mold also increased in low-altitude storages (t-test, hangar and silo data combined, p=.046). The % of kernels wrinkled apparently decreased in 2 out of 3 altitudes and both building types. *Sitophilus* numbers were higher in hangar-type coops than in silo-type coops, especially at the second sampling. In the few cases where sorghum was stored 9 months or longer, insect damage was severe (in one coop a compartment of sorghum held for 2 years was found to have 80% insect-damaged kernels).

E. RESULTS AT THE OPROVIA WAREHOUSE LEVEL

General Observations of Storage Management and Structural Conditions

GRENARWA, the Food Products Division of OPROVIA, manages 13 actual warehouses throughout the country. There are additional storage facilities at the OPROVIA Retail Outlets in the major commercial areas. Normally the warehouses store dry beans, sorghum and sorghum flour. These foodstuffs are for the most part destined to fill the contracts that GRENARWA holds with its major clients (i.e., the military, the prisons, and the refugees).

Most of GRENARWA's stocks are purchased from traders with vehicles. Farmers also bring in small quantities for sale at OPROVIA's fixed rate. The farmers' impact on pricing policy, however, is small compared to that of the traders.

Generally storage periods are short. Stocks are seldom held for more than 4-6 months. Most of the 18 month study period was not normal for OPROVIA/GRENARWA. Large quantities of food aid, stimulated by the bad harvests of 1984 and provided by the United States and various European donors, were stored and distributed by GRENARWA. During the period from October 1984 to April 1985 many warehouses were filled to capacity by food aid at least for a short period of time. GRENARWA grain handlers were obliged to handle foodstuffs to which they were not accustomed. Overall this did not pose a problem other than added pressure on space and transport capabilities.

Storage within the warehouses is almost exclusively in bagged, palletized piles. These piles vary depending on the overall capacity of the warehouse. There is segregation of stocks. Generally these piles are jute bags or plastic fiber bags. The grain stored in jute bags are standardized to hold either 80, 90, or 100 kilograms. The bag weight is always standard within a pile. New jute bags hold less than old ones because the fibers stretch. If bags are in short supply a warehouse manager will probably load the maximum. The plastic fiber bag is a relatively new innovation for large scale storage in Rwanda. They are less expensive than jute and are being imported in large quantities. The plastic fiber bags are more effective for storage of sorghum flour than jute. However, the aeration capabilities of jute are superior.

After reception of stock and construction of piles, all stocks in a warehouse are fumigated with Phostoxin (Phosphene Gas). The warehouses are not airtight (they were not designed to be) so a large polyurethene tarp is used over the piles. These tarps completely cover the pile or can cover several piles at once. The phostoxin is applied in tablet form directly on the sides of the pile, then covered with the tarp. Three to five tablets per metric ton are applied depending on the degree of attack (if any). The building is then locked for 4 days. This procedure is repeated when necessary on specific piles.

The storage conditions in the GRENARWA facilities observed were good. Generally they were clean and well swept. Some grain residue could always be found in corners, on ledges, and in the sliding door tracks. There was often a large dust buildup on top of rafters. Some warehouses had more serious problems than others. Nyanza was the oldest warehouse (built in 1948). Its steel walls and roof had many holes. The cement floor had many holes, some open enough for rodent passage through to the foundation. One consistent problem noted was that the screens over air vents were usually in disrepair or non-existent.

Overall warehouse conditions vary. Of the three, Kora is probably in the best condition but both Kora and Kibungo are small capacity. Kora and Kibungo have cement walls, a higher foundation and tin roofs, and the floors are in better condition. Nyanza is the largest of the three. The cement floor is in poor condition with many cracks and holes. Walls and roof are metal. The roof leaks. There are rodent holes through the walls and the floor leaks. Rodents are a problem in all warehouses. Proper screening is generally absent from vents and windows. Grain residue is not swept out of cracks and corners. Rafters and wall tops are common thoroughfares for rodents. Considerable rodent signs such as tracks in the accumulated dust can be seen there. Many of the same problems cited above also encourage insect infestations.

The warehouses at Kora and Kibungo, described in detail below, are more typical of GRENARWA's warehouses then Nyanza.

Kora Warehouse

The Kora warehouse is located close to the main road from Ruhengeri to Gisenyi at about 32 Km east of Gisenyi. It is constructed on a low laying fairly level site at an altitude of 2430m. Immediately to the north are a number of mountains which peak 100 - 200m higher than the warehouse.

The rectangular building (24 x 28) is constructed on a volcanic rock bed 80 cm above ground level. It contains a large storage area, a small storage room (4 x 5m) and an office (4 x 5m). Attached to the north wall of the building is a concrete drying floor (5 x 24m) which is surrounded on three sides by a stone wall (1m height).

The concrete block walls contain vertical reinforced concrete pillars spaced 4m apart and horizontal reinforced concrete bond beams at 2.0 and 3.5m height. The inside walls are whitewashed, the cement asbestos roof is supported by 7 metal rafters spaced 4m apart and 5 steel pillars down the center of the building. The roof has 12 translucent panels (3.5 x 28m) which illuminate the interior sufficiently during the daytime, although a lot of dirt and dust has accumulated on the outside. The warehouse does not have ventilation openings in the roof. Rain water is collected in ground-level concrete gutters which surround the building. The manager reported at least 5 minor holes in the roof which are a nuisance during the rainy season. The concrete floor has been poured in 6 slabs (4 x 28m) in the longitudinal direction of the building. The floor shows some long cracks and has been repaired in several spots. The manager also pointed out some long vertical cracks in the walls. The long walls have 10 small claustra (20 x 30cm) at 20cm above the floor level and 6 large claustra (40x200m) at 3m high. The small claustra are covered with insect screening at the inside and outside, the large claustus only at the inside. The north side wall has two sliding doors and 4 large covered claustra (40x350m) at 3.5m high. A large door and elevated loading area (3x5m) are present at midpoint of both long sides of the building. Electrical outlets and lamps are installed in the warehouse but electricity is not yet available in the area. The warehouse interior looks clean with minor dust collection in hard to reach places.

The warehouse has a total capacity of 500 tons. Products are stored in bags stacked in piles on wooden pallets. Beans are stored in jute bags (90kg) and woven plastic bags (100kg). Sorghum is stored in jute bags of 80 kg.

Kibungo Warehouse

The Kibungo warehouse is located close to the main paved road leading to Kibungo at less than 1 Km from the center of the town. It is constructed on a somewhat elevated, well drained and fairly level site at an altitude of 1675m.

The rectangular building is constructed on a rock bed 80 cm above ground level. It houses a large storage area (22 x 11m), a smaller storage area (6 x 11m), a store room (4 x 7m) and an office (4 x 4m). The smaller storage area was originally an open drying floor, but has been modified into a storage area to expand the capacity of the warehouse. The present total warehouse capacity is 230 tons.

The brick walls are covered with a layer of cement only at the interior of the building. The walls at the long sides are 4.5m high. The center of the building is 6.5 - 7m high. The walls contain a reinforced concrete bond beam at a height of 2m. The concrete floor is 5 cm thick and has been poured in slabs of about 4 x 11m. The control joints are filled with bitumen. A cement asbestos roof supported by wooden rafters covers the large storage area. Ten of the roof panels of the large storage area are translucent but covered with dust. Rainwater is collected in concrete ground-level gutters which drain at the N.E. corner of the building. The gutters show cracks in several places. The smaller storage area is covered with a corrugated metal roof slanting towards the east of the main door. Electricity is now available 24 hours a day.

Each long side of the warehouse has 10 small equally spaced clautras (20 x 40cm) at a height of 20m and 5 large claustra (40 x 200m) at 4m high. All claustra are covered with metal insect screening. The smaller storage area has one larger outside claustrum without screening. The wall between the two storage areas has two large (50 x 300cm) screened claustra at 4.5m high. The roof itself has no vents. All screens are covered with dust. Other hard to reach places also collect a lot of dust.

The warehouse is mainly used to store beans and sorghum. In the larger storage area products are stored in piles of jute bags on wooden pallets (100 x 200 x 7m). An average pile contains 60 to 70 tons. Corridors of 60 cm width are left between the stacks and the walls. The smaller storage area is mainly used for short term storage (food aid, etc.).

<u>Bean Quality Changes in Set Aside Stacks at OPROVIA Warehouses</u>

Most inside stack temperatures and percent moisture contents of the beans were significantly different (p less than 0.001) between warehouses within sample period and within warehouses between sample periods (Tables 64, 65 and 66). However, we presently conclude that conditions were not extreme enough (i.e., a high enough temperature or relative humidity) to cause hardness after 15 months at any of the three warehouses (Table 72). Therefore, given these bean mixture types and the environment of these warehouses, all three would be adequate for long-term storage for over one year. The temperature outside of the stacks but inside the warehouse at Kora was markedly cooler than at the other 2 warehouses, but there was little difference between the mean ambient relative humidity inside the three warehouses tested (Table 67).

Beans sampled when the set-aside stacks were constructed (5 months after the June 1984 harvest) had the same levels of <u>Aspergillus glaucus</u>

infestation (Table 75) as the last sampling from the farms. After 13 months of storage these beans did not show any increase in percent incidence of Aspergillus glaucus, suggesting favorable storage conditions.

Numbers of bruchids/sample varied significantly (0.05, 0.02, 0.01) between Nyanza and Kibungo warehouses, and between Kibungo and Kora warehouses, but did not vary significantly between the Nyanza and Kora warehouses (Tables 64, 65 and 66). Numbers of bruchids/sample at Nyanza warehouse varied significantly (0.05) between the 5th sampling (15 months after harvest) and the first three samplings (3-6 months after harvest) (Table 68). Both insect levels and insect damage levels were unacceptably high in the Kibungo warehouse stack.

There was no significant increase (0.01) in mean instrumental hardness (g. force) of beans during the period sampled (5-15 months after harvest) in any of these warehouses (Table 72).

Damage is a visible indicator that an abnormal change has occurred. Which of these beans or grain actually become or represent a loss depends on type of damage, its severity, and the end use of the beans or grain. For instance, we now know that farmers in the three agroclimatic regions we sampled discard moldy beans before preparing them for eating. With more than one insect hole, it is also discarded (not used for anything) before preparing the beans for a meal. With mold, insect, and rodent damage there also may be significant weight loss. In our survey and lab analysis, however, the 'no eat' categories is our only loss measure at present. It consists of percent kernels which is converted to grams and to R.F. (Rwanda francs). When values have been obtained for gram weight loss for various levels of each insect species we can return to the # insects obtained column and obtain another loss estimate.

The classes broken and germinated are typical of seeds that cannot be planted. Actually all six categories of typical post-harvest damage describe seeds one may not want to plant. The other four categories are presently of uncertain implication. They await instrumental hardness tests to evaluate their role in contributing to loss.

In the GRENARWA warehouses, almost 50% of the beans fell in one or more of these damage categories. Only one-eighth were of the 'known' categories (e.g., insect damage). Within category between warehouses or between sample times, there was little difference except for the mold and insect damage categories. Insect damaged kernels were three to six times greater in Kibungo warehouse beans than in Kora or Nyanza respectively. Visible mold was three times greater at Kora and Nyanza, however, than in Kibungo warehouse stacks.

Most of the recorded 'damage' (32-36% of the beans) was of the shriveled, dented, discolored and wrinkled sort. Until the instrumental hardness studies are complete we cannot interpret this information. The most interesting and indeed, the most surprising result to date is that there was no change in percent damaged kernels.

The ability of beans to germinate, however, decreased by over 50% at all locations between the time of reception of stocks (5 months after harvest and 18.5 months after harvest) (Table 72). Between 5.0 and 18.5 months of storage in stacks of bags at OPROVIA warehouses, percent germination dropped from 87 to 40 at Kora, 84 to 39 at Nyanza and 82 to 27 at Kibungo. Most of this decline occurred between 13 and 16 months at the high altitude location. The direct significance of these findings lies in what proportion of beans sold by OPROVIA are used for planting. Although major clients of OPROVIA in the past 10 years have not included those that use or sell the beans for seed, when the strategic storages are in operation this may be one major use of beans mobilized during an emergency. If such is the case, different management of these stacks is essential or strategic seed reserves will have to be kept in a different facility and or management regime. The indirect significance of these findings is that a dead germ may affect cookability and the ability of seeds to resist seed-borne fungi. Therefore, although not shown yet with the other quality factors, germinability may be a predictor of a future decline in factors shown by our data to be more closely tied to consumer preference.

Sorghum Quality Changes in Set-Aside Stacks at OPROVIA Warehouses

The stack temperature in each of the 3 warehouses declined significantly (p less than .05) over the study period. Moisture content varied somewhat but did not show a steady trend in any of the warehouses. Test weight declined significantly only in the Kibungo stack. Insect numbers were highly variable. At the Kora warehouse relatively few Sitophilus spp. and very few Rhyzopertha dominca were found throughout the study. At the Kibungo warehouse, numbers of Sitophilus and Rhyzopertha were higher, and at Nyanza Sitophilus and Rhyzopertha numbers were high and increased significantly after the first sampling. The % impurities in the stored sorghum showed a small and variable increase over time.

The highest % damage in the sorghum was generally shriveled grains, with discolored or wrinkled also accounting for much of the total damage found. Insect damage was seldom over 1%, but did show a significant increase at the Kibungo warehouse by the fourth sampling date. Rodent damage (at 1%), visible mold (at 0.2% or less) and germinated grains (at 0.2% or less) did not change over time. The % broken grains increased significantly only at Kibungo, but overall was low and variable. The % grains with torn seed coat was also low and showed no particular trend.

Overall, the typical postharvest damage increased from 2.9% to 5.8% (this includes damage due to visible mold, insects, rodents, breakage germination, or torn seed coat). Typical preharvest damage (shriveled, discolored, dented, or wrinkled) accounted for more than half the total damage.

F. FUNGAL FLORA OF BEAN AND SORGHUM SAMPLES

Species of Aspergillus, Cladosporium, Alternaria and Fusarium were isolated from surface-disinfected dry edible beans (Table 40). Species of Aspergillus, Cladosporium, Idriella and Penicillium were isolated from surface-disinfected sorghum seeds (Tables 57, 63, and 75). Aspergillus flavus was isolated from 0.3% and 1.0% of the total dry beans and sorghum seeds, respectively. Aspergillus glaucus infestation increased in beans during on-farm storage in all altitude areas sampled for both the June 1984 and January 1985 harvests. For the June 1984 harvest, the percent beans infected with A. glaucus increased during the 3.0-3.5 month storage period from 1.3 and 8.3% to 14.3 and 27.5%, respectively. The greatest percent increase in A. glaucus infected beans occurred at the low altitude locations while the lowest percent increase occurred in the middle altitude areas. It should be noted that high altitude areas were samples for the June 1984 harvest. For the January 1985 harvest, the greatest percent increase in A. glaucus infestation occurred at the high altitude locations by the low and middle altitude locations, respectively.

G. STATEMENT REGARDING ESTIMATES OF POSTHARVEST LOSS

Definition of Postharvest Loss

In the context of this report/discussion, loss is defined as that portion of a commodity which is not available for consumption. The most comprehensive way to understand postharvest loss is to picture it as a leaky pipeline. Envision a pipe direct from the field, where the commodity (such as beans or sorghum) was grown, to the table where it is eaten. From the moment it is harvested, the quantity of that harvest will never again increase. Theoretically, the beans or grain can remain unchanged until consumption. In that case one would picture all the leaks in the pipeline sealed. The most typical situation, however, is one in which a portion is lost during harvest and left in the field. Another portion is removed during preparation for storage. During storage, some of the beans or grain may be consumed by insects, birds, rodents or stolen by humans. Some may be lost in bagging or moving the commodity. Fungi will use the grain often in an invisible way, merely creating loss of mass or dry weight. In the home or an institution where the beans or grain are prepared, the person who prepares the meal may, for various reasons, discard certain kernels considered unfit or unsuitable prior to consumption.

All of these losses are postharvest losses. Postharvest losses are those losses which occur between the harvest of a crop and its consumption or use. Most postharvest losses are unseen. After harvest, a commodity can also change in value due to market price fluctuations. In a market system in which price is not fixed, the value of a commodity can increase. This discussion will not include economic losses or gains, only physical losses and certain biologic losses. The energy from a commodity may also be lost during assimilation of the nutrients within the consumers body. These physiological losses will not be included in our discussion. Many losses are extremely difficult to measure. Strictly speaking, storage losses are only a part of postharvest losses. They are the losses which occur from the moment a commodity is placed into the storage container until it is taken out of storage. The research conducted for this Project and reported here has focused on losses during storage.

Methods of Measuring Loss

Just as there are many kinds of loss and many places in the postharvest system that loss takes place, there are many methods for measuring loss.

(1) Dry Weight Loss

The most simple method of loss determination is calculation of dry weight loss. Two measurements, (1) moisture content and (2) weight per unit volume (test weight), are used to calculate the dry weight of each sample (formulas 1 and 2). The decrease in average dry weights between sampling dates is the dry weight loss for that time period.

To calculate % dry weight loss in our survey data:

1) Proportion dry matter x weight per unit volume = dry weight per unit volume.

First sample $1 - \frac{\%\ MCa}{100} \times TWa = DWa$

Second sample $1 - \frac{\%\ MCb}{100} \times TWb = DWb$

2) Difference between dry weight of the first and second sample expressed as a percent of the original dry weight.

$$\frac{DWa - DWb}{DWa} \times 100 = \%\ \text{dry weight loss}$$

Where % MCa = % moisture content of first sample

% MCb = % moisture content of second sample

TWa = test weight of first sample

TWb = test weight of second sample

DWa = dry weight of first sample

DWb = dry weight of second sample

These formulae use measurements of moisture changes in order to remove that factor from the weight loss determined. Grain which has suffered no damage whatsoever may have lost weight because its moisture content has declined. Although this loss may impact on future storability and even sale price when weight is a factor, we are not here concerned with losses of water, but rather only the dry matter that contains the food elements sought by humans.

Dry weight loss has several advantages. It will accurately measure loss of weight due to internal fungal development and insect feeding in kernels which appear sound. It will also compensate for differences in moisture content between samples.

On the other hand, dry weight loss has several disadvantages. When beans or any other commodity loses water, there is an apparent decrease in volume. Thus, simple water loss without damage will result in a net increase in weight per unit volume. This can be corrected by weighing the entire stock or using the "shrink factor", the mean decrease in bean volume due to the loss of water. Another disadvantage is the inability of this method to measure the removal of entire kernels of grain by birds or rodents. This loss can only be measured if the total stock can be weighed before and after storage. A third disadvantage is that bodies of internal feeding insects contribute to the dry weight, thus causing an underestimation of actual loss.

(2) Thousand Grain Method

Another technique for determining loss, called the thousand grain method (TGM), uses 100 to 1,000 beans or grains. It requires dividing the grain sampled into visible damaged and undamaged portions. The weight loss is determined by using the average weight of an undamaged grain (Wu/Nu) to estimate what the total sample weighted before damage occurred (Wu/Nu x Nt). The difference between that calculated "original" weight and the current sample weight (Wu + Wd) is the amount of loss. The percent loss is calculated on the basis of the "original" weight.

To calculate the weight loss due to damaged kernels:

1. Determine the average weight per undamaged grain.

$$Wu/Nu$$

2. Multiply this by the total number grains in the sample.

$$(Wu/Nu)Nt$$

3. Determine the difference between the "original" sample weight and the current sample weight.

$$\frac{(Wu/Nu)Nt - (Wu + Wd)}{(Wu/Nu)Nt} \times 100 = \%\ \text{weight loss}$$

in which Wu = weight of undamaged grains
Wd = weight of damaged grains
Nu = number of undamaged grains
Nd = number of damaged grains
Nt = total number of grains

4. If damaged grains are assumed to have no weight, i.e., are discarded before use, the formula is reduced to Nd/(Nu + Nd), and no measure of weight is required.

The advantage of this method is that it requires only one sample time. The disadvantage of this method is that it assumes that all the grains or beans have equal moisture contents when actually fungal and insect infested beans tend to have a higher individual moisture content. This may be a significant source of error. Time costs per sample are greater with this method than with the dry weight loss method due to counting and sorting needed.

The two preceding methods are general and can be used with beans or any grain. The two succeeding methods are specifically based on Rwandan beans, but the method can be adapted for other commodities and regions.

(3) Weight Loss Conversion Table

Another method proposed for converting damage data in Rwandan beans to weight loss (Hammond et al., 1987) uses a weight ratio of damaged and sound beans within damage category. The advantage is that it does not require additional weighing as the thousand grain method. The disadvantages are that the conversion values must be based on dry weight which these are not. The data collected here are based on counts, not weights (e.g., numbers of beans damaged). The data must also be obtained from a very large sample universe or population of beans which was not indicated in the above paper. Another problem with this method is that it does not account for degrees of insect damage or the unseen fungal utilization of the bean mass.

(4) Perceived Consumer Loss

The perceived consumer loss measurement is a loss determination method specifically based on which beans will likely or normally be refused for planting purposes or for preparation by the consumer prior to cooking. It is an index which subjectively measures degree of damage as well as weighs the importance of each damage class. It is expressed in percent of beans not edible or not plantable. The perceived consumer loss measurement could be combined with the weight loss index conversion table to provide weight loss data. The disadvantage of this method is that perceived consumer loss is an estimate and must be made by a specially trained technician on the damaged beans.

(5) Consumer Loss Index

The consumer loss index developed from studies of perceived consumer loss measurement which compared technician and farmer classifications of no eat/no plant.

The original data studies indicate farmers reject about 70% of those classified in the laboratory to be not edible or plantable. It is, therefore, proposed that a factor of 0.7 be used to convert lab results to a consumer loss value. It was also determined in consumer surveys that the most important visible damage categories for the consumer are:

- visible mold growth
- kernels with insect emergence holes
- rodent damaged
- germinated

Therefore, it is proposed that this 0.7 multiplication factor be used only on the sum of these four damage classes.

The advantage of this method is that this has been developed to reflect specific preferences of Rwandan consumers. The disadvantage of the method is that it is an index, based on many assumptions, not a quantitative measure for the individual sample. It is difficult to standardize. Technicians must be trained carefully to evaluate samples the same way. The conversion factor (lab to field) may vary for different parts of the country and different times of the cropping season.

Application to Rwanda

The Food and Agriculture Organization (FAO) of the United Nations has published information on postharvest loss (FAO 1977) in Rwanda. This information is read and quoted throughout the world. In one of their tables on postharvest loss in maize, there is a value of 10-20% loss in farm stored maize. There is no indication in the text over how many months of storage this loss was incurred or if this included only loss due to insects or combination of loss due to rodents, birds, theft, etc. No indication is made of whether this value was obtained from 1 or 1,000 farm visits or what region(s) of the country was sampled. There was no indication if this data had been based on measurements of dry weight loss, damage, or consumer rejection, or whether it had been based on any data at all.

There are two other sets of values for Rwandan postharvest loss. Both of these data sets were obtained from a defined population (Table 84). One of these is based on a set of twenty farms in a single hillside in the Butare Prefecture (Durnez and Dejaegher 1980). Weight loss was determined during the storage period. Mean weight loss for sorghum was 1.8% (range = 0-11.5%). For first season beans (January harvest), mean weight loss was 0.07%. For second season beans (June harvest) mean weight loss was 0.25%. These values cover a period of four months immediately after harvest.

The 1984-1986 survey by the LCS/FSMII Project, reported in this monograph (Dunkel et al., 1987) used dry weight loss (method 2.1) and the consumer loss index (method 2.5). Mean on-farm sorghum dry weight loss was -2.65 or a net weight gain during the storage period, 1-4 months after harvest. Fifteen of thirty-nine farms had sorghum for a second sampling. All of the fifteen were in low and middle altitudes. In first season beans, mean dry weight loss during on-farm storage was 2.6%. These data were obtained from twenty-six farms which had beans for a second sampling of the forty-eight total farms in the sample. These farms were located in all altitudinal areas. In second season beans (June harvest) there was a 0.49% loss in dry weight.

These data were obtained from the 14 farms which had beans for a second sampling of the forty-seven total farms in the sample. These 14 farms were located only in the low and middle altitudes. In national warehouse storage from the fifth to thirteenth month postharvest, dry weight loss was 1.96% for sorghum and 0.1% for second harvest beans.

Levels of loss reported in the pilot study of 1980 are similar to those of the national survey 1984-86. These are storage losses only. For sorghum, these levels were 2-18 times lower than the FAO figures in other developing countries. The FAO level, however, is an estimated sum of all postharvest losses in the "pipeline".

Total postharvest loss estimates should be the sum of mean values from the following data:

- losses at harvest
- losses during transport from field to home
- loss during drying (fungal growth, rodent and bird theft)
- removal of damaged beans during triage
- loss during on-farm storage
- loss during transport to commercial group
- loss during bagging or rebagging
- storage loss at a cooperative or merchant warehouse
- loss during handling and rebagging for any subsequent transactions
- storage loss in national warehouse
- loss at time of preparation for eating
- loss of seed viability reflected in loss at time of germination

One of the most striking characteristics of this list is its length. If each of these items contributed a 2% loss, there will be a 24% total postharvest loss. In Rwanda, storage may only contribute 1-2% loss as shown by the data above. If, however, only one of these categories of postharvest loss is over 25%, it is easy to approach a 50% postharvest loss. Another striking characteristic of this list is that when damage is used as a measure of loss, it is difficult to trace its origin. For instance, beans after 5 months storage on-farm, may be analyzed as being a 15% loss due to visible mold growth or discoloration. The storage method may be criticized or the storage location, when indeed, what may have happened was that rains came just after harvest and threshing. That is, the loss could have occurred when the beans needed to be sun dried and may not at all have been due to the storage container or method.

General Conclusions Regarding Loss Measurement

1. Losses due to storage methods are only part of postharvest loss. In trying to reduce postharvest loss, one must determine where the largest losses are occurring. They may not be during the storage period.

2. Loss measurements in Rwanda must be based on weight since it is by weight not volume that beans are bought and sold. This is not be confused with weight per unit volume that we used in our loss determinations. The volume in our measurements was used as a representative measure from which to work with weight.

3. Measurements of loss must include a measure of variability (standard deviation, standard error, t tests, analyses of variance) and sample size (i.e., how many different samples were analyzed to determine the

mean and from how many locations and sites within locations the samples were taken) to be meaningful.

Conclusions Regarding Losses Documented by the Present Survey Data

Three methods of determining loss were used in the Rwanda local crop storage survey (Dunkel et al., 1987):

1. % weight loss (dry basis)

2. Perceived consumer loss (= % of beans)

3. An index which converts % damaged bean data (i.e., kernels with visible mold, insect damage, rodent damage and germinated embryos) to % number of beans that will be rejected by the consumer.

The following discussion of documented losses is based on the data from the June 1984 harvest unless otherwise stated.

Bean Losses

With beans no values higher than 3.9% loss of weight (dry basis) were recorded. It is important to recall that all four values used to make each % weight loss value (i.e., 2 moisture contents and 2 test weights) are mean values with a variability. In many cases, because of this variation, the differences seen are not significant. This is especially apparent in the OPROVIA data. The total % dry weight loss recorded during an 8 month period (the fifth to thirteenth month after harvest) of storage in the OPROVIA warehouses was -0.03 or a weight gain. Because of variability of all values involved in this calculation, this value is probably not significantly different from zero. At each of the three warehouses, the values were, therefore, zero. It can be concluded that storage conditions used for these beans were ideal in preventing weight loss (dry basis) which is due primarily to insect and fungal damage.

Using perceived consumer loss (loss of edibility) as a measure of loss, there was a marked increase in the percent of beans that would be lost to eating. This loss was 6.5% for the Kibungo warehouse, 8.1% for the Nyanza warehouse and 9.6% for the Kora warehouse. When the Consumer Loss Index is used, the values are intermediate to the other two sets. For the Kibungo warehouse, a mean of 2.1%, for Nyanza also 2.1%, for Kora 1.8%, all within an acceptable range.

In the cooperative silos and hangars, bean stocks were sold soon after they had been received. The numbers of cooperatives in which a second sample was possible was too small to be used. Therefore, weight loss during storage at coops cannot be estimated. Perceived consumer loss and the Consumer Loss Index can be calculated, but we cannot obtain information from these data on how they changed during storage at the cooperatives.

On-farm for the June 1984 harvest, quantities of beans stored at high altitudes were not sufficient for analyzing loss (Table 85). At middle altitudes, a weight gain (dry basis) of 3.9% was recorded. Low altitude farm storage experienced a weight loss (dry basis) of 0.5%. In January

1985, the dry weight loss for high, middle, and low altitude farms was 3.3, 2.1 and 1.8%, respectively. The period covered by these on-farm loss figures is 1 to 3.2 months after harvest.

Using perceived consumer loss or loss of edibility as a measure of loss (Table 86), high altitude farms surveyed did not store sufficient quantities of beans to analyze loss. Middle altitude farms surveyed experienced a 1.8% loss of beans and low altitude farms experienced a 6.9% loss of edibility. This loss, as well as the consumer index is based on numbers of beans not weight.

Using the consumer loss index (Table 86), the % of the beans lost during storage in middle altitude farms surveyed is 1.9 which is actually higher than the perceived consumer loss of edibility for the same beans. This illustrates an important difference between the perceived consumer loss of edibility and the consumer loss index. The perceived loss accounts for severity of the damage i.e., not all damaged beans in certain categories are considered a loss. In the index, all damaged beans in certain categories are used for the calculation. In the above case in middle altitudes, no doubt the damage in the 4 categories used for the index was not severe and most were probably not counted in the perceived loss figures. For low altitude farms, this loss using the index was 5.0%. Damage data for this period indicate that these losses in low altitudes were primarily due to insect (bruchid) feeding activities.

Total storage losses could be calculated by adding both the weight loss of otherwise sound kernels and the weight (dry basis) of those kernels removed during the preparation process as inedible kernels. For example, from a 1 kg sample, one would remove inedible beans and measure their dry weight. Then one would measure the dry weight that was lost by the sound beans, combine the two and obtain a more accurate figure for total loss to the consumer. Total storage losses would then be calculated by adding these consumer loss figures from each level of storage the beans experience before they are consumed.

In summary, weight losses were not serious in beans at any level from which data were obtained. The highest mean value recorded was 3.3% dry weight. Perceived consumer loss and the consumer loss index produced higher values, but only for low altitude beans was this a matter of concern. This loss was due primarily to large populations of Acanthoscelides. Because loss figures due to insects can rise very rapidly and because storage losses are additive, this should be a matter of concern.

Sorghum Losses

For sorghum, no weight loss (dry basis) higher than 3.4% was recorded in any level of storage surveyed (Table 82). This occurred during an 8 month period of storage in the OPROVIA warehouse at Kibungo. These data indicate that storage conditions and sorghum management at that time could have been improved. It is evident from the damage data this was probably due to insect population development and not from that of fungi. Loss would have increased exponentially if allowed to continue. Therefore, whereas 3.4% is not an alarming % dry weight loss, other data indicated it would be rising rapidly in the future. Consumer loss indices for sorghum, have not yet been developed.

Silo and hangar-type cooperatives showed similarly low values, -5.0 to 2.0% (Table 82).

In farms surveyed, the weight loss (dry basis) for all altitudes combined was 2.6%, for high altitudes this was 0.5%, for middle altitudes 2.4%, and for low altitudes 2.8%. The period after harvest for which these values were calculated is between 1 and 2.6 months which is the mean length of time these farms kept the sorghum after harvest.

In summary, weight losses (dry basis) for sorghum, were not serious at any individual level. Losses, however, are additive. For example, if the average Kibungo farmer sold her beans after 2-3 months of storage, to the Kibungo OPROVIA warehouse, which kept them for 8 additional months, based on the present data, one should expect a 6.2% dry weight loss (2.8% on farm plus 3.4% in the warehouse). This should be a matter of concern.

IV. 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 (e.g., 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 OPROVIA and especially cooperative silos in order to detect possible problems (insects, fungi, hardness, germination) in a timely manner. It is necessary to resolve the problems of sampling large piles of bags in OPROVIA 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 which were 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 and maintain grain and beans without significant fungal growth or sensory quality changes, 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 storage losses, the presence of another typical quarantine insect, the khapra beetle (*Trogoderma granarium* Everts), should also be monitored especially in warmer regions of Rwanda.

14. Efficient and useful commercial grades and standards should be considered. Their development should be based in part on the consumer preference standards used in this report and on the range of quality factors that are perceived by the consumer.

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TABLES

Table 1. Mean annual production (metric tons MT) of dry edible beans (*Phaseolus vulgaris*), sorghum (*Sorghum bicolor*), and maize (*Zea mays*) in Rwanda (1978-1980). (Source: Ministry of Agriculture and Animal Husbandry of the Republic of Rwanda).

Prefecture	Mean Metric Tons (MT) Produced		
	Beans	Sorghum	Maize
Kigali	24,403	18,490	6,762
Gitarama	16,436	14,595	2,696
Butare	15,926	30,126	2,499
Gikongoro	12,975	19,182	6,134
Cyangugu	16,943	3,169	9,087
Kibuye	11,990	7,495	6,957
Gisenyi	15,683	12,035	17,406
Ruhengeri	20,914	19,696	14,065
Byumba	24,346	25,509	8,787
Kibungo	17,735	14,579	8,231
Total	177,352	174,773	81,347

Table 2.a. Location of farms sampled for beans and sorghum in Rwanda.

