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INVESTIGATION OF PLASTIC LINERS FOR INDIGENEOUS UNDERGROUND GRAIN STORAGE STRUCTURES

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A.I.D. Grant Project Officer **Mr. Frank Martens**

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Executive Summary

The project aimed at contributing to the reduction of post harvest losses of staple foods such as grains in underground storgae units that are used in various countries of Africa, Asia and America. Underground grain storage system represents an appropriate alternative storage technique particularly for developing countries but may suffer from underground water contamination and may lead to relatively high grain loss figures if adequate interior lining is not used.

The project consisted in carrying out a comparative, exhaustive field and laboratory evaluation of the performances of underground storage of durum wheat using two types of interior lining. The two linings considered are: water proof plastic lining, a proposed solution to be tested as an alternative improving material and straw lining, a commonly used lining. High figures of grain loss are particularly caused by inefficiency of straw lining. A multidisciplinary team of faculty members from IAV Hassan II in Rabat Morocco carried out the project work with the contribution of american researchers. The team assessed the quantitative and qualitative losses encountered in wheat stored underground using two types of lining over a period of 16.5 months. Evaluation of grain physical characteristics changes and various damage evolution were done through sampling at three months, six months, nine months and sixteen and half months. Temperature of grain soil and air, relative humidity of intersticial air were monitored remotly and continuously using computer controled data loggers. Carbone dioxide levels were evaluated by the withdrawing of gas samples using pumps and color detector tubes. The experimental set up for this study of underground grain storage systems represents an original and complete approach. The experiment was carried out on a farm in a main grain producing area, (Chaouia)in Morocco in order to enable the farmers and extension staff to make their own evaluation of the improvement brought by the plastic and disseminate the research findings while in progress.

Plastic lining offers an hermetic, oxygen starved atmosphere which prevents grain kernels and insects from respiring.
Dry weight loss figures obtained after sixteen months of storage with straw lining and plastic lining were respectively near 20 % and 1 %. Germination capability drops to 50 % with straw lining and stays around 90 % with plastic lining after 3 months of storage which represents a period between the harvest and the biginning of the following farming season when farmers take their seeds from their stored grain. Color of grain stored in straw lined pits darkens, its odor is affected and the amount of impurities increases. Mixograph properties and degree of fat hydrolysis showed that straw lining leads to quite high increases in dough mixing time, moisture content and water activity as compared to plastic lining. The placement of plastic bags as lining material for underground pits has improved the storage conditions of wheat grain by maintaining a low incidence of

storage fungi. The use of plastic lining keeps the grain temperatures at low levels which are defavorable to insect multiplication. Straw lining is a biological material which is not waterproof, decomposes and induces temperature increases. Plastic lining causes a drastic decrease in the number of fungal spores per gram of product and leads to a reduced number of contaminated seeds. The mycotoxin analysis of samples did not show any mycotoxin production neither with plastic nor with straw lining.

This project has left several positive impacts not only in Morocco where it has been conducted but also abroad. It has helped initiating a multididisciplinary scientific research geared toward agricultural development. It enhanced collaboration of IAV Hassan II with american universities and research laboratories concerned by grain storage such as in Montana, Minnesota, Kansas. The grantee institution, IAV Hassan II has acquired a solid reputation in the field of grain storage research and loss reduction techniques using appropriate technologies, i.e. being low cost, requiring no specific skills and using local construction materials. The reserach team and IAV Hassan II have gained credit nation wide because the study that has been conducted with this PSTC grant has shown that underground storage properly lined can help compensate storage capacity shortage while keeping grain losses low. Thus, the Ministry of Agriculture of Morocco has given the Institute funding to pursue reserach on other aspects of grain and legumes storage. The team has purchased a number of laboratory equipments that are being used for research on grain storage. IAV Hassan II has equipped and developed an on campus grain storage facility for research and teaching. This facility contains underground grain storage units to test long term storage. Farmers have understood the advantages of plastic lining and the savings it can help them make. The project first provided them with plastic material and assisted them in placing it in their pits. Now they are carrying on the technic alone. AID has granted IAV Hassan II an additional small fund to develop extension. Farmers from various places of the country are taught how to use plastic lined underground pits for grain storage. Brochures prepared in three languages: english, french and arabic were prepared to be distributed. Results of this reserach were presented at various scientific and extension meetings organised in Morocco or abroad. Organisers of such meetings in Europe, Asia, Africa and America showed a great interest in this research. An international seminar on Storage Structures for grains was held in Morocco recently and provided opportunity to present the research findings. This project has helped provide the ground for IAV multidisciplinary team to launch an international course on grain storage techniques in 1992, which is being considered by sponsors such as the Association for Partly or Entirely French Speaking Universities in Canada.

I. Research Objectives

I.1 Background

In 1985, the Ministry of Agriculture and Agrarian Reform assigned the task of investigating adequate solutions to enhance grain storage capacity and reduce post harvest losses to IAV Hassan II. The Department of Agricultural Engineering of IAV was then appointed to coordinate and lead an interdisciplinary research and development work.

In Morocco, the total grain storage capacity is unsufficient. This shortage becomes very noticeable in years of good harvest. Available capacity represents approximately two thirds of the required one. On the other hand, grain storage technics used particularly for on farm storage need to be improved to reduce the loss rates estimated between 10 and 20 % or more (Bartali, 1990). Given the efforts undertaken by the country to achieve self sufficiency, neither the storage capacity shortage, nor the high loss rates are to be tolerated. Increasing grain storage capacity requires both the development of appropriate on farm storage technics and the improvement of grain storage management and control.

Among the storage techniques used on farm, underground pits are very common in many areas of the country (Bartali, 1987). A total capacity of 1 million metric tons was estimated potentially available on farms. One objective of this research is to contribute to the rehabilitation of this technic which has several advantages known to the farmers: low cost, oxygen starved atmosphere, thermal insulation of the stored product. The weak point of this system however is its vulnerability with respect to underground water. Inadequate lining can lead to high loss rates that the research was proposing to rigorously assess.

Farmers use the stored grain for different purposes which include family food, cash flow, animal feed or seeds. When a deterioration in grain quality occurs due to bad storage conditions, it can affect directly or indirectly any of the previously mentioned purposes.

