A critical review of the methodology for assessing farm-level grain losses after harvest (G191)

Tropical Development and Research Institute

G191

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FOREWORD

In the past, efforts to increase world food supplies largely concentrated upon increasing production, but in the early 1970s there was developing awareness that total food availability could be improved through a reduction of post-harvest losses. This awareness culminated in September 1975 in a resolution of the Seventh Special Session of the United Nations General Assembly stating that 'the further reduction of post-harvest food losses in developing countries should be undertaken as a matter of priority, with a view to reaching at least 50% reduction by 1985'. Following the Seventh Special Session, an Interdepartmental Sub-Committee of the FAO on Reduction of Post-Harvest Food Losses in Developing Countries reviewed past and current activity and concluded: 'There is no agreed methodology of post-harvest loss assessment. Moreover, loss data are generally unrelated to the cost of loss reduction'. In its interpretation of available information on losses the sub-committee concluded that 'there can be no agreed single figure for the percentage of post-harvest losses on a global scale or even on a national basis.' There is clearly a need, already noted, for more accurate assessment of these losses, to establish firm justification for the development and introduction of measures designed to reduce them where the cost/benefit ratios of conservation measures are favourable.'

In mid-1976, the American Association of Cereal Chemists (AACC), with a grant from the US Agency for International Development to the League for International Food Education (LIFE) and recognising the need above, began the development of a methodology for assessing post-harvest grain losses with the emphasis at the farm level. As a result of the project a manual (*see* Harris and Lindblad, 1978) was published to provide the means whereby post-harvest losses might be estimated in a standardized and meaningful way so that effective grain loss reduction efforts might be undertaken in developing countries. The volume was intended for use by all who are dealing not only with post-harvest grain losses, but also with the problems involved in offering alternative storage and handling systems in developing countries. It was a pioneer work which both derived from the past experience of a team of experts and projected their hypotheses. Nevertheless, in preparing the manual it was recognised that because of the enormous variability of local post-harvest systems, no complete or definitive loss assessment methodology for all situations would be practicable. Thus, the manual was not proposed as a final and absolute piece of work and the editors realised that with field-testing experience, expansion and refinement of the loss assessment techniques would be desirable and possible. By agreement with the authors and AACC/LIFE, USAID sought the assistance of GASGA (Group for the Assistance on Systems relating to Grain After-harvest) in seeking feedback from users of the manual and co-ordination of further development of loss assessment methods. Within GASGA, the Tropical Development and Research Institute (TDRI)—a major contributor to the manual—assumed this responsibility.

Although inevitably lacking in some aspects, the manual has provided an acceptable basis to guide those intending to conduct loss assessment studies. By adopting the methodology offered, results have been obtained that are considered more reliable and comparable than has hitherto been possible. However, experience in the field has confirmed that the methods are not universally applicable and in some cases lead to erroneous results. It must be emphasised that the field experience accumulated has arisen largely from assessing losses at the farm level, and particularly in farm storage. Surprisingly, little systematic work has been undertaken on assessing losses in co-operative and central stores. It is appropriate, therefore, to review the methodology for loss assessment in the light of field data and laboratory studies as they relate to the farm level. The aim is to discuss the current state of knowledge on aspects of post-harvest loss assessment, to provide guidelines for assessing losses and to indicate where such guidelines cannot, at present, be given and where further work is needed.

Summaries

SUMMARY

In 1976, the American Association of Cereal Chemists, with a grant from the US Agency for International Development to the League for International Food Education, began to assemble a methodology for assessing post-harvest grain losses. As a result of this initiative, a manual (*Post-Harvest Grain Loss Assessment Methods*, by K. L. Harris and C. J. Lindblad) was published in 1978, detailing the techniques available for the measurement and interpretation of losses which occur after harvest at the farm level. A major difficulty experienced in compiling the methodology was that the authors necessarily drew heavily upon experiences gained from developed countries and limited specific examples from some developing countries. Nevertheless, the manual served usefully to provide guidelines to meet a wide variety of requirements. Experience from the many field studies of post-harvest losses conducted since 1978, has confirmed that the techniques are not universally applicable and that frequently some modification is required.

This report examines the current state of knowledge on aspects of post-harvest loss assessment and offers guidance to those concerned with measuring losses at the farm level.

In the first section, certain key terms, commonly used in relation to post-harvest loss assessment, are defined and the concept of the post-harvest system is discussed. This is followed by a consideration of the objectives of loss assessment projects and a discussion of the requirements, in terms of finance, equipment, manpower, etc. both for the rapid appraisal and more detailed studies of specific parts of the post-harvest system.

A section is devoted to a description of the various techniques for assessing the losses which occur during harvesting, threshing, drying and milling and attention is drawn to some of the practical difficulties which have been encountered in field studies.

The principal agents responsible for loss of grain during storage are insects, micro-organisms and vertebrate pests (rodent and birds). The techniques for measuring loss caused by these agents, originally described by Harris and Lindblad (1978), are reviewed and once again the practical difficulties of applying the techniques under field conditions are discussed. Consideration is given to the expression of the total storage loss which occurs in a season as a loss of available food rather than as a simple weight loss. A new method of assessing losses caused by insects is described.

The subject of sampling grain is given special treatment. The need for representative samples in loss assessment studies is emphasised. Guidance is offered on the appropriateness of various sampling techniques, and on the methods of packaging, labelling, transportation and storage of grain samples.

Finally, the importance of loss assessment as part of loss reduction is stressed. Loss assessment studies may serve as a means of justifying or evaluating proposed methods of reducing losses but the social and economic consequences of change must be taken into consideration before recommending a technical improvement.

RÉSUMÉ

En 1976, l'«American Association of Cereal Chemists» commença, à l'aide d'une bourse allouée par l'«United States Agency for International Development» (USAID) à la «League for International Food Education», à élaborer une méthodologie pour l'évaluation des pertes en grains post-récolte. Il en résulta un manuel (*Post-Harvest Grain Loss Assessment Methods*, par K. L. Harris et C. J. Lindblad), publié en 1978, lequel présente en détail les différentes techniques disponibles pour la mesure et l'interprétation des pertes en grains pouvant se produire après la récolte au niveau de l'exploitation. Une difficulté majeure rencontrée par les auteurs lors de l'élaboration de cette méthodologie tient au fait évident qu'ils ont dû se baser largement sur les résultats de l'expérience de pays développés et sur peu d'exemples spécifiques de pays en voie de développement. Toutefois, ce manuel s'est révélé utile en ceci qu'il contient des directives répondant à une grande variéte de besoins. A partir de nombreuses études conduites sur le terrain depuis 1978 relativement aux pertes post-récolte, l'expérience acquise a confirmé le fait que les techniques ne sont pas applicables dans le monde entier et qu'il faut fréquemment y apporter des modifications.

Le présent rapport fait le point sur les connaissances actuelles relatives à l'évaluation des pertes en grains post-récolte et offre des conseils utiles à tous ceux qui se trouvent confrontés à la tâche de mesurer les pertes en grains au niveau de l'exploitation.

Dans la premiere section sont rassemblés et définis certains termes-clés couramment utilisés dans le domaine de l'évaluation des pertes post-récolte. Le concept du sytème post-récolte y est également discuté. Viennent ensuite un examen des objectifs des projets d'evaluation de pertes ainsi qu'un état des besoins, en termes de finance, de matériel, de main-d'oeuvre, etc., permettant tout à la fois une estimation rapide et des études plus détaillées des volets spécifiques du système post-récolte.

Une section entiére est consacrée à la description des diverses techniques d'évaluation des pertes se produisant pendant la moisson, le battage, le séchage et la mouture, les auteurs attirant l'attention sur les difficultés pratiques rencontrées dans les études sur le terrain.