				Number of farmers surveyed		
				Beans		Sorghum
Altitude	Prefecture	Commune	Sector	June 1984	Jan. 1985	July 1984
Low (less than 1500m)	Kibungo	Rukira	Murama	6	4	1
		Muhazi	Munyiginya	6	5	5
	Kigali	Bicumbi	Bihembe	6	6	6
			Subtotal	18	15	12
Medium (1500-1900m)	Gitarama	Murama	Runyengando	6	5	5
		Mugina	Mbati	6	6	6
	Butare	Gishamvu	Liba	6	5	6
			Subtotal	18	16	17
High (higher than 1900m)	Gisenyi	Rubavu	Rugerero	5	4	0
	Ruhengeri	Gatonde	Munanira	6	6	0
	Byumba	Kinyami	Kagamba	0	7	4
			Subtotal	11	17	4
			Grand Total	47	48	33

Table 2.b. Location of cooperatives sampled for beans and sorghum in Rwanda.

Altitude	Prefecture	Commune	Name of Coop	Hanger (H) or Silo (S)	Beans	Sorghum
Low (less than 1500m)	Byumba	Murambi	Cocopamu	H	X	X
	Kigali	Gikoro	Cacopagi	S	X	X
	Kibungo	Rusumo	Rusumo	S	X	X
	Kibungo	Rukira	Coparu	H	-	X
Middle (1500-1900m)	Gikongoro	Kinyama-kara	Coaki	S	X	X
	Butare	Ndora	Coderu	S	X	X
	Butare	Gishamvu	Copadagi	S	X	X
	Butare	Muyaga	Copaga	H	X	X
	Butare	Mugusa	Abaticumu-gambi	S	X	X
	Butare	Rusatira	Comuru	S	X	X
	Gitarama	Nyabi-kenke	Codunya	S	X	-
	Gitarama	Bulinga	Caebu	H	-	X
High (above 1900m)	Gisenyi	Kayove	Codecoka	H	X	-
	Gisenyi	Kanama	Asicoka	S	X	-
	Ruhengeri	Butaro	Coparu	S	X	-
	Ruhengeri	Nyaru-tovu	Kopian	S	X	X
	Byumba	Cyungo	Abakocyu	H	X	X
	Byumba	Giti (Gasange)	Cocodegi	H	X	X
	Byumba	Giti (Bulika)	Cocodegi	S	X	X
	Byumba	Kivuye	Coteki	H	X	-
	Byumba	Rutare	Cocoderu	S	-	X

Table 3a. Description of set-aside stocks used for routine sampling in GRENARWA warehouses in Rwanda.

Location of Warehouse	Commodity	Size of Bags	Number of Bags	Size of Stack (M)	Total Metric Tons (MT) per Stack
Kibungo	Beans	100kg	148	3 x 5.0	14.85
	Sorghum	80kg	188	3 x 5.0	15.04
Kora	Beans	90kg	166	3 x 3.5	14.94
	Sorghum	80kg	174	3 x 3.5	15.41
Nyanza	Beans	90kg	336	x 6.0	30.24
	Sorghum	80kg	375		30.00

Table 3b. Evaluation of the efficiency of fumigation of the set aside sorghum stacks used for routine sampling in GRENARWA warehouses in Rwanda.

Warehouse Location	Date of Fumigation	Date of Sampling	Sitophilus spp[1/] Live	Sitophilus spp[1/] Dead	Rhyzopertha[1/] Live	Rhyzopertha[1/] Dead
Nyanza		05/10/85	317	0	0	0
	10/11/84					
		05/12/84	8	780	0	0
		09/02/85	45	1.401	28	212
		25/04/85	353	1.834	148	244
	26/04/85					
		21/06/85	29	1.936	30	501
		04/10/85	418	1.212	308	294
	18/10/85					
Kibungo		23/10/84	148	71	0	0
	16/11/84					
		10/12/84	6	415	0	0
		04/03/85	0	786	0	13
		08/05/85	0	63	0	0
	15/05/85					
		10/07/85	0	198	0	0
		03/10/85	1	395	40	71
Kora		11/10/84	0	0	0	0
		12/12/84	18	229	0	0
		06/02/85	0	158	0	0
		08/05/85	0	67	0	0
	06/06/85					
		10/07/85	0	198	0	0
		03/10/85	0	185	0	0

1/ = Total number of insects found in 15 samples (7.5 kg) of sorghum obtained from 15 sacs chosen at random from the 4 lateral faces and center of each pile.

Table 4. Containers used for storage of beans harvested June 1984 in Rwandan farm households.

	% Frequency									
		Interior Structures								
		With Cow Dung								
Farm Location	Exterior Grainery	Long Basket	Round Basket	Basket w/o Cow Dung	Earthen Pot	Gourd	Jute sack	Plastic/ Paper sack	Metal Drums	Imboho
Low° Altitude (n = 18)	0	27.8	55.6	0	11.1	0	22.2	5.6	0	16.7
Middle° Altitude (n = 18)	0	38.9	27.8	0	33.3	0	6.4	11.1	5.6	0
High° Altitude (n = 10)	0	60.0	10.0	0	0	10.0	10.0	10.0	0	0
% of Total Farms	0	38.3	38.3	0	17.0	2.1	17.0	8.5	2.1	6.4

° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.

Table 5. Quantity (kg.) of beans harvested June 1984 and stored on-farm in Rwanda within two months after harvest.

Farm Location	Long Basket	Round Basket	Earthen Pot	Gourd	Jute Sack	Plastic/ Paper Sack	Metal Drum	Imboho	Total
Low° Altitude (n = 18)	128 (= 4.3% of total) (9.7% of low altitude)	660 (= 22% of total) (49.8% of low altitude)	3 (0.1% of total) (0.2% of low altitude)	0	345 (= 11.5 % of total) (26% of low altitude)	180 (6% of total) (13.7% of low altitude)	0	10 (0.3% of total) (0.8% of low altitude)	1380 (76.7 kg/ household)
Middle° Altitude (n = 18)	630 (= 21.0% of total) (73.9% of middle altitude)	46 (1.5% of total) (5.4% of middle altitude)	60 (2.0% of total) (7.0% of middle altitude)	0	22 (0.7% of total) (2.6% of middle altitude)	75 (2.5% of total) (8.8% of middle altitude)	20 (0.7% of total) (2.3% of middle altitude)	0	853
High° Altitude (n = 10)	604 (= 20.2% of total) (74.1% of high altitude)	111 (3.7% of total) (13.6% of high altitude)	0	*	*	100 (= 3.3% of total) (= 12.3% of high altitude)	0	0	815
Total Kg.	1362	817	63	*	367	355	20	10	2994 (83.2 kg/ household)
% of Total	45.5	27.3	2.1	*	12.3	11.9	0.7	0.3	100

* No estimate possible.
° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.

Table 6. Environment (external structural aspects) of bean storage containers[1/] on Rwandan farms (June 1984 harvest).

Farm Location	Structural Materials of House, % Frequency (Number of Responses)**								
	Roof (42 responses)			Walls (133 responses)			Floor (133 responses)		Ceiling
	Thatch	Tile	Metal	Mud	Mud Brick	Cement or Plaster	Mud	Cement	Present (21 responses)
Low° Altitude (n = 18)	35.3 (6)	0 (0)	64.7 (11)	68.4 (13)	5.3 (1*)	26.3 (5)	88.9 (16)	11.1 (2)	36.4 (4)
Middle° Altitude (n = 18)	23.5 (4)	70.6 (12)	5.9 (1)	57.1 (4)	0 (0)	42.9 (3)	87.5 (7)	12.5 (1)	20.0 (1)
High° Altitude (n = 17)	12.5 (1)	25.0 (2)	62.5 (5)	71.4 (5)	0 (0)	28.6 (2)	71.4 (5)	28.6 (2)	80.0 (4)
Total of all Cases with Information	26.2[2/]	33.3	40.5	66.7	3.0	30.3	84.8	15.2	42.9

1 All beans samples were stored inside the house.
* This was also covered with cement.
° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.
** This information was not obtained from every interview.

2 $\frac{\text{total observed with thatch}}{\text{total observed thatch + tile + metal}} \times 100.$

Table 7. Environment (internal structural aspects) of bean storage containers within homes on Rwandan farms (June 1984 harvest).

Farm Location	% Frequency of Total Responses Obtained (Number of Responses)*									
	Location within the House[1/]				Storage Adjacent to Maize	Elevated Storage Container				
	In Cooking Area	In Separate Storage Area	In Sleeping Area	In Foyer		On Stones	On Platform	On Straw	Other	% Total Elevated
Low° Altitude (n = 18)	38.9 (7)	61.1 (11)	27.8 (5)	16.7 (3)	5.6 (1)	38.9 (7)	11.1 (2)	0 (0)	5.6 (1)	55.6 (11)
Middle° Altitude (n = 13)	53.8 (7)	61.5 (8)	15.4 (2)	7.7 (1)	7.7 (1)	38.5 (5)	7.7 (1)	0 (0)	15.4 (2)	61.5 (8)
High° Altitude (n = 11)	0 (0)	81.8 (9)	9.1 (1)	9.1 (1)	0 (0)	45.5 (5)	0 (0)	36.4 (4)	9.1 (1)	90.9 (10)
Total	33.3	66.7	19.0	11.9	4.8	40.5	7.1	3.5	9.5	69.0

° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.
* This information was not obtained or noted in all cases by the interviewers.
1 Some households had beans stored in more than one location, hence the sum of the percentages will be greater than 100%.

Table 8. Postharvest insecticidal treatment of beans harvested June 1984 in Rwanda.

	% Producers who Mentioned use of Insecticidal Treatments[1/]								
		Natural Material							
Farm Location	Commercial or Synthetic	Kaolin	Laterite	Ash	Pili-Pili	Other	Total Natural Insecticide	As Top Dressing**	Mixed w/Beans**
Low° Altitude (n = 18)	77.8 (14)	0	5.6 (1)	22.3 (4)	5.6 (1)	0	33.5	--	5.6
Middle° Altitude (n = 18)	11.1 (2)	27.8 (5)	0	5.6 (1)	0	0	33.4	--	5.6
High° Altitude (n = 10)	80.0 (8)	0	0	10	0	0	10.0	--	--
Mean (n = 46)	52.2	10.9	2.2	13.1	2.2	0	28.4	--	--

** Mentioned; not category specifically asked on survey form.
° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.
1 Some farmers used more than one insecticide treatment and some used nothing.

Table 9. Summary of moisture content and insect damage observed in farm-stored Rwandan beans during the first month after the June 1984 harvest.

Farm Location	Mean % Moisture Content	Mean Insect Damage (% kernels)
Low° Altitude (n = 18)	12.71*** (With Middle and High Altitude)	0.93* (With Middle Altitude) ***(With High Altitude)
Middle° Altitude (n = 18)	15.76	0.77
High° Altitude (n = 11)	14.94	0.27

*** Values in column are significantly different (p less than 0.01).
** Values in column are significantly different (p less than 0.05).
* Values in column are significantly different (p less than 0.10).
° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.

Table 10. Comparison of the mean % damage[4] of beans during the first month of on-farm storage in Rwandan farms in middle altitudes° and just prior to total utilization (June 1984 harvest) (n=8).

	Visible Mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)[1]	Shriv-eled	Dis-colored	Dented	Wrinkled	Subtotal (Typical Preharvest Damage)[2]	Total Damage
First Sample	0.7	0	0.08	0	0.04	0.20	0.32	1.46	5.59	4.51	2.88	14.44	14.76
					(0.574 = Consumer Loss Index)								
Last Sample[3]	2.1 **	0.66	0.66 *	0.25	0.16	1.00 **	2.73	3.26 ***	9.0	10.03 ***	5.75 *	28.04 ***	30.77
					(2.506 = Consumer Loss Index)								

*** Values in column are significantly different (p less than 0.01).
** Values in column are significantly different (p less than 0.05).
* Values in column are significantly different (p less than 0.10).
° Middle altitude = 1500-1900m.
1 Insect, Rodent, Broken, Germinated, Torn Pericarp and Visible Mold = typical post-harvest damage.
2 Wrinkled, Shriveled, Dented and Discolored = Typical preharvest damage.
3 Mean number of days after the first visit until beans stored at medium altitude were utilized = 101.5.
4 % of beans which had the damage, 300 beans per sample.

Table 11. Comparison of Rwandan bean quality during the first month of storage on-farm in middle altitudes° and just prior to total utilization (n = 8) (June 1984 harvest).

	Mean Values					
	% Moisture Content	# *Acanthoscelides obtectus* Obtained/kg. (= Total Insects)	Temperature Difference (°C) Between Ambient and Inside the Stock	Test Weight (g/0.9091)	% Dry Weight Loss	% Impurities and Broken Material
First Sample	16.11	0.16	-0.6	835.7	----	2.2
Last Sample	14.11 ***	4.13 *	0.6	847.7	-3.85[1/]	0.3

*** Significant difference between values obtained in first and last samples (p less than 0.01).
** Significant difference between values obtained in first and last samples (p less than 0.05).
* Significant difference between values obtained in first and last samples (p less than 0.10).
1 This represents a net dry weight gain.

Table 12. Comparison of mean % damaged beans in low and middle altitude farms in Rwanda just after harvest and just prior to total utilization (n = 14) (June 1984 harvest).

	Visible Mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)[1]	Shriveled	Discolored	Dented	Wrinkled	Subtotal (Typical Preharvest Damage)[2]	Total Damage
First Sample	0.65	0.16	0.04	0.26	0.09	0.41	0.96	2.65	5.56	4.79	2.76	15.76	16.72
Last Sample[3]	1.60	3.24 *	0.56 **	0.33	0.14	0.78	5.05 ***	4.29 *	9.34 ***	10.28 ***	6.46 **	30.37 ***	35.42 ***

*** Values in column are significantly different (p less than 0.01).
** Values in column are significantly different (p less than 0.05).
* Values in column are significantly different (p less than 0.10).
1 Insect, Rodent, Broken, Germinated, Torn Pericarp, Visible Mold.
2 Wrinkled, Shriveled, Dented and Discolored.
3 Mean number of days after the first visit until beans stored at medium altitude were used = 101.5; for low altitude = 79.4.

Table 13. Comparison of the quality of beans grown in middle and low altitudes (combined) in Rwanda during the first month of storage and just prior to total utilization (n = 14) (June 1984 harvest).

	Mean Values					
	% Moisture Content	# *Acanthoscelides obtectus* Obtained/kg. (= Total insects)	Temperature Difference (°C) Between Ambient and Inside the Stock	Test Weight (g/0.9091)	% Dry Weight Loss	% (w/w) Impurities and Broken Material
First Sample	14.54	8.71	-0.45	824.0	----	5.6
Last Sample	13.51 **	48.21	0.55 *	835.5	-2.62[1/]	0.6[2/] *

*** Values in column are significantly different (p less than 0.01).
** Values in column are significantly different (p less than 0.05).
* Values in column are significantly different (p less than 0.10).
1 This is a net % weight gain. This could have also occurred because farmers cleaned or triaged their stocks after the first sample was taken.
2 A decrease in foreign material and broken kernels indicates farmers may do cleaning or removing of impurities during storage.

Table 14. Comparison of the quality of Rwandan beans grown in low altitudes° during the first month of storage and just prior to total utilization (n = 6) (June 1984 harvest).

	Mean Values					
	% Moisture Content	*Acanthoscelides obtectus* per kg. (= total number of insects)	Temperature Difference (°C) Between Ambient and Inside the Stock	Test Weight (g/0.9091)	% Dry Weight Loss	% Impurities and Broken Material
First Sample	12.45	24.8	-0.3	812.3	----	9.7^{+}
Last Sample	12.70	131.0	0.5	823.0	0.90[1/]	0.9

* Values in column are significantly different (p less than 0.1).
\+ Perhaps most of these farmers cleaned their stock after the first sample was taken.
° Low altitude = less than 1500m.
1 This indicates a net dry weight loss.

Table 15. Comparison of the mean % damaged beans grown in low altitudes° in Rwanda during the first month of storage and just prior to total utilization (n = 6) (June 1984 harvest).

	Visible Mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)[1]	Shriveled	Discolored	Dented	Wrinkled	Subtotal (Typical Pre-harvest Damage)[2]	Total Damage
First Sample	0.6	0.38	0	0.61	0.17	0.70	1.86	4.23	5.52	5.17	2.62	17.54	19.40
						(0.89 = Consumer Loss Index)							
Last Sample	1.1	6.67	0.43	0.43	0.12	0.48	8.23	5.65	9.80	10.60	7.42	33.47	41.6
						(5.82 = Consumer Loss Index)							

*** Values in column are significantly different (p less than 0.01).
** Values in column are significantly different (p less than 0.05).
* Values in column are significantly different (p less than 0.10).
1 Insect, Rodent, Broken, Germinated, Torn Pericarp, Visible Mold.
2 Wrinkled, Shriveled, Dented and Discolored.
° Below 1500m.

Table 16. Comparison of Rwandan beans[1/] obtained by altitude° that were classified as not plantable and not edible[2/].

Location of Farm	Total Kg. Beans Sampled	Mean % of Beans ± Standard Error: Would not Plant	Mean % of Beans ± Standard Error: Would not Eat	Total[4/] kg. Bean Loss in Sampled Beans (kg/Farmer)	Total[4/] Cost of Loss (RF)[3/]
Low° Altitude (n=18)	1380	12.3 ± 1.20	5.4 ± 0.7	74.5 (4.1 kg./farmer)	3726 RF (207 RF/farmer)
Middle° Altitude (n=18)	853	13.8 ± 1.5	4.3 ± 0.8	36.7 (2.0 kg./farmer)	1834.0 RF (101.9 RF/farmer)
High° Altitude (n=10)	815	9.7 ± 1.7	3.8 ± 0.5	31.0 (1.6 Kg./farmer)	1548 RF (152.9 RF/farmer)
Total	2994	11.9	4.5		

1 June 1984 harvest. Samples obtained 1-2 months after harvest.
2 Determinations made by Edouard NIZEYIMANA, OPROVIA lab staff.
3 This assumes a market price of 50 Rwandan francs/kg.
4 That is, would not be eaten. This calculation is based on assumption that the % of number of beans not eaten is the same as the % of kg. that would not be eaten.
° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.

Table 17. Comparison of % Rwandan beans[1/] obtained that were not plantable[2/] or edible[2/] shortly after harvest and just prior to total utilization.

Farm Location	Total Kg. Beans Sampled	Mean % Beans ± S.E. Would not Plant First Sample	Would not Plant Last Sample	Would not Eat First Sample	Would not Eat Last Sample	Total[4/] Bean Loss	Cost of Loss (RF)[3/]
Low° Altitude (n = 7)	1380	12.5 ± 2.0	21.5 ± 2.5	5.5 ± 1.3	12.4 ± 2.6	171.12 (1.1 Kg/ farmer)	8556 RF (475 RF/ farmer)
Middle° Altitude (n = 7)	853	12.7 ± 1.8	13.7 ± 2.8	4.2 ± 0.9	6.0 ± 1.6	51.18 (2.8 Kg/ farmer)	2559 RF (142.2 RF/ farmer)
High° Altitude (n = 2)	815	8.3 ± 3.0	1.5 ± 0.2	2.9 ± 0.9	1.2 ± 0.2	9.78 (0.98 Kg/ farmer)	489 RF (48.9 RF/ farmer)

1/ June 1984 harvest.
2/ Classified by Edouard NIZEYIMANA, OPROVIA lab technician.
3/ This assumes a market price of 50 Rwandan francs.
4/ That is, would not be eaten.
° Low altitude = less than 1500m; middle altitude = 1500–1900m; high altitude = higher than 1900m.
5 Mean number of days after the first visit until beans were utilized = 79.4 for low altitude, 101.5 for middle altitude and 128.8 for high altitude.

Table 18. Mean number (and range) of insects[1/] obtained from incubated samples collected during on-farm storage of beans harvested in Rwanda June 1984.

Location of farm	First Sampling: Mean days after harvesting	First Sampling: Bruchids[3/] obtained	Second Sampling: Mean days after harvesting	Second Sampling: Bruchids[3/] obtained	Third Sampling: Mean days after harvesting	Third Sampling: Bruchids[3/] obtained	Third Sampling: Other insects
Low° Altitude (n = 18)	38	10.00 (0-70)	60 (n=7)	13.71 (2-69)	87 (n=3)	6.00 (0-9)	--
Middle° Altitude (n = 18)	39	3.28 (0-25)	105 (n=9)	2.44 (0-15)	120 (n=1)	13.00 (13)	2.00 (2)
High° Altitude (n = 11)	68	0.55 (0-3)	232 (n=2)	0	n=0	--	--
Grand Mean		4.61		5.37		6.00	0.67

° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.
1/ Mean number of insects obtained per 200 gram sample.
2/ Mean length of incubation = 46 days ± 4.70 S.D.
3/ Acanthoscledes obtectus only.

Table 19. % Frequency[1/] of containers used for storage of beans harvested January 1985 in Rwandan farm households.

Farm Location	% Frequency									
		Interior Structures								
		With Cow Dung								
	Exterior Grainery	Long Basket	Round Basket	Basket w/o Cow Dung	Earthen Pot	Gourd	Jute sack	Plastic* Paper sack	Metal Drums	Imbcho
Low° Altitude (n = 15)	0	20.0	33.3	0	6.7	0	26.7	13.3	0	6.7
Middle° Altitude (n = 16)	0	43.8	25.0	0	18.8	0	12.5	12.5	0	0
High° Altitude (n = 17)	0	47.0	23.5	17.6	0	0	11.8	0	0	0
% of Total Farms (n = 48)	0	37.5	27.0	6.3	8.3	0	16.7	8.3	0	2.1

° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.
* Plastic sack is woven of plastic fibers, not a continuous plastic sheet.
1/ Some farmers used more than one type of storage container. This is reflected in the data.

Table 20. Quantity (Kg) of beans harvested January 1985 and stored on-farm within two months after harvest in Rwanda.

Farm Location	Interior Structures								
	Long Basket	Round Basket	Earthen Pot	Gourd	Jute Sack	Plastic/ Paper Sack	Metal Drum	Imboho	Total
Low° Altitude (n = 15)	550.0 (= 21.3% of total) (68.3% of low altitude)	50.0 (= 1.9% of total) (6.2% of low altitude)	0	0	155.0 (= 6.0% of total) (19.3% of low altitude)	0	0	50.0 (= 1.9% of total) (6.2% of low altitude)	805.0
Middle° Altitude (n = 16)	650.0 (= 25.2% of total) (57.8% of middle altitude)	195.0 (= 7.8% of total) (17.3% of middle altitude)	0	0	100.0 (= 3.9% of total) (8.9% of middle altitude)	180.0 (= 7.0% of total) (16% of middle altitude)	0	0	1125.0
High° Altitude (n = 17)	590.0 (= 22.9% of total) (91.0% of high altitude)	2.0	0	0	56.0 (= 2.2% of total) (8.6% of middle altitude)	0	0	0	648.0
Total Kg.	1790.0	247.0	0	0	311.0	180.0	0	50.0	2578.0
% of Total	69.4	9.6	0	0	12.1	7.0	0	1.9	100.0

° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.

Table 21. Utilization patterns of producers of beans harvested January 1985 in Rwanda.

Farm Location	Kg. in Storage Within 2 Mos. after Harvest Total Sampled	Mean per farmer	Total # of days After First Visit Until Beans were utilized	Utilization: Auto-Consumption	Utilization: Cattle	Utilization: Seeds	Utilization: Sales	Utilization: Transfer or Gift	Utilization: Other	Price (Rwandan francs)
Low° Altitude (n = 15)	805.0	53.7	98.8	1198.0*	0	385.0	315.0	30.0	0	35.0
Middle° Altitude (n = 16)	1125.0	70.3	105.4	1447.0*	0	320.0	271.0	20.0	40.0	35-50
High° Altitude (n = 17)	648.0	38.1	81.5	593.0*	0	410.0	414.0	35.0	0	35-50
Grand Mean	2578.0	53.7	94.9							

° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.
* Apparently farmers included consumption of beans from elsewhere.

Table 22. Environment (external structural aspects) of bean storage containers[1/] on Rwandan farms (January 1985 harvest).

Farm Location	Structural Materials of House, % Frequency (Number of Responses)									
	Roof (44 responses)			Wall (37 responses)			Floor (35 responses)		Ceiling (21 responses)	
	Thatch	Tile	Metal	Mud	Mud Brick	Plaster or Kaolin˙	Mud	Cement	Present	Absent
Low° Altitude (n = 15)	21.4 (3)	0	78.6 (11)	62.5 (10)	6.3* (1)	31.3 (5)	86.7 (13)	13.3 (2)	40.0 (4)	60 (6)
Middle° Altitude (n = 16)	18.8 (3)	75.0 (12)	6.3 (1)	40.0 (2)	0 (0)	60.0 (3)	87.5 (7)	12.5 (1)	20.0 (1)	80 (4)
High° Altitude (n = 17)	21.4 (3)	14.3 (2)	64.3 (9)	87.5 (14)	0 (0)	12.5 (2)	83.3 (10)	16.7 (2)	80.0 (4)	20 (1)
Total of all Cases and Information	20.5 (n=9)	31.8 (n=14)	47.7 (n=21)	70.3 (n=26)	2.7 (n=1)	27.0 (n=10)	85.7 (n=30)	14.3 (n=5)	45.0 (n=20)	55 (n=11)

1/ All beans samples were stored inside the house.
* This was also covered with plaster.
˙ This material is made from locally available clay or kaolin.
° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.

Table 23. Environment (internal structural aspects) of bean storage containers within homes on Rwandan farms (January 1985 harvest).

Farm Location (total no. farms interviewed)	% Frequency of Total Responses Obtained (Number of Responses)									
	Location within the House				Storage	Elevated Storage Container				
	In Cooking Area	In Separate Storage Area	In Sleeping Area	In Foyer	Adjacent to Maize	On Stones	On Platform	On Straw	Other	Total % Elevated
Low° Altitude (n = 15)	14.3 (2)	42.9 (6)	14.3 (2)	28.6 (4)	no data	13.3 (2)	6.7 (1)	0	26.7 (4)	46.7 (7)
Middle° Altitude (n = 16)	0 (0)	40.0 (6)	13.3 (2)	46.7 (7)	"	0 (0)	6.3 (1)	0 (0)	6.3 (1)	12.6 (2)
High° Altitude (n = 17)	0 (0)	70.6 (12)	11.8 (2)	17.6 (3)	"	17.6 (3)	0 (0)	0 (0)	0 (0)	17.6 (3)
Total	4.3 (2)	52.2 (24)	13.0 (6)	30.4 (14)	"	10.4 (5)	4.2 (2)	0 (0)	10.4 (5)	25.0 (12)

° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.

Table 24. Postharvest preparation of beans (January 1985 harvest) for storage on Rwandan farms.

	Number of people who worked on harvest			Days for Harvesting	Number of people who worked on threshing			Days for Threshing	Number of people who worked on winnowing			Days for Winnowing and Sorting
	Male	Female	Total		Male	Female	Total		Male	Female	Total	
Low Altitude (below 1500 m)	1.0 ±0.2 1.0*	1.5 ±0.2 1.0	2.5 ±0.2 2.0	3.3 ±0.4 3.0	1.0 ±0.2 1.0	0.5 ±0.2 0.0	1.5 ±0.2 1.0	1.7 ±0.2 2.0	0.0 ±0.0 0.0	1.0 ±0.0 1.0	1.0 ±0.0 1.0	1.9 ±0.3 2.0
Middle Altitude (1500 to 1900 m)	1.3 ±0.5 1.0	1.7 ±0.2 1.5	3.0 ±0.6 2.0	3.1 ±0.4 3.0	1.0 ±0.2 1.0	0.6 ±0.2 0.0	1.6 ±0.2 1.5	1.7 ±0.2 1.3	0.0 ±0.0 0.0	1.5 ±0.3 1.0	1.5 ±0.2 1.0	1.9 ±0.3 2.0
High Altitude (above 1900 m)	1.5 ±0.3 1.0	2.4 ±0.4 2.0	3.8 ±0.6 3.0	2.6 ±0.4 2.0	1.3 ±0.4 1.0	0.4 ±0.2 0.0	1.8 ±0.3 1.0	1.6 ±0.3 1.0	0.1 ±0.1 0.0	1.7 ±0.3 1.0	1.7 ±0.3 1.0	1.7 ±0.3 1.0
All Altitudes Combined	1.3 ±0.2 1.0	1.9 ±0.2 1.5	3.1 ±0.3 2.0	3.0 ±0.2 2.5	1.1 ±0.1 1.0	0.5 ±0.1 0.0	1.6 ±0.1 1.0	1.7 ±0.1 1.0	0.02±0.02 0.0	1.4 ±0.1 1.0	1.4 ±0.1 1.0	1.8 ±0.2 1.0

*Median value. 50% of values were this value or lower, 50% were this value or higher.
When the mean and the median are not the same it indicates that a few extreme values are influencing the mean.

Table 25. Postharvest insecticidal treatment of beans harvested January 1985 in Rwanda.

Farm Location	% Producers who Mentioned use of Insecticidal Treatments (number of farmers)									
		Natural Material								
	Commercial or Synthetic	Kaolin	Laterite	Ash	Pili-Pili	Other	Total Natural Insecticide	As Top Dressing=	Mixed w/Beans=	Total Farmers using a Treatment*
Low° Altitude (n = 15)	73.3 (11)	0	0	26.7 (4)	0	6.7 (1)	33.4	0	26.7 (4)	106.7
Middle° Altitude (n = 16)	50.0 (8)	12.5 (2)	0	18.8 (3)	0	0	31.3	0	0	81.3
High° Altitude (n = 17)	29.4 (5)	0	0	0	0	0	0	0	0	29.4
Total (n = 48)	50.0	4.2	0	14.6	0	2.1	20.9	0	8.3	70.9

= Mentioned; not category specifically asked on survey form.

° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.

* Some farmers use more than one type of treatment. Therefore, when % is over 100, it means at least one farmer is using more than one treatment.

Table 26. Summary of moisture content and insect damage observed in farm stored Rwandan beans during the first month after the January 1985 harvest.

Farm Location	Mean % Moisture Content	Mean Insect Damage (% kernels)
Low° Altitude (n = 15)	14.80*** (With Middle and High Altitude)	0.0* (With Middle Altitude) *** (With High Altitude)
Middle° Altitude (n = 16)	14.68	0.06
High° Altitude (n = 17)	15.35	0.04

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
° Low altitude = less than 1500m, middle altitude = 1500-1900m; high altitude = higher than 1900m.

Table 27. Comparison of the mean % damage3/ of beans grown in low° altitudes during the first month of storage on farms in Rwanda and just prior to total utilization. (January 1985 harvest). (n = 9)+

Time of Sample During Storage Period	Visible Mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)1	Shriveled	Discolored	Dented	Wrinkled	Subtotal (Typical Pre-harvest Damage)2	Total Damage
First+ Sample	0.59	0	0	0.29	0	0.22	1.10	5.18	6.14	7.03	3.30	21.65	22.75
Last+ Sample	0	0.14	0.11	0.18	0	0.50	0.93	2.97	7.11	6.32	3.04	19.44	20.37

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
1/ Insect, Rodent, Broken, Germinated, Torn Pericarp, Visible Mold
2/ Wrinkled, Shriveled, Dented and Discolored
° Low altitude = less than 1500m.
+ n = only farms where additional samplings(s) were possible. In low altitudes 8 farms used or sold all beans between first and second visits and cannot be included in this comparison. Mean days after first visit before beans stored at low altitude were utilized = 98.8.
3/ % of beans which had the damage, 300 beans per sample.

Table 28. Comparison of Rwandan bean quality of low° altitude beans during the first month of storage on-farm in low altitudes and just prior to total utilization. (January 1985 harvest). (n = 9)+

Time of Sample During Storage Period	Mean Values							
	% Moisture Content	# Insects Obtained/kg. *Acanthoscelides obtectus*	# Insects Obtained/kg. *Sitophilus* spp.	# Insects Obtained/kg. Total	Temperature Difference (°C) Between Ambient and Inside the Stock	Test Weight (g/0.9091)	% Dry Weight Loss	% (w/w) Impurities and Broken Material
First+ Sample	14.92	0.26	0	0.26	0	843.7	---	0.26
Last+ Sample	14.27	13.35 *	2.43	15.78 **	0.50	822.2 **	1.80	0.41+

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
° Low altitude = less than 1500m.
+ n = only farms where additional sampling(s) was possible. In low altitudes, 8 farms used or sold all beans between first and second visits and cannot be included in this comparison. Mean number of days after the first visit before beans stored in low altitude were utilized = 98.8.