An experiment station on grain storage was started on the IAV campus in 1986 by the Department of Agricultural Engineering. The same Department initiated in its third cycle curriculum in agricultural engineering a collaborative teaching and research work with belgian universities. This made it possible to acquire some first temperature monitoring equipment installed on campus now.

I.2 Objectives

The main purposes of this study are:

* To conduct a comprehensive multidisciplinary evaluation of underground grain storage performances using site experiment and laboratory work.

* To analyse effect of type of underground pit liners and storage period on the quality of grain storage by monitoring physical, biological parameters either remotly or by direct sampling.

* To investigate the performance of sealed plastic bags to be used as underground pit liners as compared to conventional liners such as straw material.

* To carry out an extension activity aimed at disseminating research findings through farmers and storage specialists in Morocco and other countries.

* To present research findings in seminars and publish them in international journals.

I.3 Research Team

Research was conducted by a multidisciplinary team of scientists. This team gathered under the name GERS: Group for the Study and Research on Storage was founded by Dr. Sedrati, Director of Agronomic and Veterinary Institute in 1985. It includes the following persons and Departments from IAV Hassan II in Rabat:

Agricultural Engineering
Dr. El Houssine Bartali, coordinator
Dr. Abdelhafid Debbarh, Head
Mr. Mohamed Ben Moussa

Entomology
Dr. Khadija Bourarach

Plant Pathology
Dr. Brahim Ezzahiri

Plant Breeding
Mr. Zine El Abidine Fatemi

Food Chemistry and Biochemistry
Dr. Amar Kaanane

Food Technology
Dr. Mohamed Bakhella

Food Microbiology
Dr. Laraqui Tantaoui
Mr. Hassan Gourama

National Board for Grain and Legumes
Mr. Amine Farjane

and from the US:

University of Montana
Entomology Research Laboratory
Dr. Florence Dunkel, Head

University of Minnessota
Underground Space Center
Dr. Raymond Sterling, Director

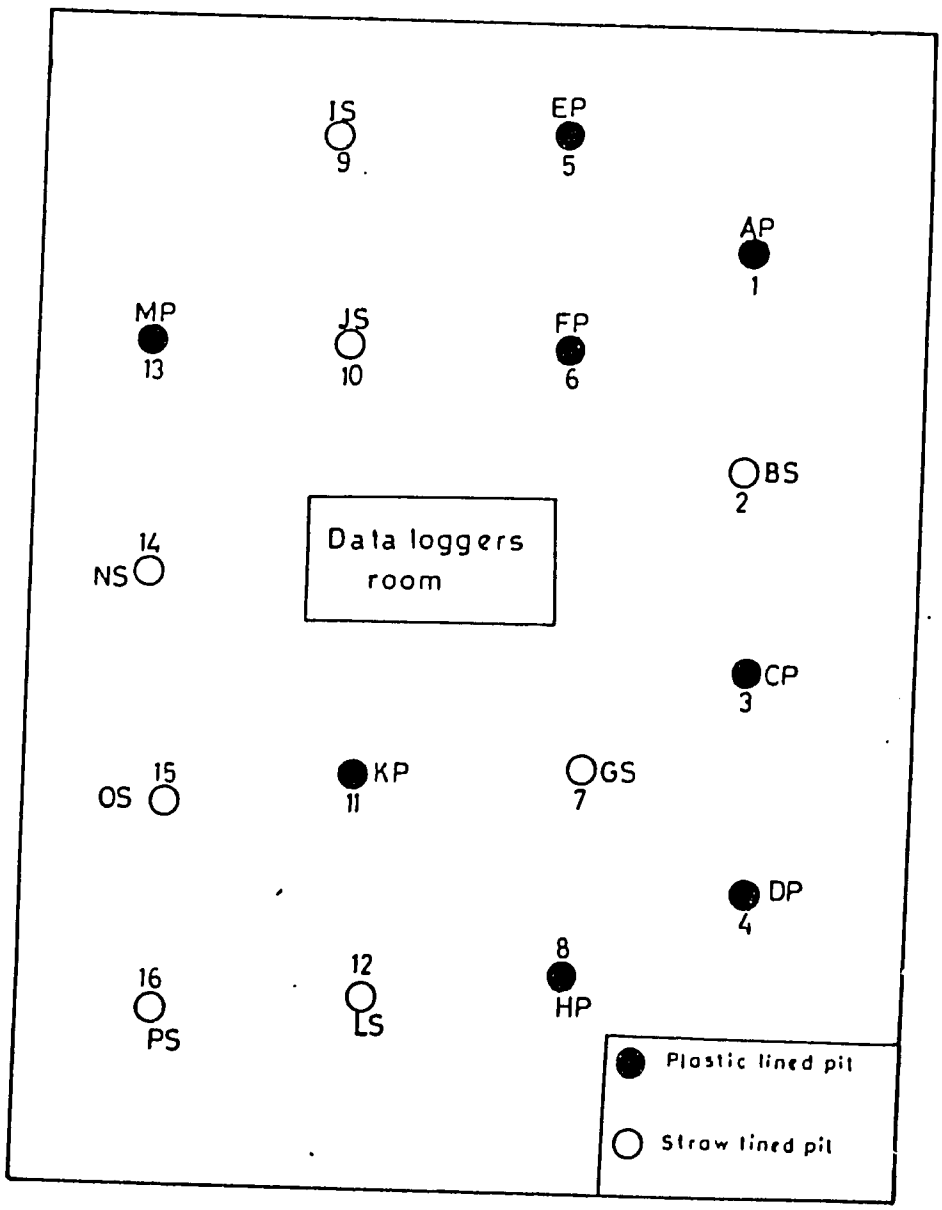
Each of the Departments of IAV intervening in this research has received appropriate equipment or chemicals needed to carry out his part of the work.