Les principaux agents responsables des pertes en grains durant le stockage sont les insectes, les micro-organismes et certains déprédateurs vertébrés (rongeurs et oiseaux). Les différentes techniques utilisées pour mesurer les pertes provoqués par les agents mentionnés ci-dessus (techniques décrites à l'origine par Harris et Lindblad (1978)), sont passées en revues, et les difficultés d'ordre pratique s'appliquant aux techniques en champ y sont à nouveau discutées. Il y est également examiné la manière d'exprimer la perte totale en stock se produisant au cours d'une saision, à savoir en termes de 'perte alimentaire' plutôt qu'en simple perte de poids. Cette section décrit également une nouvelle méthode d'évaluation des pertes causées par les insectes.

Le sujet relatif au prélèvement d'échantillon de grains est traité avec un soin particulier. On insiste sur l'importance de disposer d'échantillons représentatifs dans les études ayant trait à l'évaluation des pertes. Des conseils sont donnés sur l'opportunité des diverses techniques d'échantillonnage, ainsi que sur les méthodes de conditionnement, d'étiquetage, de transport et de stockage des échantillons de grains.

Enfin, l'importance de l'évaluation des pertes en tant qu'agent contribuant à la réduction de celles-ci y est soulignée. Les études d'évaluation des pertes peuvant servir à justifier ou à évaluer des projets de méthodes de réduction de pertes, mais il faut toutefois tenir compte des conséquences sociales et économiques de tout changement avant de recommander des améliorations techniques.

RESUMEN

En 1976, la Asociación Americana de Químicos de Cereales, con una subvención otorgada por la Agencia Estadounidense para el Desarrollo Internacional a la Liga para la Educación Alimentaria Internacional, comenzó a confeccionar una metodología para evaluar las pérdidas de granos posteriores a la recolección. Como resultado de esta iniciativa, en 1978 fue publicado un manual (Métodos de evaluación de pérdidas de granos posteriores a la recolección, por K. L. Harris y C. J. Lindblad), en el cual se detallan las técnicas disponibles para la medición e interpretación de las pérdidas producidas después de la recolección a nivel de la granja. Una importante dificultad experimentada por los autores al compilar la metodología, fue que necesariamente hubieron de basarse intensamente en las experiencias adquiridas en los países desarrollados, teniendo ejemplos específicos limitados procedentes de países en vías de desarrollo. No obstante, el manual fue de gran utilidad al ofrecer líneas de guía para satisfacer una amplia diversidad de requerimientos. La experiencia obtenida en muchos estudios sobre el terreno de pérdidas posteriores a recolección, realizados desde 1978, ha confirmado que las técnicas no son universalmente aplicables y que con frecuencia se requiere ciertas modificaciones.

En este informe se analiza el estado actual de conocimiento en el aspecto de la evaluación de pérdidas posteriores a recolección, y se ofrecen líneas de guía a aquellos dedicados a la medición de las pérdidas a nivel de la granja.

En la primera sección se definen ciertos términos clave usados comunmente en relación con la evaluación de pérdidas posteriores a recolección, al tiempo que se analiza el concepto del sistema de recolección posterior. Todo ello va seguido de un estudio de los objetivos de los proyectos de evaluación de pérdidas, así como de un análisis de los requerimientos, en lo que refiere a la financiación, equipamiento, mano de obra, etc., tanto para una evaluación rápida como para un estudio más detallado sobre las partes específicas del sistema de recolección posterior.

Una sección se concentra en una descripción de las diversas técnicas para evaluar las pérdidas que se producen durante la recolección, trilla, secado y molido, dedicándose atención especial en algunas de las dificultades prácticas que se han planteado en los estudios sobre el terreno.

Los agentes responsables principalmente de la pérdida de granos durante el almacenaje son los insectos, los microorganismos y las plagas de vertebrados (roedores y aves). Las técnicas para la medición de pérdidas causadas por estos agentes—originalmente descritas por Harris y Lindblad (1978)—son descritas y, de nuevo, son analizadas las dificultades prácticas de la aplicación de dichas técnicas sobre el terreno. Además, es considerada la expresión de la pérdida de almacenaje total ocurrida en una temporada como pérdida de producto alimentario disponible, en lugar de serlo como una simple pérdida de peso.

Es analizado de manera especial el tema del muestreo de granos. Es subrayada la necesidad de introducir muestras representativas en los estudios de evaluación de pérdidas. Es ofrecido asesoramiento en torno a la idoneidad de varias técnicas de muestreo, así como en torno a los métodos de empaquetado, rotulado, transporte y almacenaje de las muestras de granos.

Por último, es subrayada la importancia que reviste la evaluación de pérdidas como parte de la reducción de pérdidas. Los estudios de evaluación de pérdidas

peuden servir a modo de justificar o de clasificar los métodos propuestos para reducir la cantidad de pérdidas, pero las consecuencias sociales y económicas del cambio deben tenerse en cuenta antes de recomendarse una mejora técnica específica.

Section 1

Introduction

DEFINITIONS

The terminology used by authors in discussions of post-harvest loss has, in the past, been ambiguous and imprecise and so certain key terms must be defined to avoid confusion. The following definitions which are now widely accepted are based largely upon those of Bourne (I977).

Grain	Is used in this review in a broad sense and includes cereals and pulses; it includes cereals on the head, ear or cob, and after threshing or shelling, and pulses both shelled and in pod.
Food	Means the weight of wholesome, edible material, measured on a moisture-free basis, that would normally be consumed by humans.
Harvest	Is the single deliberate act of separating the food material from the site of immediate growth or production.
Post-harvest	Means after separation from the site of immediate growth or production. Post-harvest begins at cutting and ends when the food enters the mouth. However, in practical post-harvest loss studies, the end point is reached when the grain or grain product is finally prepared for consumption.
Post-production	'Harvest' and 'Post-harvest' may sometimes be combined and referred to as post-production. However in certain circumstances post-production begins at physiological maturity of the grain. For example, in parts of Latin America, the mature maize plant may be bent over or 'doubled' in the field and left for several months before the cobs are actually collected.
Grain loss	Is the loss in weight of food grain that would have been eaten had it remained in the food chain.
Harvest loss	Is the grain loss which occurs between the onset and completion of harvesting.
Post-harvest loss	Is grain loss which occurs at any time after separation from the site of immediate growth, or production up to the point at which the grain is prepared for consumption.
Post-production loss	Harvest losses are sometimes combined with post-harvest losses because there are some elements of common concern. The combined losses are known as post-production loss. The term also includes grain loss which occurs in the mature crop remaining in the field for further drying or holding.

Loss	Is a measurable decrease of food grain which may be quantitative or qualitative.
Damage	Refers to the superficial evidence of deterioration, for example, holed or broken grains, from which loss may result.

Food grain losses may be direct or indirect. A direct loss is disappearance of food by spillage, or consumption by insects, rodents and birds. An indirect loss is the lowering of food quality to the point where people refuse to eat it.

The extent of post-harvest loss expressed on a weight basis is important, but not all-important. It may be necessary at times to record loss in terms of loss of nutritional units, as economic loss, or as loss of seed material. It is difficult to categorize loss. However, the following categories are listed for convenience, to demonstrate that loss may be expressed in terms other than weight loss, and should not be regarded as exclusive. In any assessment of losses it will be necessary for the investigator to draw up his own definition relevant to his specific requirements.