Table 29. Comparison of mean % damaged beans[3/] grown in middle° altitudes during the first month of on-farm storage in Rwanda and just prior to utilization. (January 1985 harvest). (n = 11)[+]

Time of Sampling During Storage	Visible Mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)[1/]	Shriv-eled	Dis-colored	Dented	Wrinkled	Subtotal (Typical Pre-harvest Damage[2/])	Total Damage
First Sample	1.1	0.09	0.03	0.79	0.08	0.33	2.42	3.91	6.18	6.05	3.54	19.68	22.10
Last[+] Sample	0.43	0.48 *	0.08	0.39	0	0.51	1.89	7.11 **	10.6	9.9 **	4.0	31.61 ***	33.50 ***

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
1/ Insect, Rodent, Broken, Germinated, Torn Pericarp and Visible Mold
2/ Wrinkled, Shriveled, Dented and Discolored
° Middle altitude = 1500-1900m.
+ n = only farms where additional sampling(s) was possible.
In middle altitude 5 farms used or sold all beans between first & second visits and cannot be included in this comparison. Mean days after first visit before beans stored in middle altitude were utilized = 105.4
3/ % of beans which had the damage (300 beans per sample).

Table 30. Comparison of the quality of beans grown in middle° altitudes during the first+ month of storage on Rwandan farms and just prior to total utilization. (January 1985 harvest). (n = 11)+

Time of Sampling in Storage Period	Mean Values: % Moisture Content	# Insects Obtained/kg.: *Acanthoscelides obtectus*	# Insects Obtained/kg.: *Sitophilus* spp.	# Insects Obtained/kg.: *Plodia interpunctella*	# Insects Obtained/kg.: Total	Temperature Difference (°C) Between Ambient and Inside the Stock	Test Weight (g/0.9091)	% Dry Weight Loss (g)	% (w/w) Impurities and Broken Material
First+ Sample	14.46	0	0.0	0.0	0.0	0.13	852.5	----	0.23
Last+ Sample	14.54	4.02 *	0.77	0.11	4.90 *	0	835.5 *	2.09	0.39 *

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
° Middle altitude = 1500-1900m.
+ n = only farms where additional sampling(s) was possible. In middle altitude, 5 farms used or sold all beans between first and second visits and cannot be included in this comparison. Mean days after first visit before beans stored in middle altitude were utilized = 105.4.

Table 31. Comparison of mean % damage[3/] in beans grown in high altitudes° during the first month of storage on Rwandan farms and just prior to total utilization (January 1985 harvest) (n=6)[+].

Time of Sampling During Storage Period	Visible Mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)[1/]	Shriveled	Discolored	Dented	Wrinkled	Subtotal (Typical Preharvest Damage)[2/]	Total Damage
First[+] Sample	1.28	0.05	0.55	0.27	0.0	0.53	2.68	5.92	6.17	10.23	5.38	27.70	30.38
Last[+] Sample	1.22	0.05	3.28	0.05	0.0	0.32	4.92	5.18	6.93	8.33	4.40	24.84	29.76

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
1/ Insect, Rodent, Broken, Germinated, Torn Pericarp and Visible Mold.
2/ Wrinkled, Shriveled, Dented and Discolored.
° High altitude = higher than 1900m.
\+ n = only farms where additional sampling(s) was possible. In high altitudes 11 farms used or sold all beans between first and second visits and cannot be included in this comparison. Mean days after first visit before beans stored in high altitudes were utilized = 81.5.
3/ % of beans which had the damage, 300 beans/sample.

Table 32. Comparison of the quality of beans grown in high altitudes during first month of storage on Rwandan farms and just prior to total utilization (January 1985 harvest) (n = 6)+.

Time of Sampling During Storage Period	Mean Values							
	% Moisture Content	Number Insects Obtained/kg. Acanthoscelides obtectus	Other	Total	Temperature Difference (°C) Between Ambient and Inside	Test Weight (g/0.9091)	% Dry Weight (g)	% (w/w) Impurities and Broken Material
First+ Sample	14.57	0	0	0	0.3	864.7	---	0.3
Last+ Sample	15.25	0	0.39	0.39	0.3	842.5	3.34	0.4

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
° High altitude = higher than 1900m.
+ n = only farms where additional sampling(s) was possible. In high altitudes 11 farms used or sold all beans between first and second visits and cannot be included in this comparison. Mean days after first visit before beans stored in high altitudes were utilized = 81.5.

Table 33. Comparison of beans[1/] obtained from on-farm storage in Rwanda that were classified as not plantable and not to be edible[2/].

Farm Location	Total Kg. Beans Sampled	Mean % of Beans ± Standard Error: Would not Plant	Would not Eat	Total[4/] Kg. Bean Loss	Total[4/] Cost of Loss (RF)[3/]
Low° Altitude (n=15)	805	13.0 ± 1.8	2.9 ± 0.4	23.3 (1.6 Kg./farmer)	1165 RF (78 RF/farmer)
Middle° Altitude (n=16)	1125	9.4 ± 1.2	3.0 ± 0.6	33.8 (2.1 Kg./farmer)	1690 RF (105.6 RF/farmer)
High° Altitude (n=17)	648	12.3 ± 1.5	4.3 ± 0.5	27.9 (1.6 Kg./farmer)	1393 RF (82.0 RF/farmer)
Total	2578	11.6	3.4		

1/ January 1985 harvest. Samples obtained 1-2 months after harvest.
2/ Determinations made by Edouard NIZEYIMANA, OPROVIA lab Staff (300 beans/sample).
3/ This assumes a market price of 50 Rwandan francs/Kg.
4/ That is, would not be eaten. This calculation is based on the assumption that the % of the number of beans that would not be eaten is the same as the % by weight that would be a loss.
° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.

Table 34. Comparison of % beans[1/] obtained from on-farm storage in Rwanda[+] that were not plantable[2/] or edible[2/] shortly after harvest and just prior to total utilization[+].

Farm Location	Total Kg. Beans Sampled	Mean % Beans ± S.E. Would not Plant: First Sample	Would not Plant: Last Sample	Would not Eat: First Sample	Would not Eat: Last Sample	Total[4/] Kg. Bean Loss	Total[4/] Cost of Loss (RF)[3/]
Low° Altitude (n = 9)[+]	805	9.7 ± 1.8	6.4 ± 2.2	2.6 ± 0.6	2.0 ± 0.8	16.1 (1.1 Kg/ farmer)* 36.6 kg	805 RF (55 RF/ farmer)
Middle° Altitude (n = 11)[+]	1125	7.3 ± 1.1	12.9 ± 1.5	2.4 ± 0.5	5.9 ± 1.0	66.4 (4.1 Kg/ farmer)	3320 RF (205 RF/ farmer)
High° Altitude (n = 6)[+]	648	11.4 ± 1.5	13.2 ± 4.6	4.7 ± 0.4	5.6 ± 1.6	35.3 (2.1 Kg/ farmer)	1815 RF (105 RF/ farmer)

1/ January 1985 harvest.
2/ Classified by Edouard NIZEYIMANA, OPROVIA lab technician (sample size = 300 beans).
3/ This assumes a market price of 50 Rwandan francs.
4/ That is, would not be eaten.
+ n = only farms where additional sampling (3) was possible. In low altitudes 8 farms, in middle altitudes 5 farms and in high altitudes 11 farms used or sold all beans between first and second visits and cannot be included in this comparison. Mean days after first visit before beans stored in all altitudes combined were utilized were 94.9.
° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.

Table 35. Comparison of mean % damaged beans[3/] in storage on Rwandan farms just after harvest and just prior to total utilization (all altitudes combined) (January 1985 harvest) (n = 26)[+].

Time of Sampling During Storage Period	Visible Mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)[1/]	Shriveled	Discolored	Dented	Wrinkled	Subtotal (Typical Preharvest Damage)[2/]	Total Damage
First[+] Sample	0.96	0.05	0.13	0.50	0.03	0.34	2.01	4.81	6.17	7.36	3.88	22.22	24.23
Last[+] Sample	0.46	0.37 **	0.83	0.24 *	0.0	0.46	2.36	5.23	8.55	8.30	3.76	25.84	28.20

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
1/ Insect, Rodent, Broken, Germinated, Torn Pericarp, Visible Mold
2/ Wrinkled, Shriveled, Dented and Discolored
+ n = only farms where additional sampling(s) was possible. In low altitudes 8 farms, in middle altitudes 5 farms and in high altitudes 11 farms used or sold all beans between first and second visits and cannot be included in this comparison. Mean days after first visit before beans stored in all altitudes combined were utilized were 95.
3/ % of beans which had the damage. 300 beans/sample.

Table 36. Comparison of bean quality on Rwandan farms during the first month of storage and just prior to total utilization (all altitudes combined) (n = 26)+ (January 1985 harvest).

	Mean Values									
		Mean No. Insects/kg. ± S.E.								
Time of Sampling During Storage Period	% Moisture Content	*Acanthoscelides obtectus*	*Sitophilus* spp.	*Plodia interpunctella*	Other Insects	Total Insects	Temperature Difference (°C) Between Ambient and Inside the Stock	Test Weight (g/0.9091)	% Weight Loss (dry basis)	% (w/w) Impurities and Broken Material
First+ Sample	14.7 ± 0.3	0.1 ± 0.1	0.0	0.0	0.0	0.09	0.15	852.2	---	0.3 ± 0.1
Last+ Sample	14.7 ± 0.3	6.2 ± 1.5 **	1.2 ± 0.7	0.1 ± 0.4	0.1 ± 0.1	7.45 ***	0.23	832.5 ***	2.3	0.4 ± 0.1 *

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
+ n = only farms where additional sampling(s) was possible. In low altitudes 8 farms, in middle altitudes 5 farms and in high altitudes 11 farms used or sold all beans between first and second visits and cannot be included in this comparison. For this table, mean storage period after first visit was 95 days.

Table 37. Comparison of mean % damaged beans[4/] stored on-farm in Rwanda for all altitudes combined, just after harvest and just prior to total utilization (January 1985 and June 1984 harvests)[3/].

Time of Sampling During Storage Period	Total Damage	Visible Mold	Insect Damage	Rodent Damage	Broken	Germin-ated	Torn Peri-carp	Subtotal (Typical Post-harvest Damage)[1/]	Shriv-eled	Dis-colored	Dented	Wrinkled	Subtotal (Typical Pre-harvest Damage)[2/]
<u>First Sample</u>													
June 1984	20.77	0.38	0.46	0.18	0.55	0.08	0.48	2.13	2.55	6.84	5.71	3.54	18.64
Jan. 1985	27.28 **	1.26 ***	0.03 **	0.12	0.50	0.05	0.42	2.38	6.37 ***	7.05	7.68 **	3.80	24.89 **
<u>Last Sample</u>													
June 1984	33.86	1.41	2.84	0.58	0.41	0.12	0.82	6.18	4.04	8.32	9.70	5.62	27.68
Jan. 1985	28.20	0.46 *	0.37 *	0.83	0.24	0.0	0.46	2.36 *	5.23	8.55	8.30	3.76	25.84

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
1/ Insect, Rodent, Broken, Germinated, Torn Pericarp, Visible Mold
2/ Wrinkled, Shriveled, Dented and Discolored
3/ June 1984 first sample = 46, second sample = 17. Mean days between first and last visit before total utilization = 103.2.
January 1985 first sample = 48, second sample = 26. Mean days between first and last visit before total utilization = 94.9.
4/ % of beans which had the damage. 300 beans/sample.

Table 38. Comparison of bean quality during the first month of storage and just prior to total utilization (middle° and low° altitudes[1/] combined) (June 1984 and January 1985 harvests) (n = 20)[+].

Time of Sampling During Storage Period	Mean Values										
	% Moisture Content	Number Insects Obtained/Kg.: Acanthoscelides obtectus	Sitophilus spp.	Rhyzoperta dominica	Plodia interpunctella	Other	Total	Temperature Difference (°C) Between Ambient and Inside the Stock	Test Weight (g/0.9091)	% Weight Loss (dry basis)	% (w/w) Impurities and Broken Material
First Sample June 1984	13.30	9.18	0.0	0.0	0.0	0.02	9.20	-0.52	843.23	---	4.39
January 1985	14.95 ***	0.44 **	0.0	0.0	0.0	0.02 **	0.46	+0.28 ***	854.42	---	0.33 **
Last Sample June 1984	13.08	55.18	0.29	0.0	0.0	0.07	55.54	-0.13	836.94	0.49	0.55
January 1985	14.69 **	6.15	1.15	0.0	0.05	0.10	7.45	+0.13	832.54	2.26	0.39

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
1/ Insufficient quantity of high altitude farms in which a second sample was possible to include in this comparison.
° Low altitude = less than 1500m; middle altitude = 1500-1900m.
\+ June 1984: first sample = 36, second sample = 14.
January 1985: first sample = 31, second sample = 20.

Table 40. Mean[1/] incidence of beans yielding storage fungi in Rwandan farms at low (below 1500m), middle (1500-1900m), and high (above 1900m) altitude locations.

Low Altitude (below 1500m) locations	June 1984 Harvest (6 locations = 240 seeds) 1 mo. after harvest	3.5 = mean mo. after harvest	January 1985 Harvest (10 locations = 400 seeds) 1 mo. after harvest	3.8 = mean mo. after harvest
Aspergillus candidus	0.4	0.0	0.3	0.3
Aspergillus flavus	0.0	0.4	0.0	0.0
Aspergillus glaucus	1.3	14.3	2.5	11.9
Aspergillus niger	0.0	0.0	0.0	0.0
Aspergillus ochraceus	1.3	0.0	0.0	1.1
Aspergillus restrictus	0.8	0.4	0.0	0.0
Penicillium	0.8	0.0	0.9	0.8

Middle Altitude (1500-1900m) locations	(3 locations = 120 seeds) 1 mo. after harvest	3 mo. after harvest	(12 locations = 480 seeds) 1 mo. after harvest	3.7 = mean mo. after harvest
A. candidus	0.0	0.0	0.0	0.2
A. flavus	0.0	0.0	0.0	0.0
A. glaucus	8.3	27.5	4.4	14.2
A. niger	0.0	0.0	0.0	0.0
A. ochraceus	0.0	0.0	0.4	1.7
A. restrictus	0.8	10.0	0.2	1.3
Penicillium spp.	0.0	1.7	2.7	1.7

1/ 20 seeds/dish; 2 dishes/location. One dish of acid potato dextrose agar (PDA) and one of tomato juice agar (TJA) plus 6% NACl.

Table 40. (continued)

Mean[1/] incidence of beans yielding storage fungi in Rwandan farms at low altitude (below 1500m) and middle altitude (1500-1900m) and high altitude (above 1900m) locations.

High Altitude[2/] (above 1900m)	January 1985 harvest (6 locations = 240 seeds) 1 mo. after harvest	4.7 = mean mo. after harvest
Aspergillus candidus	0.0	0.0
Aspergillus flavus	0.0	0.0
Aspergillus glaucus	3.9	21.4
Aspergillus niger	0.0	0.0
Aspergillus ochraceus	0.8	2.5
Aspergillus restrictus	0.6	4.2
Penicillium spp.	3.1	2.2

2/ Not enough farms which had beans from which a second sample could be obtained. High altitudes for the June 1984 harvest.

Table 41. Containers used for storage of sorghum[+] on Rwandan farms.

Farm Location	% Frequency									
		Interior Structure								
		Lined With Cow Dung								
	Exterior Grainery	Long Basket	Round Basket	Basket w/o Cow Dung Lining	Earthen Pot	Gourd	Jute sack	Plastic/ Paper sack	Metal Drums	Imboho
Low° Altitude (n = 12)	0	41.7	16.7	0	0	0	33.3	16.7	8.3	0
Middle° Altitude (n = 17)	0	58.8	29.4	0	5.9	0	0	11.8	17.6	0
High° Altitude (n = 10)	0	80.0	10.0	0	0	0	0	0	10.0	0
% of Total Farms[1/] (n = 39)	0	60.0	20.5	0	2.7	0	7.7	10.3	12.8	0

+ 1984 June harvest.

° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = above 1900m.

1/ Some farms had more than one type of container; hence, the total will be over 100%.

Table 42. Quantity (Kg.) of sorghum+ stored on-farm within two months after harvest in Rwanda.

Farm Location	Interior Structures: Long Basket	Round Basket	Earthen Pot	Gourd	Jute Sack	Plastic/ Paper Sack	Metal Drum	Imboho	Total
Low° Altitude (n = 12)	1110 (= 22.8% of total) (42.5% of low altitude)	0	0	0	1440 (= 37.2% of total) (55.0% of low altitude)	60	0	0	2610
Middle° Altitude (n = 17)	1120 (= 23.0% of total) (94.6% of middle altitude)	80	25	0	0	5	60	0	1290
High° Altitude (n = 10)	920 (= 18.9% of total) (94.8% of high altitude)	50	0	*	*	0	0	0	970
Total Kg.	3150	130	25	*	1440	65	60	0	4870
% of Total	64.7	2.7	0.5	*	29.6	1.3	1.2	0	100

+ 1984 June harvest.
* No estimate possible.
° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = above 1900m.

Table 43. Utilization patterns by producers of sorghum[+] in Rwanda.

Farm Location	Total Kg. in Storage Within 2 2 Mos. after Harvest	Mean Qty. in Storage per household (Kg.)	Mean # of Days After First Visit Until Sorghum was Completely Utilized	Mode of Utilization (Kg.)*: Auto-Consumption	Live-stock	Seeds	Sales	Transfer or Gift	Other	Price
Low° Altitude (n = 12)	2610	217.5	97.5	360	0	10	1380	*	0	20-23
Middle° Altitude (n = 17)	1290	75.8	83.8	1355=	0	5*	970	220	50	25-30
High° Altitude (n = 10)	970	97.0	135.6	100	0	*	50	50	0	30
Total Mean	4870	124.8	104.7	1815	0	15*	2400	270*	50	

+ 1984 June

* Data for this harvest was not complete enough to make a utilization statement.

= Apparently farmers included consumption of sorghum from elsewhere.

° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = above 1900m.

Table 44. Environment (external structural aspects) of sorghum[+] storage[*] containers on Rwandan farms.

Farm Location	Structural Materials of House, % Frequency (Number of Responses): Room (n = 25)			Walls (n = 23)			Floor (n = 24)		Ceiling (n = 20)	
	Thatch	Tile	Metal	Mud	Mud Brick	Cement or Plaster[1/]	Mud	Cement	Present	Absent
Low° Altitude	20.0 (2)	0	80.0 (8)	77.8 (7)	0	22.2 (2)	77.8 (7)	22.2 (2)	16.7 (1)	83.3 (5)
Middle° Altitude	33.3 (2)	66.7 (4)	0 (0)	66.7 (4)	0	33.3 (2)	85.7 (6)	14.3 (1)	16.7 (1)	83.3 (5)
High° Altitude	44.4 (4)	0	55.6 (5)	100 (8)	0	0 (0)	100 (8)	0	12.5 (1)	87.5 (7)
Total of all Cases and Information	32.0 (8)	16.0 (4)	52.0 (13)	82.6 (19)	0 (0)	17.4 (4)	87.5 (22)	12.5 (3)	15.0 (3)	85.0 (17)

+ Harvested June 1984.

* All sorghum was stored inside the house.

1/ This material is made from locally available clay or kaolin.

Table 45. Environment (internal structural aspects) of sorghum storage* containers within homes on Rwandan farms.

	% Frequency of Total Responses Obtained (Number of Responses)										
	Location Within the House (n = 34)					Elevated Storage Container (n = 39)					
	In Cooking Area	In Separate Storage Area	In Sleeping Area	In Foyer	Storage Adjacent to Maize	On Stones	On Platform	On Straw	Other	elevated no other info.	% Total Elevated
Low° Altitude	8.3 (1)	25.0 (3)	0	50.0 (6)	-	16.7 (2)	41.7 (5)	0	0	25.0 (3)	83.3 (10)
Middle° Altitude	0 (0)	47.1 (8)	11.8 (2)	35.3 (6)	-	11.8 (2)	41.3 (7)	0	11.8 (2)	17.6 (3)	82.3 (14)
High° Altitude	20.0 (2)	20.0 (2)	0	40.0 (4)	-	10.0 (1)	0	0	0	40.0 (4)	50.0 (5)
Total	7.7 (3)	33.3 (13)	5.1 (2)	41.0 (16)	-	12.8	30.8	0	5.1	25.6	74.4

* June 1984 harvest.

° Low altitude = below 1500m; middle altitude = 1500-1900m; high altitude = above 1900m.

Table 46. Postharvest insecticidal treatment of sorghum[+] in Rwanda.

Farm Location	% Producers who Mentioned use of Insecticidal Treatments (number of farmers)							
		Natural Material						
	Commercial or Synthetic	Kaolin	Laterite	Ash	Pili-Pili	Other	Total Natural Insecticide	Total any Treatment
Low° Altitude (n = 12)	50.0 (6)	0	0	16.7 (2)	0	0	16.7	66.7
Middle° Altitude (n = 17)	17.6 (3)	0	0	17.6 (3)	0	5.9 (1)	35.3	52.9
High° Altitude (n = 10)	20.0 (2)	0	0	30.0 (3)	0	0	30.0	50.0
Total (n = 39)	28.2 (11)	0	0	25.6 (10)	0	2.6 (1)	28.2 (11)	56.4 (22)

+ 1984 June harvest.

° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = above 1900m.

Table 47. Summary of the condition of on-farm stored sorghum one month after the 1984 harvest in Rwanda.

Farm Location	Mean % Moisture Content	Mean Insect Damage (% kernels)
Low° Altitude (n = 12)	12.21	0.67
Middle° Altitude (n = 17)	12.06* (with high altitude)	0.29
High° Altitude (n = 10)	13.18	1.20

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = above 1900m.

Table 48. Comparison of mean % damaged sorghum during the first month of storage on Rwandan farms in low° altitudes and just prior to utilization (June 1984 harvest)[1/] (n = 6)[+].

	Visible Mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)[2/]	Shriv- eled	Dis- colored	Wrink- eled	Subtotal (Typical Preharvest Damage)[3/]	Total Damage
First Sample[+]	0	0.08	0	0.04	0.20	0.14	0.46	5.59	4.51	2.88	12.98	13.44
Last Sample[+]	0.66	0.66 *	0.25	0.16	1.00 **	2.73	5.46 ***	9.0	10.03 ***	5.75 *	24.75 ***	30.21

*** Values in column are significantly different (p less than 0.001) paired t-test.
** Values in column are significantly different (p less than 0.01) paired t-test.
* Values in column are significantly different (p less than 0.05) paired t-test.
1/ = % of kernels which had the damage (300 kernels/sample).
2/ Insect, Rodent, Broken, Germinated, Torn Pericarp and Visible Mold.
3/ Wrinkled, Shriveled, Dented and Discolored.
° Low altitude = below 1500m.
+ n = only farms where additional sampling(s) was possible. In low altitudes 4 farms used or sold all sorghum between first and second visits and cannot be included in this comparison. Mean days after first visit before sorghum stored was utilized = 135.6.

Table 49. Comparison of sorghum quality at low altitudes in on-farm storage in Rwanda during the first month and just prior to total utilization (June 1984 harvest) (n = 6)+.

	Mean Values ± S.E.									
		# Insects								
	% Moisture Content	*Sitophilus* spp.	*Rhyzopertha dominica*	*Plodia interpunctella*	Other	Total Insects	Temperature Difference (°C) Between Ambient and Inside the Stock	Test Weight (g/0.9091)	% Weight Loss (dry basis)	% (w/w) Impurities and Broken Material
First Sample+	11.8±0.3	0.09±0.5	0	0	0	0.80	-0.20	734.8	---	0.8±0.2
Last Sample+	12.9±0.4	16.1±7.0	0	0	1.1±0.5	16.13	+0.20	724.9	2.6	1.1±0.3

*** Values in column significantly different (p less than 0.001).
** Values in column significantly different (p less than 0.01).
* Values in column significantly different (p less than 0.05).
° Low altitude = below 1500m; middle altitude = 1500-1900m.
+ n = only farms where additional sampling(s) was possible. In low and middle altitudes each 7 farms used or sold all beans between first and second visits and cannot be included in this comparison.

Table 50. Comparison of sorghum quality during the first month of storage on Rwandan farms in middle° altitudes and just prior to total utilization (June 1984 harvest) (n = 10)+.

	Mean Values					
	% Moisture Content	*Sitophilus* spp. Obtained (= Total Insects) per Kg.	Temperature Difference (°C) Between Ambient and Inside the Stock	Test Weight (g/0.9091)	% Weight Loss (dry basis)	% (w/w) Impurities and Broken Material
First Sample+	11.83	0.5	0.2	744.2	---	0.7
Last Sample+	13.10	28.3	0.5	737.3	2.4	0.8

*** Significant difference between values, paired t-test (p less than 0.001).
** Significant difference between values, paired t-test (p less than 0.01).
* Significant difference between values, paired t-test (p less than 0.05).
° Middle altitude = 1500-1900m.
+ n = only farms where additional sampling(s) was possible. In middle altitude 7 farms used or sold all sorghum between first and second visits and cannot be included in this comparison. Mean days after first visit before sorghum was utilized = 83.8.

Table 51. Comparison of mean % damaged kernels 3/ during the first month of on-farm storage and just prior to utilization of sorghum grown in middle altitudes° in Rwanda (June 1984 harvest) (n = 10)+.

	Visible Mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage) 1/	Shriv-eled	Dis-colored	Wrink-led	Subtotal (Typical Preharvest Damage) 2/	Total Damage
First Sample+	0	0.60	0.80	0.20	0	0.40	2.00	2.4	4.6	4.0	11.0	13.00
Last Sample+	0	0.80	0.70	1.40	0	0.40	3.30	2.2	2.5	2.0 **	6.7 *	10.00 *

*** Values in column significantly different (p less than 0.001).
** Values in column significantly different (p less than 0.01).
* Values in column significantly different (p less than 0.05).
1/ Insect, Rodent, Broken, Germinated, Torn Pericarp and Visible Mold.
2/ Wrinkled, Shriveled, Dented and Discolored.
3/ = % of kernels which had the damage (10g./sample).
+ n = only farms where additional sampling(s) were possible. In middle altitudes 7 farmers used or sold all sorghum between first and second visits and cannot be included in this comparison. Mean days after first visit before sorghum was utilized = 83.8.
° Middle altitude = below 1500-1900m.

Table 52. Comparison of sorghum quality during the first month of storage on Rwandan farms in high° altitudes and just prior to total utilization (June 1984 harvest).

	Mean Values ± SE							
		# Insects Obtained						
	% Moisture Content	Sitophilus spp.	Other	Total Insects	Temperature Difference (°C) Between Ambient and Inside the Stock 1/	Test Weight (g/0.9091)	% Dry Weight Loss	% (w/w) Impurities and Broken Material
First Sample n=10	13.2 ± 0.3	0.9 ± 0.4	0.3 ± 0.3	1.2 ± 0.5	0.8 ± 0.2	750 ± 5	---	2.1 ± 1.1
Last Sample+ n=1	12.9	49.0	1.0	50.0	1.0	751	-0.5	0.9

° High altitude = above 1900m.
1/ Positive number implies stock is warmer than ambient.
+ Only one farm had sorghum left in storage at the time of the second sampling. For this reason no statistical comparisons have been performed.

Table 53. Comparison of mean % damaged kernels[3/] during the first month of on-farm storage and just prior to total utilization of sorghum grown in high° altitudes in Rwanda (June 1984 harvest).

	Visible Mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)[1/]	Shriveled	Discolored	Wrinkled	Subtotal (Typical Pre-harvest Damage)[2/]	Total Damage
First Sample+ n=10	0.0±0	0.7±0.2	0.8±0.1	0	0	0.2±0.1	1.7±0.2	1.0±0.2	2.0±0.2	1.7±0.2	4.7±0.4	6.4±0.4
Last Sample+ n=1	0.0	1.0	1.0	0	0	0.0	2.0	1.0	2.0	1.0	4.0	6.0

1/ Insect, Rodent, Broken, Germinated, Torn Pericarp and Visible Mold.
2/ Wrinkled, Shriveled, Dented and Discolored.
3/ = % of kernels which had the damage (10g./sample).
° High altitude = above 1900m.
\+ Only one farm had sorghum left in storage at the time of the second sampling. For this reason no statistical comparisons have been performed.

Table 54. Comparison of sorghum quality at low and middle altitudes° combined in on-farm storage in Rwanda during the first month after harvest and just prior to total utilization (June 1984 harvest) (n = 15)+.

	Mean Values									
		# Insects								
	% Moisture Content	*Sitophilus* spp.	*Rhyzopertha dominica*	*Plodia interpunctella*	Other	Total Insects	Temperature Difference (°C) Between Ambient and Inside the Stock	Test Weight (g/0.9091)	% Weight Loss (dry basis)	% (w/w) Impurities and Broken Material
First Sample+	11.76	0.80	0	0	0	0.80	-0.20	734.8	----	0.83
Last Sample+	12.87 *	15.00 *	0	0	1.13 *	17.19 *	+0.20	724.9	-2.6	1.05 *

*** Values in column significantly different (p less than 0.001).
** Values in column significantly different (p less than 0.01).
* Values in column significantly different (p less than 0.05).
° Low altitude = below 1500m; middle altitude = 1500-1900m.
+ n = only farms where additional sampling(s) was possible. In low and middle altitudes each 7 farms used or sold all beans between first and second visits and cannot be included in this comparison.

Table 55. Comparison of % damaged sorghum[3/] in low and middle altitudes° combined in on-farm storage in Rwanda just after harvest and just prior to total utilization (June 1984 harvest) (n = 15)[+].

	Visible Mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Sub-total (Typical Post-harvest Damage)[1/]	Shriveled	Discolored	Wrinkled	Sub-Total (Typical Preharvest Damage)[2/]	Total Damage
First Sample	0.0	0.73	0.80	0.73	0	0.33	1.99	2.40	3.87	3.73	10.29	12.20
Last Sample	0.07	0.87	0.87	1.07	0	0.33	3.14	2.60	2.40	2.00 **	7.00 *	10.10 *

** Values in column significantly different (p less than 0.01).
* Values in column significantly different (p less than 0.05).
1/ Insect, Rodent, Broken, Germinated, Torn Pericarp, Visible Mold.
2/ Wrinkled, Shriveled, Dented and Discolored.
3/ = % of kernels which had the damage (sample size = 10g.).
° Low altitude = less than 1500m; middle altitude = 1500-1900m.
\+ n = only farms where additional sampling(s) was possible. In low and middle altitudes each, 7 farms used or sold all sorghum between the first and second visits and cannot be included in this comparison.

Table 56. Mean number (and range) of insects[1/] obtained from incubated[2/] samples collected during on-farm storage of sorghum harvested in Rwanda June - July 1984.

	First Sampling[2/]			Second Sampling[1/]		
Location of Farm	Mean Days after Harvest	*Sitophilus* spp. obtained	*Plodia interpunctella* obtained	Mean Days after Harvest	*Sitophilus* spp. obtained	*Plodia interpunctella* obtained
Low° Altitude (n=12)	34	1.6 (0-7)	0	135 (n=6)	3.0 (0-5)	0
Middle° Altitude (n=17)	46	3.6 (0-40)	0	99 (n=10)	4.3 (0-17)	0
High° Altitude (n=10)	59	4.5 (0-17)	0.1 (0-1)	---	---	---
Grand Mean		3.2	0.03	---	---	---

° Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.

1/ Mean number insects obtained per 200 gram sample.

2/ Mean length of incubation = 45 days ± 4.46 S.D.

Table 57. Comparison of the mean %[1] incidence of surface sterilized sorghum kernels yielding storage fungi in Rwandan farms at low, middle and high altitude locations (1984 harvest).

Low Altitude Locations (below 1500m)	First Sampling 7 locations=420 seeds (1.1 months after harvest)	Last Sampling 7 locations=420 seeds (4.5 months after harvest)
Aspergillus candidus	0.0	0.5
Aspergillus flavus	1.2	0.7
Aspergillus glaucus	0.5	4.8
Aspergillus niger	0.0	0.7
Aspergillus ochraceus	0.2	0.0
Aspergillus restrictus	0.0	0.7
Penicillium spp.	3.1	3.3
Fusarium spp.	1.2	1.9

Middle Altitude Locations (1500-1900m)	First Sampling 9 locations=540 seeds (1.5 months after harvest)	Last Sampling 9 locations=540 seeds (3.3 months after harvest)
Aspergillus candidus	0.4	0.0
Aspergillus flavus	0.2	2.2
Aspergillus glaucus	11.9	7.4
Aspergillus niger	0.0	0.0
Aspergillus ochraceus	0.9	1.9
Aspergillus restrictus	0.0	0.2
Penicillium spp.	0.7	1.3
Fusarium spp.	4.1	0.4

1 60 seeds per location; 30 seeds/petri dish; 2 petri dishes 2 locations (one dish of potato dextrose agar (PDA), plus 1% lactic acid and one of tomato juice agar (TJA) plus 6% NaCl).

Table 57. (continued)

Comparison of the mean %[1/] incidence of sorghum kernels yielding storage fungi in Rwandan farms at low, middle and high altitude locations (1984 harvest).