II. Methods and Results

II.1 Material and Methods

An evaluation of the underground storage technique was carried out on a farm in Settat, Chaouia, where 16 experimental pits were dug and tested over a period of 16.5 months of storage of wheat (fig. 1). Two types of liners were used plastic bags made of .18 mm thick polyethylen sheets versus 5 cm straw lining (fig. 2), (Bartali et al, 1990). Straw lining is very common and farmers assume it protects well the product stored underground. The site was selected in a major grain producing area of the country, Chaouia, where on farm underground grain storage is a well known technique. The host farm is among the ones open to support extension activity. 20 metric tons of durum wheat were introduced in the 16 experimental pits, with 1.25 mt capacity each. The effects of pit lining and storage period were investigated with regard to quality and quantity changes of durum wheat. Grain samples were taken from 4 locations in the pits: top, center, edge and bottom. Frequencies of sampling considered were: 3, 6, 9 and 16.5 months. For each sampling, two plastic lined pits and two straw lined pits were opened. Grain characteristics evaluated from the samples are: unit weight, dry weight loss, impurities, insect count and damage, fungi population, germination and seedling vigor, water activity, fat content, total acidity, mixograph properties, degree of fat hydrolysis, molds and mycotoxins (fig. 3). Temperatures of soil, air and grain were remotly measured and recorded each hour at some specific locations. These locations are the same as sampling points for eight pits (4 plastic and 4 straw lined). For eight remaining pits, temperatures were taken only at the center position. Relative humidity of intersticial air was remotly measured and recorded each hour at the center of one straw lined pit. Carbone dioxide levels were evaluated from air samples periodically withdrawn from each sampling point (fig. 4).

Fig.1: Disposition of the 16 experimental pits in Settat



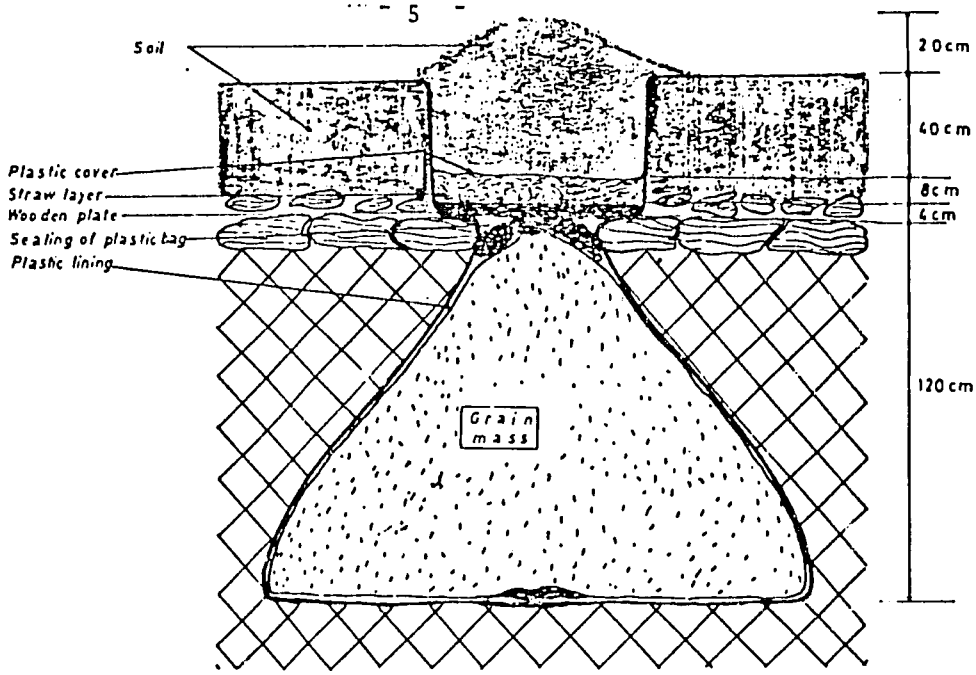


Fig.2a : Detail of plastic pit sealing.

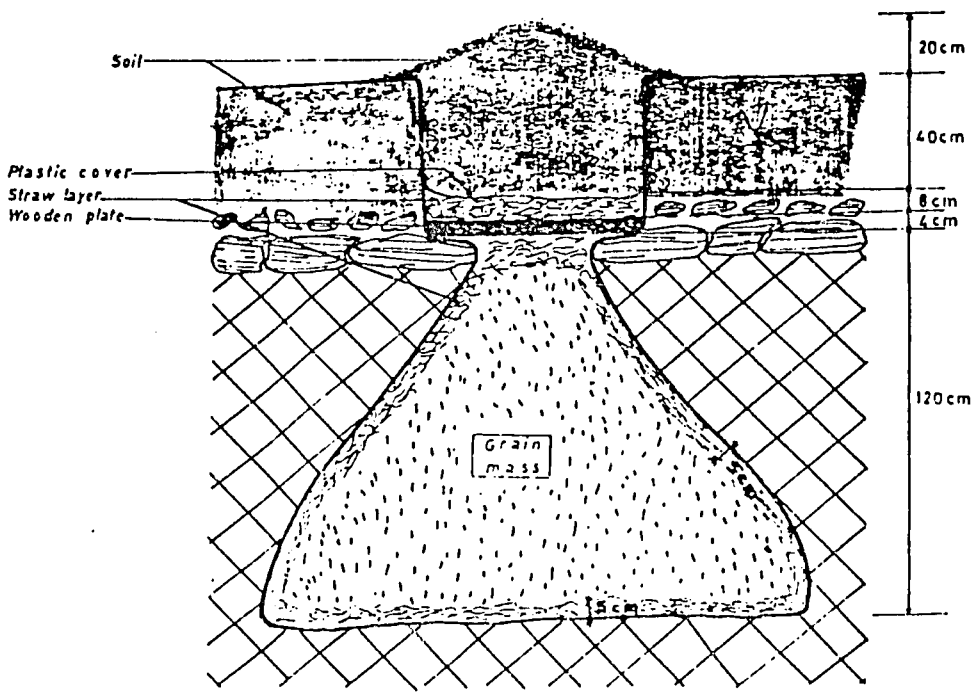


Fig.2b : Detail of straw pit sealing

Xenochept (Rendzinasoil)

Caliche (Calcareous crust)