Weight loss

Reduction in weight is obvious but it does not always indicate loss—it may be due to reduced moisture content and this is recognized in commerce by a shrinkage factor. This may be an economic loss if it is not taken into account by grading for price control, but it is an artificial loss. True weight loss may result from the feeding of insects, rodents and birds, or from spillage. The latter may be due to poor handling or the activities of pests. Moisture changes may lead to an increase in weight and, in some cases, production of water by an insect infestation may partly offset the weight loss. Consider the following example: If the weight of a sack of produce before storage is compared with its weight after storage, any reduction in weight may be described as the apparent loss. However, during the period of storage the moisture content of the commodity may have increased and insects may have consumed some of it, producing non-edible dust, frass, etc. Since the additional moisture and the non-edible results of insect attack do not constitute food, they form part of the true loss.

Quality loss

Quality of produce is assessed in different ways according to the factors considered important by the local population and traders concerned. Generally, quality is assessed and products graded on the basis of appearance, shape, size, etc., but smell and flavour are sometimes included. Foreign matter may be in the form of insect fragments, frass, rodent hairs and excreta, weed seeds, parts of plants, earth, stones, glass, etc. Contaminants, on the other hand, cannot be readily removed; they include soluble excretions of pests, oils, pesticides, pathogenic organisms spread by rodents, and toxins arising from fungal infections.

Nutritional loss

Nutritional loss, in a sense, is the product of the quantitative and qualitative losses, but more specifically, it is the loss in terms of nutritional value to the human population concerned. For example, a bruchid infestation can cause serious weight loss in pulses, such as beans, where up to 25% of the dry matter is crude protein.

Weight loss during storage, excluding loss of moisture, is a measure of food loss, but the nutrient loss may be proportionately larger due to selective feeding by the pests. Rodents and some insect larvae may preferentially attack the germ of the grain thus removing a large percentage of the protein and vitamin content, whereas weevils feeding mainly on the endosperm will mostly reduce the carbohydrate content. It is sometimes suggested that an infestation adds to the protein content of the grain. The facts are that the proportion of nitrogen, including non-protein nitrogen, may increase relative to the quantity of grain left by the insects, but there will be a net decrease in the available protein. Many pests may eat the bran of cereals, reducing the vitamins such as thiamin. Other storage factors such as moisture, temperature and fungal infection also lead to changes in vitamin content.

Loss of seed viability

Loss of seed viability relates to loss in seed germination, which is important for its effect on future food supplies.

Seed grain is usually more carefully stored than food grain owing to its greater potential value. Loss may be caused by changes of light, temperature, moisture, excessive respiration, infestation and, in some cases, the methods used to control infestation. Insects that selectively attack the germ will cause greater loss in germination than others.

Commercial losses

Commercial losses may occur as a direct consequence of any of the foregoing factors or indirectly as the cost of preventive or remedial actions required, including that of the necessary equipment. For example, any control measure that has to be employed to render or keep the commodity saleable can be counted as an economic loss and this is perhaps the most easily accountable. Indirect consequences of loss may be encountered where measures have to be taken to prevent loss of goodwill or to cover legal actions arising from the marketing of commercially unacceptable commodities.

The nature and extent of loss, then, is important, but should not be the sole consideration in deciding whether or not to undertake a loss reduction programme, how to implement it and where to concentrate efforts. Factors such as the value of grain in economic terms, the sociological changes which might result from loss reduction activities and the overall effects of a programme on producers, storers, traders and consumers, must also be considered. Too often, little attention has been paid to such factors and loss assessment projects have simply concentrated on producing figures for the extent of food loss alone, without regard to the implications of this loss.

THE FOODGRAIN SYSTEM

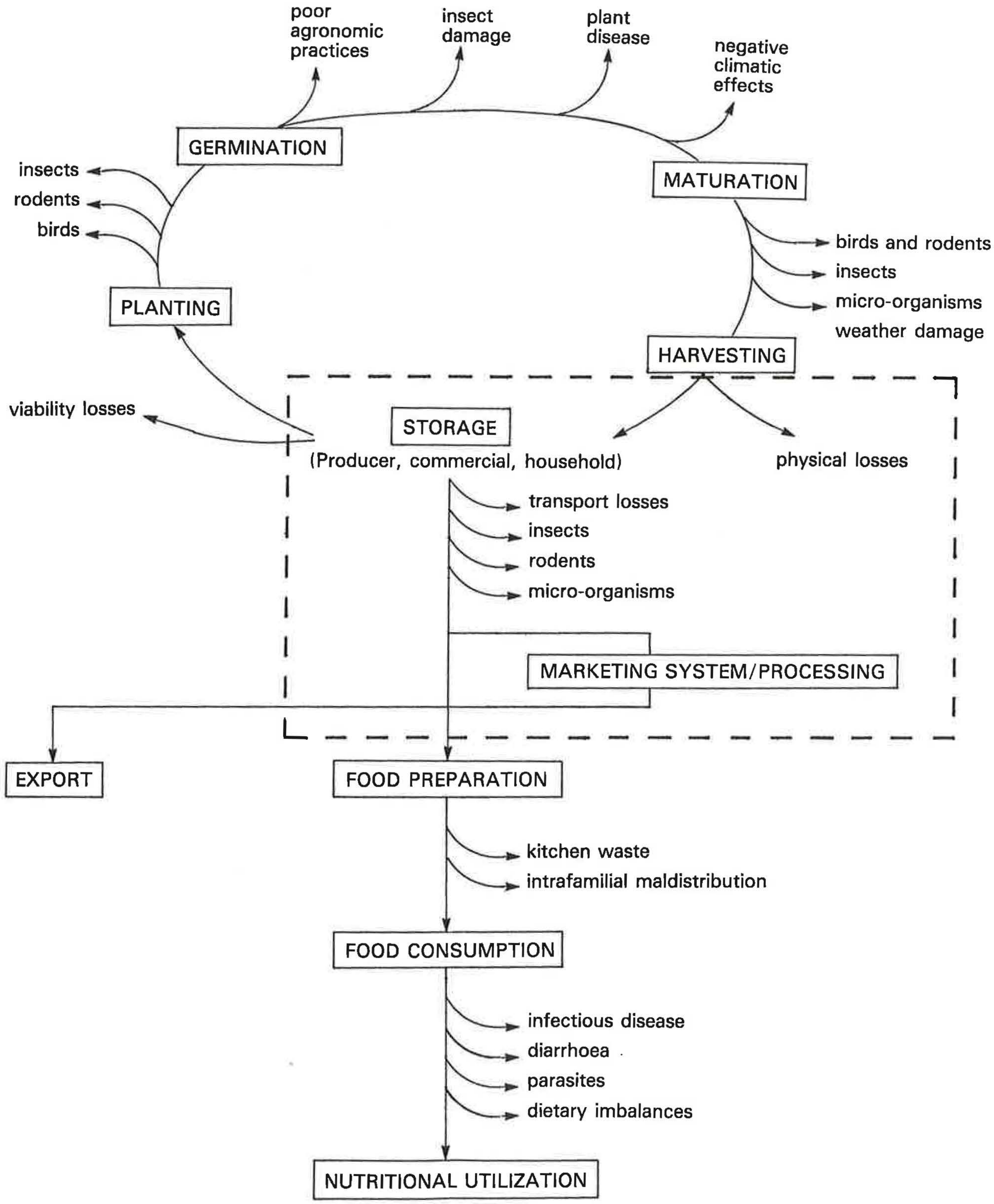
The farm level foodgrain system illustrated in Figure I shows the many points at which losses of food can occur. The focus of the loss assessment manual was the post-harvest system, i.e. the area enclosed within the box in the figure, but experience has shown that at times it is more appropriate to refer to the post-production system, which includes harvesting.

