ıo↑

COMPARISON OF TRADITIONAL AND IMPROVED METHODS OF FARM MAIZE STORAGE IN HONDURAS

by

JOSE R. ESPINAL

B.S., University of Southwestern Louisiana, 1982

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1986

Approved by:

John R. Pedersen
Major Professor

ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation and gratitude to Dr. John R. Pedersen for his assistance as major professor and for his help, advice and expertise offered during the experiment and preparation of this manuscript.

The author also acknowledges his indebtedness to COSUDE (Swiss Cooperation for Development) for the scholarship awarded through the Post-Harvest Project which enabled him to pursue his advanced studies.

The assistance of Johan Sieber, Post-Harvest Project extension expert, as co-adviser during each phase of the experiment is also gratefully acknowledged.

Gratitude is also expressed to Luis A. Guillén, Pedro Salas, Wilfredo Ortega and Rolando Rivera for their collaboration during the practical work of this experiment.

To all the author's friends for their moral support which represented a key factor for the completion of this work.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Small- and medium-sized farmers in Honduras are those who own or rent land ranging from 1.7 to 43.2 acres (Post-Cosecha, 1982). There are two main crops grown on such land: maize and dry beans, and to a lesser extent sorghum, the staple foods for the majority of Hondurans.

In terms of acreage and tons produced, maize is the most important crop. According to results obtained by a post-harvest project, in the Central-East region of the country during two periods of evaluation, small- and medium-sized farmer maize storage losses (weight losses) over 6 months were 8.8 and 7.4 percent, respectively (Raboud et al., 1984a). These losses occurred due to lack of adequate storage facilities and limited knowledge of effective management practices. Traditional storage facilities and methods of storage do not provide effective protection against the main pests that attack the maize.

At least 60 percent of the maize produced by small- and medium-sized farmers is used for their own consumption. The remainder is sold in the grain market. Any storage loss is, therefore, very important to the farmer because he is losing food for his family.

Maize is traditionally stored on the cob. However, high levels of insect infestation often force farmers to shell the grain after 5 to 6 months of storage. Since they do not have adequate storage facilities for shelled maize, they sell it. Later they will have to buy maize for their food at higher prices.

In a broad sense, this research was directed towards improvement of traditional storage systems for maize at the small- and medium-sized farm level in Honduras. Through a series of new management practices for the grain and/or the storage structure, storage losses should be reduced and better grain quality maintained.

Specifically, the goals of the research were to:

1. Compare an improved method of farm storage with the traditional method.
2. Evaluate the effectiveness of anhydrous lime (inactivated $CaCO_3$) as a preventive measure to control insects which attack stored maize.
3. Evaluate the use of an insecticide (Actellic, 2% dust) as a method to control insects that attack stored maize.

The introduction of improved practices and new products had as a general objective the reduction of storage losses and, therefore, a higher standard of living for the small- and medium-sized farmer.

LITERATURE REVIEW

Traditional Method of Storage

Loss evaluations made by the Post-Harvest Project during two consecutive storage periods in the Central-East region of Honduras indicated that maize losses, due mostly to insect attack, were critical, especially at the very end of the storage period (Raboud et al., 1984a). This also meant that the treatments commonly used to protect the maize were not effective.

Trojas. Traditionally the storage structures for storing ears of maize in the husk in Honduras are called trojas. They can be situated inside the house, or outside the house as a separate structure. Trojas when not used for storage may be used as bedrooms or for other purposes. There are no standard shapes or sizes for trojas. Usually walls are made of wood or mud blocks, the floor of dirt, and the roof of tiles (Proyecto Post-Cosecha, 1985).

Selection of Maize for Storage. The Proyecto Post-Cosecha (1982) reported that storing maize ears in the husk was a traditional custom among small- and medium-sized farmers in Honduras, especially in the Central-East region. To do so, the maize is subjected to a selection process prior to storage. Characteristics that the husks should have in order to be selected as good for storage include: tightness; must cover the ear completely; must have a strong and long end to avoid the entrance of insects; must be free of holes made either by field insects or stored-product insects. Boshoff (1977) reported that in most traditional varieties of maize in tropical areas, the husk is complete and, in general, is believed to offer protection against insects.

Traditional Chemical Treatments. In Honduras many small- and medium-sized farmers use malathion (4% dust) to protect their grain. Malathion replaced DDT and BHC formerly used as storage treatments in Honduras. Malathion is an effective product but considered unstable under warm and humid conditions making it an inappropriate product to be used in tropical countries (Proyecto Post-Cosecha, 1986). There is also considerable evidence that several species of stored-product insects have developed resistance to malathion (Champ and Dyte, 1976). In a test which compared different organophosphorous insecticides under simulated tropical conditions, malathion did not show desirable qualities for controlling stored-grain insects (Yadav et al., 1980). In another study, after a 5-month period malathion was the least effective insecticide tested, with zero percent control of *Sitophilus zeamais* (Motsch). Malathion started to decrease in effectiveness after the second month of storage when applied to maize in husk under traditional Honduran conditions (Proyecto Post-Cosecha, 1986).

The use of lime is also a widespread practice for controlling insects among farmers that store their maize traditionally. However, there is no specific dosage recommendation and, as a result, the lime is applied inconsistently. The effectiveness of lime in stored-grain insect control will be reviewed later in this section.

An Improved Method of Storage

According to the manual "Traditional Troja in Honduras" (Proyecto Post-Cosecha, 1985), the management practices to improve traditional storage methods that should be considered are: preparation of the troja prior to storage, harvest and proper selection of the ears in the husk, and treatment of the ears in the husk with a recommended insecticide or lime.

The manual suggested the following for:

Troja Preparation:

1. Clean the troja inside, outside and around; burn the residues of the last crop.
2. Spray the walls, roof and floor of the troja with liquid insecticide solution.
3. Provide a platform made of wood or stones on the floor.

Harvest and Selection of Ears in the Husk:

1. Harvest as soon as the ambient conditions and moisture content of the maize are adequate.
2. Harvest the maize with no more than 17 percent moisture content; never leave the maize in the field for a long period of time after maturity.
3. Select only the sound ears in the husk; avoid storing those which have evidence of field or stored-grain insect infestations.

Recommended Treatments of the Ears in the Husk:

1. Never use Chlordane, Lindane or DDT. Malathion (4% dust) is the most popular insecticide but it has the disadvantage that its toxic properties disappear after 2 months. For this reason malathion should not be used.
2. The recommended insecticides are Actellic (2% dust) and folithion (1% dust). Lime can also be used, but following the recommended dosages.

Recommended Chemical Grain Protectants

The Proyecto Post-Cosecha (1985) recommended the application of Actellic (2% dust), folithion (1% dust) and lime as possible grain protectants. Since it was determined that folithion was not readily available in Honduras, only Actellic and anhydrous lime will be reviewed here.

Actellic (Pirimiphos-methyl). Delmon et al. (1976) reported that pirimiphos-methyl was superior to the standard dosage of malathion in protecting maize against attack by stored-grain insects. Pirimiphos-methyl residues degraded relatively slowly with 38 percent of the initial deposit remaining on the maize after 12 months of storage in comparison to 15.6 percent for malathion spray applications. As a result, protectant sprays prepared with pirimiphos-methyl applied at selected dosages gave better protection than the recommended dosages of malathion. Ofosu (1977) reported that pirimiphos-methyl at 8 ppm and 12 ppm was effective against *Sitophilus zeamais* and *Tribolium castaneum* (Herbst) after 24 weeks of storage. In addition, at both dosage levels *S. zeamais* was prevented from multiplying. Initially pirimiphos-methyl gave complete kill of *S. zeamais* and after aging for 24 weeks, Actellic deposits on maize still gave complete kill of *S. zeamais* and *T. castaneum*. In 1979 Tsvetkov and Atanasov also classified Actellic as a promising insecticide for control of pests in stored grain at a dosage of 8 ppm.

Hsieh et al. (1982) reported the influence of post-harvest treatment temperature on toxicities of six organophosphorous insecticides to two species of storage insects. Actellic showed positive temperature coefficients of toxicities (insecticidal activity increased with increasing temperature) against the maize weevil (S. zeamais) and the lesser grain borer Rhyzopertha dominica (F). Sukprakarn (1984) reported that the insecticide used in Thailand to control stored-maize insects is pirimiphos-methyl at a dosage of 5-10 ppm.

The Post-Harvest Project of Honduras (1986), looking for better alternatives in terms of insecticides for use in storage, compared the effectiveness of malathion, folithion, Actellic and lime for control of S. zeamais, the most common species of insect found in stored maize in Honduras (Hoppe, 1986). Actellic at a dosage of 10 ppm and folithion at a dosage of 10 ppm were the most effective grain protectants, keeping insect pest populations at zero after the fifth month, while malathion showed a zero percent control of insects. Malathion's effectiveness started to decrease after one month. Lime, traditionally used as a grain protectant, was more effective than malathion.