Soft accumulation of carbonate

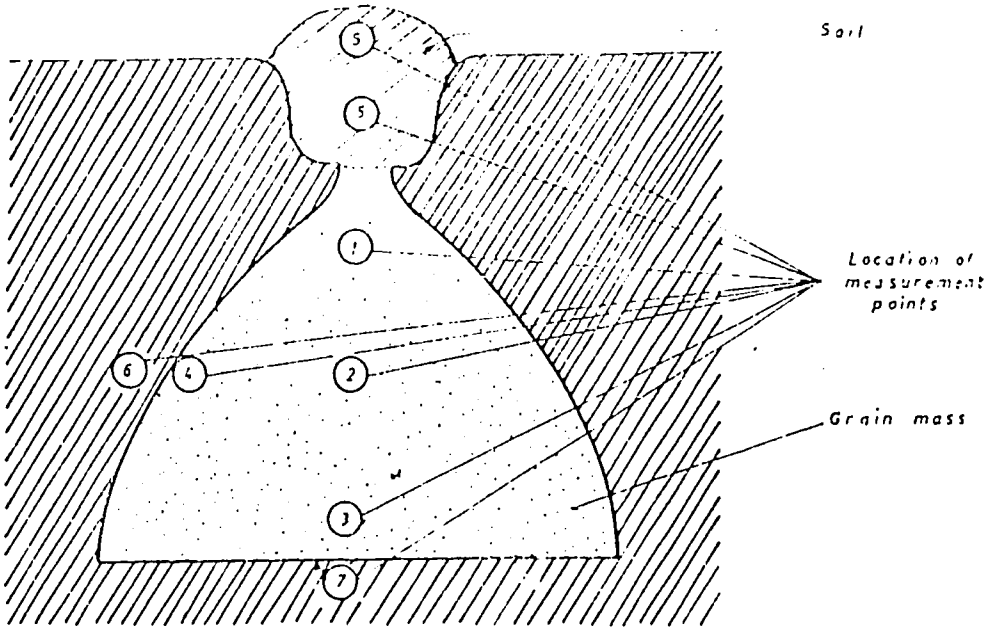
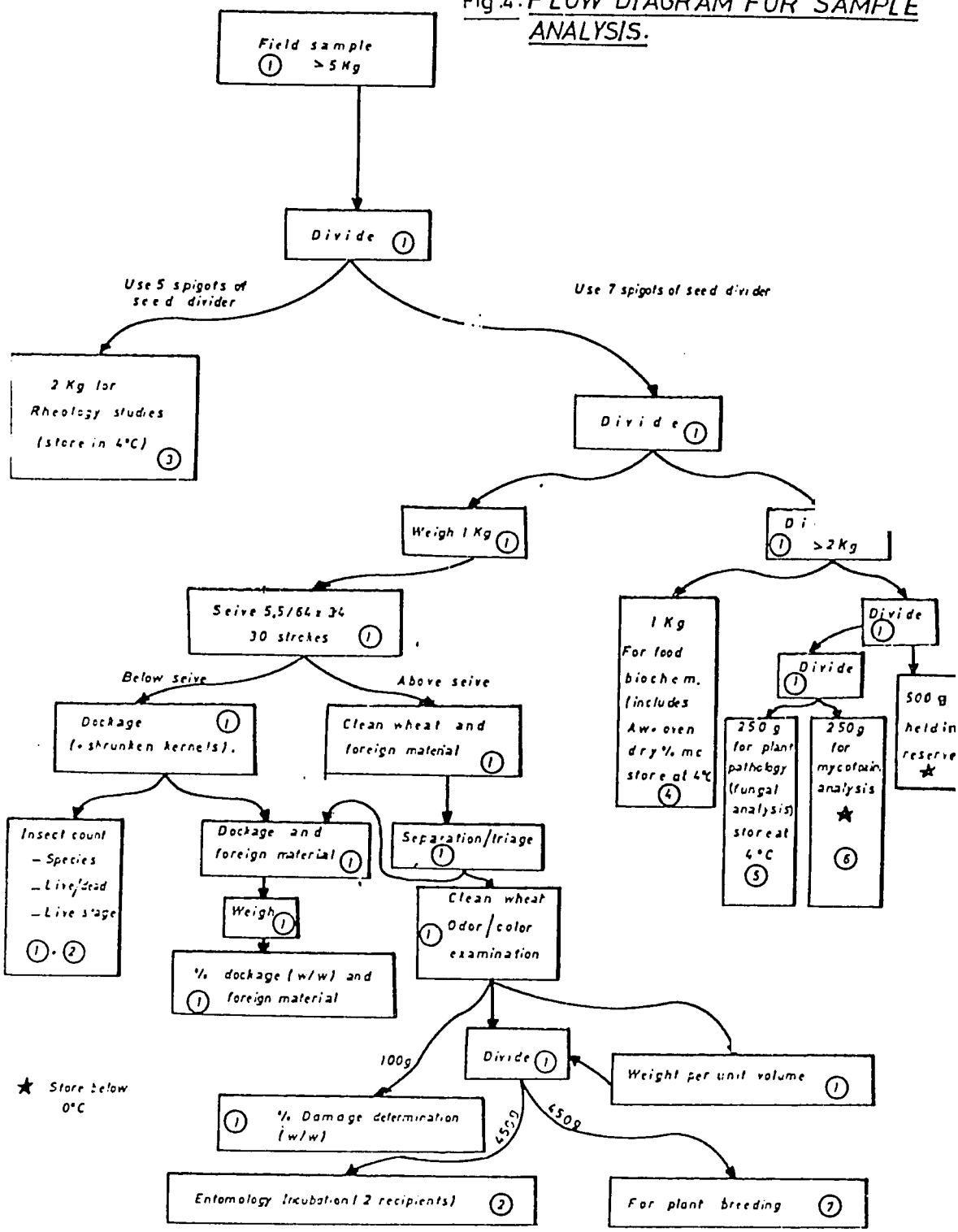


Fig 3 :POSITION OF SENSORS IN A PIT

Detail of instrumentation in the 16 pits

Pit N°	Location of thermocouples	Location of relative humidity sensor	Location of CO_2 extraction tubes
1	2		
2	1 2 3 4		1 2 3 4
3	1 2 3 4		1 2 3 4
4	2		
5	2		
6	1 2 3 4 6 7		1 2 3 4
7	1 2 3 4 6 7		1 2 3 4
8	2		
9	2 5		
10	1 2 3 4 5 6 7	2	1 2 3 4
11	1 2 3 4 5 6 7	2	1 2 3 4
12	2 5		
13	1 2 3 4		1 2 3 4
14	2		
15	1 2 3 4		1 2 3 4
16			

Fig 4. FLOW DIAGRAM FOR SAMPLE ANALYSIS.