The system illustrated is a relatively simple one, but where the urban community is increasing, the system will become more and more complex and various government departments will be charged with the responsibility for its operation in relation to national priorities or needs. Three main departments can be identified:

The Department of Agriculture—which is clearly responsible for the production part of the system—may also play an important role in the development and the implementation of foodgrain policy programmes, particularly as they apply to the farm sector. However, this responsibility is likely to be shared with the next department, the Department of Food—this department's responsibilities are directed more towards the consumer. It is usually responsible for the processing, distribution and utilization of foodgrains, but in meeting its responsibilities in distribution it is almost always assisted by the third department—the Department of Grain Marketing. As well as providing a link between the rural and urban sectors and surplus and deficit regions of a country as far as foodgrains are concerned, the Department may (and should) work closely with the Department of Agriculture, providing the necessary inputs for agricultural production.

Figure 1

The farm-level foodgrain system



Source: Harris and Lindblad, 1978

The development of national foodgrain programmes calls for co-ordination between the production and post-harvest (or post-production) sectors of the total foodgrain system and will involve at least the three departments mentioned above. Naturally, other departments will be involved and these might include Departments of Economics, Planning, Industry and Commerce.

In viewing the total foodgrain system, it is important to remember that losses occurring in the post-production part of the system are finite, unlike the growing crop losses which might be made up by further plant growth. This has led to increasing interest in and concern about post-production losses, especially post-harvest losses, and particularly in developing countries in the belief that a reduction of such losses will contribute positively to the alleviation of world food shortages.

The post-harvest system was depicted by Bourne (l977) as a pipeline through which food passes from field to consumer. The purpose of viewing the foodgrain supply system in this way was to enable the identification of individual points where losses may occur and to determine their relative importance in terms of loss in other parts of the pipeline. This relative perspective is necessary to see the importance of the total amount of grain actually lost at any given point as opposed to the percentage of grain lost which passes through that point. Furthermore, it ensures an understanding of the relationships between the different parts of the system and the importance of various factors on the levels of loss at specific points of the system. Observations of a single point in the system do not allow losses to be put into perspective. Losses during storage, for example, are affected by conditions prevailing in the pre-storage stages (harvesting, threshing, drying) and similarly, post-storage losses may be affected by conditions during storage. It is possible, therefore, that the real extent of loss which arises at a given stage of the system may not become apparent until very much later. For example, grain which is physically damaged during harvesting or threshing may be more susceptible to pest attack in store. Similarly, the result of insect infestation during storage may lead to an inferior and unacceptable milled or processed product.

In countries where farming is predominantly at the subsistence level, it has been estimated that approximately 70% of cereal grain production is retained and stored at the farm level. It is not surprising, therefore, to find that many post-harvest loss reduction programmes have concentrated on the small farmer whose post-harvest practices, especially the storage methods, are considered inefficient and wasteful though this is certainly not always the case. The published methodology for assessment of post-harvest losses has been developed primarily for use at the farm level in recognition that the loss may be greatest in this sector. The early methodology was based largely upon experience from basic research caried out at the farm level, e.g. by Schulten (l972) and Adams and Harman (l977), and the opinions of a number of post-harvest specialists.

Section 2

Project planning

OBJECTIVES—THE NEED FOR RELIABLE ESTIMATES OF LOSS

The primary objective of undertaking measurements of post-harvest losses must be to establish the justification for the development, and where feasible, the introduction of methods designed to reduce them. The extent of loss occurring after harvest may not be sufficient to justify remedial action. Nevertheless, the action may be more than justified when other factors—economic, sociological or political—are taken into consideration. A major criticism of many of the early surveys of post-harvest losses is that objectivity was often lacking.

Literature reviews undertaken by TDRI (Adams, 1977) and FAO (UN:FAO, 1977) to determine the extent of available information on post-harvest losses in cereals have demonstrated that there are numerous examples of extremely high estimates of unsubstantiated losses and that confusion has often arisen because of the terminology used by authors. Aggregated data reflecting losses on a world-wide basis are of little value and similarly, high figures such as 35% for grain losses in India and 46% for sorghum losses in Nigeria (Scrimshaw, 1978) would be grossly misleading and give a greatly distorted view of the real situation. There is always a temptation to cite extreme figures for loss, to dramatize a problem or to attract assistance from a donor agency. Misinterpretation of high figures may also result from arithmetical errors arising from a misunderstanding of the correct basis of their calculation. In quoting figures at different stages of the post-harvest system, the loss at each stage has sometimes been totalled, leading to over-estimates of loss. This is because it was assumed that each loss figure is a percentage of the original weight of material, whereas in fact each figure for loss is a percentage of the amount remaining in the previous stage of the system (*see* Table I).

Table I

Illustration of how post-harvest losses may be overestimated

Stage	*% loss*	*Weight loss (kg)*	*Balance (kg)*
Start	—	—	1,000.00
Harvesting	15	150.00	850.00
Threshing	10	85.00	765.00
Drying	5	38.25	726.75
Transport	5	36.34	690.41
Storage	10	69.04	621.37
Processing	10	62.14	559.23
	55%	440.77	

The total loss, 55%, obtained simply by adding the loss at each stage, is an overestimate. The actual loss can be seen from the weights recorded in the last two columns, in this example, 440.77 kg loss from the potential 1,000 kg, or 44.07%.

Farm storage losses are susceptible to exaggeration if the pattern of grain withdrawal from the store is overlooked. Losses recorded at one period during the storage season will not give an indication of overall losses throughout the year. If the objective is to know what losses farmers are suffering then a study over the whole storage season is vital. If grain remains untouched throughout the storage period and at the time of removal, the estimated loss due to insects is 10%, then this indeed represents the loss over the storage period. However, in most cases grain is removed for consumption at intervals. Consequently, each quantity removed will have suffered a different degree of loss, since it will have been exposed to deterioration for a different length of time, and allowance has to be made for this when determining the total estimate of loss (Adams, 1978).

Furthermore, in such a survey, the loss must be seen from the viewpoint of the person suffering the loss. It will be found that a relatively large loss in times of plenty may be quite acceptable to the farmer whereas he would regard even a small loss in times of shortage as important. Consumer practices must also be considered. A failing of many early projects has been that insufficient attention has been paid to qualitative deterioration. The expression of storage loss as a weight loss caused, say, by insects, fails to highlight the fact that considerable deterioration due to insect activity may have occurred, and that a portion of the grain removed from store would be rejected as unfit for consumption. The amount of grain rejected would of course depend upon the crop yield and the status of the farmer. In a good year, all farmers may be able to exercise a high level of selection, but in poor years the poorer members of the community at least may have no option but to consume substandard grain.

Isolated measures of loss, for example the much-quoted global figure of 10% for post-harvest losses of cereal grains to insects after harvest, may serve as a preliminary indicators to draw the attention of administrators and others responsible for post-harvest matters to the fact that some loss is occurring—and the need for more detailed study. With figures from observations of loss at one point in time, it is quite impossible to decide on the nature and the scale of priorities for a programme to reduce losses. Only when the whole post-harvest system (from threshing through storage to processing) has been fully understood can accurately determined estimates of losses of grain be realistically related to the system. The figure obtained (whether for high or low losses) can then be used in the determination of priorities for loss reduction work in a positive way. Moreover, when remedial measures have been introduced, subsequent measurements of loss made using the same technique will enable the effectiveness of the remedial measures to be determined. Repeated measurements can be used to provide permanent monitoring of a potential loss situation and can be used as an indication of the efficiency of the system or process.

It will be necessary to assess the scale of the study and the level of reliability needed, and to set realistic objectives. The objectives may initially be prepared by those with no local knowledge of the system to be studied or, alternatively, by those with little concept of what is involved in the practical aspects of the work. There may be a temptation to strive for detailed, accurate figures, when gross estimates will suffice. Where high and obvious losses are occurring, and where all that is needed is a reference point from which improvements can be judged, crude measurements alone can be justified. The detailed measurements will be needed only where losses are not so obvious.