High Altitude Locations (above 1900m)	First Sampling 1 location=60 seeds (2.0 months after harvest)	Last Sampling 1 location=60 seeds (4.8 months after harvest)
Aspergillus candidus	0.0	1.7
Aspergillus flavus	0.0	0.0
Aspergillus glaucus	0.0	0.0
Aspergillus niger	0.0	0.0
Aspergillus ochraceus	0.0	0.0
Aspergillus restrictus	0.0	0.0
Penicillium spp.	5.0	0.0
Fusarium spp.	5.0	0.0
Idriella spp. (tentative identification)	35.0	41.7

Table 58. Comparison between altitudinal regions of bean quality in cooperative silos and hangars in Rwanda for crop years 1984 and 1985.

Location of Storages[3/]	Mean Value ± S.E.[1/2/]						
	Number (± S.E.) Insects Obtained/Kg.				% Moisture Content	Test Weight (g/0.9091)	% (w/w) Impurities
	Acanthoscelides obtectus	*Sitophilus* spp.	*Rhyzopertha dominica*	*Plodia interpunctella*			
Low altitude (n=4)	8.8 ± 4.4	0.3 ± 0.2	0.0	0.0	15.8 ± 0.3	817.5 ± 3.3	1.3 ± 0.1
Middle altitude (n=6)	7.8 ± 4.6	0.0	0.0	0.0	14.8 ± 0.2	828.2 ± 5.8	0.8 ± 0.1
High altitude (n=7)	20.7 ± 10.8	1.1 ± 0.8	0.0	0.0	15.3 ± 0.4	809.4 ± 0.4	0.6 ± 0.1

1/ S.E. = standard error.

2/ In only 5 cases was it possible to sample the same stock on the second visit. This was for one coop at low, one at medium and three at high altitude. For the coops from which a second sample could be obtained, the mean ± S.E. data were (first sample/second sample):

A. obtectus 7.8 ± 6.2/63 ± 54.5
Sitophilus spp. 0.3 ± 0.3
% moisture content 15.03 ± 0.14/14.67 ± 0.81
test weight 898.2 ± 13.4/890.2 ± 6.9
% (w/w) impurities 0.63 ± 0.15 /0.93 ± 0.14

3/ Low = below 1500m; middle = 1500-1900m; high = above 1900m.

Table 59. Comparison between altitudinal regions of mean % damaged beans in cooperative silos and hangars in Rwanda for crop years 1984 and 1985.

Location of Coop[3/] (number stock sampled per altitude)	Mean Values (%) ± S.E.[1/2/] Visible Mold	Insect Damage	Rodent Damage	Germinated	Broken	Torn Pericarp	Subtotal (typical post-harvest damage)[4/]	Shriveled	Discolored	Dented	Wrinkled	Subtotal (typical pre-harvest damage)[5/]	Total Damage
Low altitude (n=4)	3.4 ± 1.5	1.4 ± 1.0	0.0	0.3 ± 0.1	0.1 ± 0.1	0.3 ± 0.1	5.5	9.9 ± 2.0	7.6 ± 3.8	9.9 ± 1.5	3.2 ± 0.2	30.6	36.1
Middle altitude (n=8)	1.8 ± 0.5	0.0	0.2 ± 0.1	0.0	0.1 ± 0.1	0.5 ± 0.1	2.6	9.7 ± 0.9	8.1 ± 0.8	11.3 ± 0.7	3.2 ± 0.7	32.3	34.9
High altitude (n=7)	1.6 ± 0.6	0.2 ± 0.1	0.2 ± 0.1	0.1 ± 0.1	1.2 ± 0.5	0.2 ± 0.1	5.5	8.7 ± 1.0	9.9 ± 1.0	9.5 ± 0.8	5.9 ± 0.9	34.0	39.5

1/ S.E. = standard error of the mean.

2/ In only 5 cases was it possible to sample the same stock on the second visit. This was for one coop at low, one at medium and 3 at high altitudes. For cooperatives with second samples, the following mean ± S.E. data were obtained (first sample/second sample):

visible mold 0.3 ± 0.3/1.1 ± 0.5
insect damage 2.2 ± 1.2/0.0
rodent damage 0.1 ± 0.1/0.0
germinated 0.0

broken 1.2 ± 0.9/0
pericarp torn 0.2 ± 0.1/0.9 ± 0.4
subtotal (typical postharvest damage) 4.0/2.0
shriveled 9.0 ± 0.1/11.7 ± 1.1
discolored 10.7 ± 1.4/8.6 ± 0.9

dented 11.3 ± 0.8/12.2 ± 0.8
wrinkled 3.9 ± 0.8/2.4 ± 0.7
subtotal (typical postharvest damage) 34.9/34.9
Total damage 38.9/36.9

3/ Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = higher than 1900m.

4/ Insect, Rodent, Broken, Germinated, Torn Pericarp and Visible Mold.

5/ Wrinkled, Shriveled, Dented, Discolored.

Table 60. Mean ± S.E.[1/] quality and/or insects in sorghum stored in silo-type cooperatives[2/] in Rwanda for crop years 1984 and 1985.

Cooperative Location[3/]	% Moisture Content (Motomco)	*Sitophilus* spp.	*Rhyzopertha dominica*	*Plodia interpunctella*	Other Moths	Other Beetles	Total Insects	(°C) Temperature Differential within stock or bulk	Test Weight (g/0.9091)	Dry Weight % Loss (g)	% Total Impurities
	Number Insects Obtained/Kg.										
Low Altitude (n=9)											
First Sampling	12.3 ± 0.3	9.6 ± 4.0	0 ± 0	0.8 ± 0.8	4.7 ± 2.6	0 ± 0	15.0 ± 6.4	0	715 ± 2		1.7 ± .4
Second Sampling	12.1 ± 0.2 NS	10.1 ± 3.7 NS	2.3 ± 2.3 NS	0 ± 0 NS	0 ± 0 P = .105	0 ± 0 NS	12.4 ± 4.6 NS	0	719 ± 3 NS	-5.0	1.5 ± .2 NS
Middle Altitude (n=9)											
First Sampling	11.6 ± .2	7.4 ± 4.0	0 ± 0	0 ± 0	0.2 ± .2	0 ± 0	7.7 ± 2.3	-0.2 ± .2	731 ± 4		1.2 ± .2
Second Sampling	12.7 ± .3 P = .014	3.6 ± 0.9 NS	0 ± 0	0 ± 0	0 ± 0 NS	0 ± 0	3.6 ± 0.9 NS	1.4 ± .2 P = .033	731 ± 2 NS	+1.2	1.3 ± .3 NS
High Altitude (n=6)											
First Sampling	14.0 ± .7	5.4 ± 2.6	0 ± 0	0 ± 0	0.8 ± 0.8	0 ± 0	6.2 ± 2.8	0	729 ± 11		0.9 ± .3
Second Sampling	14.1 ± .6 NS	10.2 ± 3.4 NS	1.6 ± 1.6 NS	0 ± 0	6.2 ± 6.2	0 ± 0	18.0 ± 10.3 NS	0	715 ± 13 NS	+2.0	0.8 ± .2 NS
Combined Altitudes (n=24)											
First Sampling	12.5 ± .3	7.8 ± 1.9	0 ± 0	0.3 ± .3	2.1 ± 1.1	0 ± 0	10.2 ± 2.7	-0.2 ± .2	724 ± 3		1.3 ± .2
Second Sampling	12.8 ± .2 NS	7.7 ± 1.7 NS	1.3 ± 1.0 P = .20	0 ± 0 NS	1.3 ± 1.3 NS	0 ± 0	10.2 ± 3.0 NS	-1.4 ± .2 P = .03	722 ± 4 NS	+0.6	1.2 ± .2 NS

1/ P = result of t-test comparing first and second samples.
2/ Kg. stored; 1000-9000 kg. 25%; 10,000-15,000 kg. 65%; 20,000 kg. 8%; (other unknown kg.).
3/ Low altitude = less than 1500m; middle altitude = 1500-1900m; high altitude = above 1900m.

Table 61. Mean ± S.E. % damaged[1/] kernels of sorghum stored in silo-type cooperatives in Rwanda for crop years 1984 and 1985.

Location[2/] of Cooperative and Time of Sampling	Visible Mold	Insect	Rodent	Germinated	Broken	Torn Pericarp	Typical Post-Harvest	Shriveled	Discolored	Dented	Wrinkled	Typical Pre-Harvest	Total
Low (n=9)													
First	0 ± 0	0.8 ± .2	1.1 ± .2	0 ± 0	0.4 ± .2	0.2 ± .1	2.5	6.1 ± 3.2	2.3 ± .5	0 ± 0	3.6 ± .6	12.0	14.5
Second	0.6 ± .3	1.0 ± .0	0.9 ± .1	0.1 ± .1	1.0 ± 0	0.2 ± .1	3.8	3.2 ± 0.3	1.1 ± .1	0 ± 0	0 ± 0	4.3	8.1
	P = .14	NS	NS	NS	P = 0.13	NS		NS	P = .066		P = .00		
Medium (n=9)													
First	0.1 ± .1	1.0 ± .2	0.8 ± .2	0 ± 0	0.8 ± .1	0.2 ± .1	2.9	2.2 ± .2	2.6 ± .4	0 ± 0	2.9 ± .7	7.7	10.6
Second	0.8 ± .2	1.1 ± .1	0.6 ± .2	0 ± 0	0.9 ± .1	0.2 ± .1	3.6	2.2 ± .2	1.8 ± .3	0 ± 0	0 ± 0	4.0	7.6
	P = .022	NS	NS		NS	NS		NS	P = .193		P = .002		
High (n=6)													
First	1.0 ± .3	1.3 ± .4	0.8 ± .2	0.3 ± .2	0.5 ± .2	0 ± 0	3.9	2.0 ± .6	1.0 ± 0	0 ± 0	0.5 ± .3	3.5	7.4
Second	0.2 ± .2	1.2 ± .2	0.8 ± .2	0 ± 0	0.8 ± .2	0.7 ± .2	3.7	1.7 ± .5	1.3 ± .2	0 ± 0	0.3 ± .2	3.5	7.0
	P = .099	NS	NS	NS	NS	P = .025		NS	NS		NS		
Combined (n=24)													
First	0.3 ± .1	1.0 ± .1	0.9 ± .1	0.1 ± .1	0.6 ± .1	0.2 ± .1	3.1	3.6 ± 1.2	2.0 ± .3	0 ± 0	0.1 ± .1	5.7	8.8
Second	0.6 ± .2	1.1 ± .1	0.8 ± .1	0.0 ± .04	0.9 ± .1	0.3 ± .1	3.7	2.5 ± .2	1.5 ± .1	0 ± 0	0.1 ± .1	4.1	7.8
	NS	NS	NS	NS	P = .008	NS		NS	P = .060		P = .00		

1/ By number of kernels; P = result of t-test comparing first and second samples.
2/ Low = altitudes below 1500m; middle = altitudes 1500-1900m; high = altitudes above 1900m.

Table 62. Mean ± SE % damaged[1/] kernels, insects and other quality factors of sorghum stored in hangar-type cooperatives, in Rwanda for crop years 1984 and 1985.

Combined Altitudes (n=6)	Visible Mold	Insect	Rodent	Germinated	Broken	Torn	Typical Post-harvest Damage	Shriveled	Discolored	Dented	Wrinkled	Typical Pre-Harvest Damage	Total
First	0.7 ± .3	1.7 ± .3	1.3 ± .2	0 ± 0	0.5 ± .2	0 ± 0	3.2	2.0 ± .4	1.8 ± .9	0 ± 0	1.0 ± .5	4.8	8.0
Second	0.8 ± .2	1.0 ± .0	0.8 ± .2	0.2 ± .2	0.8 ± .2	0 ± 0	3.6	3.8 ± .3	1.8 ± .4	0 ± 0	0 ± 0	5.6	9.2
	NS	P = .102		NS	NS			P = .002	NS		P = .111		

Mean ± S.E. Quality For Insects

Combined Altitudes (n=6)	% Moisture Content	Insects (per Kg.) Sitophilus spp.	Rhyzopertha dominica	Plodia interpunctella	Other Moths	Other Beetles	Total Insects	Temperature Difference	Test Weight (g/.9091)	% Dry Weight Loss (g)	% Total Impurities
First	12.0 ± .6	15.7 ± 8.0 (21.9/Kg.)	0 ± 0	0 ± 0	0.7 ± 0.7 (1.0/Kg.)	0 ± 0	16.3 ± 7.8 (22.9/Kg.)	0 ± 0	717 ± 7	----	1.0 ± .1
Second	12.6 ± .3	23.0 ± 5.9 (32.2/Kg.)	8.8 ± 7.7 (12.3/Kg.)	0 ± 0	0.8 ± 0.8 (1.1/Kg.)	0 ± 0	32.7 ± 9.4 (45.6/Kg.)	-1.0 ± 0	715 ± 8	1.0	0.9 ± .1
	NS	NS	NS		NS		NS	NS	NS		NS

Table 63. Mean %[1] incidence of sorghum kernels yielding storage fungi in Rwandan cooperatives at low, middle and high altitude locations.

Low Altitude Locations (below 1500m)	First Sampling 4 locations=240 seeds months after harvest	Last Sampling 4 locations=240 seeds months after harvest
Aspergillus candidus	1.3	6.3
Aspergillus flavus	0.4	0.4
Aspergillus glaucus	15.0	16.7
Aspergillus niger	0.0	0.0
Aspergillus ochraceus	2.1	2.5
Aspergillus restrictus	0.0	0.0
Penicillium spp.	7.5	4.2
Fusarium spp.	1.3	0.0
Idriella spp. (tentative identification)	4.2	24.2

Middle Altitude Locations (1500-1900m)	First Sampling 9 locations=540 seeds months after harvest	Last Sampling 9 locations=540 seeds months after harvest
Aspergillus candidus	0.7	0.0
Aspergillus flavus	0.7	0.7
Aspergillus glaucus	10.4	23.0
Aspergillus niger	0.0	0.4
Aspergillus ochraceus	1.5	1.9
Aspergillus restrictus	0.0	0.0
Penicillium spp.	8.0	2.4
Fusarium spp.	0.9	0.4
Idriella spp. (tentative identification)	7.0	7.0

[1] 60 seeds/location; 30 seeds/petri dish; 2 dishes/location (1 dish of potato dextrose agar (PDA) plus 1% lactic acid and 1 dish of tomato juice agar (TJA) plus 6% (NaCl).

Table 63. (continued)

Mean %[1/] incidence of sorghum kernels yielding storage fungi in Rwandan cooperatives at low, middle and high altitude locations.

High Altitude Locations (above 1900m)	First Sampling 6 location=360 seeds months after harvest	Last Sampling 6 location=360 seeds months after harvest
Aspergillus candidus	3.9	1.7
Aspergillus flavus	0.0	1.4
Aspergillus glaucus	27.0	28.1
Aspergillus niger	0.3	0.3
Aspergillus ochraceus	1.4	7.2
Aspergillus restrictus	0.3	0.6
Penicillium spp.	12.8	9.4
Fusarium spp.	0.6	0.0
Idriella spp. (tentative identification)	1.9	0.8

1/ 60 seeds/location; 30 seeds/petri dish; 2 dishes/location (1 dish of potato dextrose agar (PDA) plus 1% lactic acid and 1 dish of tomato juice agar (TJA) plus 6% (NaCl).

Table 64. Comparison of Rwandan bean quality and weight loss (dry basis) at the low altitude (1675m) Kibungo OPROVIA Warehouse in set aside stacks during one year of storage (June 1984 harvest) (1 stack/location; 5 sites/stack; 3 samples/site).

	Mean Values ± S.E.						
Time of Sampling in Storage Period	% Moisture Content (Motomco) (n=15)	Insects *Acanthoscelides obtectus*[3/] (n=15)	Obtained/kg. *Sitophilus* spp. (n=15)	Temperature (°C) Inside the Stack	Test Weight (g/0.9091) (n=5)[2/]	% Dry Weight Loss/Volume[1/]	% w/w Impurities and Broken Material (n=15)
5 mo.	11.22 ± 0.02	47.1	0.0	22.5	825.7 ± 2.0		0.41 ± 0.03
6 mo.	11.68 ± 0.05	60.0	0.3	21.0	816.8 ± 3.3	+1.6	0.86 ± 0.12
9 mo.	11.94 ± 0.17	48.9	0.0	23.0	824.3 ± 1.7	-0.5	0.96 ± 0.17
11 mo.	13.86 ± 1.11	43.1	0.0	21.1	817.5 ± 2.2	+1.4	2.08 ± 0.17
13 mo.	11.04	56.2	0.0	20.3	824.1	-2.5	1.28
Grand Mean	11.95	51.2	0.1	21.6	821.7		1.12

1/ Negative values would = a net gain.

2/ Data for test weight was obtained from the pool of the 3 samples/sites.

Table 65. Comparison of Rwandan bean quality and weight loss (dry basis) at the middle° altitude (1760m) Nyanza (OPROVIA) Warehouse in set-aside stacks during one year of storage (June 1984 harvest) (1 stack/location, 5 sites/stack, 3 samples/site).

Time of Sampling in Storage Period	Mean Values ± S.E.: % Moisture Content (Motomco) (n=15)	# insects Acanthoscelides obtectus[3] (n=15)	Obtained/Kg. Sitophilus spp. (n=15)	Temperature (°C) Inside the Stack	Test Weight (g/0.9091) (n=5)[2]	% Dry Weight Loss/Volume[1]	% w/w Impurities and Broken Material (n=15)
5 mo.	11.96 ± 0.4	6.3x	0.0	21.1	838.1 ± 3.2		0.45 ± 0.1
6 mo.	12.32 ± 0.2	9.9x	0.0	20.4	843.6 ± 5.0	-0.2	0.51 ± 0.1
9 mo.	12.00 ± 0.2	8.4x	0.0	20.3	842.5 ± 2.6	-0.1	0.92 ± 0.4
11 mo.	12.54 ± 0.0	4.7xy	0.1		837.9 ± 2.4	+1.1	0.87 ± 0.2
13 mo.	12.02	2.7y	0.0	20.2	840.9	-0.8	0.66
Grand Mean	12.17	6.4	0.0	21.0	840.6	0.0	0.68

1/ Negative values would = a net gain.
2/ Data for test weight was obtained from the pool of the 3 samples/sites.
3/ Means followed by the same letter indicate no significant difference at p less than 0.05.

Table 66. Comparison of Rwandan bean quality and weight loss (dry basis) at the high (2430m) altitude Kora OPROVIA Warehouse in set-aside stacks during one year of storage (June 1984 harvest) (1 stack/location, 5 sites/-stack, 3 samples/site).

Time of Sampling in Storage Period	Mean Values ± S.E.						
	% Moisture Content (Motomco) (n=15)	# insects Obtained/Kg. *Acanthoscelides obtectus* [3] (n=15)	*Sitophilus* spp. (n=15)	Temperature (°C) Inside the Stack	Test Weight (g/0.9091) (n=5) [2]	% Dry Weight Loss/ Volume [1]	% w/w Impurities and Broken Material (n=15)
5 mo.	12.86 ± 0.10	7.4xy	0.0	15.4	827.0 ± 3.4		0.82 ± 0.28
6 mo.	13.46 ± 0.18	8.2xy	0.0	15.4	830.9 ± 4.6	0.1	1.30 ± 0.13
9 mo.	12.74 ± 0.10	10.0x	0.0	----	857.6 ± 7.0	-3.8	0.75 ± 0.11
11 mo.	13.56 ± 0.24	6.7xy	0.0	15.6	830.4 ± 1.9	+3.9	1.03 ± 0.19
13 mo.	13.08	4.5y	0.0	14.0	830.2	-0.5	0.65
Grand Mean	13.13	7.4	0.0	15.1	835.2		0.86

1/ Negative values would = a net gain.
2/ Data for test weight was obtained from the pool of the 3 samples/sites.
3/ Means followed by the same letter indicate no significant difference at p less than 0.05.

Table 67. Monthly mean temperatures and % relative humidity in Rwanda inside OPROVIA warehouses adjacent to set-aside stacks.

Location of Warehouse (altitude)	Year	Month	°C Temperature			% Relative Humidity		
			Minimum	Maximum	Mean	Minimum	Maximum	Mean
Kibungo (1675 m)	1985	March	20.6	27.1	23.9	64.1	73.9	69.0
		April	21.6	27.5	24.6	69.7	78.8	74.3
		May	21.7	26.4	24.1	69.5	75.8	72.7
		June	17.5	23.8	20.7	47.8	57.2	52.5
		July	17.4	24.3	20.9	44.6	55.5	50.1
		August	18.2	25.5	21.9	43.6	53.5	48.6
		September	18.1	24.1	21.1	55.2	65.0	60.1
		October	18.1	24.6	21.4	62.9	73.3	68.1
		November	19.1	24.8	21.9	66.0	76.2	71.1
Nyanza (1760 m)	1984	June	21.1	26.3	23.7	47.3	52.7	50.0
		July	19.7	26.1	22.9	49.0	58.7	53.9
		August	19.8	30.9	25.4	39.2	60.2	49.7
		September	21.1	31.2	26.2	41.7	60.9	51.3
		October	19.9	28.8	24.4	52.5	64.5	58.5
		November	19.7	26.3	23.0	60.4	68.9	64.7
		December	19.4	27.7	23.6	54.3	68.3	61.3
	1985	January	19.6	27.9	23.8	52.9	67.2	60.1
		Febuary	19.2	27.0	23.1	53.3	71.0	64.7
		March	20.2	28.3	24.3	55.5	68.0	61.8
		April	19.1	26.4	22.8	61.3	71.3	66.3
		May	19.4	26.2	22.8	60.3	69.8	65.1
		June	19.6	26.6	23.1	53.4	63.5	58.5
		July	19.9	27.1	23.5	44.6	57.5	51.1
		August	20.8	28.6	24.7	41.0	52.2	46.6
		September	20.6	27.9	24.3	48.5	60.0	54.3

		December	19.1	27.9	23.5	68.8	70.6	65.7
Kora (2430 m)	1985	May	15.1	22.2	18.7	61.3	74.4	67.9
		June	12.0	20.5	16.4	57.2	71.4	64.3
		July	10.0	22.1	16.1	47.8	65.1	66.5
		August	12.5	24.4	18.5	44.0	63.5	53.8
		September	12.9	24.1	18.5	50.3	67.8	59.1

Table 68. Mean number[1/] of bruchids[2/] per kg. obtained[3/] in Rwandan beans[4/] in stacks of bags set aside in OPROVIA Warehouses.

Location of Warehouse	Period after harvest[4/]				
	5 months	6 months	9 months	11 months	13 months
Low altitude (Kibungo) 1675m	47.1a^{x}	60.0a^{x}	48.9a^{x}	43.1a^{x}	56.2a^{x}
Middle altitude (Nyanza) 1760m	6.3c^{x}	9.9b^{x}	8.4b^{x}	4.7c^{xy}	2.7c^{y}
High altitude (Kora) 2430m	7.4b^{xy}	8.2b^{xy}	10.0b^{x}	6.7b^{xy}	4.5b^{y}

1/ Means followed by letters a, b or c indicate a significant difference of p less than 0.05 within sample period between warehouses. Means followed by x or y indicate a significant difference of p less than 0.05 within warehouse between sample periods.

2/ Live and dead bruchids.

3/ 1 stack/location, 5 sites/stack, 3 samples/site.

4/ Harvested June 1984.

Table 69. Comparison of damage in beans during one year of storage (June 1984 harvest) in low altitude (1675m) Kibungo OPROVIA Warehouse (1 stack location; 5 sites/stack; 3 samples/site).

Time of Sample During Storage	Mean % ± S.E. of beans counted with damage												
	Visible mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)[1/]	Shriveled	Discolored	Dented	Wrinkled	Subtotal (Typ. Preharvest Damage)[2/]	Total Damage
5 mo.	0.7±0.3	8.2±1.0	0.5±0.2	0.3±0.1	0.1±0.1	0.4±0.2	10.2±1.2	9.1±1.0	14.2± 1.3	10.5±0.1	6.3±1.2	40.1±1.8	50.3±2.9
6 mo.	0.5±0.3	8.0±1.0	0.1±0.1	0.3±0.2	0.1±0.1	0.3±0.2	9.4±1.1	4.6±1.6	12.3± 1.6	12.7±1.0	6.4±1.0	36.1±2.6	45.4±3.3
9 mo.	0.8±0.2	3.0±0.6	0.1±0.1	1.2±0.2	0.0	0.6±0.3	5.7±0.6	11.5±1.0	12.6± 1.3	7.0±1.1	0.9±0.2	32.0±1.5	37.7±1.2
11 mo.	0.5±0.3	7.1±0.9	0.3±0.2	0.8±0.4	0.1±0.1	0.4±0.2	9.3±1.0	9.3±0.8	12.2± 0.7	12.7±1.7	2.3±0.2	36.5±1.4	45.7±2.3
13 mo.	1.6	8.9	0.3	0.3	0.3	1.1	12.5	7.2	15.9	12.1	2.0	37.5	49.7
Grand Mean	0.8	7.0	0.3	0.6	0.1	0.6	9.4	8.3	13.4	11.0	3.6	36.4	45.7

1/ Insect, Rodent, Broken, Germinated, Torn Pericarp and Visible Mold

2/ Wrinkled, Shriveled, Dented, and Discolored

Table 70. Comparison of damage in beans during one year of storage (June 1984 harvest) in the middle (1760m) altitude Nyanza OPROVIA Warehouse (1 stack/location; 5 sites/stack; 3 samples/site).

Time of Sample During Storage	Mean % ± S.E. of beans counted with damage												
	Visible mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharv. Damage)[1]	Shriveled	Discolored	Dented	Wrinkled	Subtotal (Typ. Preharvest Damage)[2]	Total Damage
5 mo.	1.9±0.3	1.1±0.6	0.3±0.3	0.2±0.1	0.1±0.1	0.1±0.1	3.6±1.0	6.9±1.0	11.0±0.9	11.1±1.4	5.9±1.2	34.9±2.5	38.5±3.0
6 mo.	2.1±0.3	0.5±0.3	0.4±0.1	0.3±0.2	0.1±0.1	0.5±0.2	3.9±0.6	4.5±0.6	10.7±0.7	10.2±1.0	7.9±0.6	33.1±0.9	37.0±1.3
9 mo.	0.6±0.3	0.5±0.2	0.4±0.2	1.0±0.3	0.1±0.1	0.7±0.1	3.4±0.7	7.5±0.6	8.5±1.2	10.1±1.1	3.3±0.1	29.5±2.1	32.8±2.0
11 mo.	4.3±1.1	0.9±0.5	0.4±0.2	0.2±0.1	0.1±0.1	0.9±0.4	6.6±1.0	10.0±0.4	13.1±0.7	14.4±0.4	3.7±0.4	41.3±0.5	47.9±0.7
13 mo.	3.5	2.6	0.3	0.1	0.2	0.9	7.4	9.9	11.6	13.3	2.0	36.8	44.2
Grand Mean	2.5	1.3	0.3	0.4	0.1	0.6	5.2	7.8	11.0	11.8	4.6	35.2	40.4

1/ Insect, Rodent, Broken, Germinated, Torn Pericarp and Visible Mold

2/ Wrinkled, Shriveled, Dented, and Discolored

Table 71. Comparison of damage in beans during one year of storage (June 1984 harvest) in the high altitude (2430m) Kora OPROVIA warehouse (1 stack per location; 5 sites within stack, 3 samples/site).

	Mean % ± S.E. of beans counted with damage												
Time of Sample During Storage	Visible mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)[1/]	Shriveled	Discolored	Dented	Wrinkled	Subtotal (Typ. Preharvest Damage)[2/]	Total Damage
5 mo.	2.3±0.4	3.7±1.2	0.1±0.1	0.2±0.2	0.0	0.5±0.2	6.8±1.4	8.3±1.5	13.3±1.7	14.3±4.1	6.5±1.0	42.5±5.5	49.3±5.9
6 mo.	1.9±0.3	2.2±0.6	0.2±0.1	0.4±0.2	0.3±0.2	0.4±0.2	5.4±0.6	5.2±0.7	10.5±0.5	8.6±1.0	9.1±0.5	33.3±1.4	38.7±1.3
9 mo.	2.2±0.5	0.5±0.4	0.2±0.1	1.1±0.4	0.1±0.1	0.4±0.2	4.6±1.0	10.9±0.6	9.0±0.7	8.5±0.5	2.1±0.3	30.5±0.4	35.1±1.2
11 mo.	4.0±0.6	2.1±0.5	0.3±0.2	0.1±0.	0.1±0.1	0.3±0.2	6.8±0.6	8.7±1.0	10.7±1.2	12.7±0.7	4.5±1.1	32.5±2.7	43.4±2.7
13 mo.	1.5	2.3	0.3	0.3	0.0	0.5	4.9	7.3	15.5	10.7	3.4	36.9	41.8
Grand Mean	2.4	2.2	0.2	0.4	0.1	0.4	6.5	8.1	11.8	11.0	5.1	36.0	41.7

1/ Insect, Rodent, Broken, Germinated, Torn Pericarp and Visible Mold

2/ Wrinkled, Shriveled, Dented, and Discolored

Table 72. Changes in mean % hard beans[a/] in OPROVIA warehouse set-aside stacks in Rwanda.

Location of Warehouse	Period after harvest[b/]					
	5 months	6 months	8 months	10 months	13 months	16 months
Low altitude (Kibungo) 1675m	28.0	___ c/	___ c/	16.0	9.6	28.2
Middle altitude (Nyanza) 1760m	26.4	18.6	___ c/	26.2	15.0	26.8
High altitude (Kora) 2430m	27.8	21.6	27.6	16.6	17.4	25.0

a/ 'Hard' is defined as cooked beans having a mean gram force of 450g. using a Chartillon tester.
b/ Harvested June 1984.
c/ Sample not obtained.

Table 73. Comparison of the percent beans classified as not plantable and not edible during a 15-month period of storage in government warehouses (OPROVIA) in Rwanda.

Warehouse Location (altitude)	Mean % Beans[1/] (± S.E.) Time of Sampling in Storage Period[2/]													
	5 mo		6 mo		9 mo		11 mo		13 mo		15 mo		Mean	
	no plant	no eat	no plant	no eat	no plant	no eat	no plant	no eat	no plant	no eat	no plant	no eat	no plant	no eat
Kibungo (1675m)	28.1 ±2.2	12.9 ±0.7	23.0 ±2.2	11.9 ±0.9	24.3 ±0.9	12.1 ±0.9	26.7 ±1.1	13.5 ±1.2	29.7 ±1.2	21.1 ±0.8	26.8 ±3.1	17.4 ±3.8	26.1 ±0.9	14.8 ±2.2
Nyanza (1760m)	17.6 ±2.1	9.1 ±1.4	17.1 ±0.9	7.5 ±0.6	20.9 ±0.1	9.9 ±0.7	18.5 ± .2	10.3 ±1.2	18.7 ±1.3	11.5 ±0.7	26.7 ±1.2	17.2 ±0.9	19.9 ±0.4	10.9 ±0.2
Kora (2430m)	18.1	7.7	13.1	5.4	16.9	5.3	22.3	12.5	25.3	16.9 ±1.0	21.4	13.7 ±0.8	19.5	10.2

1/ 1 stack/location; 5 sites/stack; 3 samples/site.
2/ Months after harvest (June 1984 harvest).

Table 74. Changes in the ability to germinate of beans harvested June 1984 and placed in set-aside stacks in OPROVIA warehouses during storage 5 to 18 months after harvest (1 stack/location; 5 sites/stack).

Location of Warehouse	Time of Sampling During Storage	% Beans which Germinated: Location of Sample Site within Stock: North	South	East	West	Center	Mean ± S.E. (n=5)
High Altitude (Kora) 2430m	5.0 months	90	83	88	91	85	87.4 ± 1.7
	6.0 months	80	88	78	85	85	83.2 ± 2.1
	9.0 months	70	81	74	71	75	74.2 ± 2.2
	13 months	68	50	60	45	58	56.2 ± 4.6
	16 months	38	42	50	35	52	43.4 ± 4.2*
	18.5 months	36	12	56	33	34	39.4 ± 8.0*
		27	49	60	36	51	
Middle Altitude (Nyanza) 1760m	5.0 months	83	88	85	87	80	84.6 ± 1.6
	6.0 months	73	86	80	92	73	80.8 ± 4.8
	9.0 months	91	81	66	84	52	74.8 ± 8.1
	13 months	61	74	69	67	63	66.8 ± 2.6
	16 months	50	47	40	44	38	43.8 ± 2.5
	18.5 months	40	64	19	40	24	39.8 ± 8.1
		49	59	24	39	40	
Low Altitude (Kibungo) 1675m	5.0 months	74	86	84	84	84	82.4 ± 2.5
	6.0 months	76	83	78	--	78	78.8 ± 1.5
	9.0 months	81	80	87	75	80	80.6 ± 2.2
	13 months	85	68	56	90	79	75.6 ± 7.1
	16 months	38	35	29	40	45	37.4 ± 3.1
		40	33	32	32	55	
	18.5 months	41	30	26	38	13	26.5 ± 5.0
		18	24	34	22	19	

*(n=10)

Table 75. Comparison of mean %[1/] incidence of Rwandan beans [2/] from yielding storage fungi in set-aside stacks in OPROVIA warehouses during storage 5 to 18 months after harvest (1 composite sample/location; 3 sample times) (40 seeds/sample time).