(1) DEPARTEMENT OF AGRICULTURAL ENGINEERING.
(2) DEPARTEMENT OF ZOOLOGY.
(3) DEPARTEMENT OF CHEMISTRY AND FOOD TECHNOLOGY.
(4) DEPARTEMENT OF CHEMISTRY AND FOOD BIOCHEMISTRY.
(5) DEPARTEMENT OF PLANT PATHOLOGY.
(6) FOOD MICROBIOLOGY AND BIOTECHNOLOGY DEPARTEMENT
(7) DEPARTEMENT OF AGRONOMY AND PLANT BREEDING.

II.2 Results and Analysis

In the previous annual reports, a continuous and progressive analysis of pit environment and grain characteristics were presented. This section summarises the important results obtained over a storage period of 16.5 months.

II.2.1 Physical parameters and grain characteristics monitoring

Temperature levels reached in grain bulk were higher (a difference of about 6 C) in straw lined compared to plastic lined pits. This indicates that some biological activity (of grain kernels, insects, fungi) takes place within the straw lined pits and generates some heat. This activity is made possible due to water and air crossing of through the straw lining. Any heat generated is trapped within the grain mass because straw acts as a thermal insulator. This phenemenon was confirmed by the study of on IAV campus pits where plastic bags alone were compared to a combination of plastic bag and straw lining. Plastic lining makes good use of temperature reduction offered by soil layers between air and grain, this reduction was about 10 C in summer. In plastic lined pits, grain temperature remains constant and generally inferior to 20 C year round. With plastic lining, grain keeps within a safe zone in the temperature/moisture content diagram (Bartali and Debbarh, 1990).

Also, measurements of relative humidity of intersticial air over the entire storage period showed that this value reached 89 % in straw lined pits and 66 % in plastic lined pits. Moisture contents of grain was 18 % from straw pits and 12.5 % from plastic pits. Carbone dioxide levels reached in straw and plastic pits were respectively 20 % and 14 %. Percentage of grain damage evaluation reached were 26.5 % in straw pits and 9.3 % in plastic pits. Dry weight loss for grain stored in straw pits was nearly 20 % and around 3 % for that stored in plastic (Bartali and Tlemçani, 1989). The method used to evaluate damage consisted in differentiating between damaged zones in each pit and averaging over the pit. Grain drawn from plastic pits has kept a color and odor similar to when it was first introduced in the pits whereas a dark color and mold odor have been noticed on grain drawn from straw pits.

II.2.2 Food technology and biochemistry aspects

Mixographic properties and the degree of fat hydrolysis showed that wheat underwent some changes that became important as storage duration increased (Bakhella et al. 1990). The main effects of storage were an increase in dough mixing time and an irregular increase in fat acidity, moisture content and water activity. Variations in mold count were also noted. In general, the magnitude of these changes was quite high in straw lined pits. Correlation coefficients showed that the chemical and

rheological changes are better related in straw lined pits compared to those lined with plastic. In all the pits, regardless to pit sampling position and liner type, alpha amylase activity stayed fairly constant until nine months of storage where a gradual decrease started to occur. Results showed that the shelf life of cereals stored in plastic lined pits, where the final moisture content and total fat acidity reached only 13.8 % and 33 mg KOH/100g respectively, would be about four times higher than shelf life of cereals stored in straw lined pits where the final moisture content and total fat acidity reached respectively 18.3 % abd 156 mg KOH/100g (Kaanane, 1990). For all the parameters analysed, the sampling position did not appear to be a critical factor. Generally, the pits lined with plastic performed well compared to those lined with straw in terms of maintaining much of the initial properties of wheat (Bakhella et al., 1990).

II.2.3 Insects study

The experiment carried out showed that the use of sealed plastic bags can defintely improve the efficiency of underground storage with respect to insect infestation. Underground pits have a particular ecosystem characterized by a low temperature and a reduced air exchange. As soon as conditions become favorable, some depredators resume their development (Bourarach, 1990). Straw lining is a biological material which generates heat when it decomposes which leads to an increase in temperature and humidity and creates a favorable environment to the development of Sitophilus spp. Plastic lining, an inert material does not generate any heat and maintains relatively low temperatures and a dry medium. However this did not prevent the presence of Rhizopertha Dominica in plastic pits. Species distribution is governed by its requirements in temperature and grain humidity. In this sens, a number of researchers have shown that weevils cannot develop when grain humidity is below 14 %, even when temperatures are favorable, whereas R. Dominica is capable of developing at grain humidities less than 14 %. It has been demonstrated that this insect can multiply in grain with 9 % m.c at a temperature ranging from 26 C to 36 C. This study has shown that plastic lining does not allow any major depredator infestation. It keeps temperatures at low levels which are defavorable to depredator multiplication during nine months of storage. During summer, a slight grain temperature increase may take place but as it is combined to other factors such as humidity, carbone dicxide levels, no strong infestation is to be feared.

II.2.4 Germination aspects

The effects of plastic lining and straw lining and the impact of storage period on percentage germination and seedling vigor of durum wheat showed the following: The plastic lining seems to protect the best the germination and the seedling vigor. However beyond nine months of storage, this protection becomes unsatisfactory (Fatemi, 1990). The important point is that seed

is better stored in plastic lined pits for storage periods up to nine months, which means at least from harvest (June) to the start of the next planting season (October). After three months of storage, from an initial value of 95 % germination percentage decreased to a value between 50 and 60 % for the seed from straw lined pits and stayed between 80 and 90 % for seed from plastic pits.