Lime. Very little has been published about the practice of insect control with lime. Fitzgerald (1944) classified lime as a material with definite but poor effect. El Halfawy et al. (1977) showed that fewer Oryzaephilus surinamensis L. were obtained from lime-treated grain than from untreated controls. Lime-treated grain also produced the lowest mean number of progeny (28) compared with the control (426 adults). The Proyecto Post-Cosecha (1986) reported that lime gave better control of S. zeamais in maize than malathion over a 5-month period.

According to Fitzgerald (1944), the manner in which lime kills insects is not precisely known, but it is thought that it causes an abnormal loss of water from the tissues although the mechanism of this loss has yet to be explained. Grain weevils living on material with a very low moisture content can not readily cope with an unusually large water loss, and should therefore be particularly susceptible to inert dusts if dessication is the primary cause of death. The high alkalinity of lime may lead to saponification of the epicuticle. According to Brown (1951), the high alkalinity and the high sorptiveness of lime may be the two main factors responsible for its effectiveness.

David and Gardiner (1950) reported that more dust adheres to rough insects than the smooth-surfaced insects. Other workers (Germar, 1936; Chiu, 1939b) reported that effective dusts readily lodge in crevices in the insect's body, causing irritation and restriction of movement. It has been observed that the mouth parts are affected in this way. This blocking of the mouth has been considered only as it affects the length of life of those insects which are hindered in their feeding. Although it has previously been overlooked, the effect on oviposition may be more important. If the mouth were blocked, weevil oviposition might cease long before the insect is killed since weevils chew holes for egg deposition. From this point of view, dust might be as effective at high as well as low humidities, although this latter point has not been determined.

Fitzgerald (1944) defined atmospheric humidity, size of dust particles (mortalities are low with particles over 20 microns and the fraction below 10 microns is by far the most effective), and dosage as factors affecting the action of dusts. Other workers have also shown that to be effective, dust particles must be less than 10 microns in diameter (Germar, 1936; Zacher and Kumike, 1930; and Chiu, 1939a).

The use of lime and other natural materials has been recommended when chemical control is not available. The use of pesticides on grain may be limited in the future because of residues appearing in foodstuffs, and the development of insect pest resistance to grain protectants has become a limiting factor in long-term storage of grain. For those reasons, other means of control which are easier to practice have to be found (Sukprakarn, 1984).

In 1984, Sukprakarn reported that for non-chemical control, admixtures of maize grain with ash, lime, rock phosphate and castor oil were recommended to farmers in tropical regions.

Methodology of the Post-Harvest Project

Raboud et al. (1984b) reported that an evaluation method for the post-production losses of basic grains (maize, dry beans and sorghum) by small- and medium-sized farmers was developed by the Post-Harvest Project of Honduras. This methodology included and distinguished between damage (physical alteration of the grain) and loss (total grain damage minus the grain that was classified as recoverable or good for consumption). This method used sampling as an instrument to show the losses in the field and monthly sampling to calculate the losses in storage. The analysis of the sample allowed the determination of the level and causes of damage and loss based on the relation between real and potential weight of the shelled and unshelled product sampled. The information obtained from the samples (intake and analysis) was complemented through observation and information collected with a questionnaire. At this level the confident relationship between the farmer and the technician played a fundamental role in obtaining valid and accurate information.

Loss Assessment Methodology: Summary of Other Methods

Despite the limitations inherent in the identification of food losses, properly selected estimation methods can provide the information essential for reducing losses. Although the accuracy of the individual loss estimates may be low, large numbers of such observations can provide a useful basis for more general estimates and for decisions involving extended geographical regions or a substantial number of food stores. Large-scale surveys raise the question of how much accuracy is necessary to make loss estimates that are generally useful. The answer depends upon the purpose for which the estimates are to be used (National Academy of Science, 1978).

There is no agreed methodology of post-harvest loss assessment. Moreover, loss data are generally unrelated to the cost of loss reduction. A loss assessment study that does not have built into it the strong possibility and intention of benefiting the situation under study is of no consequence. In short, loss assessment need not and should not be a largely academic exercise (Harris and Lindblad, 1976).

Adams and Harman (1978) reported that information on the technical aspects of losses should be obtained by:

1. Collecting the necessary baseline data on the moisture content, damage and bulk density (bushel weight) of the commodity immediately prior to storage and recording any procedures involving selection or treatment of the product for storage.

2. Recording the quantity of the commodity placed in storage.

3. Recording the date on which some of the commodity is first removed from the store. Thereafter samples of the commodity should be taken at monthly intervals.

4. Collecting information on the rate of consumption of the stored commodity over the storage period. This should be done on each sampling visit.

5. Analyzing the samples to obtain estimates of loss and applying these to the consumption pattern to obtain an estimate of loss over the complete storage period.

6. Setting up simulation stores, if necessary, which are under the control of the investigator and which simulate the farmers' pattern of consumption. The commodity should be accurately weighed in and out of the store. Care should be taken that the grain placed in these stores is of the same quality and selected in the same way as the grain placed in the farmers' stores.

For traditional on-farm storage situations, the degree of accuracy of loss estimates is likely to be low, as are resources for available corrective measures. Here loss estimation is limited by the variety and dispersal of storage facilities among families and villages in a given area and by problems both in sampling procedures and in making generalizations based upon individual observations. These problems are likely to be exacerbated by the reluctance of farmers to provide accurate information and by the efficiency of the traditional storage methods (National Academy of Science, 1978). FAO (1977) reported average maize losses from 9.6 to 20.2 percent, mainly in storage and due primarily to insect damage, followed by mold and rodent damage. However, the data are markedly inadequate and, as the FAO report concludes, "The estimates of losses of durable commodities and the methods by which they are derived were inadequately refined." Much painstaking work that has been published on farm-level maize storage is of limited use in determining weight losses because of the difficulty of measuring and interpreting losses due to "insect damage" reported as a percentage of damaged grains. Adams and Harman (1978) note the lack of information from Central America and South America in contrast to the considerable attention paid to cereal losses in most regions of Africa.

MATERIALS AND METHODS

The research was divided into two parts: a field experiment at farm sites and a parallel experiment at the experiment station of the Proyecto Post-Cosecha in Tegucigalpa. The parallel experiment was to compare field results (where considerable variability was expected to occur) with results obtained from a controlled situation.

Selection of Villages for Field Tests

Villages were selected according to the following criteria:

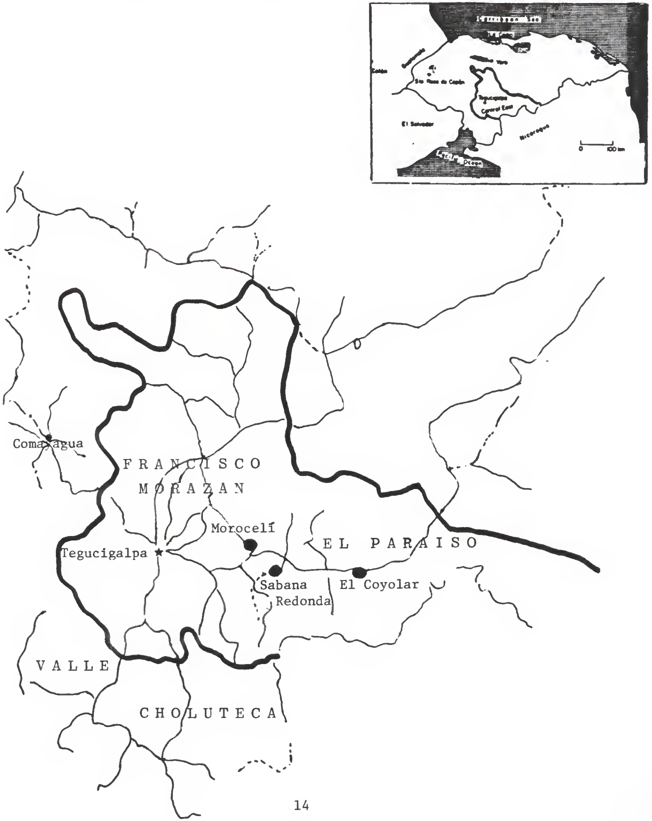
- Maize is commonly produced in the area.
- Improved post-harvest practices are not commonly used.
- Maize is commonly stored at least 6 months.
- Farmers are willing to collaborate.

El Coyolar, Morocelí and Sabana Redonda were the three villages selected for the field experiment. They are located in the Central-East region of Honduras and are typical maize-producing areas (Figure 1).

Even though the traditional post-harvest practices undertaken in each village were similar, there were some differences which could influence results of the experiment.

El Coyolar is located 85 miles east of Tegucigalpa. Its population is approximately 300 people, most of them farmers who produce maize and dry beans. It is located in the Jamastran Valley, one of the most fertile lands in the country. In this village the storage structures (trojas) were separate units but attached to the house (living

FIGURE 1. Map of Honduras central-east region villages where the field experiment took place



quarters). Individual farms were located quite close to one another in a cluster.