Location of Warehouse	Months after Harvest	Fungi Identified: Aspergillus species: A. candidus	A. flavus	A. glaucus	A. niger	A. ochraceus	A. restrictus	Penicillium species	Fusarium species
Kora (altitude = 2430 m)	5.0 months	1.7	0.0	57.5	0.0	0.8	0.0	2.5	0.0
Kora (altitude = 2430 m)	9.0 months	0.0	3.3	15.8	0.0	5.8	0.8	4.2	5.0
Kora (altitude = 2430 m)	13 months	0.0	0.0	18.3	0.0	5.0	0.0	3.3	2.5
Nyanza (altitude = 1760 m)	5.0 months	0.0	0.0	8.3	0.8	0.0	0.0	0.8	1.7
Nyanza (altitude = 1760 m)	9.0 months	0.8	1.7	19.2	0.0	4.2	0.0	1.7	2.5
Nyanza (altitude = 1760 m)	13 months	0.0	0.0	25.0	0.0	6.7	1.7	0.8	0.8
Kibungo (altitude = 1675 m)	5.0 months	0.0	0.8	18.3	0.8	0.0	0.0	4.2	3.3
Kibungo (altitude = 1675 m)	9.0 months	14.2	0.8	27.5	0.8	36.7	13.3	0.8	2.5
Kibungo (altitude = 1675 m)	13 months	0.0	0.8	19.1	0.0	4.2	1.7	2.5	5.8
Mean	5.0 months	0.6	0.3	28.0	0.5	0.3	0.0	2.5	1.7
Mean	9.0 months	5.0	2.0	20.8	0.3	15.6	4.7	2.2	3.3
Mean	13 months	0.0	0.3	20.8	0.0	5.3	1.1	2.2	3.0

1/ 20 beans/petri dish; 2 petri dishes/location [one dish of potato dextrose agar (PDA) plus 1% lactic acid and one of tomato juice agar (TJA) plus 6% NaCL].

2/ Beans were surface sterilized before incubation.

Table 76. Comparison of Rwandan sorghum quality and weight loss (dry basis) at the low altitude (1675m) Kibungo OPROVIA warehouse in a set-aside stack during one year of storage (June 1984 harvest) (5 sampling sites/stack, 3 samples/site).

Time of Sampling in Storage Period after Harvest	Mean Values ± SE[1/]: % Moisture Content (Motomco) (n=15)	Temperature (°C) Inside the Stack (n=5)	Test Weight (g/0.09091) (n=5)	% Dry Weight Loss[2/]	% (wt/wt) Impurities & Broken (n=5)
5 months	11.8 ± 0.9bc	23.7 ± 0.1a	710 ± 4a		0.7 ± 0.2a
6 months	12.9 ± 0.1b	21.7 ± 0.2b	703 ± 5bc	2.2	1.2 ± 0.1ab
9 months	13.0 ± 0.1b	23.9 ± 0.2a	705 ± 5ab	-0.2	0.9 ± 0.2ab
11 months	13.2 ± 0.1a	21.9 ± 0.2b	697 ± 6c	1.4	1.5 ± 0.1b
13 months	12.3 ± 0.1c	20.3 ± 0.2c	696c		0.6
17 months	12.3 ± 0.0c	22.2	698 ± 3c		1.0 ± 0.1

1/ Means followed by the same letter within a column are not significantly different (p less than 0.05) (paired t test). n = 15 for % moisture content and temperature, n = 5 for test weight, % dry weight loss and % impurities.

2/ Calculated as (dry weight 1 - dry weight 2)/dry weight 1) x 100. Negative values indicate an increase in dry weight. Dry weights based on test weight and % moisture content.

Table 77. Comparison of Rwandan sorghum quality and weight loss (dry basis) at the middle altitude (1760m) Nyanza OPROVIA warehouse in a set-aside stack during one year of storage (June 1984 harvest) (5 sampling sites/stack, 3 samples/site).

	Mean Values SE[1/]				
Time of Sampling in Storage Period	% Moisture Content (Motomco) (n=15)	Temperature (°C) Inside the Stack (n=5)	Test Weight (g/0.09091) (n=5)	% Dry Weight Loss[2/] During Interval	% (wt/wt) Impurities & Broken (n=5)
5 months	12.2 ± 0.2a	24.6 ± 0.4a	704 ± 2a		1.0 ± 0.2a
6 months	12.5 ± 0.1a	22.1 ± 0.4b	699 ± 8a	1.1	0.8 ± 0.2a
9 months	11.8 ± 0.9a	20.7 ± 0.1c	708 ± 6a	-2.1	1.5 ± 0.3b
11 months	12.0 ± 0.9a		703 ± 7a	0.9	1.0 ± 0.1ab
13 months	12.5 ± 0.1a	20.2 ± 0.1d	694		2.5
17 months	12.5 ± 0.0a[3/]	22.0	695.2 ± 2a		2.1 ± 0.5c

1/ Means followed by the same letter within a column are not significantly different (p less than 0.05) (paired t test). n = 15 for % moisture content and temperature, n = 5 for test weight, % dry weight loss and % impurities.

2/ Calculated as (dry weight 1 - dry weight 2)/dry weight 1) x 100. Negative values indicate an increase in dry weight. Dry weights based on test weight and % moisture content.

3/ n = 14

Table 78. Comparison of Rwandan sorghum quality and weight loss (dry basis) at the high altitude (2430m) Kora OPROVIA warehouse in a set-aside stack during one year of storage (June 1984 harvest) (5 sampling sites/stack, 3 samples/site).

	Mean Values ± SE[1/]				
Time of Sampling in Storage Period	% Moisture Content (Motomco) (n=15)	Temperature (°C) Inside the Stack (n=15)	Test Weight (g/0.9091) (n=15)	% Dry Weight Loss[2/] During Interval (n=5)	% (wt/wt) Impurities & Broken (n=5)
5 months	12.7 ± 0.3ab	15.8 ± 0.1a	723 ± 7a		0.5 ± 0.1a
6 months	13.0 ± 0.3b	15.6 ± 0.1a	716 ± 6a	1.3	1.5 ± 0.1b
9 months	12.6 ± 0.2a		721		0.8 ± 0.1a
11 months	13.3 ± 0.2b	15.7 ± 0.1a	718 ± 8a	0.1	1.9 ± 0.1b
13 months	13.2 ± 0.2b	13.7 ± 0.2b	714		0.9
17 months	13.3 ± 0.0b	15.1	721 ± 2a		0.9 ± 0.1a

1/ Means followed by the same letter within a column are not significantly different (p less than 0.05) (paired t test).

2/ Calculated as (dry weight 1 - dry weight 2)/dry weight 1) x 100. Negative values indicate an increase in dry weight. Dry weights based on test weight and % moisture content.

Table 79. Number of insects found in Rwandan sorghum in set-aside stacks in OPROVIA warehouses during one year of storage (June 1984 harvest) (1 stack/-location, 5 sampling sites/stack, 3 samples/site).

Location and Time of Sampling after Harvest	*Sitophilus* spp. Mean ± SE[1/] per unit volume[2/3/]	*Sitophilus* spp. Mean per kg.	*Rhyzopertha dominica* Mean ± SE[1/] per unit volume[2/3/]	*Rhyzopertha dominica* Mean per kg.
Low Altitude (Kibungo) 1675m				
5 months	8.0 ± 1.8a	11.3	0.5 ± 0.3a	0.7
6 months	25.9 ± 9.4ab	36.8	4.7 ± 1.8cb	6.7
9 months	45.4 ± 14.3c	64.4	7.7 ± 2.6c	10.9
11 months	36.8 ± 12.5cb	52.8	2.5 ± 1.4b	3.6
13 months	41.5 ± 18.8c	----	2.6 ± 1.1b	----
17 months	24.4 ± 2.4ab	----	6.0 ± 0.5c	----
Middle Altitude (Nyanza) 1760m				
5 months	11.5 ± 4.6a	16.3	0.9 ± 0.3a	1.3
6 months	92.3 ± 37.7b	132.0	9.5 ± 2.7b	13.6
9 months	91.0 ± 26.9b	130.4	13.1 ± 3.1b	18.5
11 months	137.5 ± 59.8b	195.6	22.1 ± 8.8b	31.4
13 months	129.9 ± 57.3b	----	32.8 ± 12.6b	----
17 months	80.0 ± 8.4[4/]	----	38.2 ± 5.1[4/]	----
High Altitude (Kora) 2430m				
5 months	4.1 ± 3.7a	5.7	0.1 ± 0.1a	0.1
6 months	12.4 ± 7.3a	17.3	0 a	0
9 months	9.3 ± 7.0a	12.0	0 a	0
11 months	3.7 ± 1.7a	5.2	0 a	0
13 months	12.4 ± 7.1a	----	0.0 ± 0.1a	----
17 months	10.0 ± 2.3a	----	0.1 ± 0.0	----

1/ n = 15
2/ Winchester bushel (0.909 liter)
3/ Means followed by the same letter within a column are not significantly different (p less than 0.05) (paired t test).
4/ n = 14

Table 80. Comparison of damage in sorghum at the low altitude (1675m) Kibungo OPROVIA warehouse in a set-aside stack during 17 months of storage in Rwanda (June 1984 harvest) (5 sampling sites/stack, 3 samples/site).

Time of Sample During Storage	Mean % ± S.E. of beans counted with damage[3/]												
	Visible mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)[1/]	Shriveled	Discolored	Dented	Wrinkled	Subtotal (Typical Pre-harvest Damage)[2/]	Total Damage
5 mo.	0 a	1.0 a ±0	0.8 a ±0.2	0 a	0.2 a ±0.2	0.4 ab ±0.2	2.4 a ±0.4	1.6 a ±0.4	1.8 a ±0.2	0	1.8 a ±0.4	5.2 a ±0.4	7.6 a ±0.5
6 mo.	0 a	1.0 a ±0	1.0 a ±0	0.6 ab ±0.2	0 a	0 a	2.6 a ±0.2	1.4 a ±0.2	2.0 a ± 0.3	0	1.8 a ±0.2	5.2 a ±0.5	7.8 a ±0.4
9 mo.	0 a	1.0 a ±0	1.4 a ±0.4	0.8 b ±0.2	0 a	0.2 ab ±0.2	3.4 a ±0.4	5.8 b ±0.8	2.8 a ±0.6	0	1.0 a ±0.3	9.6 b ±1.1	13.0 b ±1.2
11 mo.	0.4 a ±0.2	3.0 b ±0.9	1.0 a ±0.3	0.8 b ±0.2	0.2 a ±0.2	1.0 b ±0.3	6.4 b ±1.1	7.2 b ±1.0	1.6 a ±0.2	0	0 b	8.8 b ±1.1	15.2 c ±1.5
13 mo.	0.4	3.0	0.8	0.8 b	0.2	0.4	5.6	6.6	1.4	0	0	8.0	13.6
17 mo.	0 a	2.0	2.0 ±0.3	1.8 ±0.1	0	1.0 ±0.3	6.8	4.0	5.8 ±0.8	0	0	9.8	16.6

1/ Insect, Rodent, Broken Germinated, Torn Pericarp and Visible Mold.
2/ Wrinkled, Shriveled, Dented, and Discolored.
3/ Means followed by the same letter within a column are not significantly different (p less than 0.05) (paired t-test).

Table 81. Comparison of damage in sorghum at the middle altitude (1760m) Nyanza OPROVIA warehouse in a set-aside stack during 17 months of storage in Rwanda (June 1984 harvest) (5 sampling sites/stack, 3 samples/site).

Time of Sample During Storage	Mean % ± S.E. of beans counted with damage[3/]											
	Visible mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage)[1/]	Shriveled	Discolored	Dented	Wrinkled	Subtotal (Typ. Preharvest Damage)[2/]	Total Damage
5 mo.	0 a	1.2 a ±0.2	1.0 a ±0	0.6 a ±0.2	0 a	0 a	2.8 a ±0.4	1.6 a ±0.2	2.2 a ±0.4	0	1.4 ab ±0.4	5.2 a ±0.4	8.0 a ±0.6
6 mo.	0.2 a	0.8 a ±0.2	1.0 a ±0	0.8 a ±0.2	0 a	0.2 ab ±0.2	3.0 a ±0.3	1.2 a ±0.2	1.6 a ±0.2	0	2.0 b ±0.3	4.8 a ±0.4	7.8 a ±0.5
9 mo.	0 a	1.0 a ±0	1.0 a ±0	0.4 a ±0.2	0 a	0.8 b ±0.2	3.2 a ±0.2	7.8 b ±1.2	5.8 b ±0.9	0	0.6 a ±0.2	14.2 c ±1.7	17.4 b ±1.9
11 mo.	0.2 a ±0.2	4.2 a ±2.0	0.8 a ±0.2	1.0 a ±0	0.2 a ±0.2	0.4 ab ±0.2	6.8 a ±2.1	4.8 b ±0.4	1.8 a ±0.4	0	0.2 a ±0.2	6.8 b ±1.4	13.6 a ±2.1
13 mo.	0	4.0	0.8	1.0	0.4	0	6.2	6.0	2.0	0	0	8.0	14.2
17 mo.	0	4.0	1.2 ±0.2	2.8 ±0.4	0	1.6 ±0.6	9.6	3.4	6.0 ±0.4	0	0	9.4	19.0

1/ Insect, Rodent, broken Germinated, Torn Pericarp and Visible Mold.
2/ Wrinkled, Shriveled, Dented, and Discolored.
3/ Means followed by the same letter within a column are not significantly different (p less than 0.05) (paired t-test).

Table 82. Comparison of damage in sorghum at the high altitude (2430m) Kora OPROVIA warehouse in a set-aside stack during 17 months of storage in Rwanda (June 1984 harvest) (5 sampling sites/stack, 3 samples/site).

	Mean % ± S.E. of beans counted with damage 3/												
Time of Sample During Storage	Visible mold	Insect Damage	Rodent Damage	Broken	Germinated	Torn Pericarp	Subtotal (Typical Postharvest Damage) 1/	Shriveled	Discolored	Dented	Wrinkled	Subtotal (Typ. Preharvest Damage) 2/	Total Damage
5 mo.	0	1.0 a ±0	1.0 a ±0	0.6 a ±0.2	0 a	0.8 a ±0.4	3.4 a ±0.5	1.2 a ±0.2	1.2 a ±0.5	0	1.8 a ±0.4	4.2 a ±0.7	7.6 a ±0.4
6 mo.	0	1.2 a ±0.2	1.0 a ±0.2	0.6 a ±0.2	0 a	0.2 a ±0.2	3.0 a ±0.3	2.2 b ±0.2	1.2 a ±0.2	0	1.2 a ±0.4	4.6 ab ±0.5	7.6 ab ±0.7
9 mo.	0	1.0 a ±0	1.0 a ±0	0.8 a ±0.2	0 a	1.0 a ±0.8	3.8 a ±0.8	6.6 c ±1.2	3.6 a ±1.2	0	0.8 a ±0.4	11.0 b ±2.5	14.8 b ±2.2
11 mo.	0	1.2 a ±2.0	1.0 a ±0	0.8 a ±0.2	0.4 a ±0.2	0.6 a ±0.2	4.2 a ±0.2	5.6 abc ±1.6	1.4 a ±0.2	0	0.4 a ±0.4	7.4 ab ±1.6	11.6 ab ±1.6
13 mo.	0.4	0.8	0.8	0.8	0	0	2.8	6.4	1.2	0	0.4	8.0	10.8
17 mo.	4.6 ±1.3	4.6 ±1.3	3.2 ±0.3	1.8 ±0.3	0.2 ±0.1	0	14.4	4.6	5.0 ±0.4	0	0	9.6	24.0

1/ Insect, Rodent, Broken Germinated, Torn Pericarp and Visible Mold.
2/ Wrinkled, Shriveled, Dented, and Discolored.
3/ Means followed by the same letter within a column are not significantly different (p less then 0.05) (paired t-test).

Table 83. Mean % incidence of Rwandan sorghum kernels yielding storage fungi in set-aside stacks in OPROVIA warehouses at low, middle and high altitude locations (1984 harvest).

Location and altitude	Time of sampling in storage period after harvest	% Incidence of Fungal Species Obtained							
		Aspergillus Species							
		A. candidus	A. flavus	A. glaucus	A. niger	A. ochraceus	A. restrictus	Penicillium	Fusarium
Kibungo (1675m)	* 5 months	0.0	0.0	27.8	0.0	5.0	0.0	0.0	6.1
	* 9 months	2.2	1.1	22.2	0.6	3.9	0.0	3.9	1.1
	* 13 months	0.0	2.5	35.0	0.0	5.8	0.0	2.5	0.8
Nyanza (1760m)	* 5 months	1.1	2.8	38.3	0.6	3.9	0.0	10.0	2.8
	* 9 months	2.2	1.1	53.9	2.2	12.2	0.0	9.4	0.0
	* 13 months	0.0	0.6	53.3	0.0	11.7	0.0	3.3	0.0
Kora (2430m)	* 5 months	1.7	0.0	2.8	1.7	1.1	0.0	5.6	0.0
	* 9 months	0.0	0.6	5.6	5.6	1.1	0.0	3.3	4.4
	* 13 months	0.6	0.0	10.0	0.6	2.2	0.6	4.4	0.0

* Samplings are a composite sample of 3 locations within each bin (North, South, Central).
** Samplings are a composite sample of 2 locations within each bin (North, South).

Table 84. Comparison of mean % postharvest loss given by data sets published for Rwanda.

Source of Published Data (publication date)	Type of Loss (units)	Mean % Loss by Commodity (number of sampled sites)		
		Sorghum	First Season Beans (January)	Second Season Beans (June)
FAO (1977)	None given	25 (n=?)	25 (n=?)	25 (n=?)
Durnez and Dejaegher Pilot Study Butare Prefecture (Gatsve Colline) (1980)	Storage weight loss (% g)	1.8 (n=20)	0.07 (n=20)	0.25 (n=20)
LCS/FSM II - national farm survey (1987)	Storage dry weight loss (% g)	-2.6[1,2] (n=15)	2.28 (n=26)	0.49[2] (n=20)
- Cooperatives (1987)	Storage dry weight loss (% g)	1.0[3/] (n=6)	---	---
- national warehouse survey (1987)	Storage dry weight loss (% g)	1.96[4/] (n=15)	---	0.14 (n=15)

1/ A negative dry weight loss indicates a weight gain. If this is significantly different from zero, it could be due to additional triage that farmers may have done with their stock during storage.

2/ Only farms from low and middle altitudes had beans and sorghum to sample a second time.

3/ Hangar-type cooperatives. The interval of sampling was 2 months. The time at which this took place after harvest, however, varied.

4/ Between 5 and 13 months after harvest, the typical storage period at national warehouses.

Table 85. Weight loss (dry basis) in beans and sorghum during storage at national warehouses, cooperatives and on farms in Rwanda.

Type of storage	Location (number	Period of storage after	% dry weight loss Beans	Sorghum
National Warehouses (OPROVIA)	Kora (n=15)	from 5-6	0.1	1.3
		6-9	-3.8	
		9-11	3.9	0.1
		11-13	-0.5	
		Total 5-13		
	Nyanza (n=15)	from 5-6	-0.2	1.1
		6-9	-0.1	-2.1
		9-11	1.1	0.9
		11-13	-0.8	
		Total 5-13	0.0	-0.1
	Kibungo (n=15)	from 5-6	1.6	2.2
		6-9	-0.5	-0.2
		9-11	1.4	1.4
		11-13	-2.5	---
		Total 5-13	0.0	3.4
Cooperatives	Silo type	Period of		
	high (n=6)	sampling	---	2.0
	middle (n=9)	after harvest	---	1.2
	low (n=9)	was variable.	---	-5.0
	combined (n=24)	Samples taken at ca. 2	---	0.6
	Hangar type	month intervals.		
	all altitudes		---	1.0

Type of storage	Location (number of sites)	Period of storage after harvest (months)	% dry weight loss	
			Beans	Sorghum
on-farm	high altitude	1-3.4	1.2	---
		1-2.7	3.3[3] (n=6)	---
		1-3.0	---	-0.5 (n=1)
	middle altitude	1-3.4	3.9[2]	---
		1-3.5	2.1[3] (n=11)	---
		1-2.8	---	2.4 (n=10)
	low altitude	1-3.3	0.9[2] (n=6)	---
		1-3.3	1.8[3] (n=9)	---
		?	---	5.3 (n=4)
	all altitudes combined	1-3.2	0.5[2] (n=14)	---
		1-3.2	2.3[3] (n=26)	---
		1-? mo.	---	2.6 (n=15)

1 Quantity not sufficient for a second sample.
2 June 1984 bean harvest.
3 January 1985 bean harvest.

Table 86. Consumer perception of loss and consumer loss index[1/] in beans during storage at national warehouses, cooperatives and on farms in Rwanda (June 1984 Harvest).

Type of Storage	Location (Number of Sites)	Period of Storage After Harvest (Months)	Perceived Consumer Loss of Edibility[2/] %	% Loss	Consumer Loss Index[3/] %	% Loss
National Warehouses	Kora	5	7.7	---	4.7	---
		6	5.4	1.7	3.2	1.5
		9	5.3	-0.1	2.1	1.1
		11	12.5	6.8	4.6	2.5
		13	16.9	4.4	2.9	-1.7
		15	13.7	-3.2	---	---
		Total		9.6		-1.8
	Nyanza	5	9.1	---	2.4	---
		6	7.5	-1.6	2.2	-0.2
		9	9.9	2.4	1.1	-1.1
		11	10.3	0.4	4.0	2.9
		13	11.5	1.2	4.5	0.5
		15	17.2	5.7	---	---
		Total		8.1		2.1
	Kibungo	5	12.9	---	5.7	---
		6	11.9	1.0	6.1	0.4
		9	12.1	0.2	2.7	-3.4
		11	13.5	1.4	5.6	2.9
		13	21.1	7.6	7.8	2.2
		15	17.4	-3.7	---	---
		Total		6.5		2.1

Type of Storage	Location (Number of Sites)	Period of Storage After Harvest (Months)	Perceived Consumer Loss of Edibility 2/ %	% Loss	Consumer Loss Index 3/ %	% Loss
Cooperatives	High altitude (n=3)	Period of sampling after harvest was variable. Samples taken at ca. 2 month intervals.	---	---	0.4	---
					2.3	1.96
	Middle altitude (n=3)		---	---	1.3	---
					4.7	3.45
	Low altitude		--- 2/		--- 2/	
On-farm	High altitude		--- 2/		--- 2/	
	Middle altitude (n=7)	1	4.2±0.9	---	0.57	---
		3.4	6.0±1.6	1.8	2.51	1.9
	Low altitude (n=7)	1	5.5±1.3	---	0.81	---
		2.7	12.4±2.6	6.9	5.82	5.0

1/ [(% kernels with visible mold, insect damage, rodent damage and germinated embryos) x 0.7].

2/ Not sufficient quantity of beans stored.

FIGURES

Figure 1. Cross sectional map of the main Rwandan elevations and their rock composition (Sirven et al. 1974).

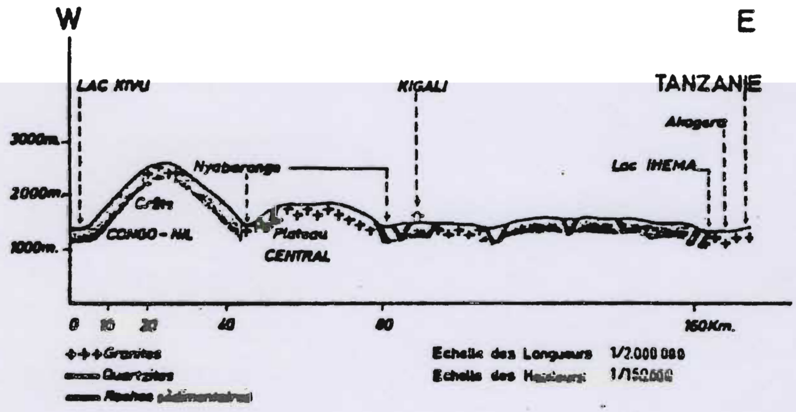
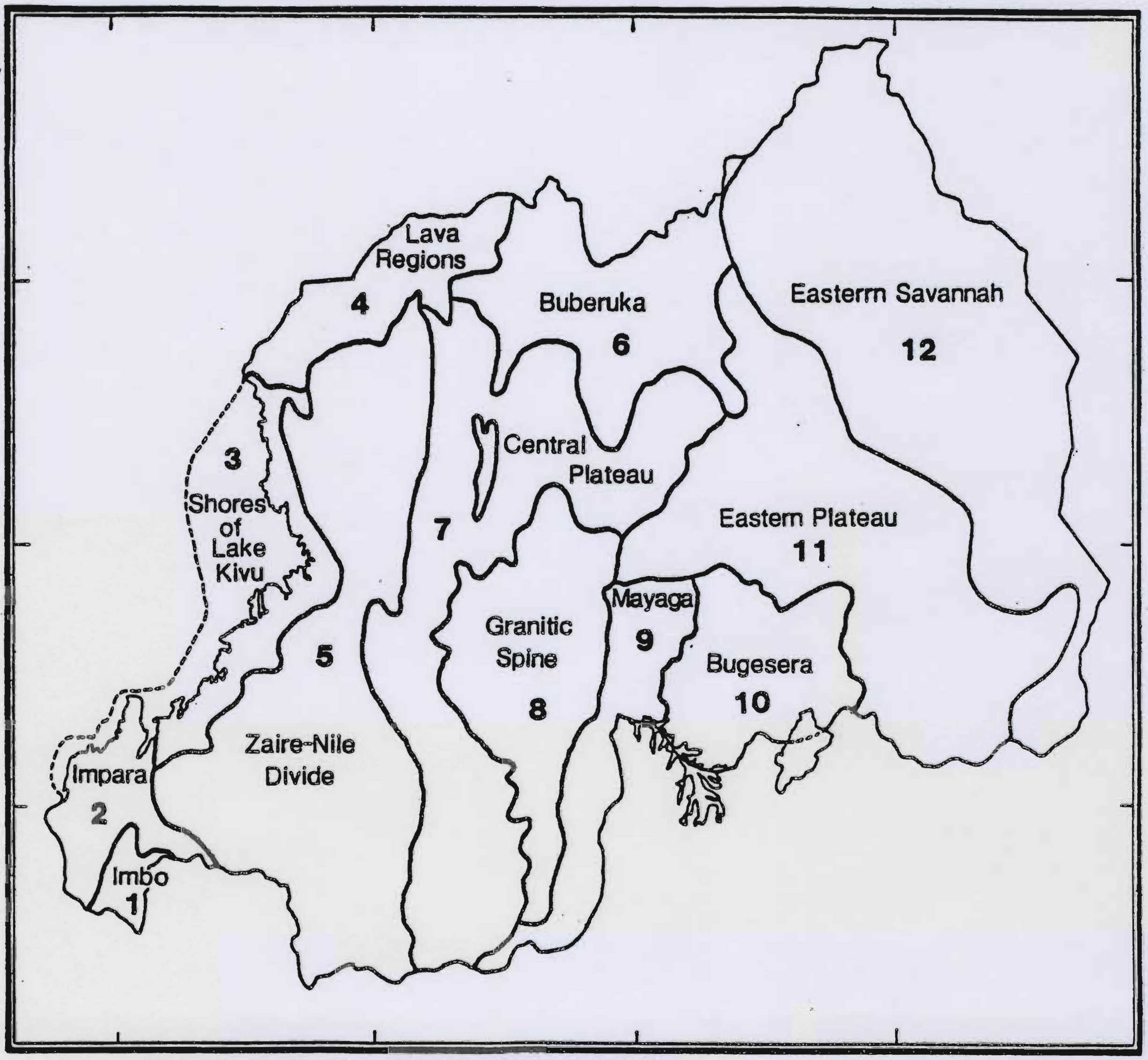


Figure 2. Map of the twelve agroclimatic zones of the Republic of Rwanda.



AGROCLIMATIC ZONES OF RWANDA

Figure 3. Map of the three altitudinal regions superimposed on the twelve agroclimatic zones of Rwanda.

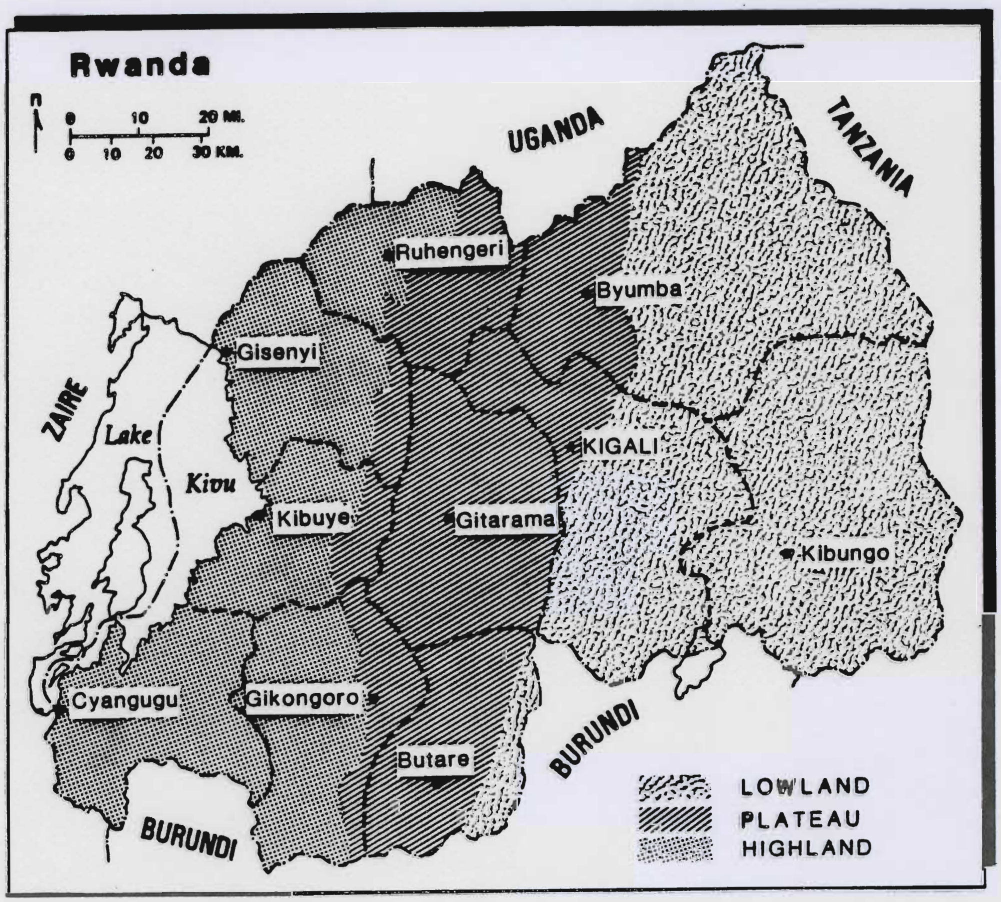


Figure 4. Map of Prefectural regions of Rwanda and OPROVIA warehouses sampled for sorghum and beans in 1984 and 1985.

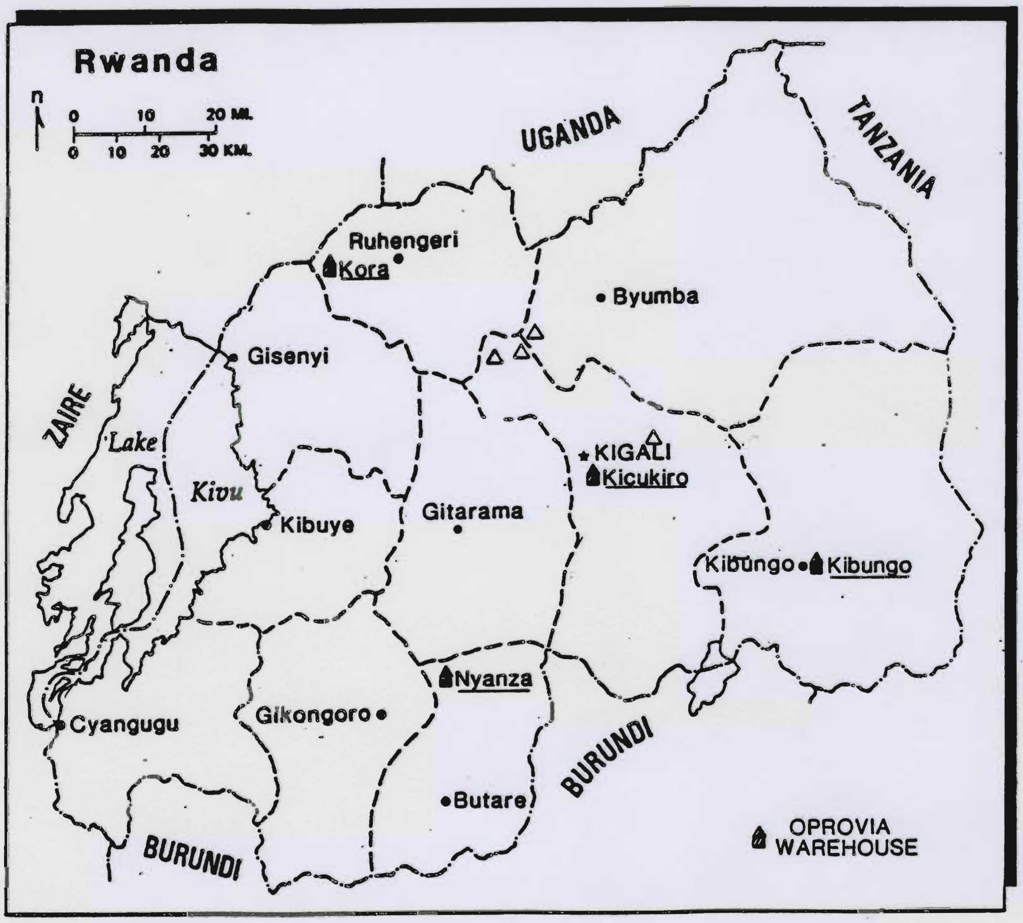


Figure 5. Map of prefectural regions of Rwanda showing location of farms sampled for sorghum and beans in 1984 and 1985.