II.2.5 Fungi study and mycotoxin analysis

Depending on the storage conditions, fungi, beside insects, may affect the quality of the grain, i.e. discoloration and decay, reduce germination, and produce toxins (Ezzahiri et al., 1990). Kinds and frequencies of storge fungi were studied under the two types of lining. The two types of pits differed significantly in the kind and in the amount of storage fungi. The most dominant specy found was Aspergillus glaucus. It was found at frequencies of 31 % and 50 % of the kernels from straw lined pits, after 3 and 6 months of storage respectively. Other species were also more frequent on kernels from straw than plastic pits such as A. flavus A. candidus, A. versicolor and A. fumigatus. The use of plastic sheets as lining material in underground pits has improved the storage conditions of wheat grain by maintaining a low incidence of storage fungi.
Grain samples were analysed for Aflatoxin B_1, Ochratoxin A. and Zearalenon. None of the samples was contaminated with any of the three mycotoxins (Tantaoui L., 1989).

III. Project Activities/Output

The quality of the research work undertaken under this grant can be assessed from the number of papers accepted for presentation at international scientific meetings or for publication at international journals. The list of papers is presented in the following. Some letters from organising committees are also attached.

III.1 Publications.

The following papers are published or in the process of acceptance by pier reviewed journals:

Bartali H., Dunkel F., Afif S. and Sterling R., 1990 "Performance of Plastic Lining for Storage of Barley in Traditional Underground Structures in Morocco" , Journal of Agricultural Engineering Research, vol. 47, U.K.

Bakhella M., Kaanane A. and Labuza T.P., 1990 "Effect of Underground Storage on Some Chemical and Rheological Properties of Wheat" Paper submitted for publication in the Journal of Cereal Chemistry, USA.

Bourarach K., Bartali H., Dunkel F. and Debbarh H.. 1990 "Evolution of Arthropods Population and Their Impact on Two Types of Underground Pits", Paper submitted for publication in Journal of Applied Zoology., Germany

Bartali H., 1990 "Use of underground space for grain storage", Journal of Tunneling and Underground Space Technology., U.K.

A quarterly international scientific and technical Journal "Hommes, Terre et Eaux" published in Rabat, Morocco will publish in its issue of September, 1991, four articles presented by research team members at the November 1990 international conference on grain storage.

III.2 International Seminars

The project has presented research results at the following seminars and congresses:

-International Conference on Underground and Earth Sheltered Constructions. Shangai, China, September 1 to 6th, 1988.
"Grain Storage in Underground Structures" Bartali and Afif.

-11 th International Congress of Agricultural Engineering, Dublin, Ireland, September, 4 to 8 th, 1989.
"Environment Control in Underground Storage Structures" Bartali H. and Tlemçani K.

-Séminaire International sur les Systèmes Post Récolte en Afrique. AUPELF, Abidjan, Ivory Coast, February, 1990. Seminar sponsored by AUPELF (Association of Partly or Entirely French Speaking Universities)
"Stockage des Céréales dans les Entrepôts Soutérrains" Bartali H., Invited Key note paper.

-4 th International Conference on Stored Products Protection. Bordeaux, France, September 5 to 8 th, 1990.
"Storage Structures and Equipment" Bartali, H., Invited key note paper.

-International Seminar on "Storage Structures for Grains, Legumes and their Derivatives" November, 28 to 30, 1990.

This seminar of the International Commission of Agricultural Engineering (CIGR) was organised by IAV Hassan II in collaboration with the moroccan national committee of CIGR. This seminar offered an opportunity to present a state of the art of the research on the design and management of grain storage structures. 200 participants from 15 countries attended this seminar. 80 participants came from out of Morocco. The proceedings of this seminar edited by Dr. H. Bartali, represents a consistent reference document of 660 pages and include 4 themes of which the third one deals with controlled atmosphere and

underground storage. A copy of the proceedings was sent to the Project officer in Washington. 5 papers dealing with underground grain storage research funded by AID Science Advisor grant were presented. They are:

*"Evaluation and improvment of the traditional underground grain storage technic." Bartali H. and Debbarh A.

*"The effect of pits liner type on physico-chemical characteristics of cereals during storage." Kaanane A.

*"The effect of storage in underground pits on wheat quality assessed by the mixograph test, the Hagberg test and degree of fat hydrolysis."
Bakhella M. et al.

*"The effect of underground storage with two different pits lining on wheat germination and seedling vigor" Fatemi Z.

*"Microfaune found in underground grain storage with two different interior linings." Bourarach K.

-8 th Congress of the Mediterranean Phytopathological Union
Agadir, Morocco, October 28 th - November 3 rd, 1990.
"Fungi associated to wheat stored in plastic and straw lined underground pits" by Ezzahiri B., Ibrahim A. C., Hamama H., and Guennouni Z.

-Journées d'Etude de l'Association Marocaine des Travaux en Souterrain (AMTES)-Association Internationale des Travaux en Souterrain(AITES) sur l'Utilisation de l'Espace Souterrain
Casablanca, Morocco, February 21-22nd, 1991.
The paper "Utilisation de l'Espace Souterrain pour le Stockage des Céréales" was presented by Dr. Bartali. It was related to the results of the Science Advisor funded grant. This paper was accepted for publication by the Journal Tunneling and Underground Space Technology.

-International Symposium on Stored Grain Ecosystems. Winnipeg, Manitoba, Canada, June 7 - 10, 1992.
An invitation was extended to Dr. Bartali H. by the Organising Committee to present a poster on the research accomplished on Grain Storage Structures.

Through these various seminars, approach and results of this PSTC funded research were exposed and discussed with knowledgeble persons in the field of grain storage. This has contributed to consolidating the role of IAV as one of the leading research and teaching institutions in this field.