Morocelí is located 30 miles east of Tegucigalpa. Its population is approximately 600 people, all of them farmers and basically maize producers. Stores in this village were situated inside the house (living quarters) usually in a corner of a room or passageway between rooms. Morocelí was a more organized village, with streets.

Sabana Redonda is located 40 miles east of Tegucigalpa. Its population is approximately 250 people, all of them farmers producing mostly maize and coffee beans. Storage structures (trojas) in this village are separate structures apart from the house. More yellow maize was grown here than in the other two villages. Farms were more widely separated from one another than in Morocelí or El Coyolar.

Selection of Farmer Collaborators

Villages were visited and meetings arranged to explain the purpose of the study. Farmers were then interviewed to determine whether they met the four criteria set forth for selection of villages.

Based on questionnaires completed during the interviews as well as their interest in collaboration, twelve farmers were selected from each of the three field locations. In some cases more than twelve farmers were selected to prevent having a low number of replications during the last month of the storage period. Four farms were selected at random for each of the three treatments to be evaluated.

Maize

In the region where the field tests were conducted and where maize was obtained for the controlled test, maize commonly matures in September but is left on the stalks until January. At this time the maize is hand-harvested and brought to the farm for selection and storage (Figure 2).

Newly-harvested, 1984 crop white native maize was used in the field experiment. Each selected farmer used his own maize. For the experiment station the maize used was obtained from a single source and from the same region where the field experiment was conducted.

Preparation of Trojas for Maize Storage

Troja is the name given in Honduras to the traditional place for storing ears of maize in the husk either in a heap or in an orderly way. Trojas can be situated inside the house (Figure 3), attached to the house (Figure 4) or as a separate structure (Figure 5). There are no standard shapes or measures. When they are built as separate structures, usually the walls are made of wood, the floor of dirt, and the roof of tiles. When they are attached to the house, they are usually of plastered mud bricks or wood similar to the house construction.

Traditionally trojas are not well cleaned. Maize is stacked directly on the ground and a variety of "treatments" may be used. In the field tests, control treatments used the farmer's customary preparation for storage. The degree of cleaning and preparation were quite variable.

The improved storage management practices employed a thorough cleaning of the troja, provision of a raised floor on which to store the maize, and spraying with malathion to disinfest the troja prior to storage of maize.

FIGURE 2. Phenology of maize in the central-east region of Honduras: physiological maturity (September), maize harvested and taken to farmyard (January), storage (January, February or March)

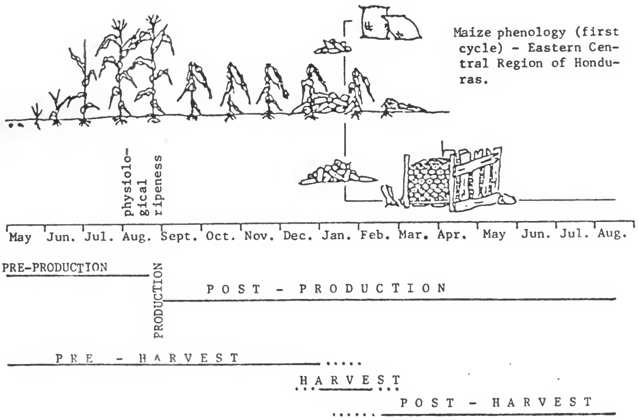


FIGURE 3. Traditional storage structure (troja) situated inside the house and typical of Morocelí

FIGURE 4. Traditional storage structure (troja) attached to the house and typical of El Coyolar

FIGURE 5. Traditional storage structure (troja) separated from the house and typical of Sabana Redonda

FIGURE 6. Simulated trojas used for the Swiss-Honduran Proyecto Post-Cosecha experiment station trials in Tegucigalpa

Malathion was used as a means of protection against insects found on the walls, roof and floor of the troja. A commercial formulation of 57% malathion emulsifiable concentrate was used containing 600 g A.I. per liter. The dosage used was that recommended on the label of the commercial product.

Description of Treatments

The three treatments tested were:

1. An improved method of storage management using pirimiphos-methyl (Actellic) as a grain protectant.
2. The improved method of storage management using lime as a grain protectant.
3. The traditional method of storage as a control treatment.

Although 36 farms were originally selected, a total of 34 trojas were carried through to the end of the tests in the field experiment. Twelve (12) had the improved method using Actellic, 11 the improved method using lime, and 11 controls which were managed traditionally and did not include any of the improved practices but rather relied only on the selection of ears of maize. This has been a common practice of the small- and medium-sized farmers of Honduras for many years.

The treatments by village were as follows:

	Improved Method Using		
	Actellic	Lime	Traditional Control
El Coyolar	4	4	4
Morocelí	4	4	3
Sabana Redonda	4	3	4

Improved Storage Management Practices

The improved method of storing maize included new practices for the storage structure as well as for the maize. The ears of maize in the husk were brought from the field and put in the farmyard, then subjected to a selection process for separating the good ears for storage from the bad ones. Selection was made on the basis of tightness of the husk, how well the husk covered the ear, and if there was evidence of insect damage on the husk.

After separation of the ears, trojas were prepared by:

1. Repairing the roof when necessary.
2. Setting a platform made of wood or stones on the floor to avoid contact of the ears with the ground.
3. Cleaning the structure completely, inside as well as outside, and disposing of the residues by burning.
4. Applying 57% liquid malathion (20 cc/liter of water) to the walls, roof and floor at a dosage of 8 cc/m^2.

After preparation of the trojas, selected ears of maize were set in the stores. Every layer of ears of maize received either an Actellic or lime treatment. Emphasis was placed on keeping the storage structure as clean as possible during the entire period of the experiment.

Actellic. A 2% dust powder was used as the grain protectant. The active ingredient of Actellic is pirimiphos-methyl, a broad spectrum organophosphorous insecticide of low mammalian toxicity. The dosage used was 1 oz/2.5 m^2 (approximately one layer of 250 husked ears of maize).

Lime. Anhydrous lime (inactivated $CaCO_3$) was used at a rate of 1 lb/2 m^2 (approximately 200 husked ears of maize). Lime was purchased from a single source and sifted through a 9K 2.5/64 round sieve to obtain a uniform particle size.

Traditional Method of Storage

Control trojas were handled in the same way they have been managed for many years. The traditional method of storage did not include any new practices for the storage structure or for the maize. No recommendations were given to farmers. Individual farmers had different ways to handle their structures and grain.

Experiment Station Trials

Nine simulated trojas were constructed and used at the experiment station. Six of the trojas had the improved method, three using Actellic and three using lime. Three controls used the traditional method. The trojas were made of wood of the same kind as used on the farms and each held 5.4 quintals of maize (1 quintal = 100 lb) (Figure 6). The maize was obtained from a single farmer in Jutiapa, a typical village of the Jamastran Valley. A total of 22,000 ears with husk were obtained, and from those a total of 14,000 were selected for storage. The controls were not treated at all, even though an analysis of random samples taken before and after selection showed field infestation of insects, mostly Sitophilus zeamais.

The trojas were artifically infested and exposed to this species of insect. Each troja was infested with 100 insects which were set randomly in the storage units so as to have an even distribution of the insects on the ears of maize. In addition, a source of infestation was kept close to the storage units to assure continuous reinfestation of the grain.

Sampling of Trojas

Initial Sampling. Maize designated for each of the 34 trojas in the field experiment as well as for the 9 trojas at the experiment station was sampled before storage and treatment to provide a baseline for loss assessment. Samples were taken and observations made at each storage unit to obtain information regarding the initial condition and quantity of maize. The information gathered was recorded on a computation sheet (Appendix I). This information included the condition of the maize and the quantity in store, change over a period of time as the maize was subjected to its environment (pests, temperature, humidity), and the usage of the maize (consumption, marketing, seeds). The data on damage and loss were calculated by the integration of observations made on each sample.

Monthly Sampling. Samples for determination of losses occurring in storage were taken from each farmer's troja at 30-day intervals for 6 months. Samples consisted of 10 ears selected randomly from the layer of maize which the farmers were consuming. At the experiment station, a complete layer was withdrawn each month and the 10-ear sample was taken from that layer. Since storage is a dynamic process in continuous evolution, monthly samples were necessary to evaluate this evolution. A single sample is a static image that gives information about the state of the product at a given point in time. In order to evaluate the real dynamics of storage it is necessary to have a series of samples and data on the condition of the product in storage. This was provided by the information that was logged into the registration and computation sheet.

Data Collection. The damage and loss estimates represent the amount deteriorated between full storage and empty storage (Appendix II and V). The periodic samples taken from the trojas gave information about damage and losses occurring in the specific quantity of maize farmers were consuming and the status of the maize removed between samplings (difference between the two sampling visits corresponding to the average state of the two samples). These data also considered the damage at the time the maize was stored (equivalent to the damage and loss of the sub-sample good for storage from the average level of damage and loss of the storage sample). Applying these last values to the percentage of maize removed, the level of damage and loss caused in storage corresponding to the period between consecutive samples was determined. The cumulative level of damage and loss in storage was obtained by adding the monthly losses. Negative damage and loss values are errors in the method. Distribution of damage in storage is not homogeneous. In subtracting the loss estimate for the maize sample obtained from the site in storage from which the farmer is consuming, the cumulative estimate can be over- or underestimated. This error is minimized by averaging the result of the quantity taken between the two samples. It is considered necessary to have at least five or six storage samples to minimize the effect of these errors.