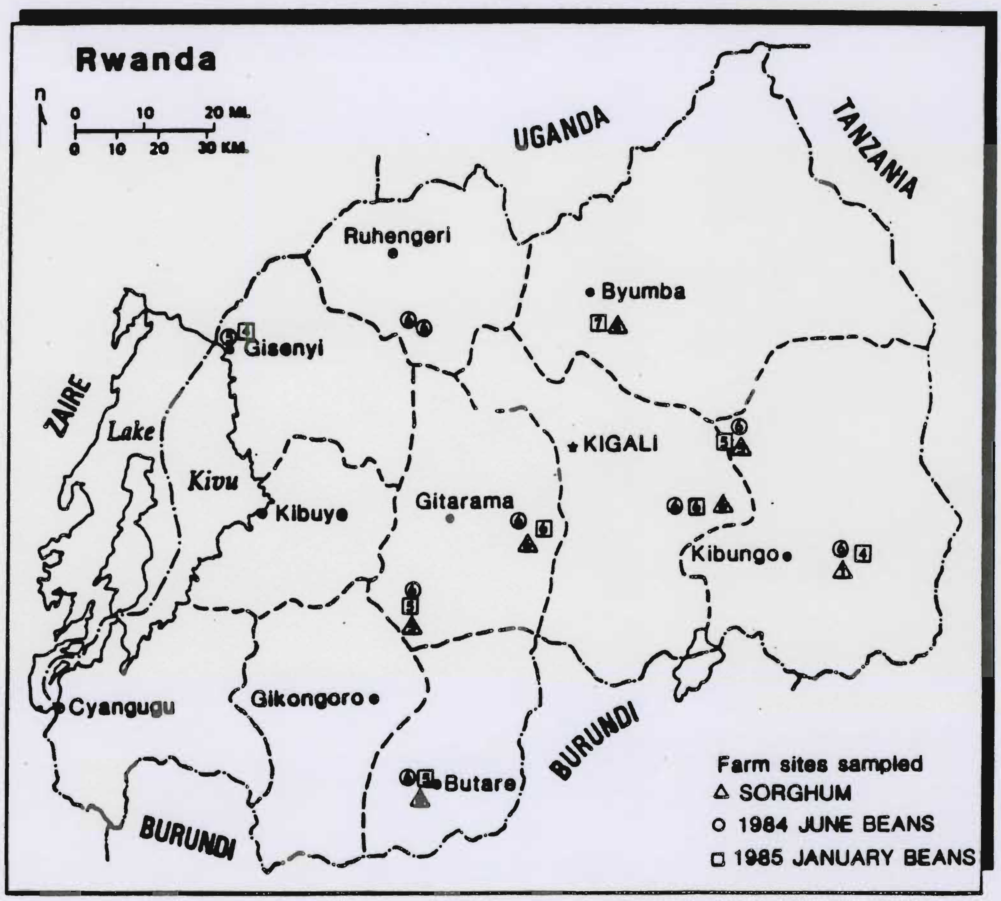


Figure 6. Map of prefectural regions of Rwanda showing location of cooperative silos and hangars sampled for sorghum and beans in 1984 and 1985.

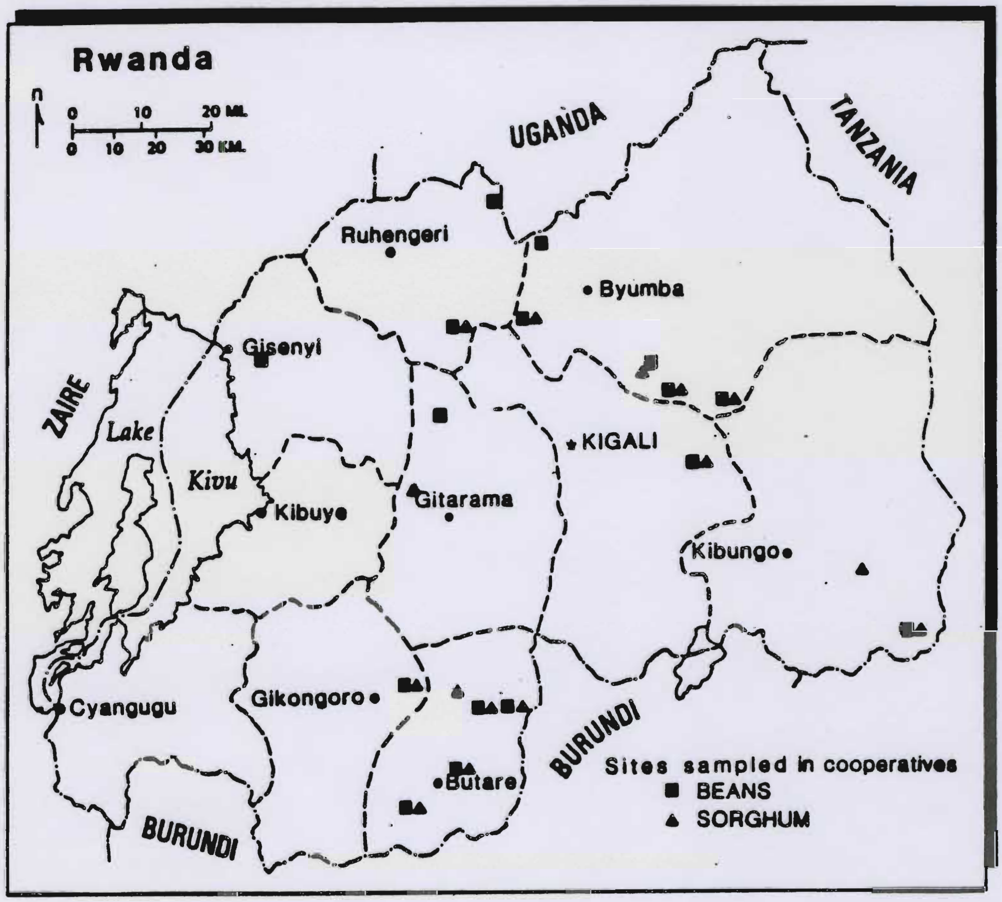
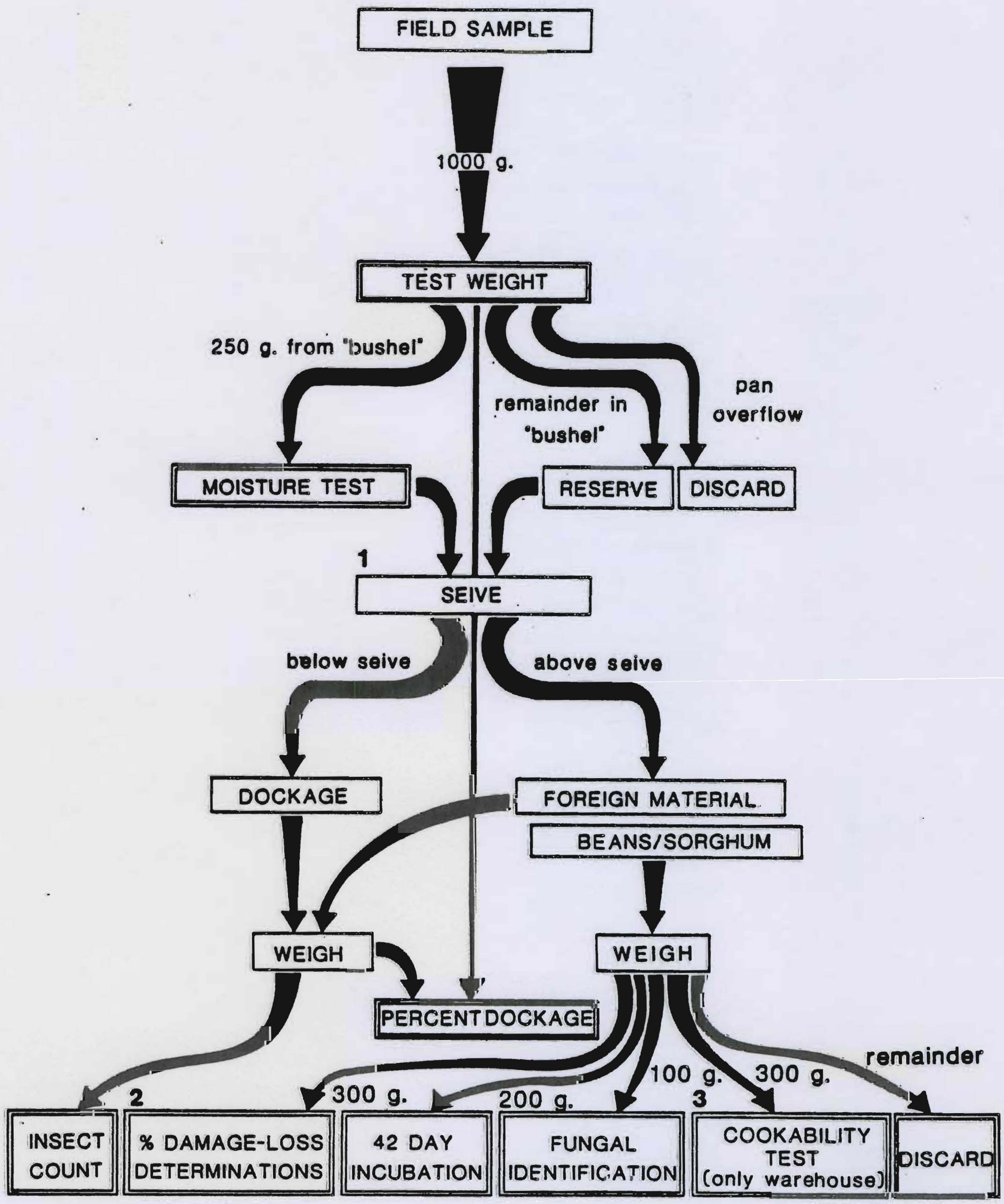


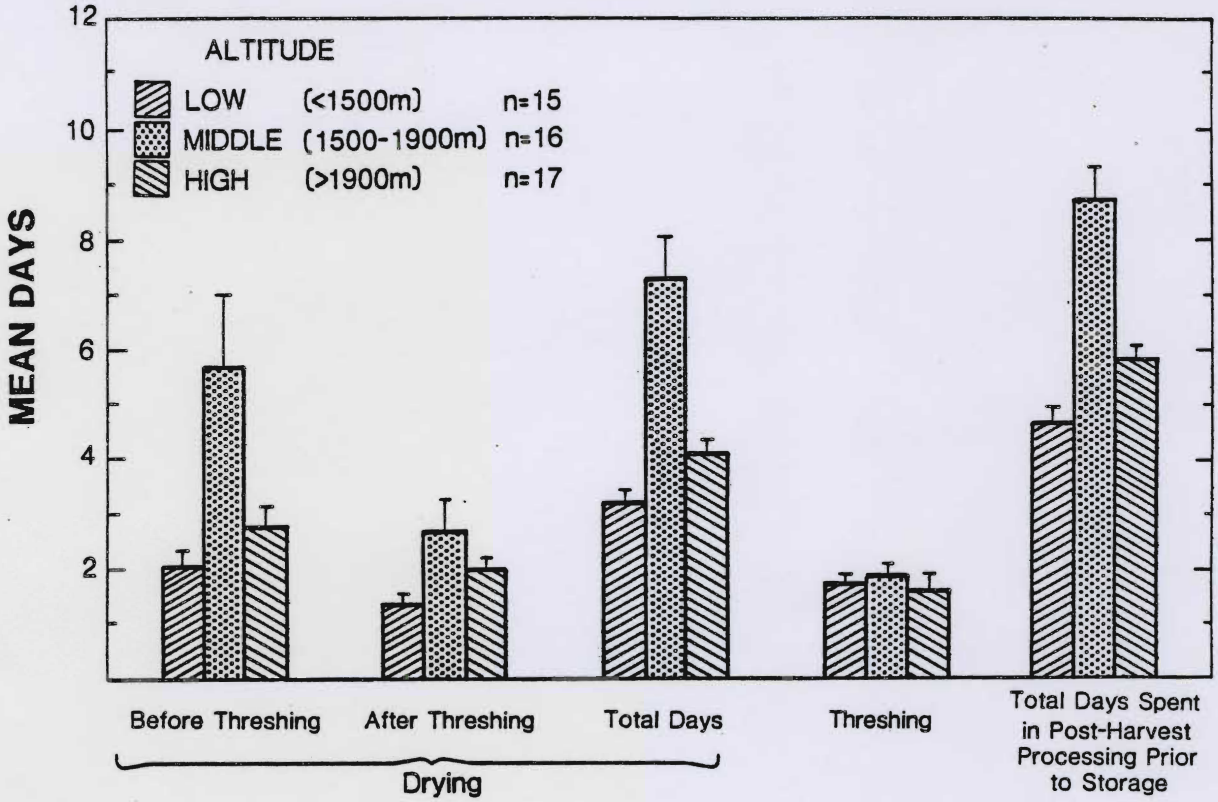
Figure 7. Flow chart for laboratory analysis of field samples of Rwandan beans and sorghum.



1: 1/8 x 3/4 seive with oblong holes for beans.
8/64" seive with triangular holes for sorghum.
2: for sorghum, only 100 g. are used and no loss determination is made.
3: only for beans

Figure 8.

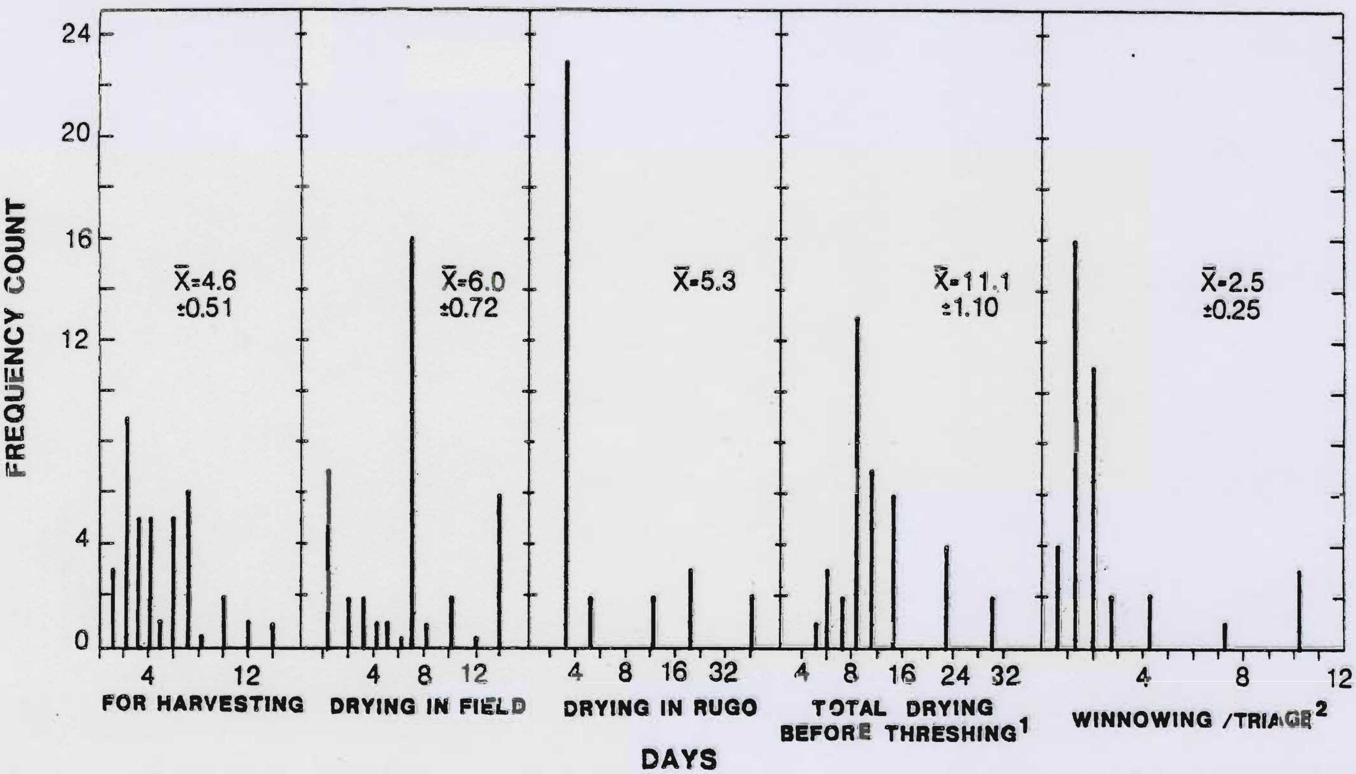
Post Harvest Treatment of First Crop Beans[1] on Rwanda Farms



[1] **Harvested January 1985**

Figure 9.

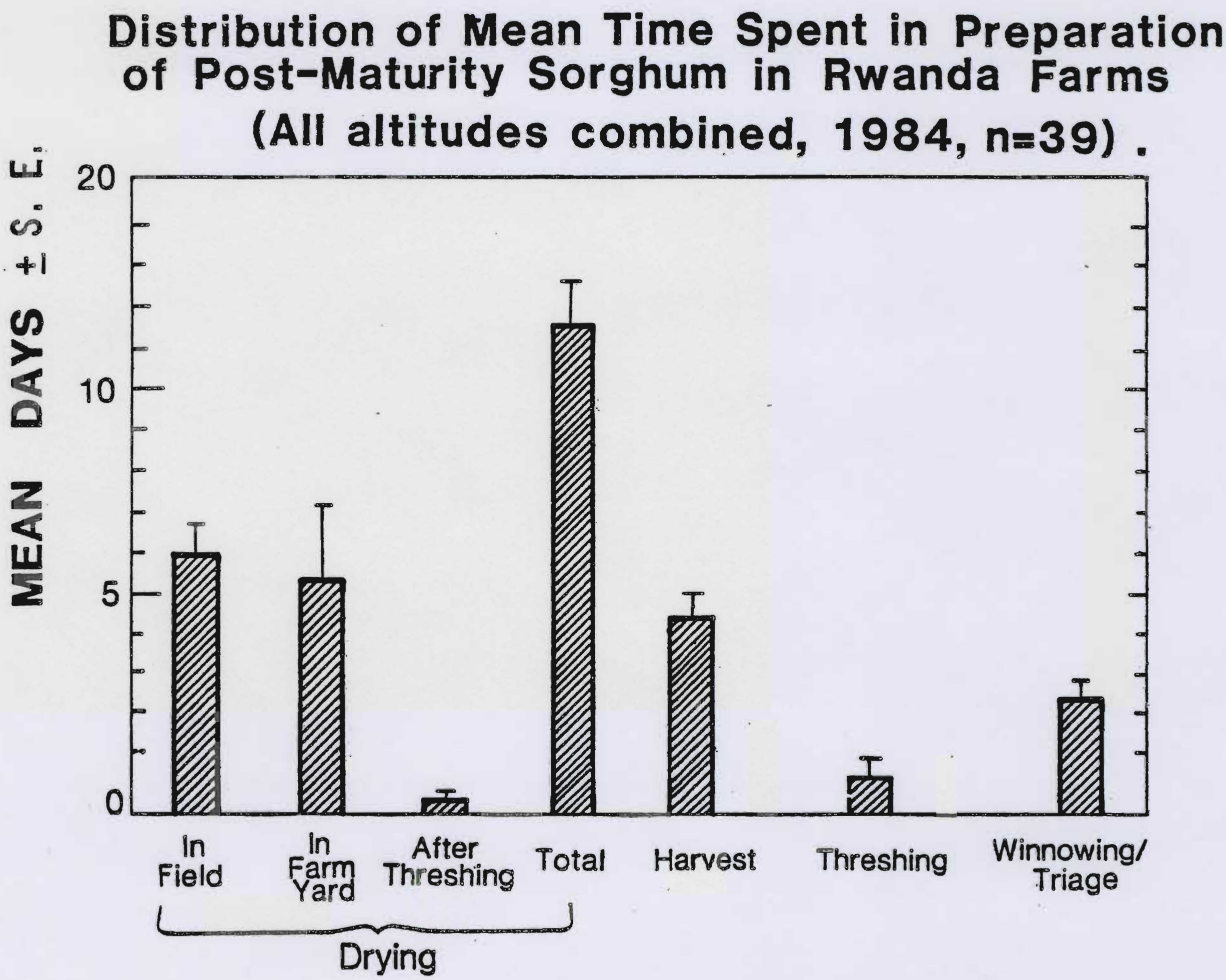
Post-Harvest Management of Sorghum Harvested June 1984 in Rwanda. (n=39)



Mean total days drying after threshing =0.1

[2] Total days for triage and winnowing were the same since these two actions occurred simultaneously.

Figure 10.



Distribution of Mean Time Spent in Preparation of Post-Maturity Sorghum in Rwanda Farms
(All altitudes combined, 1984, n=39).
MEAN DAYS ± S. E.
20
10
5
0
In Field
In Farm Yard
After Threshing
Total
Harvest
Threshing
Winnowing/ Triage
Drying

APPENDICES

APPENDIX A: Form Used for National Storge Survey at Producer Level in Rwanda.

OPROVIA/GRENARWA II RESEARCH

Rwandan Bean and Sorghum
Storage Survey

Data Sheet
Producer Level

Producer's Name ____________________

Hill ______________ Sector ______________

Commune ______________ Prefecture ______________

Survey Number ____________________

Name of Surveyor ____________________

Date of Survey ____________________

Storage Method

Structure	Produce Stored	Placement	Remarks
Grainery	______	______	______
Long Basket	______	______	______
Round Basket	______	______	______
Earthen Pot	______	______	______
Gourd	______	______	______
Metal Drum	______	______	______
Sack	______	______	______
Other	______	______	______
______	______	______	______
______	______	______	______

Description and diagram of structure sampled.
(Dimensions, material, condition, faults)

____
____
____
____
____
____
____
____
____
____

Appendix A (Cont.)

INVENTORY AND CALENDAR OF GRAIN HANDLING FROM PHYSIOLOGICAL MATURITY UNTIL PLACEMENT IN STORAGE

OPERATION	METHOD	PLACE	WORKERS (NUMBER & SEX)	DURATION (NUMBER OF DAYS)
1. drying on plant				
2. harvest				
3. drying after harvest				
4. hitting threshing				
5. cleaning				
screening				
winnowing				
triage (hand picking)				
other				
6. drying				
7. insecticidal treatment				
8. other				
9. placement in storage				

Appendix A (Cont.)

Quantity placed in storage (in kg.) ______________________________

Date of harvest: ______________________________

Method of drying (panicle, pod, grain) ______________________________

Method of storage (panicle, pod, grain) ______________________________

Approximate time from maturity to
placement in storage: ______________________________

Labor used: women x days: ______________________________

men x days: ______________________________

Total: ______________________________

Other remarks: ______________________________

____

____

____

____

____

Appendix A (Cont.)

OPROVIA/GRENARWA II: RESEARCH

Data Sheet (continued)
Producer Level

Name of producer: ______________________________
Hill: ____________________ Prefecture: ____________
Quantity stored at
last visit (kg.): ______________________________
Quality used or sold
since last visit (kg.): ______________________________

Kind of use

Kind	Quantity (kg.)
Home consumption	________
Feed for animals	________
Seed	________
Sales	________
Gift or other transfer	________
Other	________
Sale price	________

Treatment of this stock since last visit (ex: drying, insecticide application, etc.): ______________________________

____

____

____

Condition of Stock

Observations (mold, insects, odors, rodent signs, dirt, etc.): ________

____

____

____

____

____

Temperature	Level	Location
________	________	________
________	________	________

Appendix A (Cont.)

OPROVIA/GRENARWA II: RESEARCH

Data Sheet (continued)
Producer Level

Type of sample: ______________________ ______________________
______________________ ______________________
______________________ ______________________

Number of sample: ______________________ ______________________
______________________ ______________________
______________________ ______________________

Date sample taken: ______________________ ______________________
______________________ ______________________
______________________ ______________________

Name of sampler: ______________________ ______________________
______________________ ______________________
______________________ ______________________

APPENDIX B: Form Used for National Storage Survey at Warehouse and Community Levels in Rwanda.

OPROVIA/GRENARWA II: RESEARCH
Rwandan Stored Bean and Sorghum Survey

Data Sheet for Warehouses of GRENARWA
or Community Storages

Name and location
of warehouse or silo: ______________________________

Commune: ______________ Prefecture: ______________

Managers name: ______________________________

Name of survey taker: ______________________________

Survey number of this structure: ______________________________

Detailed description and diagram
of structure (dimensions,
materials, peculiarities, faults): ______________________________

____

____

____

____

Description of reception and
handling methods: ______________________________

____

____

Description of stock sampled: ______________________________

____

Drawing of
cooperative or warehouse
floorplan: ______________________________

____

____

Approximate quantity stored (kg.) ______________________________
Reception date: ______________________________
Origin of stock: ______________________________
Purchase price: ______________________________
Place of production: ______________________________
Date of harvest (month & year): ______________________________
Treatment of this stock (ex: screening, winnowing, triage, drying, etc.
techniques and dates): ______________________________

____

____

____

Application of insecticides and fungicides (kind, concentration, dose, and
date): ______________________________

____

____

Appendix B (Cont.)

Data Sheet (continued)

Warehouse or Community Storage

Sales Since Last Visit

	A	B	C	D
Quantity (kg.)				
Purchaser				
Uses				
Price (Fr/kg.)				

Quantity transferred and its destination since last visit/treatment (ex: drying, fumigation, etc.):

Observations (mold, insects, odors, rodents, etc.):

Temperature	Level	Location

Type of sample:
Number of sample:
Date sample taken:
Name of sampler:
Name and location of warehouse or silo:

APPENDIX C: Report form used to make recommendations to managers of Rwandan cooperatives following visits in which samples were obtained by the team.

OPROVIA/GRENARWA II
(Research)
B.P. 953 Kigali

Report of the Analysis of Grain and Bean Sampling

Cooperative name: ______________________________

Commune: ______________ Prefecture: ______________

Date of sampling: ______________________________

The sample of ______________ (product) that we have taken from your stock on ______________ (date) contains the following numbers of insects __________ live adults/kilogram __________ dead adults/kilogram.

Depending on the degree of infestation we recommend the following:

Number of Live Insects	Degree of Infestation	Council
1-5	low	No treatment is necessary at the moment but examine stock regularly.
6-20	moderate	Immediately treat stock and check each month.
more than 20	severe	Treat immediately.

Comments: ______________________________

____

____

____

Do not hesitate to contact us if you have questions regarding this information or other storage problems.

APPENDIX D:

AN INDIGENOUS STRUCTURE

USED FOR STORAGE OF DRY PULSES IN RWANDA

Florence V. Dunkel
Theodore P. Wittenberger
Evariste Munyarshoka
Edouard Nizeymana

revised 29 July 1986

INTRODUCTION

Frequently farmers in one area develop by trial and error an agricultural technique which works particularly well for the conditions they experience. Because farming techniques are often family secrets or because extension systems are undeveloped and national meetings of e.g. bean or sorghum growers do not exist, such successful techniques frequently do not become widely adopted in a country or even in a similar region of the country. Often it is not until a national survey is conducted by persons interested in indigenous farming practices that such techniques surface and become disseminated.

No previous mention of the Imboho[1] has been located in the literature of any country. There are, however, similar structures that appear in records of this area and in Rwandan oral history. The closest such record is the Burundi storage survey in which an "impeche" is described (Mertens, 1982) for holding beans after harvest. Structures of this type were made of plant materials and held each 50 kg. In the Congo Republic an oblong structure of natural materials is used on-farm for storage (Wittenberger 1985). Staff at OPROVIA[1/] indicate that structures similar to the imboho were used in the past for transport of beans. There also is a folk tale about a giant imboho. The only historical written or photographic record was found in a text (Paterson, 1907) with no explanation but shown carried on the head of a Ugandan woman.

Of the 9 sectors and 9 collines sampled in our 1984-85 survey only one colline in one sector used the structure. We present the following observations because we consider this pulse storage structure to warrant a careful evaluation. Following this survey of bean and sorghum storage methods, local structures such as the imboho and modified structures were evaluated under somewhat controlled conditions at research laboratories in OPROVIA headquarters in Kigali and some will be evaluated in selected fields or farm sites throughout Rwanda.

INVESTIGATION METHODS

The imboho was first observed during the first visit of our storage survey team to Nyakabanga colline, Murama sector, Rukira commune in the Prefecture of Kibungo, southeast Rwanda (Figure 1). The purpose of the visit was the primary site verification of a sector randomly chosen for the National Grain Storage Survey (see Site Selection Farm Level). The initial observation was made on 22 June 1984 by Ted Wittenberger (Storage Survey Resident Scientist) and his Rwandan counterpart, Joel Kayumba. Three imbohos were observed in one room of a farmer in this area. Two contained beans of the January harvest and one held groundnuts. Arrangements were immediately made to observe the fabrication of a new imboho which would hold dry beans of the new harvest (June 1984). Wittenberger and Kayumba

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[1] Imboho is a Kinyarwandan term and it is plural. The singular term does not exist. Because Rwandans which we worked with began calling it imboho, we will use this term in both a singular and plural sense.
P. Kayinamura, E. Munyarshoka, B. Ntibitura, E. Nizeyimana

returned to the sector on 28 July 1984 and observed the construction. On 10 July 1985, a return visit was made to the farm to videotape the construction process.

In total, three farmsteads with imbohos were observed within the storage survey which included 47 farms in 3 agroclimatic areas of Rwanda for the June 1984 harvest of beans and 48 farms in the January 1985 harvest. Bean storage practices were followed in 54 different households. A total of 12 visits were made to observe the structure during the course of the survey including a trip by Drs. Harold Cloud and Paul Hanegreefs, agricultural engineers.

On 26 April, 1985 the Rwandan counterpart, Evariste Munyarushoka and Dr. Florence Dunkel, storage entomologist, returned to the colline Nyakabanga to conduct in depth interviews on the cultural history of the imboho. Utilization patterns for the structure obtained during other visits were also confirmed. The following questions were asked:

1) Who taught you how to make the imboho? Was it someone from outside your family?

2) Do you know of any nearby collines that use the imboho?

3) How long have you or your family lived in this colline? Where (what region) did you come from? Where (in what region) did you grow up?

4) Do any of your neighbors in the colline use the imboho for storage?

5) When do you use the imboho? For June beans? For January beans? For what other crops do you use it?

6) When do you open the imboho? Is it a long-term, untouched strategic storage? Do you reuse the imboho or make it new for each crop and each season?

RESULTS AND DISCUSSION

Construction Procedure (based on observation of construction)

The imboho is made primarily from the dried primary sheaths of banana plants. These dry sheaths are collected the evening before construction and moistened with water just prior to construction (Figure 2). They are then shredded into strips longitudinally. These strips are about 1.5m long. Strip length depends, however, on the overall size of the imboho to be built. The strips are shredded into two widths 3 to 5 cm and 10 to 20 cm. At this point a frame or building guide[1] consisting of 2 parallel logs (8cm diameter) was placed on ground. The narrower strips are twisted and are laid parallel on the ground 10 cm apart (Figure 3a). If the frame is used,

---

[1] We were told this is not usually used, but was used at this time to facilitate the construction. It was not used in the construction observed in 1984.

the twisted strips are laid over the log building frame and perpendicular to it. Then, the wider strips are laid flat, perpendicularly over the twisted pieces (and parallel to log frame) until an area of about 75cm x 150cm is covered.

A bed of dry grass (cut 2 days prior to construction) is then laid on top of the flat strip (Figure 3b). The species of dry grass is apparently not important but the length is (0.5m). At the ends of the imboho under construction they are placed in a v-shape.

At this point, the beans to be stored are emptied onto the grass bed. During one construction the farmer indicated Malathion had been previously applied to the stock which they were presently encasing. Ash and kaolin were also sometimes used. The leaves of a local plant ("UMWISHEKE") (Ocimum kilimunjarum, related to sweet basil, Ocimum bascillicum) were also mixed into the beans during both of the imboho constructions observed. These leaves had a strong pungent odor. Their function was insect repellency and/or insecticidal. Bunches of the small leaves were plucked from the flowering green plant and dropped onto the beans.