III.3 National Seminars and Meetings

These seminars include those organised on the occasion of pit opening and sampling and on the occasion of farmers visits to experiment sites in Chaouia and IAV.
During these seminars, the project team met with farmers, technicians, students and administrators in order to present research findings and demonstrate project objectives and plastic lining procedures. The list of the seminars is as follows:

-Pit filling,December 31, 1987
-First opening, April 5, 1988
-Second opening, June 30, 1988
-Third opening, September 30, 1988
-Last opening, May 18,1989
-Demonstrations of plastic liners use, June 23, 29 and 30 th, July 7 and 8th, 1989 (34 plastic bags distributed)
-Graduate student seminar and team evaluation, November 27, 1989
-Farmers visit to IAV campus, April 1988, February 1991
-2 Seminars on the occasion of the Agricultural fair of Chaouia in June 1988 and June 1989.
-Research team meeting with Dr Sedrati, Director of IAV and founder of GERS, January 19, 1990
-Research team members seminars on agricultural engineering, plant pathology, plant breeding, entomology, food technology, food biochemistry, food microbiology for global evaluation of research, February 2, 10, 24 and March 15, 1990.

-Seminars on post harvest loss reduction organised as extension activities on grain storage in Saiss, Morocco: November 19, 1989, April 4, 1990, October 18, 1990.

IV. Impact, Relevance and Technology Transfer

IV.1 Farmers level

The findings of the project shed light on advantages and weak points of the use of underground storage system. Straw lining or any other non waterproof lining were shown to be source of major dry weight loss, about 20 %, of a drastic reduction in germination capability of seeds as well as other loss in quality and marketability of grain. All these factors are taken into account by farmers who are sensitive to possible ways to reduce the losses. A polyethylen plastic bag is an affordable item for the farmer. Cost of a plastic bag for a 1.25 metric ton capacity underground pit is about $ 12, less than 30 % of the digging cost of the same pit. This bag allows the farmer to reduce the dry weight loss of stored grain of about 20 % . The cost of 1 quintal of durum wheat grain (.1 metric ton) is approximately $ 33. This bag can be reused for two to three years. Plastic lined underground storage is suitable to on farm storage for small and medium farms. Grain storage units up to .4 metric ton capacity each can use plastic linings. Larger underground grain stores

need additional investigation on structures and handling equipment aspects.

IV.2 Teaching and Research

AID grant contributed to the institution building operation of IAV Hassan II. It developed the research capability of the latter in the area of grain storage. The project has helped seven departments of IAV Hassan II acquire laboratory equipments for data analysis or data acquisition. These equipments comprise a mixograph, microscope, an oven, incubator, water activity apparatus, a rotavapor, a microcomputer, data loggers, an air conditioner, a videocamera and a project car. These departments can individually or as group develop or tackle new research subjects related to grain storage.
This research has thus created an opportunity for a number of graduate and undergraduate students of IAV Hassan II to do research on topics related to underground storage and complete their training. The number of students who were trained in this field since the project started is as follows: 4 MS students in agricultural engineering with Dr. Bartali as major advisor and Dr. Debbarh as coadvisor, one BS student, a citizen of Mauritius Iland, in plant pathology with Dr Ezzahiri as major advisor and one BS student in food microbiology with Dr Tantaoui as major advisor. These students are providing assistance to public or private sector in the field of post harvest loss reduction in Morocco and abroad.

Excellency scholarship

Based on the research experience developped in the area of grain storage improvement, particularly with the Science Advisor grant on underground structures, Dr. Bartali has obtained an excellency scholarship for one of his graduate students. This scholarship is awarded by the Association of Partly or Entierely French Speaking Universities (AUPELF). The graduate student will pursue his training for a Ph. D. on appropriate storage structures design under the supervision of Dr. Bartali. The candidate will spend one year at the Department of Agricultural Engineering of Gembloux University in Belgium as part of his training.

IV.3 Extension

One major caracteristic of this project resides in its conception and implementation where extension activity was coupled to the experiment as much as possible. At the filling of experimental pits and at each of the 4 pit openings scheduled, the research team held extension seminars on the experiment site. The participants were farmers as well as administrators, storage extension and private. Farmers were also invited to visit on campus grain storage facility and the laboratories of IAV Hassan II where grain samples were analysed for loss evaluation.
Plastic sheets were distributed free by the project to 34 farmers in Spring of 1989 in order to try the plastic bags on their own

pits and provide their own evaluation. A survey undertaken by the project showed that farmers were satisfied with the performances of the plastic lining. This operation made it possible to ensure the technology transfer to farmers regarding how to make plastic bags from plastic rolls and to seal the bags and pits. Additional funding obtained by the project from the Science Advisor specially to enhance extension has made it possible to reach more areas of the country. Farmers in various regions of the country other than the Chaouia, home of the present project, were briefed and advised on how to prepare grain pits and practice plastic lining of pits. Among the regions covered are the Saiss plain where soft wheat is mostly grown and the Atlas mountains where farmers need to store barely to feed their sheep herds.
The project has videotaped all the sequences of the research carried out and managed through video show sessions and slide projections to explain the benefits of plastic lining. Copies of this videotape were given to the Project Officer in Science Advisor Office in Washington and to the principal coinvestigator in University of Montana, US.
Extension spots on adequate grain storage practices were prepared for and presented by the moroccan televison.

IV. 4 Brochure

Through the additional funds allocated to IAV Hassan II by the Science Advisor, a brochure is prepared for extension purposes. This brochure is in three languages: arabic, english and french and will serve to disseminate the methodology and of plastic lining of underground pits and the advantages it provides in underground grain storage systems. The brochure is well provided with illustrations in order to serve as an extension tool to the maximum number of user categories.
The brochure presents the features of underground storage and the methodology for digging, lining with plastic and sealing. The content of the brochure has been presented at various extension meetings in Morocco.

IV.5 Interviews

Two interviews were organised by the P.I, Dr. Bartali with national TV. The first one in 1988 at the biginning of the project. AID project was then introduced as well as the initiation of a multidisciplinary research on grain storage nation wide. The second one was given in 1990 toward the end of the project on the occasion of the international seminar on storage structures organised in Morocco and the presentation of the research findings. The two interviews were aired nation wide.

IV.6 Articles for newspapers and magazines

- AID Magazine HOT LINES, July, 1990. This paper describes the objective of the project and the succes it knew with recipient farmers. Citations from P.I Dr Bartali and Co P.I. Dr Dunkel are included in that article.