Calculation of Storage Losses. The samples withdrawn were taken to the laboratory in order to analyze them and determine the damage and loss using the loss assessment methodology developed by the Honduran-Swiss Post-Harvest Project (Appendix III). After husking the ears of maize, the number of removed kernels (rem) was determined. Then the ears were shelled and damaged kernels (d) were separated from undamaged (nd) and each separation giving weight (d) and weight (nd). From the undamaged (nd) the moisture content was determined using a Burrows Digital Moisture Computer 200. The causes of damage (pregerminated, field fungi, storage fungi, field insects, storage insects, other or multiple causes) were determined from the 250 damaged kernels. The number and weight of recoverable grain was also determined (grecu) from the damaged portion. For comparison, 500 undamaged kernels were counted and weighed. The calculation procedure (Appendix IV and V) provided an estimation of the damage and loss of the sample.

Statistical Analysis. Field tests and laboratory experiments were analyzed using SAS (Statistical Analysis Systems). Tests for significant differences among means were computed using the Fisher LSD test, at the 5 percent confidence level.

RESULTS AND DISCUSSION

Field Experiment

Effectiveness of three methods of village maize storage was determined by comparing the reduction in weight expressed as percent weight loss over a 6-month storage period. The Proyecto Post-Cosecha loss assessment method was used to calculate the percentage weight loss (Appendix III). The improved method of storage using Actellic showed the lowest mean overall percent weight loss (6.53 percent). The improved method using lime had a mean percentage weight loss of 11.33 percent. The loss was greatest in the traditional method (15.02 percent). The mean overall percent weight losses do not show a significant difference between the improved methods of storage using either Actellic or lime and the traditional method of storage (Table 1).

The non-significant differences suggest that some factor or factors may have been responsible for variability in the data used to calculate the overall mean percent losses for the three treatments.

Variances of the three treatments of the field experiment were compared (Table 2). The high variability that occurred in the improved method using lime and in the control could contribute to the non-significant differences when the overall mean losses were compared. The way individual farmers handled their grain was probably an important factor in this variability.

Storage losses and average quantities stored by individual village and treatments are shown in Table 3. In Sabana Redonda and Morocelí

TABLE 1. Mean percent overall losses of maize in the villages of El Coyolar, Morocelí and Sabana Redonda over 6 months of storage

Method	Treatment of the Ears	Mean Percent Loss[1]	Percent Loss Reduction of Improved Method Over Traditional
Improved	Actellic	6.53 a	56.5
Improved	Lime	11.33 a	24.6
Traditional	None	15.02 a	

[1]According to the analysis of variance, losses followed by the same letter within treatments are not significantly different.

TABLE 2. Comparison of treatment variances for field and laboratory tests

Method	Field Experiment	Laboratory Experiment
Improved method using Actellic	20.43	0.37
Improved method using lime	169.78	3.80
Control	266.66	5.15

TABLE 3. Mean percent weight loss by village when the traditional method of storage was compared with an improved method using Actellic or lime

Village	Method	Treatment of the Ears	Mean Percent Loss[1]	Average Quantity Stored in Quintals[2]
El Coyolar	Improved	Actellic	12.49 a	47.46
	Improved	Lime	20.77 b	47.07
	Traditional	None	11.31 a	44.06
				46.19
Morocelí	Improved	Actellic	3.34 a	24.38
	Improved	Lime	3.31 a	16.34
	Traditional	None	15.26 b	17.86
				19.52
Sabana Redonda	Improved	Actellic	4.04 a	28.74
	Improved	Lime	7.89 a	31.82
	Traditional	None	21.79 b	47.32
				35.96
				Overall average 33.89

[1]Losses followed by the same letter within villages are not significantly different.

[2]One quintal = 100 lb.

the improved treatments using Actellic and lime resulted in losses which were not significantly different but which were significantly less than those in the traditional control treatments. In El Coyolar results were not rational, or as expected. There was no significant difference in losses between the traditional control treatment (11.31 percent) and the improved method using Actellic (12.49 percent). In fact, the traditional control treatment had the lowest percent weight loss. The improved treatment using lime showed a significantly greater loss (20.77 percent).

Numerically, improved treatments in Morocelí resulted in least amounts of loss. In Morocelí, trojas were inside living quarters or in corridors between living quarters. Morocelí was also a more organized form of living environment (streets, etc.) than the other two villages. Whether this, especially storage within the living quarters, provided a "cleaner" storage environment and affected the results of this experiment is unknown. However, observations made during sampling trips indicated that Morocelí had the fewest comments about poor hygiene (Table 4). This should be considered a potential contributing factor. The smallest quantities of maize were stored in Morocelí in comparison to the other two villages. The average store sizes are shown in Table 3.

Data in Table 2 indicate that in general greater losses occurred in El Coyolar than in Morocelí or Sabana Redonda. Greatest losses in lime treatments and lower, non-significant differences in the Actellic treatment and the traditional control in El Coyolar are not readily explained.

TABLE 4. Comparison of qualitative observations made in El Coyolar, Morocelí and Sabana Redonda during a 6-month storage period

		Presence of *P. truncatus* (P) and *S. zeamais* (S)						Incidence of Rodent Activity						Poor Hygiene					
Sampling		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
El Coyolar																			
Actellic	1				P	P	P			+	+	+	+				+	+	+
	2											+	+			+		+	
	3								+	+	+	+	+						
	4			P	P	P	P		+	+	+	+				+		+	+
Lime	1					S	S			+									
	2			S		S				+									
	3	S	S	S	S					+	+		+						
	4	S	S		S	S				+		+	+						
Control	1			S			P		+										+
	2			S	S				+						+				
	3			S	S		P						+						
	4		S				S												
Morocelí																			
Actellic	1																		
	2			S															
	3																		
	4		S									+							
Lime	1	PS			PS	PS													
	2		S				S												
	3					P													
	4						S												
Control	1			S	S	SP	SP						+			+	+	+	+
	2				S		SP												
Sabana Redonda																			
Actellic	1						S												
	2																		
	3		S			S								+					
	4				S				+										
Lime	1			S			S				+								
	2			S			S												
	3						S					+							
Control	1		S		S									+	+	+			
	2		S		S	S	S		+			+	+		+	+		+	+
	3					S	SP				+	+							
	4		S	S	S					+	+	+							

In an attempt to explain the unexpected results reported for El Coyolar, the various factors used to calculate losses were examined to determine which may have had the greatest effect on percentage weight loss. Percent damage after 6 months due to field fungi, dead cob fungi, field insects and storage fungi, stored-grain insects and other factors were examined (Table 5). Total percent damage in each village was least in the improved method of storage using Actellic, greatest in the traditional method of storage (control) and intermediate in the improved method using lime. Total percent damage in samples from El Coyolar were greater for each of the corresponding treatments than in the other two villages. In general, percent damage due to field fungi, dead cob fungi and stored-grain insects was greater in El Coyolar than in Morocelí or Sabana Redonda.

Two aspects of percent damage are important when considering the percent weight loss. First, percent damage due to factors other than stored-grain insects involves virtually an equivalent percentage weight loss since these kernels would generally be discarded and considered a total loss. Secondly, kernels damaged by stored-grain insects would generally be considered "recoverable" (according to the method of loss assessment used) and would be reflected as a comparatively lower percentage weight loss. Therefore the percentage weight losses recorded for El Coyolar might be expected to be greater than in other villages because of the greater percentage of "non-recoverable" damaged kernels.

It should be pointed out also that two of the four lime trials in El Coyolar were determined to have relatively heavy insect infesta-

TABLE 5. Average percent damage in three maize treatments due to various causes in the villages of El Coyolar, Morocelí and Sabana Redonda over 6 months of storage

Treatment	Total Percent Damage	Percent Damage Caused by Various Factors[1] Field Fungi	Dead Cob Fungi[2]	Field Insects and Storage Fungi	Other[3]	Stored-Grain Insects	Percent Weight Loss
El Coyolar							
Actellic	13.87a	3.56a	4.07a	2.12a	1.53a	2.60b	12.49a
Lime	21.40a	2.46a	2.82a	0.53b	1.71a	13.88a	20.77b
Control	24.86a	5.20a	4.72a	1.09a	0.90a	12.95a	11.31a
Morocelí							
Actellic	5.23b	0.96a	0.00b	0.25b	2.71a	1.31b	3.34a
Lime	11.57a	1.34a	0.32b	0.29b	1.00a	8.61a	3.31a
Control	16.28a	1.09a	1.77a	1.29a	1.48a	10.65a	15.26b
Sabana Redonda							
Actellic	7.82b	1.34a	0.26b	2.33a	2.32a	1.57b	4.04a
Lime	10.61a	2.05a	1.01b	2.10a	1.62a	3.83b	7.89a
Control	22.60a	4.23a	0.76b	0.83b	4.73b	12.05a	21.79b

[1]Damages followed by the same letter within villages are not significantly different.