THE RAPID APPRAISAL

It is prohibitively expensive and unjustifiable to conduct country-wide loss assessment studies throughout the whole post-harvest system. An expert judgement is needed to identify the most serious grain loss points in order to prepare in-depth assessments of those points where losses are significant, but at the same time ensuring that the assessments can realistically be achieved given the resources available. An essential prerequisite of any post-harvest loss assessment programme is, therefore, a rapid appraisal of the whole physical and social system in which grain is passing from producer to consumer. This appraisal identifies (a) how commodities are handled and treated and by whom, (b) the number and types of intermediate steps in the system, (c) the types and causes of loss, and (d) the points at which most food loss is occurring, and their relative importance. The objective is to permit judgements to be made about the nature of interventions to reduce losses or whether there is a need to intervene at all and to enable decisions on the resources required for a detailed study if this is deemed necessary. It will provide a certain amount of background or baseline information and will indicate the need for additional data collection in the main or detailed study of losses.

The objectives of the main study of losses should be drawn up during the rapid appraisal, but some allowance should be made for their revision at the initial stages since the scale of the work may have been over- or underestimated.

Timing of loss assessment studies in relation to the state of the crop season is of the utmost importance. Studies must start at the beginning of the season, i.e. at harvest time, and to achieve this, sufficient preparation time must be allowed to complete the selection of sample sites, selection and training of staff, development and testing of the methodology, especially in relation to data collection and sample analysis. The planning of loss assessment studies should therefore be scheduled for the crop season immediately before the season of the actual loss assessment study.

The movement of foodgrain from producers to consumers may involve an extremely complex system but, despite the complexities, experienced members of a preliminary appraisal mission can focus on significant loss points, sometimes making useful estimates of loss and identifying possible intervention methods. This first appraisal of a system has become accepted by the international agencies as a 30-60 day exercise, but in reality no hard-and-fast rule can be applied. The length of time needed to complete the exercise is determined by the complexity of the system and the nature and degree of information being sought.

The composition of the mission undertaking such an exercise will vary according to the complexity of the system under study and the size of the task to be undertaken, but a multi-disciplinary approach has been recommended. For example, the mission might draw upon the specializations of a grain marketing economist, a grain storage technologist, a processing specialist and an engineer. When working at the farm level it must be remembered that in many developing countries it is the women who play an important role in post-harvest operations and in order to retrieve information on those practices carried out by women, the mission (and subsequent loss assessment projects) should include one or more female investigators, with knowledge of the post-harvest system. Collaboration with local official bodies is essential in reaching a thorough understanding of the system, since they will be able to provide information on economic, social, political and cultural factors which must be considered as well as grain movement logistics and personnel. The local organizations may also be able to provide specialist manpower to support the mission, particularly if a discipline is not represented on the official team.

The terms of reference for a rapid appraisal mission will include the following:

(i) describing the post-harvest system using available local, official statistics, and other information from key informants;

(ii) undertaking a broad survey of the post-harvest system to identify:
- the individuals responsible for handling, storing, marketing and processing the crops;
- the quantities of grain handled/stored at each stage and the period of storage;
- the reasons for storage at each stage (grain use);

—the general conditions for handling, storing and processing, including an assessment of adequacy in capacity and design;

(iii) reviewing all available data on post-harvest losses to identify the major causes and extent of losses and where such information is lacking;

(iv) reviewing the present loss reduction activities and identifying how existing techniques might be improved; and

(v) designing a suitable programme of further investigation and/or loss reduction; identifying the resources required for implementation.

General, or specific conclusions based on known scientific principles can be drawn from an expert evaluation of the points at which grain losses occur and the evidence of loss. The following factors may be considered in a rapid appraisal of the post-harvest system:

—harvesting, threshing and drying procedures
—the types and condition of the grain handling, storage and processing facilities and their relative importance one with another
—the period during which grain is held at each stage of the post-harvest system
—grain moisture content, and temperature; ambient relative humidity and temperature; quality control procedures (including use of pesticides) at each stage of the post-harvest system
—evidence of pests, including the species present, the kind and amount of damage, such as insect-damaged grains, insect frass, grains gnawed by rodents and rodent excreta
—evidence of mechanical damage arising from handling and processing equipment

The significance of individual factors or a combination of factors in relation to a particular stage of the post-harvest system will lead the experienced individual to a general conclusion about the extent of losses. This, in addition to contributing to a decision on whether the stage of the system should be surveyed in depth, may be as much as the situation warrants, especially if losses are low. At low levels of loss even an in-depth assessment based on currently recommended sampling procedures may be subject to an error as great as the loss itself.

There is a need to guard against the specific or individual approach where a biased assessment may be made by an expert from a single discipline. For example, the storage entomologist may study the problem area in terms of maximum loss that insects could cause, or the engineer may see the problem in terms of justification for better storage structures or drying facilities, and the economist may see it in terms of credit availability. All these factors may be important but, so may many others. No single one can be considered in isolation from the whole system.

The systematic approach, which is recommended here, implies studying the system as it exists and then devising as a concept the perfect system, one that is completely free of constraints. This may naturally be too idealistic, but one can determine the important constraints that can be removed and how, thus arriving at a pragmatic system which, though not perfect, is significantly better than that which exists.

A checklist of sources of information likely to be useful during the planning of a post-harvest loss assessment project and questions to be used during the early stages of a farm level survey are given in Appendix I.

STAFFING

Two key issues which need careful consideration in determining the staffing requirements of a loss assessment programme are (i) the specializations needed and (ii) the extent to which specialist staff need to be involved in full-time supervision, as distinct from supervisory visits at predetermined intervals.

A full-time, multidisciplinary team has been favoured for loss assessment studies, particularly during the preliminary stages and more especially during the rapid appraisal. Multidisciplinary teams may be difficult to manage and specialist interests may tend to lead towards a number of individual approaches to loss assessment, rather than the systematic approach. However, Hildebrand (1981) quotes an example of the success of a multidisciplinary approach to the identification of constraints to agricultural development in Latin America. He considered that the individuals concerned must be well trained in their own field and need a working understanding of one or more of the other fields represented. The team members must not feel the need to defend themselves and their field from intrusion by others and must work to achieve together a final product for which all are equally responsible. He further considered that the multidisciplinary approach frequently fails because teams are organized as committees which meet only occasionally to co-ordinate efforts, but in which the specialist topics are dealt with solely by the individual specialists.

With regard to post-harvest loss assessment studies it has usually been found difficult to field teams comprising more than a post-harvest technologist and an economist, although this two-man team may have received occasional support from other specialist disciplines from local institutions. The systematic approach has been largely achieved where enthusiastic generalists (or specialists) who have exhibited a capability over a range of aspects of the problems have been involved. This is not to suggest that the concept of a multidisciplinary approach should be abandoned altogether, rather that an individual can cope adequately so long as he understands the complexities of the post-harvest system and is willing and able to call upon the specialist advice of other disciplines at appropriate times throughout the duration of the loss assessment programme.

The need to employ full-time staff will depend to a large extent upon the scale of the loss assessment study. Ideally, an individual experienced in post-harvest loss assessment should be employed full time in a project but, invariably, generally-qualified local staff, inexperienced in loss assessment techniques are entrusted with the day-to-day operation of a project and consultants used at important stages, e.g. planning, mid-term evaluation and final evaluation. This approach has been adopted in many projects undertaken under the auspices of the Food and Agricultural Organization's Prevention of Food Losses Programme (UN:FAO, 1978). The approach can work efficiently but provision for adequate training of local staff in loss assessment techniques designed to the local situation must be made at the planning stage. Furthermore, the local supervisory staff must be employed full time in the loss assessment project. There is sometimes a tendency to fit a loss assessment study into an organization's already full programme, with the result that a project programme may fall behind, or collapse between consultancy visits leading to a situation in which the consultant has to carry a disproportionate burden of the work. Unsupervised staff may be directed by local management to other duties at crucial times of the loss assessment project and local staff may, in addition, be incapable of analysing data and samples due to lack of experience.