-CAURIS, Revue mensuelle d'information économique et sociale, No. 7 April, Mali, 1991, "Stockage des Récoltes: la Tradition Conserve."

-National newspapers: l'Opinion and le Matin

V. Project Productivity

The project has accmoplished all of the proposed goals. All the equiments used in the experiement set up worked well except one relative humidity sensor out of two purchased by the project. This sensor that was installed in the center of one plastic lined pit ceased functionning and was taken out for reparation. On the scientific level it made a rigorous evaluation of the interior environment of underground grain storage pits, by the on site monitoring of the physical parameters and the laboratory samples analysis. It answered a question related to agricultural development, that is plastic lined underground pits can serve as a reliable low cost storage technique both in Morocco and in other countries. Watertight plastic bags were introduced for the first time for grain storage purpose and samples were distributed free to a number of farmers. Industrial production of plastic bags of various sizes for underground pits has been proposed to IAV Hassan II by a private company. The project brought a major support to the extension in the field of grain storage. All the activities scheduled took harmoniously place on the field from the pit preparation and filling to the last opening. The project has helped establish a strong IAV interdepartmental collaboration on one side and IAV international relations on the other. (Dunkel, 1990)

VI. Future work

In Morocco, central management authority of agricultural extension continues to call upon IAV Hassan II in order to assist in the diffusion of plastic lining technology and prepare TV spots. Underground storage management will remain a substantial part in on going and future grain storage projects. A comparative study of plastic lining and cement lining was undertaken as well as the investigation of repetitive pit opening on carbone dioxide levels and loss rates.
Data collected is being analysed and used to validate theoretical models of heat and mass transfer in underground storage. This provides teaching material for graduate students. Investigation of the performance of large underground storage units will be focused on in the future.
An educational activity is planned for 1992. An international course on mastering post harvest technologies is being prepared with an international and national cosponsorship.
Innsect resistance to low oxygen atmosphere and insect repellent plants, performances of large underground units represent areas

worth studying for underground grain storage systems. Above ground clay straw silos is an original technique for grain storage that IAV Hassan II wishes to develop and for which it has submitted a new preproposal to the Science Advisor.
Collaboration will be developed particularly with researchers such as Dr. Hassan Shazali, Grain Storage Section, Shambat Research Station, Khartoum in Sudan where a Ford Foundation project on underground grain storage has been accepted ,Mr. Phocas, OPROVIA, Kigali, Rwanda where an AID project on underground storage of edible beans was carried out and Dr. Foua Bi, Ecole Nationale d'Agriculture d'Abidjan, Ivory Coast where a Master degree program on Post Harvest is being initiated, Dr. Sinha, Canadian Research Station in Winnipeg, Canada. Continuation of existing collaboration with Dr Dunkel in Montana State University, Dr Sterling at the University of Minnessota and Dr. M. Sartori, ITAL, Campinas Brasil as well as Belgian Universities of Louvain la Neuve with Dr. Persoons and Gembloux with Dr. Verbrugge, is also one of our goals.

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THE SITUATION

Morocco is undertaking a continuing effort to support self sufficiency in cereals. The area cultivated in soft wheat attained 1.5 x million hectares in 1987.

The storage of cereals in inadequate conditions continue to hinder this effort because of the large losses.

On-farm storage utilizes mainly traditional techniques including the "Matmora".

A mastery of the conditions of storage in the matmora will contribute to a reduction in postharvest loss and a better utilization of this low cost technique in storage design.

THE APPROACH

A multidisciplinary team of faculty of the Hassan II Institute of Agriculture and Veterinary Medicine and two American collaborators has been assembled to scientifically evaluate the limits and advantages of the storage of cereal in the matmora by:

1) Conducting a regional survey of storage practices using underground silos.
2) Evaluating the causes of loss which are related to underground storage.
3) Establishing the correlations between various factors which influence the environment in the matmoras.
4) Evaluating appropriate improvements in the plastic sheeting used to line the matmora.
5) Conducting an experiment with these storage practices on a farm where the understanding of the technique already exists.
6) Developing a guide for good management of underground storage.
7) Ensuring that the supporting organization charged with agricultural information dissemination takes advantage of these findings.

Faculty charged with these tasks are from the following departments of Hassan II Institute of Agriculture and Veterinary Medicine:

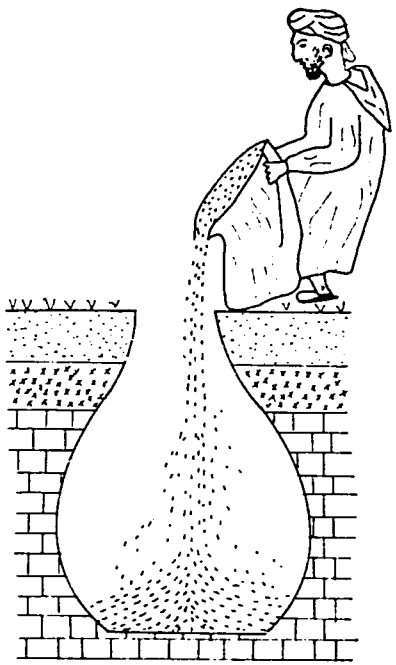
- Agriculture Engineering
- Zoology
- Food Technology
- Food Chemistry and Biochemistry
- Microbiology
- Agronomy and Plant Breeding
- Plant Pathology

THE OBJECTIVE

To reestablish techniques of storage for the small producer

Provide more storage capacity by developing on farm storage

Promote the national effort in self-sufficiency by the reduction of loss in cereal grains



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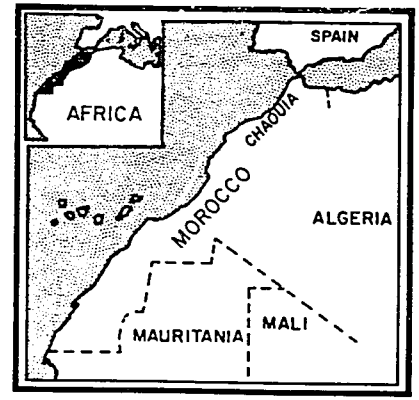
STORAGE SYSTEMS

Research on the Improvement of Matmoras for Underground Storage



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