After the beans were emptied onto the grass bed, a stout stick 1.5 meters long, 5 to 7 cm thick with a tied "ball" of banana leaf strips at one end was laid on the beans and half buried in the beans with the ball in the beans about one- fourth of the distance from the end of the bed (Figure 3b). The other end of the stick extended out past the bed and underlying mat. The main purpose of this pole is support, but it may serve to be a rodent barrier and provide a passive aeration effect around the entire bulk of beans or other legume.

Additional grass was then laid over the bed and stick. Subsequently, another layer of wide flat sheath material was laid to cover the grass. When this was completed, the ends of the twisted strips were tied up, starting with the apical end. This formed a cocoon like structure (Figure 3c). The loose ends were trimmed off with a knife. A final twisted strand was tied to each encircling strand and it ran the length of the entire structure. The purpose of this final strand is apparently to keep the other tied off strands from slipping. Tying of the strings requires the help of 3 to 4 persons. While the tying occurred, the farmer continually pounded the side of the imboho with his fist to reposition the beans more compactly.

The entire construction process took about 1.5 hours not including the time it took to collect materials. This particular imboho held about 60 kg. but the builder commented that he was capable of fabricating one with a 200 kg capacity.

Umushenga Variation of Imboho

Another variation on the imboho is the umushenga. The umushenga has a similar construction but the wooden shaft running up the center is absent. It is also suspended from a rafter or overhead beam inside the house and no part of it touches the walls or floor. The imboho on the other hand, leans up against the wall on its wooden foot or a hole is dug for the foot to be inserted and the container stands upright. One farmer mentioned that the umushenga was used for soybeans or peanuts but not beans. Beans are stored in the imboho.

Location within the House

In 100% of the visits to 47 farms after the June 1984 harvest and to 48 farms after the January 1985 bean harvest (for a total of 52 different farms), beans were stored inside the house. Within the house, the most frequently encountered location was an actual storage area or store room. Other areas used were the sleeping area, foyer and cooking area. All imbohos observed were stored in a storage area in the house. Two farmers interviewed indicated their family has in the past placed the imboho outside the house and constructed it much larger when yield was greater and theft was not as much a problem.

Utilization

The imboho and umushenga storages are not built immediately after the harvest and post-harvest treatment of the crop. The crop, instead, is placed in temporary storage first, usually a basket lined with cow dung. The duration of this temporary storage is apparently 4 to 8 weeks and during this period some insecticidal application may be performed either with ash or a synthetic insecticide such as malathion. The beans in imbohos we observed were used up 4-5 months after harvest. The farmers indicated that when possible they keep beans in these containers up to 2 years.

Although only beans (*Phaseolus vulgaris*) were sampled in the imboho, the imboho may be used for other legumes. The umushenga is used for soybeans and peanuts but not beans. Neither structure is used for storage of peas, sorghum, or maize.

Once the imboho or umushenga is constructed, access to the stock is accomplished by simply spreading the wider sheaths apart at the lower 1/3 of the container and letting the stock fall into a waiting receptacle. After the stock has been reduced, the beans or other legumes are removed by hand from the upper portion of the structure. When a sufficient quantity has been removed, the hole is closed by shifting or gently pushing the sheaths back into position. It is a 'disposable' structure, used only as long as the stock that was put in it when it was made, lasts.

Farmers claimed this structure was superior to the open baskets in maintaining bean quality during storage. The open basket was used by 77% of the farmers in the national survey. The specific types of bean quality mentioned as being improved by the imboho were insect infestation, lack of mold problems, and bean cookability. Bean cookability, after a long storage period, was particularly superior in imboho beans. It is possible that the imboho is particularly used after small harvests due to e.g., low rainfall. In that case, the imboho would create conditions which will maintain bean quality longer, possibly over another dry season.

Of the beans harvested, 59.1% are consumed directly on the farm. The next most frequent mode of utilization is to sell them in the market. Approximately 39 markets were visited during the varietal survey (Lamb and

Hardman, 1986) and 4 markets were separately visited in the Storage Survey (Dunkel et al., 1986) at no time was an imboho observed being carried to market. It is possible that the imboho is either not widely used or the beans placed in the imboho are consumed on-farm and not sold. It is also possible that small quantities from the imboho are placed in another container. The imboho is not presently a typical transport structure for beans. It was never observed in transit in Rwanda during the project January 1983 to October 1985. Rwandan coworkers, however, upon seeing video tapes of the construction process or seeing them at our experiment station site indicate that these were once very common transport containers in Rwanda. When used for transport, however, they were much smaller.

Hypotheses Regarding Origin

Three hypotheses have arisen from this preliminary investigation of the imboho. First, one can hypothesize that the colline Nyakabanga or that commune in which it is located is the evolutionary center of origin of this storage structure. The evidence for this is the lack of observation of this structure in any of the 51 other households surveyed for storage practices in Rwanda during 2 bean harvests (June 1984 and January 1985) and during a preliminary survey in a commune in Butare (DeJaegher 1980). Additional support of this hypothesis is from the people we interviewed who use the imboho. They all indicated the structure was always made by their ancestors and all their family use it.

A second hypothesis is that the structure is an ancient one once used throughout Rwanda, but it was used for transporting food rather than for food storage. The evidence for this is that there are folk tales in the oral tradition of Rwandans from at least the Rutobwe Commune in the Gitarama Prefecture (180km from the Nyakabanga colline - 3 hours on present roads). Actually, the first and second hypotheses are not mutually exclusive. A combined hypothesis could be made as follows: the imboho was an ancient structure used for carrying food on long journey. Someone in the colline Nyarabakura evolved a similar, but bigger structure that could be propped up or hung inside the home for stationary storage of pulse crops. Due to lack of surveys of this type and an absence effective extension system in Rwanda, the success of this method never spread. Meanwhile, the use of the structure for general transport of food disappeared. Perhaps it was replaced by the locally manufactured plastic bags or buckets now seen throughout Rwanda.

A third hypothesis is that it is an indigenous storage or food transportation structure in a neighboring country and someone from the colline in Kibungo visited this country and brought it back to Rwanda. The evidence for this is a photograph of Ugandan women carrying on their heads a similar but smaller structure (Patterson 1907, Figure 4).

Other evidence is the similar structure (impeche) used for storage of beans in Burundi (Mertens 1982).

Further surveys in other geographical regions of Rwanda and research in the cultural anthropological literature of the area is warranted to test these 3 hypotheses.

CONCLUSIONS

At this point in our investigation the imboho/umushenga can be described as a form of traditional storage unique to Rwanda and indeed found only in one region of this country. Farmers who employ this method of storage have claimed that they encounter fewer insect problems than with other forms of containers. They say that they have no mold problems at all. Further, and perhaps most important, individuals who use these storages have claimed that the hardness problem encountered in dry beans stored over 6 months is less pronounced than in beans stored by other traditional methods.

These statements coupled with the fact that the imboho and umushenga are made completely out of indigenous material and cost nothing to make except for a minor labor commitment indicate that these structures might be a viable item for extension to other parts of Rwanda and other areas where beans and other dry pulses are stored adjacent to banana groves. Bananas are grown virtually everywhere in Rwanda yet these containers are apparently found only in this one region.

Not only is the banana sheath package a previously undocumented kind of storage container, but leaves themselves and leaf wrap are unusual storage containers. Leaves, thought to be banana, were found used in a Badeku village for kola nut storage (Williams 1973). In this case, the wrapping was replaced with fresh leaves every three weeks. A suspended structure made of leaves and tied with fiber ropes was also observed in use for on-farm storage in the Congo (Wittenberger 1985).

Additional research in the following areas is necessary prior to an extension commitment: a) a broader survey of indigenous storage practices which would determine if the imboho is used in other areas of Rwanda or if different methods of on-farm storage, which also would be worth investigating, have evolved in Rwanda, b) controlled comparative experiments conducted by the OPROVIA Grain Quality Laboratories, using the imboho intact and testing the properties of its components, e.g., the banana leaf, c) on-farm trials to test the claims that this is indeed a better form of storage than the other indigenous storage structures, such as open baskets lined with cow dung, d) an etymological analysis of the term imboho and a historical study, and e) a planned series of interviews with farmers who use the imboho to determine why certain portions of the construction are included and what the 'safe storage' parameters of it are.

ACKNOWLEDGEMENTS

The authors particularly appreciate the advice and manuscript critique by other University of Minnesota faculty Drs. Lansine Kaba, College of Liberal Arts, Department of History[1], Earl Scott, College of Liberal Arts, Department of Geography and Sonia Patten, cultural anthropologist in the School of Medicine, Department of Family Practice.

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[1] Now at the University of Chicago, Chicago, Illinois.

Figure 1. Location of oral reports and observations of the imboho in use, either as a storage or as a transport structure.

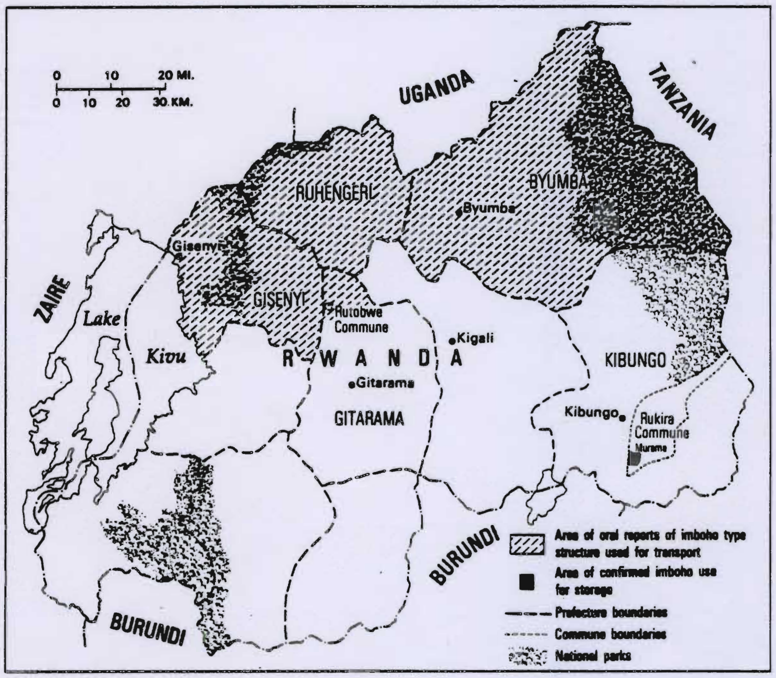

Figure 2. Photos of imboho from previous storage period, after beans contained in it had been used and just prior to discarding structure. (Photos by F.V. Dunkel).

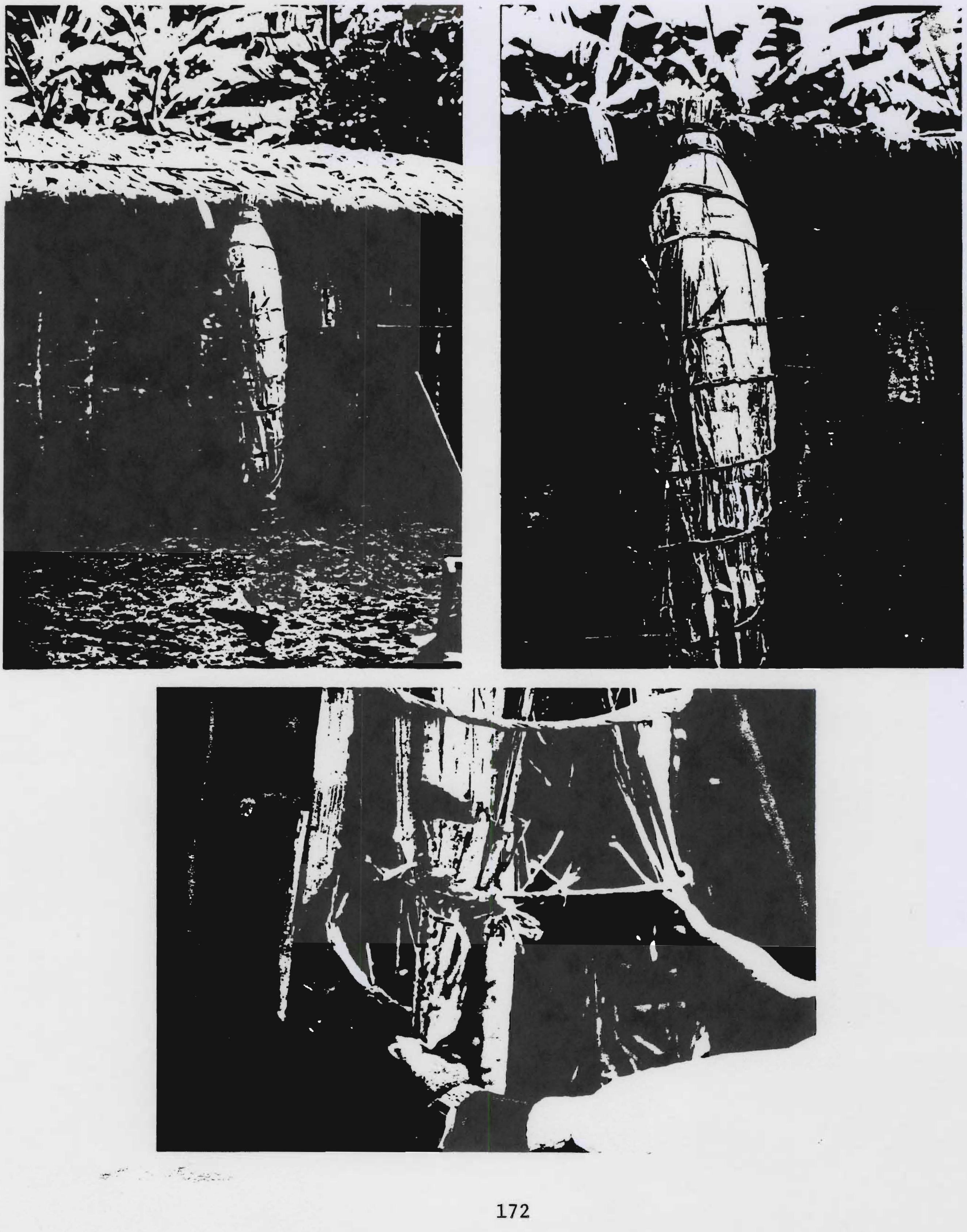

Figure 3. Imboho during construction process a) top view before placement of grass or beans, b) side view after placement of support stick, half of the beans and half of the banana sheaths, c) after completion of tying.

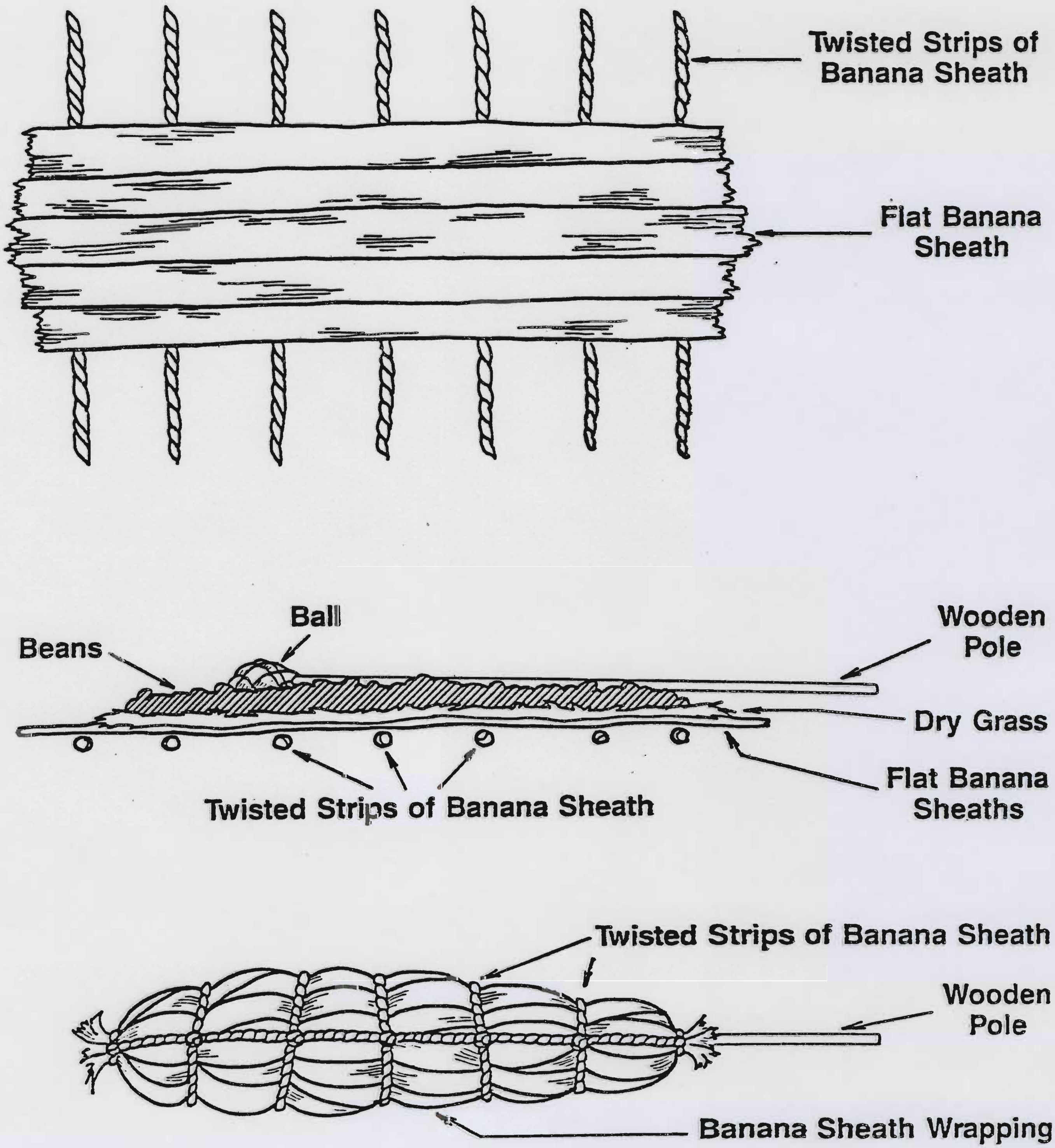

Figure 4. Illustration from Patterson (1907) of Ugandan women carrying supplies of food in structure similarly shaped to imboho.

APPENDIX E:

The Larger Grain Borer, *Prostephanus truncatus* Horn, as a Threat to Rwandan Beans: Results of a National Survey.

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Evariste MUNYARSHOKA
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June 27, 1988

INTRODUCTION

Infestations of the larger grain borer, Prostephanus truncatus Horn, have occurred in the Tabora region of Tanzania and most recently in Burundi. Another outbreak occurred near Taveta in Southern Kenya (1979) which was apparently controlled. Interceptions have also been made in recent years in Israel, Togo, Iraq, and Thailand.

There is a distinct possibility that an outbreak of Prostephanus could occur in Rwanda as the country has common borders with both Tanzania and Burundi (Figure 1). Maize is cultivated throughout Rwanda but the national production average (usually from two harvests) is only about 40kg per household (Golob 1982). The mean annual production (1978-1980) was 81,347 MT. The Nyirakagoli variety is the most popular. Also cultivated are the imported Katumani and Bambu varieties. Although some maize is cultivated by almost every farm family, maize production is more important in certain areas than others. The prefectures of Ruhengeri and Gisenyi in the high altitude north and Cyangugu in the southwest are the leading maize producing areas (Figure 2). In Cyangugu most maize production is localized in the Bugarama/Rusizi region adjacent to the Burundi border. This region is the northern most extension of the Tanganyika Plain and has the lowest altitude of Rwanda. Also worth noting are localized areas of high maize production, Southern Kigali and Kibungo Prefectures and the Mutara region (western Byumba Prefecture). Southern Kigali (Bugesera) and Southern Kibungo share borders with Burundi and Tanzania. Human population density, however, is rather sparse in these areas.

In Rwanda storage and consumption patterns for maize vary. Most maize is consumed fresh although some is always stored dry for seed. Inhabitants of Ruhengeri and Gisenyi have a preference for dry maize. On farms this is usually stored on the cob, but is removed for commercialization. Maize on the cob is rarely seen in the markets. In Ruhengeri and Gisenyi unshelled maize is stored without the sheath in outdoor granaries. Maize on the cob is also stored without the sheath, hung up under the roof on the outside of houses. These same structures can be seen in Southern Kigali and Southern Kibungo where they are often built by immigrants who originally came from Ruhengeri/Gisenyi. Shelled grain is almost universally stored inside the house in baskets or in bags made of jute or plastic fiber. Perhaps the most unique form of maize storage can be found in the northern regions. Here, maize cobs are stored outside, on a trellis with their sheath intact and the sheathed cobs pointed down to deflect precipitation (Figure 3).

Prostephanus is known to attack a variety of commodities other than maize including rice (Chittenden, 1911), wheat (Shires personal communication), chickpeas (Calderon and Donahaye, 1964), dry cassava (Golob and Hodges, 1982), and wood (Okumura and Strong). Hodges also reports that the beetle will damage beans, sorghum and groundnuts. To date, however, the only evidence of actual reproduction has been in maize and dry cassava. Cassava is produced in Rwanda but is partially fermented before storage. This apparently makes the tuber resistant to insect activity.

Previous investigations into the possible establishment of Prostephanus in Rwanda have been limited. Peter Golob of TDRI (Tropical Development and Research Institute) visited Rwanda at the request of GOR

(Government of Rwanda) for 12 days in November 1982. He did not find evidence of the insect at that time but did note that climatic conditions, sufficient quantities of stored maize, and the proximity to neighboring countries make Rwanda a likely place for an outbreak of the pest. Before Golob, the GOR sent a two-person team to Tanzania in December 1981 to obtain backround in identification and control. Extension agents and agriculturalists remain largely unaware of the potential hazard posed by Prostephanus. In 1984 the authors (Dunkel, Wittenberger) conducted an introductory session on Prostephanus, its biology, seriousness, and identification for managers of OPROVIA prefectural warehouses. Laboratory staff at the National Bean and Grain Quality Laboratories (OPROVIA) have also been trained to trap, inspect for and identify the insect and closely related species of Bostrichidae.

Customs officials were contacted at Gisenyi, Cyangugu, Rusumo Falls, and Kigembe commune adjacent to the Akanyaru River. The first two are major border crossings to Zaire. The others are major border crossings to Tanzania and Burundi respectively. In all cases the officials stated that maize does not enter Rwanda via these routes as demand for this crop is more pronounced in the adjacent countries. An exception to this is the border with Uganda where considerable quantities of maize enter Rwanda. Much of it is sold in Rukomo Market (Byumba Prefecture) which is known in Rwanda as a maize commercialization center. Much maize passes into the Ruhengeri Prefecture from Uganda as well. One possible reason that the insect has not easily been transported from Tanzania and Burundi (where Prostephanus has been identified as the cause of storage problems.) into Rwanda is the shortage of food in these countries. Beans are known to pass into Rwanda from all adjacent states attracted by the high demand. Rwandan border authorities do not try to control the importation of beans, but exportation is forbidden. Dry edible beans, *Phaseolus vulgaris* L., are the primary source of protein and caloric intake for Rwandans. Food aid is not often needed by Rwanda, but when it is requested from the US, this is usually as shelled corn. From the farm to the largest government warehouses beans are stored adjacent to maize, when maize is being stored. Studies of Rwandan beans indicate that although reproduction of Prostephanus was not supported by the 5 bean seed types tested, some feeding damage did occur in some of the seed types (Cutkomp and Subramanyam unpublished data).[1/] Therefore, although maize production and utilization in the Rwandan diet is much lower than beans, it is hypothesized that Prostephanus can also be an important agent of loss in Rwandan bean supplies. If the Rwandan population continues to increase at an annual rate of 3.5% from a current density of about 400 persons per km^2, any agent of loss in food stocks such as Prostephanus should be considered of utmost importance.

MATERIALS AND METHODS

The major maize production areas in Rwanda were identified by information from SESA (Service des Enquetes et Statistiques Agricoles) (Figure 2). In these areas maize stocks at all organizational areas were searched, i.e., farms, cooperatives, merchants in the open market,

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1/ University of Minnesota, Department of Entomology, St. Paul, MN 55108 merchants that used shops adjacent to the market, project storages (magasins) and GRENARWA Prefectural warehouses. Major national markets in non-maize producing areas were also visited. In Byumba Prefecture, the Rukomo and Gatsibo were visited April 16 and May 1, 1985, respectively. In Gitarama Prefecture, the Ruhango market was visited April 19, 1985. On May 2, 1985 the Kanama market in Gisenyi Prefecture was visited. Location of merchants, small storehouses and farmers with stored corn was difficult and obtained primarily by inquiry. Customs officials were interviewed at Gisenyi, Kigembe, Cyangugu, and Rusumo Falls regarding inspection procedures and maize movements.

A simple survey instrument was used to determine history of the corn stock. Several methods were used to locate *Prostephanus* in the corn sample. First, cardboard traps baited with 'truncall' were placed in areas adjacent to corn stocks.[1/] The number of traps placed depended on size of stock (less than 100 kg., 1 trap; between 100 and 500 kg., 2 traps; above 500, 3 or more traps). These were left for 2 weeks with verbal instructions given to managers of the facility. The area and maize was visually searched for 10 minutes by 2 investigators. Then a 1 kg. sample of maize was obtained in a whirlpack bag and placed in a cooler. Within 48 hours, these samples were sieved (12/64 round hole) for insects and then each kernel was examined on all surfaces for damage. In most cases part of the sample was incubated for 6 weeks.

RESULTS AND DISCUSSION

The most significant result of this survey of stored maize is that *Prostephanus* was not located. Maize stocks in 9 farms were investigated and 59 farms were visited to locate stored maize. Stocks held by merchants of 2 types were surveyed, 6 in the open market and 24 that had a small shop adjacent to the open market area (Table 1). Stocks in 1 OPROVIA warehouse and 30 small storages (government/aid projects such as OVAPAM and DERVAM) were also investigated. A total of 65 maize stocks in 8 prefectures and 2 locations in Zaire were searched. Sixty-four additional storages, farms or merchants were visited in 7 prefectures but did not have maize. All visits were made April 10 to June 13, 1985 and October 1985 to August 1986. Moreover, in the national survey of dry edible beans and sorghum (1984 and 1985) no individuals or feeding damage of *Prostephanus* was observed. In this survey, stocks were inspected every 2 months for over 1 year in 48 farms, 21 cooperatives and 3 OPROVIA warehouses. This is significant because in each 1% of these cases, maize is stored adjacent to beans and because *Prostephanus* does not cause serious feeding damage in beans. In the laboratory (University of Minnesota) one of 5 seed types of beans (large red) exposed to *Prostephanus* (15 adults per kg.) was severely attacked in their feeding activities (Cutkomp and Subramanyam 1985 unpublished data). Although no successful reproduction was observed, the threat is clear that maize infested with *Prostephanus* and stored in or near bean stocks is a serious threat to stored beans.

1/ Traps and pheromones were donated to the project by the Tropical Development and Research Institute, Slough, England.

Also significant is the observation of several infestations of Dinoderus minutus. This species is also a bostrichid and is similar in appearance to Prostephanus. Only with magnification can it be distinguished with certainty from Prostephanus. Likewise, the damage caused by Dinoderus is not easily indistinguishable from that of Prostephanus (Figure 4). The largest infestation of Dinoderus encountered was at the seed production field station in Kigali Prefecture (Semences Selectionnees). Seeds were in the process of being removed from the cob for bagging and storage there. After storage for months, the seeds are distributed throughout Rwanda along with the Dinoderus infestation.

Rhyzopertha dominica and Sitophilus spp. were the most commonly encountered other species (Figure 5). Parasites and predators also made up a significant proportion of the total maize insects in warehouses and cooperatives.

RECOMMENDATIONS

Prostephanus has been shown by this research and reported in the literature to be a serious threat to maize, cassava and possibly stored beans. It is therefore recommended that at border crossings all goods are inspected. If maize is being carried across the border it is either not allowed entry or very carefully inspected by trained customs officers, trained, that is, by the Grain/Bean Quality Laboratory staff and advisors. Unfortunately because most new agricultural commodities probably do not cross at the border, a serious campaign should be launched to inform farmers, merchants, cooperative managers, and OPROVIA personnel what signs to look for and why this is important. About the time the first Prostephanus infestations were identified in Burundi, a national educational campaign on identification and dangers was begun. Some of the techniques and models of dissemination developed there may be adapted for use in Rwanda. The key is the urgency.

It is also recommended that an investigation be undertaken to determine the ability of Dinoderus minutus to cause loss in stored corn, cassava and beans. Damage caused by this species is indistinguishable from Prostephanus. If the high reproductivity and ability to thrive in low moisture content (equilibrium relative humidity) environments is indistinguishable from Prostephanus then the above recommendations for Prostephanus should be immediately begun for Dinoderus.

ACKNOWLEDGEMENTS

The authors particularly appreciate the field and laboratory assistance of Joel Kayumba in Rwanda and Dr. Lawrence Cutkomp and B. Subramanyam in the Department of Entomology, University of Minnesota. The traps and pheromones were graciously provided by the Tropical Development and Research Institute (TDRI), Slough, England via Dr. Richard Hodges.

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Table 1a. Geographic and organizational levels of maize supplies searched.[1]

Prefecture or other Location	Number of individual corn storages or warehouse maize stocks searched[3]						
	Government (GRENARWA) Warehouse	Cooperative (Silo or Hanger)	School Center or Government Project	Merchant with small shop	Open Market Merchant	On-farm	Total
Cyangugu	0	0	0	3	0	3	6
Kigali	1	0	7	2	0	0	10
Gitarama	0	0	0	0	0	0	0
Kibungo	0	0	3	1	0	1	5
Byumba	0	0	3	3	3	3	10
Ruhengeri	0	0	0	0	0	2	2
Gisenyi	0	0	0	5	0	0	5
Zaire (Goma and Bukavu)	0	0	0	1	1	0	2
Total	1	0	13	15	4	9	42

1 10 April - 4 May 1985

2 e.g. belonging to projects such as DERVAM, OVAPAM, ISAR, SSS (Service des Semences Selectionnes) OPROVIA outlet. These are usually small stocks in bulk or bag.

3 = actual lots of corn searched summed over time (some storages were visited 3 times during the sample period).

Table 1b. Geographic and organizational levels of maize supplies searched.[1]

Prefecture or other Location	Number of individual corn storages or warehouse maize stocks searched[3]: Government (GRENARWA) Warehouse	Cooperative (Silo or Hanger)	School Center or Government Project	Merchant with small shop	Open Market Merchant	On-farm	Total
Cyangugu	0	1	4	0	2	1	8
Kigali	0	0	4	1	0	1	6
Gitarama	0	0	0	0	0	0	0
Butare	0	0	7	0	0	0	7
Kibungo	0	0	1	0	0	0	1
Byumba	0	0	1	2	0	0	3
Ruhengeri	0	0	0	4	0	1	5
Gisenyi	0	1	0	2	0	0	3
Kibuye	0	0	2	0	0	0	2
Zaire (Goma and Bukavu)	0	0	0	0	0	0	0
Total	0	2	19	9	2	3	35

1 October 1985 - August 1986

2 e.g. belonging to projects such as DERVAM, OVAPAM, ISAR, SSS (Service des Semences Selectionnes) OPROVIA outlet. There are usually small stocks in bulk or bag.

3 = actual lots of corn searched summed over time (some storages were visited 3 times during the sample period).

Markets Visited in *P. truncatus* Survey

Prefecture	Name of Market	Date
Byumba	Rukomo	April 16, 1985
	Gatsibo	May 1, 1985
Gitarama	Ruhango	April 19, 1985
Gisenyi	Kanama	May 2, 1985

Figure 1. Areas of countries neighboring Rwanda in which populations of the larger grain borer, Prostephanus truncatus Horn have been identified.

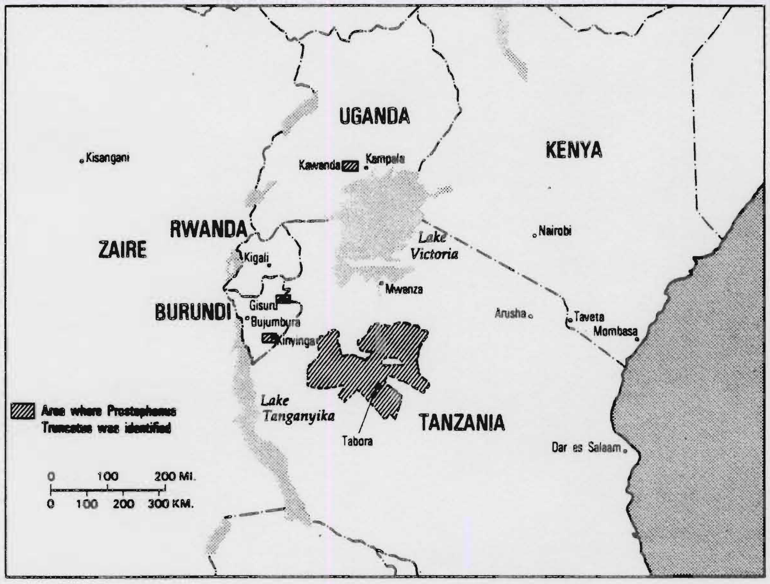


Figure 2. Areas of Rwanda investigated for Prostephanus truncatus Horn in maize stocks and the relation of major maize production areas to major border crossing and customs officers interviewed.