[2]Dead cob fungi was defined as *Aspergillus* spp.

[3]"Other" causes include pre-germinated kernels, multiple causes.

tions. At the time maize was placed in storage, observations indicated that an infestation of Sitophilus zeamais existed and that an initial weight loss of 10.03 percent had already occurred in one trial. This farmer stored 44.1 quintals (4,410 lb) initially and as a result of the initial infestation and its subsequent increase, had to terminate his storage before the end of the observation period. Data from observations made until the time of disposition were used in the analysis reported here.

A second lime treatment was also observed to have a lighter infestation of S. zeamais at the time of storage with a 3.05 percent weight loss. This farmer stored approximately 17.2 quintals of maize and the percentage of loss increased quite rapidly during storage.

Observations indicating the presence of Prostephanus truncatus (Horn) and S. zeamais, incidence and/or damage by rodents and/or poor hygiene were made during monthly sampling trips (Table 4). In the village of El Coyolar, Actellic treatments had a greater incidence of P. truncatus, greater incidence of rodent activity and poor hygiene compared to the other treatments in the same village and compared to the other treatments in the other two villages. In El Coyolar the lime treatments showed a higher incidence of S. zeamais than the controls and the Actellic treatments had only P. truncatus. Poor hygiene was not reported in control or lime treatments in El Coyolar. The high incidence of S. zeamais in lime treatments due to field infestation was discussed earlier. In Moroceli and Sabana Redonda observations indicated better housekeeping for Actellic and lime treatments whereas poor hygiene was reported in half of the controls. The incidence of rodent activity was greater in Sabana Redonda than in Morocelí. In general, incidence of P. truncatus was greatest in El Coyolar and in Morocelí. The greatest incidence of S. zeamais was in El Coyolar and Sabana Redonda. It is obvious that S. zeamais was the main insect pest of the stored maize.

The incidence of rodent activity in lime and Actellic treatments in El Coyolar as well as the poor hygiene reported in Actellic treatments probably contributed to the erratic loss results obtained in this village.

Controlled Experiment

The three methods of storage were simulated under more controlled conditions at the Swiss Proyecto Post-Cosecha experiment station, using 5.4-quintal lots of maize. Average quantities stored in the field test ranged from 16.3 to 47.5 quintals (Table 3).

When the improved methods using either Actellic or lime were compared with the traditional method of storage, the Actellic treatment had a significantly lower percent weight loss (Table 6). The improved method using lime was not significantly different from the traditional method.

These results differ from those obtained in the three villages used in the field test where, in two villages, the improved treatments using lime or Actellic were not significantly different from each other but resulted in significantly lower losses when compared to the traditional

TABLE 6. Mean percent weight loss in experiment station simulated storage when the traditional method of storage was compared with an improved method using Actellic or lime

Method	Treatment	Mean Percent Loss
Improved	Actellic	4.67 a
Improved	Lime	7.02 b
Traditional	NONE	7.26 b

method of storage. Whereas losses in the Actellic treatments in both the field and experiment station tests were of the same general magnitude, experiment station losses in the traditional controls (7.26 percent) were only one-half to one-third of those in the Morocelí and Sabana Redonda field tests (15.26 and 21.79 percent, respectively).

The variances for the three treatments in the controlled experiment station test were much lower than those in the field experiment (Table 2). Here, as in the field experiment, variance was least in the Actellic treatments ($\sigma^2 = 0.37$) and greatest in the traditional control treatments ($\sigma^2 = 5.15$), with the lime treatment intermediate ($\sigma^2 = 3.80$). This reduced variance when compared to the field test is due, in part, to the use of a single source of maize for all treatments. Whereas each individual farmer's production was used for field test treatments, the experiment station treatments and replicates came from a single lot of maize obtained in Jutiapa (a location near El Coyolar).

Another factor which could have affected the variance was the selection of maize cobs for the controlled experiment station tests. In the field tests, each individual farmer selected the cobs for his storage. At the experiment station all maize cobs for the various treatments were carefully selected by Project personnel. This was viewed as providing a better cob selection (tighter husk, undamaged, etc.) as well as a more uniform selection.

The reason for obtaining lower losses than the field experiment and no significant difference between the lime treatment and the traditional method in the station may be the proper selection of the cobs for all treatments. Selection of cobs represents one of the key factors for successful storage at the farm level in Honduras.

It should also be pointed out that good hygiene was maintained throughout the experiment station test area.

Effectiveness of Actellic

In field tests, the improved method using Actellic reduced losses overall by 56.5 percent when compared to the traditional method of storage (Table 1). In Sabana Redonda and Morocelí (excluding El Coyolar) losses were reduced by 80.1 percent (Table 3). In experiment station trials, the reduction in loss was 35.7 percent (Table 6).

In El Coyolar, two of the four Actellic treatments were repeatedly observed to be infested with *Prostephanus truncatus*. There was an average of 2.6 percent stored-grain insect damage (Table 5). If the *Prostephanus* infestations originated in the field and were inside the maize cobs at the time of treatment and storage, they may not have been affected by the Actellic dust treatment applied to the outside of the cobs. Actellic has been said to have a vapor action but this has not been fully documented (Int. Pest Control, 1976). There are also indications that Actellic may not be as effective in controlling *Prostephanus* as other species of stored-grain insects (Golob, 1983).

In Morocelí, *Sitophilus zeamais* was observed one time each in two Actellic treatments. In Sabana Redonda *S. zeamais* was observed once or twice in three of the four trials. Stored-grain insect damage percentages in Morocelí and Sabana Redonda were 1.31 and 1.59 percent, respectively (Table 5) for Actellic treatments.

Percent damage due to stored-grain insects was lowest for Actellic treatments when compared to lime and traditional treatments in each of the villages (Table 5) as well as in experiment station trials (Table 7).

To confirm the effectiveness of the Actellic and/or lime treatments in field trials, the adjusted average stored-grain insect damage by consecutive months for each type of treatment was determined (Appendix VI). The percent stored-grain insect damage present in maize at the time it was stored was subtracted from that determined at each monthly sampling. The effect of pre-storage damage by the various factors included in the loss assessment methodology was removed and only damage caused by stored-grain insects during storage was compared (Figure 7). Actellic effectively limited the percent increase of insect damage in the stored maize. Lime treatments in field trials were much less effective than Actellic treatments and only slightly more effective than control treatments.

Since both of the improved methods of storage included a raised floor in the troja as well as a thorough cleaning and spraying of the troja, the comparatively lower storage losses when the improved method with Actellic was used in the villages and the experiment station can be attributed to the 2% Actellic dust treatment of the maize ears in the husk.

Effectiveness of Lime

Overall, lime treatments in the field tests reduced losses by 24.6 percent when compared to traditional controls (Table 1). The improved

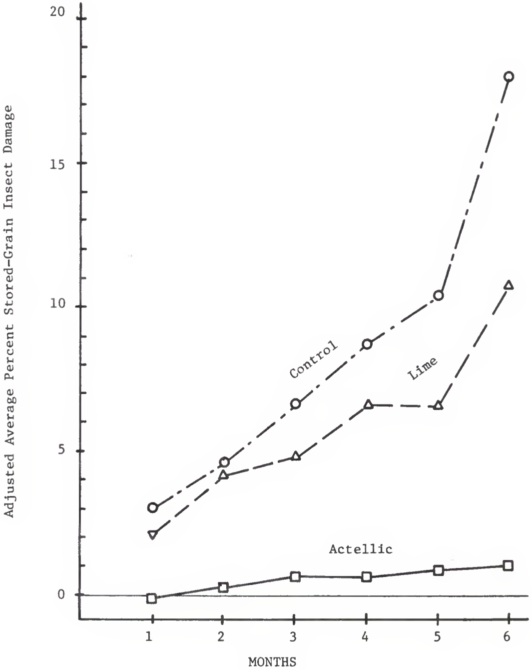
TABLE 7. Percent damage in three maize treatments due to various causes in the experiment station test after 6 months of storage

		Percent Damage Caused by Various Factors					
Treatment	Total Percent Damage	Field Fungi	Dead Cob Fungi[1]	Field Insects and Storage Fungi	Other[2]	Stored-Grain Insects	Percent Weight Loss
Actellic	6.86	0.63	1.52	1.35	2.81	0.55	4.67
Lime	10.55	0.64	1.46	0.57	2.42	5.46	7.02
Control	10.95	2.11	0.78	0.77	1.45	5.84	7.26

[1]Dead cob fungi was defined as Aspergillus spp.

[2]"Other" causes include pre-germinated kernels, multiple causes.