In addition to the specialist(s) and supervisory staff, a loss assessment team will include a number of field investigators, to conduct questionnaire surveys and to collect samples, etc., and supporting technicians to undertake analysis of samples and data. The number of support staff required will depend upon the scope of the project to be undertaken, but difficulty is often encountered in providing adequate numbers. It may prove too expensive to engage support staff full-time in a loss assessment project and organizations may be called upon to provide manpower services for specific periods. Some projects have, however, engaged survey and/or laboratory technicians on a full-time basis (Boxall *et al.*, 1978; Huq and Greeley, 1980; Boxall and Gillett, 1982), but agricultural extension services have sometimes provided the manpower for routine sampling of farmers' grain stores in studies of farm storage losses (Golob, 1981). Extension agents who are normally in regular contact with the farming community should be able to make regular visits to a number of farmers' stores to collect samples without adding too much of a burden to their routine work. Extension agents must of course be sufficiently mobile to be able to visit the survey area on the occasions demanded by the sampling programme. Close liaison with the extension department will be necessary to ensure that the department's own scheduled activities do not clash with the project activities and that the project's activities in turn will not be seriously interrupted by local leave arrangements.

In some circumstances it may be more appropriate for investigators to have more frequent contact with farmers and this may only be achieved by employing staff full-time for the duration of the study. If this approach is adopted, the preparation time required may be somewhat extended since the investigators will need to establish a rapport with the communities in which they will be working, since rural communities invariably treat newcomers with suspicion, whereas a regular extension worker will already have been accepted by the community.
Consideration is sometimes given to employing students of agricultural schools or colleges as field investigators or laboratory technicians, but this is rarely satisfactory except perhaps for preliminary appraisals or studies of post-harvest operations which extend over only a few weeks, e.g. harvesting, threshing, etc. Students usually cannot be released to undertake studies of storage losses (which must necessarily extend over a full season) except for very limited investigations conducted as part of a school or college research project.

FINANCE

It is usually possible to identify within a country one specific organization with responsibility for the sector of the post-harvest system to be studied in detail, but occasionally two or more organizations may have an interest in and wish to contribute to a loss assessment project. When this occurs, problems may arise over the financing and financial control of the project. Care must be taken to establish at the outset the contribution that collaborating organizations will make. Staff may be permitted to work on a loss assessment project, but their parent organization may not be prepared to cover the travel and *per diem* costs incurred by this work. Similarly, vehicles may be provided but the contributing organization may require reimbursement of drivers' salaries, running costs, etc.

Where these problems are likely to arise, an independent supervisor or co-ordinator should be sought, to be responsible for the day-to-day general and financial administration of the project. Ideally a national co-ordinating body should accept this responsibility.

EQUIPMENT

It is impossible to give firm guidelines on the equipment that will suit every type of study; nevertheless the manual *Post harvest Grain Loss Assessment Methods* referred to certain items that would be needed. Few details or specifications were given.

The Food and Agriculture Organization of the United Nations recognised, in relation to its Action Programme for the Prevention of Food Losses (FAO/PFL) the need for a reference list of equipment which includes more precise descriptions, and requested the Tropical Development and Research Institute to prepare this. The document that was subsequently produced (Tyler and Boxall, 1979) was primarily intended for use in conjunction with the manual. The compilers consulted 'all those who had made technical contribution to the manual but were also mindful of the need to identify suppliers to provide a regional or even world-wide service'.

The list had a rather limited distribution and use and so a revised version has been included in this review (*see* Appendix II). The revision incorporates experiences derived from a number of loss assessment studies, and some items of equipment for which no specification is necessary are included for the sake of completeness. It must be stressed that the final choice will be governed by several factors, for example the field of work under study, the scale of the exercise to be undertaken, the size of the budget allocation and the degree of accuracy required.

RECORDING INFORMATION

Questionnaires and data-sheets

Any survey of post-harvest losses will generate a wealth of information which eventually will have to be carefully analysed. The analysis will be made that much simpler if the information collected is assembled in an orderly manner. This means that the information, whether it relates to observations or measurements in the field or to the results of laboratory analyses, will inevitably be recorded on a series of forms designed specifically for the project.

It is impossible to describe a standard set of forms that will meet every eventuality, but some examples of forms used in loss assessment studies and some guidance on the design of such forms are given in Appendix III.

It is important to remember to collect only that information which is relevant to the specific objectives of the project. There is sometimes a tendency to collect vast amounts of information simply because the project has a team of investigators and it is considered that the results may be useful at some later stage. Whilst essential information must be collected, it may be possible to reduce the amount of form-filling by referring to readily available sources of information. For example there would be little point in attempting to collect crop-production data prior to selection of field survey areas for a loss assessment study if that same information was available in agricultural year books or in reports of a central statistics office.

Record forms for post-harvest loss assessment surveys can be placed into four main categories.

(I) *Background*—To provide information of a general and specific nature on the survey area, agricultural, especially post-harvest practices, the community—its organization, and economic and social structure, etc. These forms of course include the questionnaires, some of which might be used once, for example, at the beginning of the season, or at regular intervals,for example, to monitor seasonal changes throughout the duration of a survey.

(2) *Field observations and measurements*—To record details of post-harvest operations under study and measurements made in the field. For example,details of grain storage structures, construction, maintenance, etc. and measurements of moisture content, temperature and quantities of grain handled.

(3) *Analyses*—These forms may be used in the field or laboratory or for some studies, in both. They will be used mainly to record the results of sample examination.

(4) *Summary*—In order to calculate losses, the results of analyses of grain samples will have to be related to information collected in the field. For example, in an assessment of storage losses, measurements of loss obtained from sample analysis in the laboratory must be related to quantities of grain removed from store and this is best achieved by assembling the information from both field and laboratory into a summary form.

Information from questionnaires, relating, for example, to consumption patterns, farm income, etc. also needs to be summarized. In preparing the forms thought must be given to the order in which data are to be collected and recorded. The form can then be laid out in such a manner that the recorder can follow it through in a logical progression without the need to study a separate set of lengthy instructions.

Inevitably instructions will be needed for some types of form but if the forms are designed and tested in 'dry runs' before the actual data collection begins, an optimal design needing the minimum amount of explanation can be achieved. A set of instructions on how to complete forms should, however, be prepared and be readily available for reference by field workers so that there can be no mistake about what or how information should be recorded. It should be stressed here that questions must be asked every time, otherwise there may be a tendency for an investigator to assume that he knows the answers in advance. This may sound obvious, but once an investigator has received the same answer to the same question a number of times, he may tend to overlook it.

Field notebooks

Field investigators will invariably record their observations or measurements on field record or sample forms which will be returned to the survey headquarters. Sometimes this is the only record that is made and there is often a risk that the information will be lost. To guard against this a duplicate set of forms could be completed, to be retained by the investigator or, alternatively, the information could be recorded in a bound notebook. This notebook could also be used to record instructions for completion of forms, details of how, when and where to collect samples, lists of sample households, as well as serving as a diary for the investigator's day-to-day activities.

Computer records

Computer facilities are being used more frequently for assembling and analysing data from loss assessment studies. When it is intended that computer facilities will be used it is essential that the advice of a computer programmer should be sought in designing the record forms to determine how units of measurements should be recorded, what information can be precoded and how, etc., otherwise a lengthy transcription process will be needed.