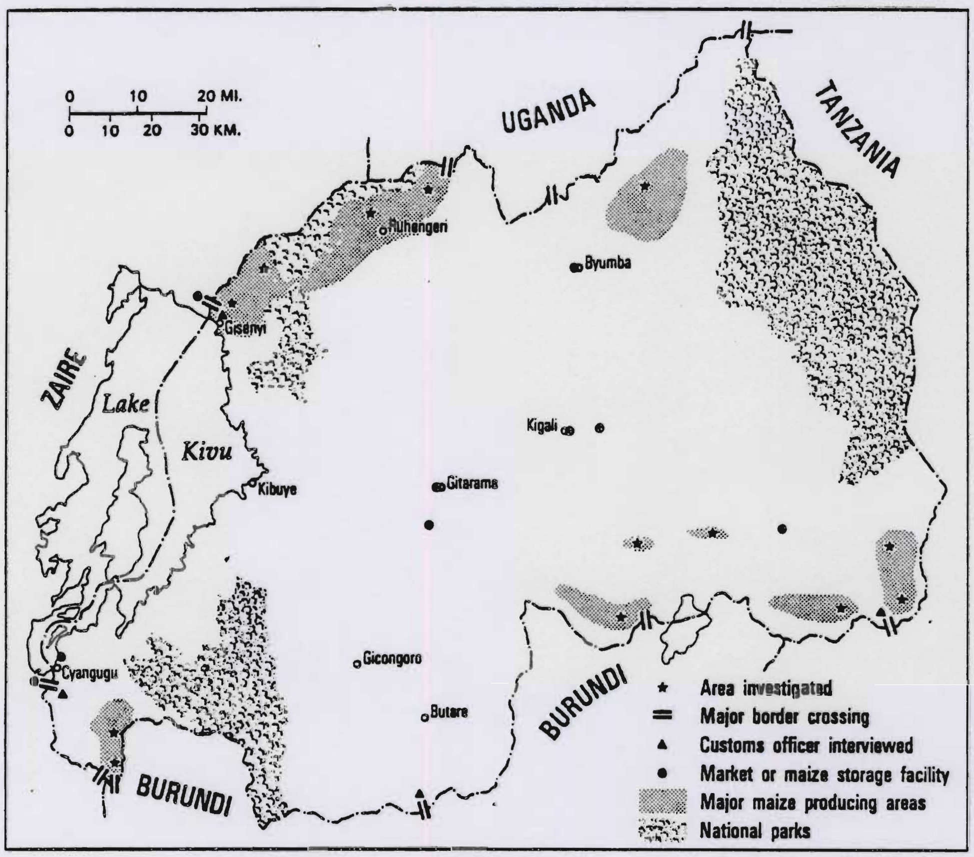


Figure 3. Trellis storage of maize in sheath (on farm) near DERVAM Project, Mutara area Byumba Prefecture, Rwanda.

Figure 4. Comparison of feeding damage in maize by Dinoderus minutus (photo on left) and Prostephanus truncatus Horn (photo on right).

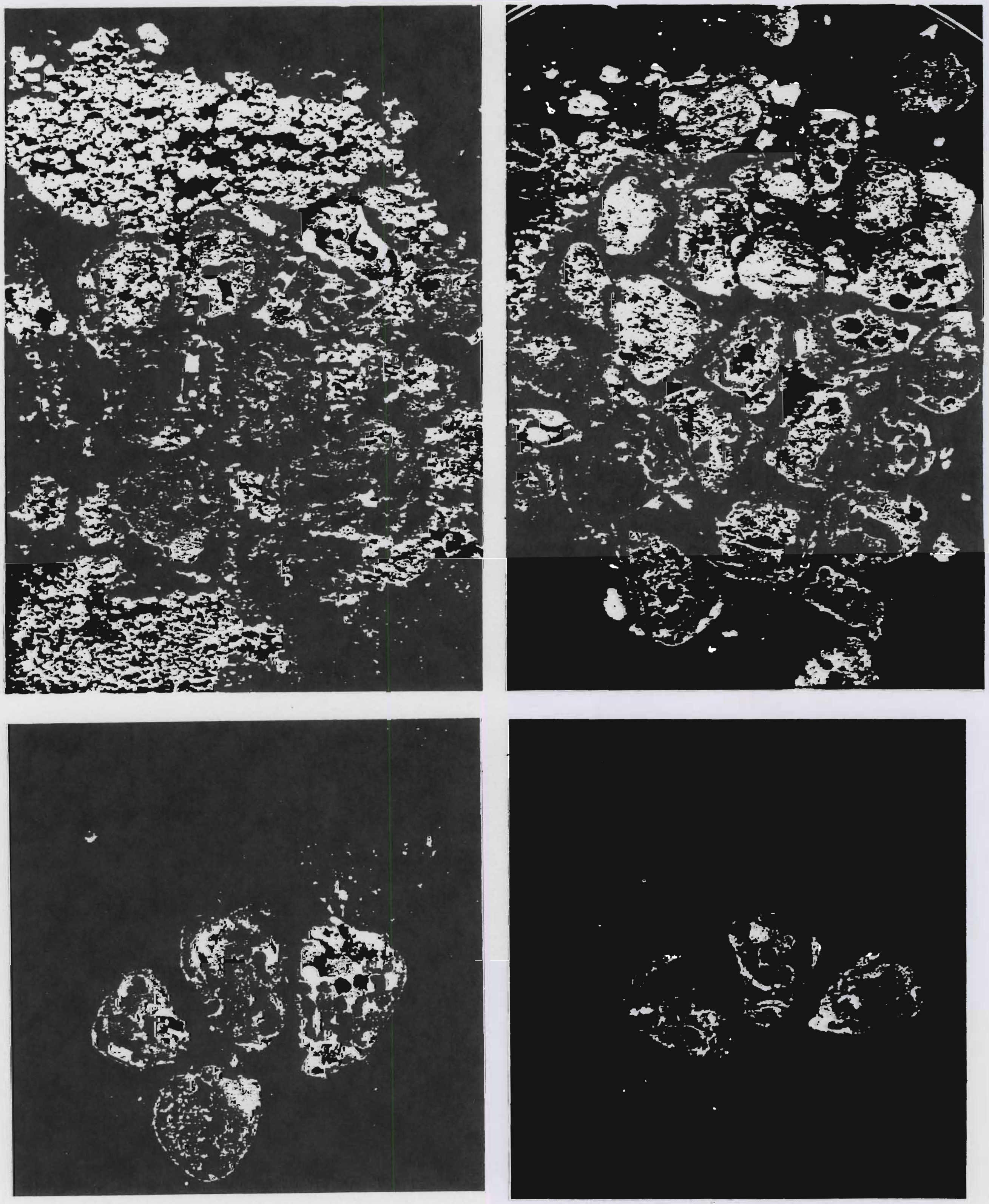
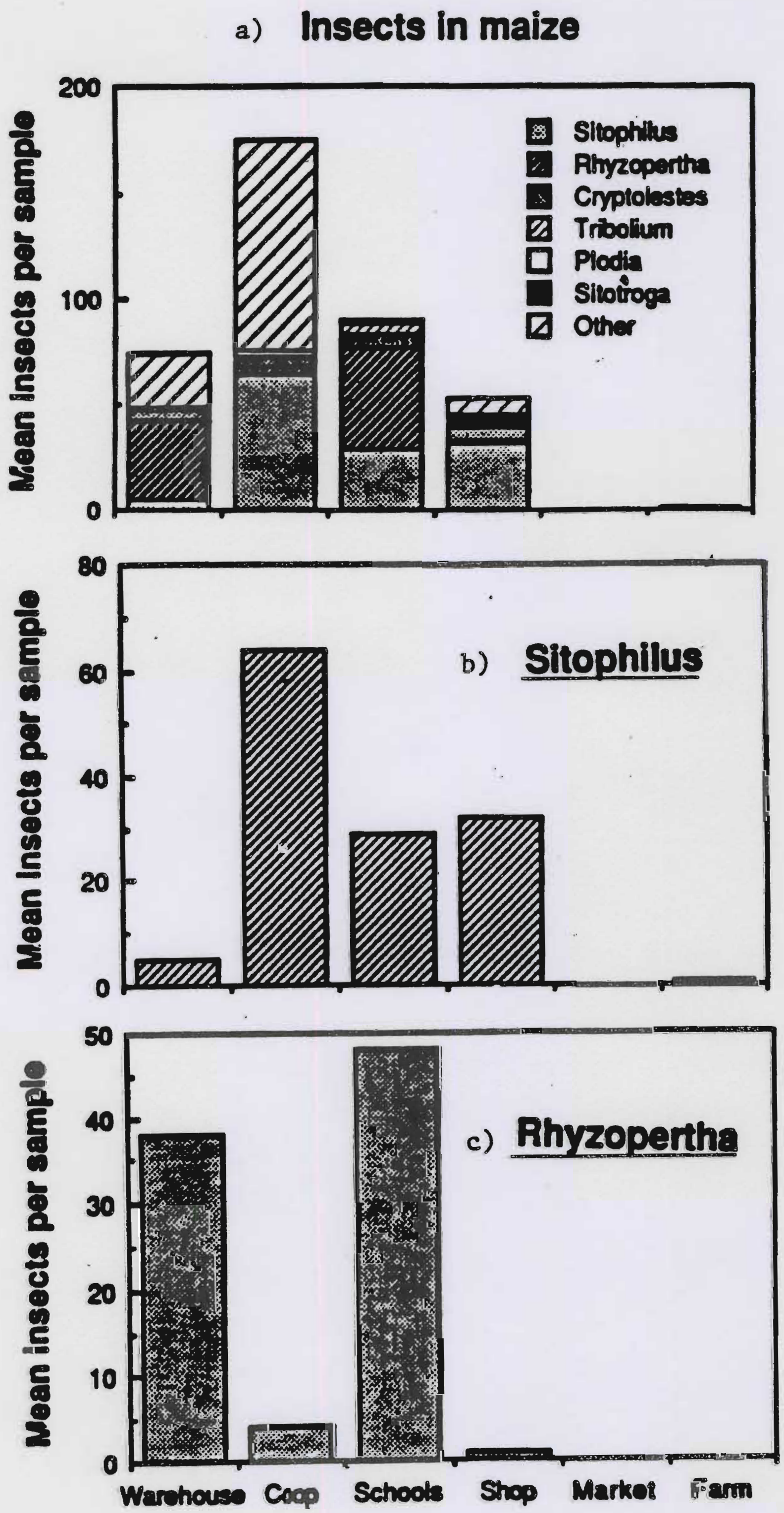


Figure 5. Graphic summary of insects obtained in maize from various organizational levels of storage in Rwanda. a) Total mean insects per composite sample; b) Sitophilus spp.; and c) Rhyzopertha dominica (F.).



APPENDIX F: Effect of Variety and Percent Damage on Test Weight Analysis of Rwandan Beans.

N.R. Read
July 1984

Abstract

An experiment was conducted to determine the influence of bean variety and % damage on test weight. Four varieties of different shapes were used: Ikinimba (round, oval), Kicaro (round, flat), Tostado (long, oval) and Rubona (long, flat). Test weight and moisture content were measured 4 times on each variety. Damaged beans were removed and test weight was again run 4 times. Results showed that test weight was constant within variety, but large differences were apparent between varieties that could not be accounted for by moisture or damage differences. Thus for a given variety test weight reduction is a reasonable predictor of % damage by weight, but in a mixture of varieties the difference due to mixed bean shapes may be greater than the difference due to damage.

Introduction

Test weight is a measure of the weight of a specific volume of a commodity, such as the weight of a level quart. This volumetric weight is influenced by moisture content, insect damage, and the size, shape, and density of the individual grains. In a given variety of beans, for example, it is expected that test weight will decrease as insect damage increases. However, in a mixture of several varieties, the effect of the size shape of the beans may affect test weight. This experiment was designed to test the influence of varietal size and shape on test weight, and to compare that with the influence of insect damage.

Materials and Methods

Four varieties of Rwandan beans were chosen representing the four major shapes of beans (round, oval, round flat, elongated oval, elongated flat). Samples of these four varieties were obtained from ISAR and used for the analysis. Test weights were measured using a standard funnel and one quart measure ("Winchester bushel"). Each sample was tested and the moisture content measured using Motomco moisture meter. The sample was then remixed and the process repeated for a total of four replicates. Following this, each sample was examined and the damaged beans (any damage type) were weighed and removed. Test weight was again run four times on the damage-free samples.

Results

The results are given in Table 1. It appears from these data that test weight is fairly consistent within each variety, but there was a fairly large difference between the varieties. Several statistical analyses were run to test these differences.

First, the effect of variety (shape) alone in the samples without damage is given in Table 2. The high F-value for this ANOVA shows that the variation between the varieties is much greater than the variation within each variety.

The variability in moisture content, however, was not very high in each variety and a significant difference between varieties was detected (Table 3). However, this difference did not seem to affect test weight.

The effect of each component of shape (r or l, o or p) was evaluated separately using a 2-way ANOVA on the means (Table 4). While the results were not statistically significant, a trend is clearly visible with l lower than r and o lower than p. This would be expected given the packing characteristics of these shapes.

The effect of damage was evaluated three ways. Table 5 shows an overall ANOVA of test weight without damage vs. test weight with damage combining data from all four varieties. The variability within each group (mostly due to the varieties) was much greater than the variability between the groups due to damage. Table 6 shows the effect of damage within each variety. For two of the four varieties damage had a significant effect. In these varieties the principle damage types were dented and shriveled (variation 1) and insects (variation 2). For the other two varieties damage did not have a significant effect on test weight (i.e., the variability within the variety was high in comparison with the difference due to damage). In these varieties the principle damage types were discolored and minced (shriveled and small) (3) and wrinkled (4). Both of these varieties had some insect damage as well.

When test weight reduction due to damage was compared with the % damage by weight for all the varieties, a linear relationship was found (Table 7). In other words, for samples containing a single variety, test weight reduction (TW without damage - TW with damage) is a good predictor of % damage by weight.

Discussion and Conclusions

This experiment has shown that varietal differences in beans may have a greater effect on test weight than does the % damage. Within a given variety, the effect of % damage on test weight may depend in part on the type of damage, with dents and insects having more effect than discoloration or wrinkles. Thus, within a variety, weight loss can be evaluated using test weight, but given a mixture of varieties the variability due to variety will mask this effect. The effect of varietal mix will be minimized if repeated samples from the same stock are evaluated over time. However, variation in varietal mix over time should be closely monitored. Other measures of weight loss should be compared to reduction in test weight before any conclusions are drawn.

Table 1: Test Weight and % moisture content in 4 varieties of Rwandan beans, with and without damaged beans.

Shape (Type)	Variety (Variete)	Test Weight w/o Damage (Poids volumetrique sans degats)				Test Weight with Damage (Poids volumetrique avec degats)				Motomco Reading (Lecture Motomco)			
1) ro	Ikinimba	815.0	810.7	816.4	807.1	806.7	804.0	803.6	802.5	18.5	20.0	19.5	18.5
2) rp	Kicaro	830.5	828.0	825.4	824.7	808.4	812.2	808.8	809.8	21.0	20.0	20.0	20.0
3) lo	Tostado	774.1	755.7	762.0	757.4	751.7	759.3	750.4	756.2	20.0	20.0	19.5	19.5
4) lp	Rubona	794.6	786.3	804.0	790.5	780.3	774.9	798.0	786.1	21.5	22.5	22.0	22.0

Table 2: Effect of variety on test weight of undamaged Rwandan beans (Analysis of variance by variety).

	SS	df	MS	F	
Trt	9370.74	3	3123.58	82.67	$p < .01$
Error	453.42	12	37.79		
Total:	9824.16	15			

Means:
1) 812.3 (4.23)
2) 827.15 (2.65)
3) 762.3 (8.30)
4) 793.85 (7.57)

Table 3: Relationship between moisture content and variety in Rwandan bean samples (damaged beans included).

Analysis of Variance:

	SS	df	MS	F	
Trt	18.3	3.0	6.10	22.96	$p < .01$
Error	3.19	12.0	0.27		
Total:	21.48	15.0			

Means:
1) 19.13 (0.75)
2) 20.25 (0.50)
3) 19.75 (0.29)
4) 22.00 (0.41)

Table 4: Effect of shape on test weight of undamaged Rwandan beans.

2 way Analysis of Variance:

	O	P
r	812.3	827.15
l	762.3	793.85

	SS	df	F	
Row	1734.72	1	24.88	NS
Column	538.24	1	7.72	NS
Error	69.72	1		
Total	2342.69			

Table 5: Effect of damage on test weight of Rwandan beans (data from all varieties pooled, damage vs. no damage).

Analysis of Variance:

	SS	df	MS	F	
Trt	908.44	1	908.44	1.54	NS
Error	17656.68	30	588.56		
Total:	18565.12	31			

Means: Without 798.9
With 788.0

Table 6: Effect of damage on test weight of Rwandan beans, separated by variety.

	Without Damage Mean + SD	With Damage Mean + SD	Pooled SE*1	t, p*2
1)	812.3 (4.23)	803.95 (1.33)	2.217	3.766, --
2)	827.15 (8.30)	809.80 (1.70)	1.574	11.02, --
3)	762.3 (8.30)	754.40 (4.10)	4.629	1.707, --
4)	793.85 (7.57)	783.83 (9.90)	6.23	1.608, --

*1 pooled SE = $\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}$

*2 $\frac{\text{mean (without)} - \text{mean (within)}}{\text{pooled SE}} = t_{(n-1df)}$ (n=# replicates per mean)

Table 7: Relationship of Test Weight Reduction to % Damage in 4 Rwandan bean varieties.

Ho: The amount of test weight reduction in each variety of beans is linearly related to the % damage by weight.

Average Test Weight Reduction		% Damage by Weight
lo	7.90	4.35
ro	8.35	4.08
lp	9.02	5.86
rp	17.35	8.91

slope = 0.74
int = 0.475
corr = 0.97

slope = 0.4749	SE (slope) = 0.0962	t = 4.936	2df	p 0.05
intercept = 0.7376	SE (int) = 1.09	t = 0.676	2df	NS

APPENDIX G:

RWANDAN CONSUMER STANDARDS FOR DRY BEANS: RESULTS OF A DAMAGE PERCEPTION SURVEY.

Nancy R. Read

Edouard Nizeyemana

Introduction

Damage can be estimated for scientific purposes by describing abnormal beans and categorizing them. This scientific estimate describes as damaged many beans which are still viable for seed and food. For commercial purposes however, the most appropriate measure of damage is the proportion of beans which are unacceptable for use, either for seed or for food. The Damage Perception Survey was designed to evaluate consumer's concepts of which beans are acceptable and which are unacceptable for planting in their fields or for eating. The study compares scientific descriptions of damage with actual loss to consumers.

Materials and Methods

Standardized samples were made consisting of 100 beans of known varieties and known numbers of each damage category. Each sample included 10 different types of damage in different degrees of severity as well as sound beans of the same varieties (Table 1). The samples were kept frozen in the laboratory when not in use to retard changes in quality. The beans used were of the most recent harvest. The survey was carried out in the farms in July, 1985, which is 3 to 4 weeks after the minor bean harvest and during the sorghum harvest.

Three sectors were surveyed using families who had participated in the ongoing Bean and Sorghum Storage Survey and/or the National Agricultural Survey. The three communes observed were Rubavu (sector Rugerero) (high altitude-Gisenyi Prefecture), Gishamvu (sector Liba) (middle altitude Butare Prefecture), and Rukira (sector Murama) (low altitude Kibungo Prefecture). The identified farms all cultivated beans. At each farm the person responsible for triage was identified. In all cases the respondent was female. In other portions of the storage survey it was determined that in 94% of the farms surveyed it was the responsibility of the female adult to conduct the triage of beans to be used for eating or planting.

The 200 beans (including those with visible damage) were presented to the respondent on a circular metal tray (30 cm in diameter) while she was seated beside the interviewer in her farmyard outside the house. The respondent was then requested to sort through the sample and identify which individual beans she would not plant. Then the beans were recombined and the respondent was asked again to choose which beans she would not eat. Once these processes were completed the surveyor asked questions regarding the separation procedures she generally uses for beans. Respondents were also asked to rate the perceived severity of each of the 10 types of damage. The number 1 was assigned to damage perceived as serious; number 2 to damage perceived as moderately important and number 3 to insignificant. The survey was always performed out-of-doors to take advantage of natural light. Additional observations were made such as which damaged beans were chosen in the not plantable or not edible categories. The survey form used is shown in Figure 1.

Results and Discussion

Sixteen farmers in 3 altitudinal regions participated in the survey. One part of the Damage Perception Survey requested the farmer rank each of the 10 damage categories by severity (Table 2).

Interpretation of Severity of various types of damage perceived by Rwandan farmers:

1. Sixteen farmers in 3 altitudinal areas participated in the survey.

2. Part of the Damage Perception Survey was to rank each of the 10 damage categories by severity, (1) serious (2) somewhat serious and (3) unimportant. Therefore a combined rank total for the farmers would look like 16 for very serious and 48 for not important. None of the 10 categories were considered insignificant by all farmers.

   Visible mold was perceived as a very serious category. All farmers surveyed ranked this as serious. Next most serious were rodent and insect damage categories. Both of these received a rank of 19. All farmers felt these were important. Germinated beans were next most serious with a collective rank of 22. Broken and discolored and shriveled categories were perceived by the farmers as important but not serious.

   Wrinkled and Dented were given collective ranks of 35 and 38 respectively and would, therefore, be considered between slightly serious and insignificant. Torn seed coat was perceived as least important by all farmers combined for a total rank of 41. By 'severity', it was not indicated whether the former respondent considered them not plantable or inedible.

3. It is not yet known if discolored, wrinkled, shriveled, and dented are perceived by the farmers to be related to cooking and sensory qualities. In so far as persons and economic loss, the farmers picked these categories easily and ranked them i.e. visible mold, rodent and insect damage, then germination in order of severity.

4. The individual farmers varied between 15 and 20 with a mean of 17.7 in total perceived severity of damage in beans presented.

Figure 2 shows the mean % of damaged beans selected as not edible by the Rwandan consumers surveyed. Most of the beans with visible mold or insect holes were considered too damaged to eat, as were over half of the rodent damaged or germinated beans. Some of the broken, shriveled or discolored beans were also considered too damaged to eat. Wrinkled or dented beans or beans with a torn seed coat were very seldom considered inedible.

Figure 3 shows the mean % of damaged beans selected by the consumers as not plantable. Most or all of the beans with visible mold, insect holes, rodent damage, or germinated were rejected for planting. Most of the shriveled, broken or discolored beans were also rejected. Some beans with torn seed coat or dented or wrinkled beans were also set-aside as too damaged to plant.

The standards for plantability were much more stringent than the standards for edibility, as would be expected. Significantly, at the .05 level, more beans were rejected in every category except visible mold, which was high for both (Table 2).

The standards for edibility were similar in all 3 prefectures surveyed for almost every damage category. (The one exception was a lower rejection rate of germinated beans in Butare prefecture, Table 3). This uniformity of standards is important to the development of a commercial bean grading system that includes a measure of % edible beans. The standards for plantability were not as uniform, with consumers in Kibungo prefecture rejecting significantly (at the .05 level) fewer beans in many categories than did consumers from Butare or Gisengi prefectures (Table 4). This could be a regional preference or could be due to current conditions in the prefecture or in the households sampled.

When asked about the different types of damage, consumers surveyed ranked visible mold, insect holes or rodent damage as serious damage (Table 5). Germination was also often ranked as serious, although not as consistently as the first 3. The other damage types were rated moderately important or unimportant, with responses varying considerably among consumers. By 'severity' it was not indicated when the respondent considered them not plantable or not edible.

Table 1. Damage categories and % frequency in standard mixture presented to farmers.

Damage Type[1/]	(French equiv.) & abbreviation)	No. of Beans	% Frequency
Insect	(Insecte, in)	12	6
Visible Mold	(Moissisure Visible, mv)	6	3
Rodent	(Rongeur, rgr)	4	2
Wrinkled	(Froisse, fr)	9	4.5
Shriveled & Small	(Mince, mc)	9	4.5
Discolored	(Decolore, dc)	9	4.5
Torn Seed Coat	(Dechire, de)	6	3
Germinated	(Germe, ge)	6	3
Broken	(Casse, cs)	6	3
Dented	(Creux, cr)	6	3
Total Damaged		73	36.5
Undamaged		127	64.5
Total Presented		200	

1/ Objective analysis of type of damage only. Not a measure of degree or severity of damage.

Table 2. Comparison of "not edible" and "not plantable" categories of Rwandan beans by damage type.

Damage Type	Actual # of damaged beans in sample	Classified not edible by producers	Classified not edible by lab staff	Classified not plant-able by producers	Classified not plant-able by lab staff
Insect	12.0	9.3a	12.0	10.9*b	12.0
Visible Mold	6.0	5.0a	6.0	5.6a	6.0
Rodent	4.0	2.4a	4.0	3.9*b	4.0
Wrinkled	9.0	0.2a	0.0	1.7*b	0.0
Shriveled & Small	14.0	2.6a	6.0	5.8*b	14.0
Discolored	9.0	1.3a	3.0	5.8*b	3.0
Torn Seed Coat	6.0	0.1a	0.0	2.6*b	0.0
Germinated	6.0	3.4a	6.0	5.4*b	6.0
Broken	6.0	1.5a	0.0	4.8*b	6.0
Dented	6.0	0.1a	0.0	1.6*b	0.0
Total	78.0	25.9	37.0	50.0	51.0
%	39.0	13.0	18.5	25.0	25.5

1. Comparison shows significant difference for specified damage type at the 0.05 level of probability.

2. Objective analysis of type of damage only. Not a measure of degree of severity of damage.

3. Based on evaluation of a standard 200 bean sample by 16 women producers in July 1985, within 2 months after harvest.

Table 3. Comparison of standards by prefecture for bean edibility in Rwanda[1/].

Damage[2/] Type	Number of beans Beans Perceived Inedible[3/]: Kibungo Colline Rukira Section Murama	Butare Colline Gishamvu Section Giba	Gisenyi Colline Rubavu Section Rugerero	Total number of damaged beans by category[4/]
Insect	10.0	9.7	8.2	12
Visible Mold	5.5	4.3	5.2	6
Rodent	3.0	2.2	2.2	4
Wrinkled	0.0	0.2	0.3	9
Shriveled & Small	2.2	1.3	4.3	14
Discolored	2.2	0.8	1.0	9
Torn Seed Coat	0.0	0.2	0.0	6
Germinated	4.8a	1.8b	3.7ab	6
Broken	1.3	1.3	1.8	6
Dented	0.2	0.0	0.0	6
Total	29.2	21.8	26.7	78
%	14.6	10.9	13.3	39

1/ These evaluations were made by 16 women producers in July 1985, within 1-2 months after harvest.

2/ Objective analysis of type of damage only. Not a measure of degree or severity of damage.

3/ Numbers followed by the same letter or no letter not significantly different (p less than .05, ANOVA, a priori contrasts).

4/ Number of damaged grains in the sample of 200 beans that are presented to the producers/preparators.

Table 4. Comparison of standards by prefecture for bean plantability in Rwanda[1/].

Damage Type[2/]	Number of beans Beans Perceived Not Plantable[3/] Kibungo Colline Rukira Section Murama	Butare Colline Gishamvu Section Giba	Gisenyi Colline Rubavu Section Rugerero	Total number of damaged beans by category[4/]
Insect	10.1a	11.0a	11.5a	12
Visible Mold	5.5a	5.3a	5.8a	6
Rodent	3.7a	4.0a	4.2a	4
Wrinkled	0.0a	2.8b	2.2b	9
Shriveled & Small	3.3a	9.7b	10.2b	14
Discolored	3.2a	7.5b	6.8b	9
Torn Seed Coat	0.0a	4.0b	3.8b	6
Germinated	5.2a	5.5a	5.7a	6
Broken	4.5a	5.5a	4.5a	6
Dented	0.3a	2.3a	2.0a	6
Total	35.8a	57.6b	56.7b	78
%	17.9	28.8	28.4	39

1/ These evaluations were made by 16 women producers in July 1985, within 1-2 months after harvest.

2/ Objective analysis of type of damage only. Not a measure of degree or severity of damage.

3/ Numbers followed by the same letter not significantly different (p less than .05, ANOVA a priori contrasts).

Table 5. Severity rating[1/] of various types of postharvest bean damage as perceived by Rwandan farmers in 3 Prefectures within 1-2 months following harvest.

	Damage Type										
Location	Insect Damaged	Rodent Damaged	Visible Mold	Torn Seed Coat	Germinated	Broken	Discolored	Wrinkled	Dented	Shriveled	Total
Kibungo Prefecture (n=5)	1.2	1.0	1.0	3.0	1.2	2.0	2.2	2.2	2.8	2.0	18.6
Gisenyi Prefecture (n=6)	1.2	1.2	1.0	2.5	1.3	2.0	2.0	2.2	2.2	1.7	17.3
Butare Prefecture (n=5)	1.2	1.4	1.0	2.2	1.6	1.8	1.6	2.6	2.2	2.0	17.6
Grand Mean	1.2	1.2	1.0	2.6	1.4	1.9	1.9	2.3	2.4	1.9	17.8

1/ 1 = serious damage, 2 = moderately important damage, 3 = not important damage.

Figure 1. Survey instrument used to determine perception of various types of damage in stored beans and severity of the damage.

Perception of Damage of Stored Beans by Rwandan Farmers

I. Name ______________________________
Cell ___________ Sector ________________ Commune _____________
Prefecture _______________________
Code Number ______________________
Date ______________________________

II. Separation Procedures used by farmer for threshed beans: (circle 1 or more)
- Sieving
- Winnowing
- Triage

III. Triage criterion (in general) ____________________________________
____
____
____

Number of Steps or Procedures ____________

Triage by winnowing ____
____
____

Triage for seed ____
____
____

Triage for cooking ____
____
____

IV. Type of Damage	Number	Explanation
1. Don't Plant	________	
2. Don't Eat	________	

V. Observations

____
____
____
____
____
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Figure 2. Percent of damaged beans selected by Rwandan farmers or household preparators as not edible (± 95% confidence interval).

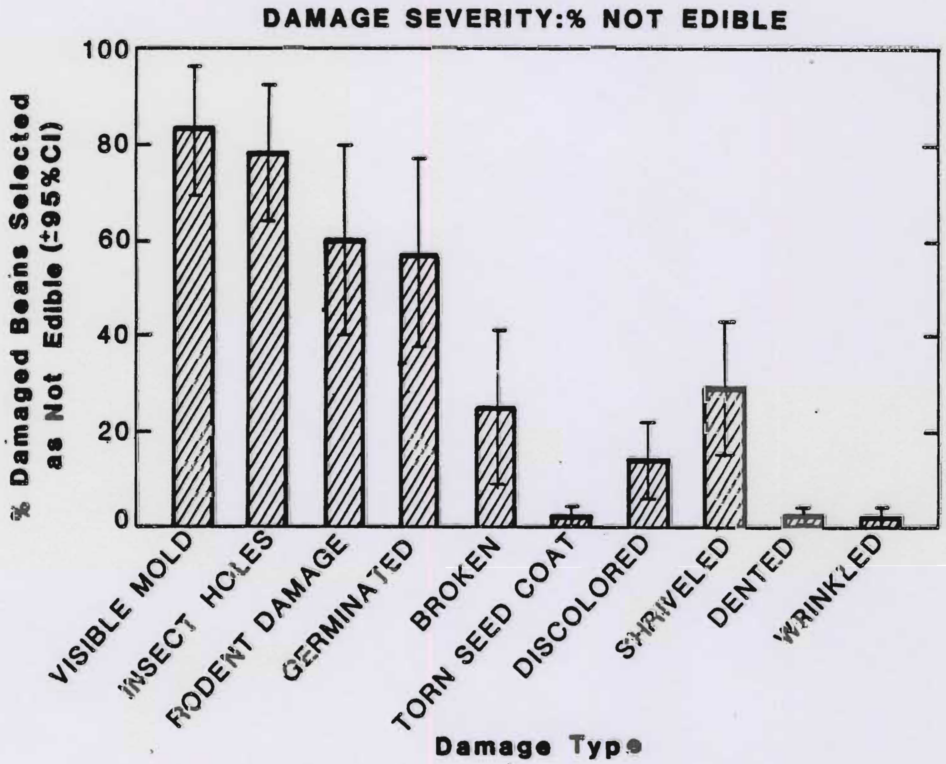

Figure 3. Percent of damaged beans selected by Rwandan farmers or household preparators as not plantable (± 95% confidence interval).