FIGURE 7. Average adjusted percent stored-grain insect damage[1] for Actellic, lime and control field trials over 6 months of storage



[1]Adjusted for percent damage at time of storage.

method using lime showed a high percent of stored-grain insect damage, especially in El Coyolar (Table 5). There were, however, two trials in El Coyolar where very poor selection of cobs resulted in S. zeamais infested maize being placed in storage. This infestation, inside the husks, probably would not have been affected by the lime. In Morocelí and Sabana Redonda, S. zeamais infestations were observed and stored-grain insect damage in lime was 8.61 and 3.83 percent, respectively. In both of these villages, stored-grain insect damage was less than in the traditional controls.

Sukprakarn (1984) and the Honduran-Swiss Proyecto Post-Cosecha (1985) recommended the use of lime as an alternative method of insect control which, although probably not as effective as Actellic, might be expected to keep the population of insects at a reasonable level. In addition, it is locally available and inexpensive. Field test results reported here tend to support this recommendation. However, experiment station trials indicated that lime did not significantly reduce the percentage loss when compared to control trials. This suggests that the good hygiene and proper selection of cobs used in the experiment station trials were the most important factors in reducing storage losses.

Effect of Improved Methods of Storage

In general, the "improved" methods of storage using Actellic and lime appeared to provide degrees of protection for stored maize when compared to the traditional method.

The improved methods of storage using Actellic or lime have to be viewed as a whole. Their performance should never be attributed to a single factor but rather the sum of all practices undertaken. Credit for reducing storage losses should also be given to the other practices included in the improved method: housekeeping, spraying the structure with a liquid insecticide solution, the use of a platform to avoid contact of the maize with the floor, and proper selection of cobs for storage.

Data collected and personal observations made during this study indicated varying degrees of good hygiene (housekeeping) on farms (Table 4). Farms in El Coyolar were observed repeatedly to have poor hygiene in Actellic treatments. In Morocelí and Sabana Redonda poor hygiene was observed primarily in association with traditional control storage sites. In this respect, the farms in Morocelí and Sabana Redonda appeared to be more cooperative in the application of the improved methods (hygiene, etc.) using Actellic or lime.

Observation of rodent activity appeared to be associated with poor hygiene. Although no quantitative measure of rodent damage was made, the greatest frequencies of rodent activity were associated with poor hygiene in Actellic treatments in El Coyolar and with traditional controls in Sabana Redonda (Table 4). Rodent activity was frequently reported in lime treatments in El Coyolar also.

It was also suspected that some farmers whose trojas were used as test sites may have applied insecticides or other treatments to the trojas or maize cobs as part of their "traditional" treatment without the knowledge of the investigator.

Proper selection of the ears in the husk is one of the most important factors for successful storage with a low percentage of loss at the end of the storage period. The Honduran-Swiss Proyecto Post-Cosecha (1985) in its manual "Traditional Troja in Honduras" recommends that only sound ears in the husk be selected for storage. The husks must be free of any evidence of field infestation, be very tight, cover the ear completely, and have a very long and strong end. It was obvious in the improved method with lime treatments in El Coyolar that strict adherence to this recommendation was not followed. In the traditional control treatments where farmers were not given specific guidance on cob selection, less careful selection was probably used than in the improved treatments where farmers were encouraged to select sound cobs for storage.

Estimated Value Gained Using Improved Methods of Storage

To determine the economic advantage from the improved methods, overall mean percent weight losses obtained in the field experiment (Table 1) were used to calculate and compare net savings (Table 8).

Although the average amount of maize stored per farm was about 33 quintals (1 quintal = 100 lb), net savings were calculated for 20 and 45 quintals also. The market price per quintal in the months of June and July (months when farmers commonly do not have maize remaining in storage) was $7.50. This value was used to calculate the dollar loss for each of the treatments.

The cost of treatment was based on pesticide costs only and did not include cost of labor, insecticide sprayer, troja repair materials,

TABLE 8. Net savings to farmers when improved methods of storage with lime or Actellic were used

		Amount of Maize Stored (Quintals)					
		45		33		20	
Treatment	Percent Weight Loss	Weight Loss	Dollar Loss[1]	Weight Loss	Dollar Loss[1]	Weight Loss	Dollar Loss[1]
Traditional	15.0	6.75	50.62	4.95	37.12	3.00	22.50
Lime	11.3	5.08	38.10	3.72	27.90	2.26	16.95
Actellic	6.5	2.92	21.90	2.14	16.05	1.30	9.75

[1]Loss at $7.50 per quintal.

Net Savings with Lime Treatment:

Cost of Treatment	45 Quintals	33 Quintals	20 Quintals
Lime	$ 2.00	$ 1.50	$ 0.90
Malathion 57% E.C.	1.37	1.37	1.37
	$ 3.37	$ 2.87	$ 2.27
Value of Maize Saved	$12.52	$ 9.22	$ 5.55
Net Value Saved	$ 9.15	$ 6.35	$ 3.28

Net Savings with Actellic Treatment:

Cost of Treatment	45 Quintals	33 Quintals	20 Quintals
Actellic	$ 4.25	$ 3.01	$ 1.84
Malathion 57% E.C.	1.37	1.37	1.37
	$ 5.62	$ 4.38	$ 3.21
Value of Maize Saved	$28.72	$21.07	$12.75
Net Value Saved	$23.10	$16.69	$ 9.54

etc. It was assumed that malathion spray treatment of the troja would be the same whether 20, 33 or 45 quintals were stored since the entire troja would require treatment. Cost of the maize protectant was varied dependent on the quantity of maize stored.

The values of maize saved by the improved treatments were calculated by subtracting the value of the improved treatment loss from that lost under traditional storage methods. The net value saved was determined by subtracting the cost of treatment from the value of maize saved. For example, the overall mean percent weight loss reported for the traditional storage method was 15.0 percent. If 33 quintals were stored, 4.95 quintals would be lost with a value of $37.12 (based on $7.50 per quintal). The improved treatment with lime (11.3 percent loss) resulted in a $27.90 loss in value. The value of maize saved using the improved treatment with lime is the difference in value lost between the traditional and lime treatments ($37.12 - $27.90 = $9.22). To determine the net value saved, the cost of pesticides ($2.57/lb) was subtracted from the value of maize saved ($9.22 - $2.87 = $6.35).

Whereas the improved method using lime resulted in a net savings of $6.35 (0.85 quintals of maize), the improved treatment using Actellic resulted in a net savings of $21.07 (2.81 quintals of maize). Storage of smaller amounts would have resulted in less net savings. However, even at 20 quintals (the average amount stored in Morocelí) there was still an advantage using the improved treatments. Storage of 45 quintals of maize was estimated to provide greater savings than at 33 quintals. These results indicate that improved practices, if adopted by small- and medium-sized farmers in Honduras, can reduce storage losses and be economically profitable to the farmer.

CONCLUSIONS

On the basis of data collected in three villages and in the experiment station it was concluded that:

1. The improved method of storing ears of maize in the husk using Actellic was effective in reducing storage losses.
2. The use of lime in conjunction with the improved method of storage gave variable results and its effectiveness should be more fully evaluated.
3. The improved methods of storage tend to reduce losses of maize in storage but do not eliminate them.
4. Good hygiene and proper selection of cobs for storage are the most important aspects of the improved method.
5. Based on the overall mean percent losses, the improved method of storing ears of maize in the husk using Actellic or lime resulted in an economic advantage to the farmer.

LITERATURE CITED

Adams, J.M. and Harman, G.W. 1978. The evaluation of losses in maize stored in a selection of small farms in Zambia with particular reference to the development of a methodology. Report G109. London: Trop. Prod. Inst. 149 pp.

Boshoff, W.H. 1977. Grain drying and storage structures in humid West Africa. Paper presented at the Regional Conference on Post-Harvest Losses, sponsored by the Commonwealth Secretariat, London, in Accra. 7 pp.

Brown, A.W.A. 1951. Insect control by chemicals. London, Chapman and Hall.

Champ, B. and Dyte, C. 1976. Pesticide susceptibility of stored-grain pests. Plant Production and Protection Series No. 5. Rome: FAO. 297 pp.

Chiu, S.F. 1939a. Toxicity studies of so-called "inert" materials with the bean weevil. J. Econ. Ent. 32:240-248.

Chiu, S.F. 1939b. Toxicity studies of so-called inert materials with the rice weevil and the granary weevil. Ibid. 32:810-821.

David, W.A.L. and Gardiner, B.O.C. 1950. Factors influencing the action of dust insecticides. Bull. Ent. Res. 41:1-61.

Delmon, W., La Hue and Dicke, E.B. 1976. Evaluating selected protectants for shelled corn against stored-grain insects. Marketing Report No. 1058. USDA, Washington, D.C.

El Halfawy, M.A., Essa, N.H. and Nakhla, J.M. 1977. Ovicidal effect of certain inert dusts against some stored-grain insects. Plant Protection Res. Inst., Agr. Res. Cent., Minis. of Agri.