Section 3

The main survey of post-harvest losses

SCOPE OF THE SURVEY

The main survey of losses typically results from the rapid appraisal of the post-harvest system which will have identified the critical points of potential or actual loss. The broad objectives of the main survey may have been defined at this stage, but allowance must still be made for some modification during the preparatory stages of the field investigation. The main survey must have a pattern that is replicable so that comparisons of loss can be made. These comparisons must be statistically valid and must be undertaken within a logical framework of field investigation (survey and sampling) and scientific measurement (sample analysis).

The rapid appraisal of the post-harvest system will have provided much information about the sector to be studied in detail, but further investigation may be necessary before the main survey can begin. The objectives must now be clearly defined and the survey planned in detail. Decisions must be made concerning the following:

- the area to be covered by the survey
- the nature of the information to be collected
- the methods of collecting the data
- the sampling units, the type and size of sample and the methods of selection
- the type of sample analysis

The correct decisions are only possible when one has sufficient knowledge of the nature of the situation to be studied and the possible variability of the sample. For example, many factors, such as climate, farm size, grain variety, traditional practices and extension activity will influence the extent of loss and these factors may have to be considered when making a selection of farms for a loss assessment study.

A knowledge of the practicality of collecting the required information is also required. This may be obtained from the rapid appraisal but more frequently it is necessary to conduct a pilot or preliminary survey because this knowledge is lacking, or as a means of checking the time and resources needed in the main survey. The preliminary survey also provides the opportunity for testing procedures and techniques and for training field investigators.

This review is not the place for a detailed discussion on survey methodology, although reference must be made to basic principles and practical experiences from loss assessment studies. A standard textbook should be consulted for a full discussion of survey techniques. For example Yates, (1981) provides comprehensive coverage of the subject and includes a short course of reading which provides a good introduction to the statistical basis of sampling. Nevertheless, it is strongly recommended that the advice of a statistician with experience of agricultural surveys should also be sought during the planning of the main survey.

SELECTION OF THE SURVEY AREA AND SAMPLES

Nation-wide surveys of post-harvest losses can rarely be undertaken and usually studies will be limited to a specific part of the country. The decision on the boundaries of the survey area will usually be taken during the rapid appraisal and will be affected by a number of factors, for example:

(i) the area may be defined by the national government—purely on a political basis,

(ii) the area may be a major development area which might derive benefit from a well justified loss reduction programme,

(iii) the presence of a suitable project base such as a research institute or field station,

(iv) the degree of communication within the area and with other parts of the country, and

(v) the importance of the crops grown in relation to national production.

Once the boundaries of the area have been established, the preliminary survey can be made to determine the locations at which the assessment of loss will take place and the units from which samples will be taken. A recognized statistical procedure should be employed for selecting farms or villages if it is intended to apply the resultant loss data to an estimate of loss over the area as a whole. The survey should provide information from truly representative samples of the area under study, not just from locations which are convenient to visit or known to the extension service.

Before selecting a sample, the population in the survey area must be divided into units (e.g. villages or farms) which can then be listed. From this list, or sampling frame, samples can be drawn at random by giving each unit in the frame a number and choosing as many units as necessary using random tables (*see* Appendix IV). In this way each unit has an equal chance of selection, irrespective of which other units are included.

Simple random sampling may be possible if the survey area is small and when the population is uniform, i.e. every unit has similar characteristics. However, this is not usually the case with loss assessment surveys.

When the survey area is large, such as a whole country or a region, the sample population must be divided into manageable proportions using a multistage, stratified, random sample. This involves dividing the population into a number of first-stage units with selected units being divided into smaller second-stage units and so on, each selection being made at random.

Ideally, specialist advice from a statistician should be sought before a decision is taken on the way in which the sub-divisions are made. Much will depend upon local conditions, but an area may be divided by political boundaries, geographical divisions or agro-climatic regions as the first stage in stratification. Within each of these divisions, a sample of units is then selected at random, but usually these units will be too large to be used for the detailed investigations and a further sub-division will be necessary.

The selection of the sub-divisions may be in relation to the impact of conditions upon the post-harvest losses being studied and marginal areas may be excluded without seriously affecting the results of the study, thereby making the collection of information simpler.

For example, a study may be concerned with one particular crop, and so the areas where the crop is not grown, or is of very minor importance, may be excluded. The next sub-division might be on the basis of villages or small administrative units, and in this case the units should be listed and random numbers used to choose as many units as can be measured with the resources available. The procedure can be repeated to obtain a final selection of sample units (individual farmers).

This approach might be possible in theory, at least in those areas where lists of farmers exist, but there may be constraints to obtaining a pure random sample. For example, the degree to which a farmer is prepared to co-operate with the loss assessment project, and the accessibility of the farm households (houses or groups of houses may be entirely cut off for long periods during the rainy season). Often, the selection of farm households is made more difficult because lists of individual farms or farmers do not exist, or the available information is out of date. In the latter case it would be possible to overcome the problem by selecting more farms than necessary so that a reserve list could be used if farms selected by strict random sampling were no longer available. In some countries, villages, as such, may not exist because farmers live on their own holdings or on one of several scattered holdings. Attempts to compile lists might require more effort than the loss assessment exercise itself and other methods of sampling, such as area or cluster sampling, may be more appropriate, (De Lima, 1973, 1978).

It is, however, necessary to add a world of caution with respect to the random selection of survey sites. The loss figure obtained from such a selection will be an average for several different agro-climatic zones, regions, farm sizes and, depending upon the stage being studied, different harvesting, threshing, storage or processing sytems. Furthermore, when stratified sampling is adopted, the variables which affect the extent of loss may be so numerous that only small samples of each sub-group can be obtained, thereby limiting the statistical value of the loss estimates. Such results will be unhelpful when it comes to recommending a loss reduction programme. Under some circumstances it may, therefore, be appropriate to modify the method of random selection described above, in the light of observations made during the rapid appraisal or preliminary survey, or to meet the specific objectives of the loss assessment exercise. The following examples serve to illustrate these points:

(a) preliminary observations of farm-level grain storage reveal that of the many different types of store in a region only three are widely used. In this case it would be appropriate to select stores in four groups; three representing each of the major store types and one which included all other types of store,

(b) where improved post-harvest practices have already been adopted by some farmers, the loss assessment study might be more concerned with an evaluation of the new techniques rather than deriving an average figure for loss in the area. However, the improvements might be poorly represented in the sample if the selection was entirely at random and so it would be advisable to select approximately equal numbers of improved and traditional units in this case.

Some examples of sampling plans are given in Appendix V.

Sampling units

The ultimate observational unit (sampling unit) from which a sample will be removed will differ according to the stage of the post-harvest system being studied. It is the smallest unit in which grain is held. In studies of harvesting, it may be individual plots in a farmer's field; at threshing it may be stacks of unthreshed panicles, and during storage it may be a storage bin or similar structure or even an individual bag within a store. It is important to remember that the accuracy of the entire survey will depend upon the accuracy with which the loss is determined in each sampling unit. It is therefore essential that the investigator should record exactly what was done and why, so that the significance of the data can be understood by all those who will use it.

Numbers of samples

The number of sampling units needed to achieve a given degree of precision can be calculated given two pieces of information:

(i) the desired precision of the result—(i.e. the estimate of the overall average loss within 1, 2, 5 or 10%).
and

(ii) the range of loss to be expected (i.e. the difference in per cent, between the highest and the lowest expected loss).

The number of sampling units required to obtain a representative sample can be predicted from Table 2 below.