El Halfawy, M.A. 1977. A study of the effect of certain inert dusts on some biological effects of Callosobruchus chinensis L. (Coleoptera: Bruchidae). Agric. Res. Rev. V. 55(1):121-124.

Fitzgerald, J.S. 1944. The effectiveness of various mineral dusts for the control of grain pests. Bull. 182. Council for Scientific and Industrial Research Organization, Commonwealth of Australia.

Food and Agriculture Organization of the United Nations. 1977b. Analysis of an FAO survey of post-harvest crop losses in developing countries. (AGPP: Misc/27). Rome: Food and Agriculture Organization of the United Nations.

Germar, B. 1936. Versuche zur Bekampfung des Kornkäfers mit Staubmitteln. Zeit. Angew. Ent. 22:603-630.

Golob, P. 1983. Preliminary field and laboratory trials to control Prostephanus truncatus Horn infestation of maize. Report of the Tropical Products Institute, G164. pp. 62-69.

Harris, Kenton L. and Lindblad, Carl J. 1976. Post-harvest grain loss assessment methods. A manual of methods for the evaluation of post-harvest losses. St. Paul, Amer. Assoc. Cereal Chemists, Inc. 193 pp.

Hoppe, T. 1986. Storage insects of basic food grains in Honduras. Trop. Sci. 26:25-28.

Hsieh, F.K., Hsu, S.L. and Hung, L.M. 1982. Influence of post-treatment temperature on toxicities of 6 organophosphorous insecticides to two species of storage insects. Plant Prot. Bull. (Taiwan) 24:37-48.

International Pest Control. 1976. Actellic - a broad spectrum pesticide for agriculture and public health. International Pest Control 18(1):4-6, 18.

National Academy of Science. 1978. Post-harvest food losses in developing countries. Washington: National Academy of Science. 206 pp.

Ofosu, A. 1977. Persistence of Fenitrithion and Pirimiphos-methyl on shelled maize. Ghana Gour. Agric. Sci. 10:213-216.

Proyecto Post-Cosecha. 1982. Informe sobre los primeros resultados. Ministerio de Recursos Naturales (Honduras), Cooperación Suiza al Desarrollo (COSUDE). Junio. 126 pp. 1 vol. Anexos.

Proyecto Post-Cosecha. 1985. Troja tradicional en Honduras. Ministerio de Recursos Naturales (Honduras), Cooperación Suiza al desarrollo (COSUDE). Tegucigalpa, Honduras. 126 pp.

Proyecto Post-Cosecha. 1986. Evaluación de cuatro tratamientos utilizados para el control del gorgojo de maíz Sitophilus zeamais, Ministerio de Recursos Naturales (Honduras), Cooperación Suiza al desarrollo (COSUDE). Tegucigalpa, Honduras. 11 pp.

Raboud, G., Narvaez, M. and Sieber, J. 1984a. Evaluación de las pérdidas post-producción de maíz a nivel de pequeños y medianos productores en Honduras (América Central). Cooperación Suiza al Desarrollo (COSUDE), Berna, t. 311. Honduras 8, Secretaría de Recursos Naturales.

Raboud, G., Narvaez, M. and Sieber, J. 1984b. Método de evaluación de pérdidas post-producción de granos básicos (maíz, frijol, maicillo) a nivel de pequeños y medianos productores en Honduras (América Central). Cooperación Suiza al Desarrollo (COSUDE), Berna, t. 311. Honduras 8, Secretaría de Recursos Naturales.

Sukprakarn, Chuwit. 1984. Control of stored-grain insect pests in maize. 1984 Grains Post-Harvest Workshop, Kuala Lumpur, Malaysia. Paper No. 8422, 9 pp.

Tsvetkov, D. and Atanasov, K.H. 1979. Promising pesticides for controlling stored-grain pests by mixing with the grain. Plant Protec. Inst. Vol. 16(1):105-114.

Yadav, T.D. et al. 1980. Toxicity of organophosphorous insecticides against stored-product beetles. Indian J. Ent. 42 (1):28-33.

Zacher, F. and Kunike, G. 1930. Beitrage zur Kenntnis der Vorratsschädlinge. 5 Beiträg. Untersuchungen über die insektizide Wirkung von Oxyden und Karbonaven. Arbeit aus der Biol. Reichsanstalt f. Land und Forstwirts 18:201-231.

APPENDIX I

Registration and Calculation Sheet of the Losses in Storage
Proyecto Post-Cosecha - Honduras

B. CALCULATION IN STORAGE

MAIZ, BEANS, SORGHUM

Name:	Code:
Village:	Date of storage:
Municipality:	Form of storage:
Crop, variety:	Type of storage:
Destination 0):	Date of empty storage:

	REGISTER	
Date of sample taken		
N° ears of corn, acorn or fist		
Removed grains: \ <N (rem.)		
Unshelled grains		
Weight r damaged(d) grains		
Weight r 250 (o.....) grains (d)		
Weight r grains none damaged (nd)		
Weight r 500 (o......) grains (nd)		
Weight r total (d + nd)		
Shell product		
500 grains: Number damage (d)		
500 grains: Weight r (nd)		
500 grains: Number none damage (nd)		
500 grains: Weight r (nd)		
Recoverable grains 1): Number		
Weight (grecu)		
Moisture content \		
Existence: In storage under		
Existence: Evaluation		
Unit of measure and equivalent		

	CALCULATION
Non shelled products	
Weight $\bar{x}$ grain (d)	
Weight $\bar{x}$ grain (nd)	
1. Weight p grains (d) = $\frac{\text{Weight r grains (d)}}{\text{Weight X grains (d)}}$ x Weight X grain (nd)	
2. Weight p grains (nd) = Weight r grains (nd)	
3. Weight p grains removed = N (rem.) X Weight $\bar{x}$ grain (nd)	
Weight p total = Weight p (1+2+3)	
\ damage to the sample: $\frac{\text{Weight p (1+3)}}{\text{Weight p (1+2+3)}}$ X 100	
\ sample loss: $\frac{\text{Weight p (1+3) - Weight (grecu)}}{\text{Weight (1+2+3)}}$ X 100	
Shelled product 2)	
Weight $\bar{x}$ grain (d)	
Weight $\bar{x}$ grain (nd)	
Weight p (d) = N (d) X Weight $\bar{x}$ grain (nd)	
Weight p (d+nd)	
\ damage of the sample: $\frac{\text{N (d)}}{500}$ X 100	
\ loss of the sample: $\frac{\text{Weight p (d) - Weight (grecu)}}{\text{Weight p (d+nd)}}$ X 100	
Distribution of the \ of the damage according to cause	

Causes of damage 1)	Causes	Number	100\ of the damage		Damage of the sample	
(a) Pregermination, (b) field fungus, (c) ear of corn fungus "dead", (d) storage fungus, (e) field insects, (f) storage insects, (g) others (specify), or multiple causes (b+d, b+c, b+f, etc...)						
			Removables			
Sub-total pre-production						
Sub-total post-production						
Chemical treatment: product			Total	100\	Total damage 3)	
amount			Moisture content (\): $\bar{x}$			
concentration						
application						
Physical treatment: type						
application			Observations:			
duration						
Retailer's price			0) Consumption, seed, marketing			
Wholesaler's price			1) In case of recuperable grains (prick beans) weight			
Farmer's price			2) It is estimated that we cannot consider the number of removable grains because they do not leave a print			
Observations:			3) The total damage is a percentage of the sample damage			

APPENDIX II

Procedure for the Calculation of Storage Losses and Registration of All Information Derived from Storage Sampling
Proyecto Post-Cosecha - Honduras

NAME OF FARMER OR AREA: ______________________________

VILLAGE: ______________ MUNICIPALITY: ______________ DEPARTMENT: ______________

CROP: ______________________ TYPE OF STORAGE: ______________

VARIETY: ______________________ FORM OF STORASHING: ______________

	M O N T H S / D A T E	*	0	1	2	3	4	5	6	7	8	9
	Treatment											
1	% occasional damage of the sample % occasional loss of the sample											
2	% occasional average damage of the sample % occasional average loss of the sample											
	Amount stored taken out added											
	Total amount stored											
3	Amount taken for total % total stored											
4	% Period damage % Period loss											
5	% Sample storage damage % Sample storage loss											
6	% Period of storage damage % Period of storage loss											
7	% Accumulative storage damage % Accumulative storage loss											
	Causes of damage: a) pre-germination b) field fungus c) fungus of "dead" ears of corn d) storage fungus e) field insects F) storage insects g) others (specify)											

APPENDIX III

Outline of the Loss Assessment Methodology Developed by the Honduran-Swiss Post-Harvest Project

LOSS IN STORAGE

MAIZE
(ears of corn)

Storage
estimate existence

take sample
(10 ears of corn)

shell

determine the % of
removed grains

shell and selection

damage grains (d) | none damage grains (nd)

weigh Weight r (d) | weigh Weight r (nd)

count 250 grains and weigh them | measure the moisture content (%)

determine the cause of damage | count 500 grains and weigh them

determine the weight
(and number) of the
recoverable grains
(grecu)

APPENDIX IV

Procedure for the Monthly Calculation of Storage Damage and Loss

B. CALCULATION IN STORAGE — MAIZ, BEANS, SORGHUM — ACTELLIC TREATMENT

Name:	GUILLERMO VALLEJO	Code:	
Village:	EL COYOLAR	Date of storage:	JAN. 10-85
Municipality:		Form of storage:	EARS of maize in the husk
Crop, variety:		Type of storage:	TROJA
Destination 0):		Date of empty storage:	

	REGISTER	
Date of sample taken	APRIL 9-85	
N° ears of corn, acorn or fist	10	
Removed grains: % N (rem.)	0	
Unshelled grains		
Weight r damaged (d) grains	161.8	
Weight r 250 (o.....) grains (d)	56.3	
Weight r grains none damaged (nd)	1920.9	
Weight r 500 (o......) grains (nd)	159.7	
Weight r total (d + nd)		
Shell product		
500 grains: Number damage (d)		
500 grains: Weight r (nd)		
500 grains: Number none damage (nd)		
500 grains: Weight r (nd)		
Recoverable grains 1): Number	29	
Recoverable grains 1): Weight (grecu)	7.0 gm	
Moisture content %	13.7	
	13.8	
	14.0	
Existence: In storage under		
Existence: Evaluation	16 layers	
Unit of measure and equivalent		

	CALCULATION
Non shelled products	
Weight x̄ grain (d)	0.23
Weight x̄ grain (nd)	0.32
1. Weight p grains (d) = $\frac{\text{Weight r grains (d)}}{\text{Weight } \bar{x} \text{ grains (d)}}$ x Weight x̄ grain (nd)	259.48
2. Weight p grains (nd) = Weight r grains (nd)	1920.90
3. Weight p grains removed = N (rem.) X Weight x̄ grain (nd)	
Weight p total = Weight p (1+2+3)	2150.38
% damage to the sample: $\frac{\text{Weight p (1+3)}}{\text{Weight p (1+2+3)}}$ X 100	10.67
% sample loss: $\frac{\text{Weight p (1+3) - Weight (grecu)}}{\text{Weight (1+2+3)}}$ X 100	9.74
Shelled product 2)	
Weight x̄ grain (d)	
Weight x̄ grain (nd)	
Weight p (d) = N (d) X Weight x̄ grain (nd)	
Weight p (d+nd)	
% damage of the sample: $\frac{\text{N (d)}}{500}$ X 100	
% loss of the sample: $\frac{\text{Weight p (d) - Weight (grecu)}}{\text{Weight p (d+nd)}}$ X 100	

Distribution of the % of the damage according to cause

Causes of damage 1)	Causes	Number		100% of the damage		Damage of the sample
(a) Pregermination, (b) field fungus, (c) ear of corn fungus "dead", (d) storage fungus, (e) field insects, (f) storage insects, (g) others (specify), or multiple causes (b+d, b+c, b+f, etc...)	b	27		10.5		1.15
	c	184		73.6		7.85
	e+d	34		15.6		1.66
			Removables			
Sub-total pre-production						
Sub-total post-production						
			Total	100%	Total damage 3)	

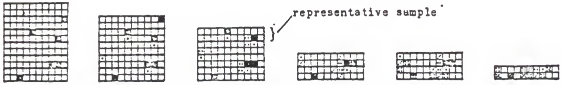
Chemical treatment: product		Moisture content (%): x̄
amount		
concentration		
application		
Physical treatment: type		
application		Observations: incidence of Rodent activity.
duration		
Retailer's price		0) Consumption, seed, marketing
Wholesaler's price		1) In case of recuperable grains (prick beans) weight
Farmer's price		2) It is estimated that we cannot consider the number of removable grains because they do not leave a print
Observations:		3) The total damage is a percentage of the sample damage

APPENDIX V

Estimation of Cumulative Storage Damage Over a 6-Month Storage Period

			0	1	2	3	4	5	6	7	8	9
	Months (Month 0 = Intake month) Date	11.1.52	11.1.52	6.2.52	10.3.52	5.4.52	5.5.52	10.6.52	6.7.52			
	Treatment											
1	% occasional damage of the sample % occasional loss of the sample	*5	0	5	20	30	35	65	65			
2	% occasional damage of the sample % occasional average damage of the sample			2.5	12.5	25	32.5	50	65			
	amount stored		60	50	40	20	20	10	0			
	taken out			10	10	20	0	10	10			
	added											
	total amount stored		60									
3	amount taken into % of the total store			0.16̄	0.16̄	0.33̄	0	0.16̄	0.16̄			
4	% damage in the period % loss in the period											
5	% damage of the sample stored % loss of the sample stored (5 = 2 - *)			-2.5	7.5	20	27.5	45	60			
6	% damage of the storage period % loss of the storage period (6 = 3×5)			-0.42	1.25	6.67	0	7.5	10.0			
7	% damage of accumulative storage % loss of accumulative storage			-0.42	0.83	7.5	7.5	15.0	25.0			

* 5% Storage damage at intake (see graph 4).



Graphic representation of maiz stored in the troja in ears of corn

1		0 →	5	20	30	35	65
2		2.5	12.5	25	32.5	50	65
5	= 2 - *	-2.5	7.5	20	27.5	45	60
		×					
3		0.1667	0.1667	0.3333	0	0.1667	0.1667
		=					
6	= 3×5	-0.42	1.25	6.67	0	7.5	10.0
7	= 6 accumulative	-0.42	0.83	7.5	7.5	15.0	25.0

APPENDIX VI

Percent Stored-Grain Insect Damage in Three Maize Treatments in the Villages of El Coyolar, Morocelí and Sabana Redonda During 6 Months of Storage

		Treatments					
		Actellic		Lime		Control	
Village	Months of Storage	% Damage	Adjusted*	% Damage	Adjusted*	% Damage	Adjusted*
El Coyolar	0	2.23	-	5.68	-	3.31	-
	1	2.24	0.01	8.21	2.53	7.86	4.55
	2	2.61	0.38	10.19	4.51	7.02	3.71
	3	3.42	1.19	12.12	6.44	8.68	5.37
	4	1.69	-0.54	14.35	8.67	8.26	4.95
	5	2.72	0.49	15.27	9.59	9.78	6.47
	6	2.78	0.55	23.14	17.46	26.26	22.95
Morocelí	0	0.51	-	1.22	-	0.20	-
	1	0.18	-0.33	4.21	2.99	4.65	4.45
	2	1.12	0.61	6.78	5.56	7.88	7.68
	3	1.21	0.70	7.21	5.99	9.71	9.51
	4	2.01	1.50	9.86	8.64	12.06	11.86
	5	1.75	1.24	10.21	8.99	13.75	13.55
	6	1.59	1.08	13.39	12.17	15.85	15.65
Sabana Redonda	0	1.01	-	1.97	-	4.73	-
	1	1.02	0.01	2.88	0.91	4.85	0.12
	2	0.85	-0.16	4.17	2.20	7.21	2.48
	3	1.12	0.11	3.98	2.01	9.88	5.15
	4	1.95	0.94	4.25	2.28	14.21	9.48
	5	2.06	1.05	2.97	1.00	16.02	11.29
	6	2.42	1.41	4.73	2.76	20.13	15.40
Village Average	0	1.25	-	2.96	-	2.75	-
	1	1.15	-0.10	5.10	2.14	5.79	3.04
	2	1.53	0.28	7.05	4.09	7.37	4.62
	3	1.92	0.67	7.77	4.81	9.42	6.67
	4	1.88	0.63	9.49	6.53	11.51	8.76
	5	2.18	0.93	9.48	6.52	13.18	10.43
	6	2.26	1.01	13.75	10.79	20.75	18.00

*Adjusted for percent damage at time of storage.

COMPARISON OF TRADITIONAL AND IMPROVED METHODS OF FARM MAIZE STORAGE IN HONDURAS

by

JOSE R. ESPINAL

B.S., University of Southwestern Louisiana, 1982

ABSTRACT OF

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1986

ABSTRACT

The traditional method of storing ears of maize in the husk in Honduras was compared to an improved method of storage using Actellic or lime. The improved method including cleaning, repair and insecticide spraying of the storage unit (troja) as well as careful selection of maize cobs for storage. Field experiments were conducted in three villages in the Central-East region of Honduras. In two villages, the improved method using Actellic or lime resulted in significantly lower losses than the traditional method. Factors responsible for variable results obtained in the third village are discussed.

A controlled comparison, made at the Honduran-Swiss Post-Harvest Project station, verified the importance of cob selection and good hygiene. Actellic used with the improved method resulted in the least amount of loss due to insect damage.

Overall mean percent weight losses were used to calculate estimated net savings when the improved method was used. Actellic was the most cost-effective treatment.