Table 2

Number of sampling units required to achieve a given degree of precision

	Range of losses expected (%)								
	100	80	60	50	40	30	20	10	5
Desired ± 1%	5,625	3,600	2,025	1,406	900	506	225	54	14
Precision ± 2%	1,406	900	507	351	225	126	57	14	4
± 5%	225	144	81	56	36	20	9	2	—
± 10%	57	36	21	14	9	5	3	—	—

Source: Harris and Lindblad, 1978.
Note: This table was derived by standard calculations based on a conservative estimate of population defined standard deviation = range/4. From: Recommended practice for choice of sample size to estimate the average quality of a lot or process—ASTM: E122-58. American Society for Testing Materials (1958).

If a loss assessment team felt that it could not cope with the predicted number of samples, a lower degree of precision would have to be accepted. If the range of loss were underestimated the samples will be insufficient. It is therefore recommended that liberal estimates should be made of the expected range.

Table 2 is mathematically calculated to ensure representative sampling regardless of the total population size. If the actual number of units in the population is less than the number given in the table, then all the units should be sampled.

Example of how to use the table:

In a study of farm storage losses, the highest expected loss is estimated to be 60% and the lowest expected loss estimated to be 10%. The range is therefore 50%. If the desired precision is ±5%, then according to the table, the survey must include at least 56 sampling units.

In practice, it may be difficult to predict the range of losses, especially where there is little information regarding the extent of damage to grain. Golob (1981), investigating storage losses of maize and sorghum in Malawi, was faced with this situation. The maximum range of losses he predicted, in this instance 30%, was derived as follows:

'Early work in Malawi by others had indicated a maximum loss of 10% (range 0-10%) for maize in a full season, and it was assumed that in the current study, losses would not exceed this value. Little field information was available for sorghum, but in the laboratory it was found that grain weevils, the major pest, readily attacked the sorghum and it was estimated that as much as 60% of the grain might be lost in a season. With this information a pattern of sampling could be estimated. The damage caused by insects would increase with time, but the level of loss measured between one month and the next (i.e. between two sampling visits) would not be great. It was assumed that the loss between any two consecutive months would be most unlikely to exceed half the total estimated loss (60%). It was therefore reasonable to take 30% as the predicted range of loss.'

Section 4

Losses which occur during pre-storage handling and grain processing

GENERAL PRINCIPLES

The handling and processing operations to be considered include harvesting, threshing, drying and milling. The losses which occur during these stages may be direct physical losses, such as spillage and grains removed by vertebrate pests or indirect losses, such as heat damage resulting in food of lower nutritional value or lower commercial value. Many of the losses are, at least in part, avoidable by improved techniques, changes or adjustments in machinery, etc. but the processor will have to decide whether the modifications to the processing system to improve yield or quality are justified in terms of increased returns. It is common to regard the processes through which grain passes as 'continuous' or 'batch' (Dendy and Harris, 1978).

When studying losses in a continuous process, e.g. commercial rice milling, it will be necessary to collect samples at regular, timed intervals from the input and output sides of the process under investigation. However, farm and village level studies are more likely to be concerned with batch processes, e.g. involving a single bag of grain. In this case single samples will be collected at input and output. There are two basic methods for assessing losses during processing and these involve either:

(a) measurement of the total system, or

(b) comparison with a standard.

Measurement of the system usually relates to batch processes in which the loss itself can sometimes be measured. For example, grain left on the straw during threshing, or on the cob during maize shelling (i.e. the loss) could be recovered by hand stripping and weighed. In other processes the loss must be determined by comparing the weight of grain entering the process with the total weight of the product(s).

Losses, particularly in continuous processes, may be determined by comparison with an optimum or standard process. For example, the products from a commercial rice mill might be compared with products from a laboratory mill using the same source of paddy. The loss here is not so much a loss of food material, but a lowering of value; for example, rice which contains a high proportion of broken grains may be regarded as being of lower quality compared with whole grain rice.

The approach is not ideal because the laboratory unit must be closely controlled and standardized to ensure an optimum procedure. Examples of the use of a laboratory standard are discussed later in a consideration of the measurement of paddy drying losses and losses in rice milling.

In order to make comparisons of grain weights recorded at different times in a loss assessment study, all measurements should be converted to a standard moisture content or to a dry weight. Different workers often choose different standard moisture contents—for example, Dendy and Harris (1978) recommend that when studying losses in threshing, drying, milling, etc. weights should be expressed at 15% moisture content. Toquero (1981), however, suggests that a 14% standard moisture content is most commonly used. There is no reason why one moisture content should be used in preference to another, but it must be clearly stated at the outset which standard moisture content is to be adopted throughout a particular study. The adjustment of grain weights to a standard moisture content is given by the formula:

$$\text{Wt. of grain at std. \% m.c.} = \frac{\text{Wt. of grain} \times (100 - \text{\% m.c. of grain})}{(100 - \text{std. \% m.c.})}$$

Toquero (1981) provided a table of conversion factors to obtain grain weights at 14% m.c. (*see* Table 3). The weight of grain at a given moisture content should be multiplied by the appropriate factor. However, it would seem more convenient to work on the basis of the dry weight of grain which can be simply calculated from the formula:

$$\text{Dry wt. of grain} = \frac{\text{Wt. of grain} \times (100 - \text{\% m.c. of grain})}{100}$$

Losses which occur during any type of grain processing are likely to depend to some extent on the efficiency of the processor or operator and it may be difficult to decide whether or not he is working normally. There may be a tendency to work more diligently simply to impress the investigator with the result that losses may be greater or lower than normal. This possible source of bias to measurement of loss may be overcome more readily in farm-level studies if the various operations are carefully observed to establish the norm before beginning actual measurements.

Table 3

Conversion factors to obtain grain weights at 14% moisture content

Multiply by

Moisture content %	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
8	1.0698	1.0686	1.0674	1.0663	1.0651	1.0640	1.0628	1.0616	1.0605	1.0593
9	1.0581	1.0570	1.0558	1.0547	1.0535	1.0523	1.0512	1.0500	1.0488	1.0477
10	1.0465	1.0453	0.0442	1.0430	1.0419	1.0407	1.0395	1.0384	1.0372	1.0360
11	1.0349	1.0337	1.0326	1.0314	1.0302	1.0291	1.0279	1.0267	1.0256	1.0244
12	1.0233	1.0221	1.0209	1.0198	1.0186	1.0174	1.0163	1.0151	1.0140	1.0128
13	1.0116	0.0105	1.0093	1.0081	1.0070	1.0058	1.0047	1.0035	1.0023	1.0012
14	1.0000	0.9988	0.9977	0.9965	0.9953	0.9942	0.9930	0.9919	0.9907	0.9895
15	0.9884	0.9872	0.9860	0.9849	0.9837	0.9826	0.9814	0.9802	0.9791	0.9779
16	0.9767	0.9756	0.9744	0.9733	0.9721	0.9709	0.9698	0.9686	0.9674	0.9663
17	0.9651	0.9640	0.9628	0.9616	0.9605	0.9593	0.9581	0.9570	0.9558	0.9547
18	0.9535	0.9523	0.9512	0.9500	0.9488	0.9477	0.9465	0.9453	0.9442	0.9430
19	0.9419	0.9407	0.9395	0.9384	0.9372	0.9360	0.9349	0.9337	0.9326	0.9314
20	0.9302	0.9291	0.9279	0.9267	0.9256	0.9244	0.9233	0.9221	0.9209	0.9198
21	0.9189	0.9174	0.9163	0.9151	0.9140	0.9118	0.9116	0.9105	0.9093	0.9081
22	0.9070	0.9058	0.9047	0.9035	0.9023	0.9012	0.9000	0.8988	0.8977	0.8965
23	0.8953	0.8942	0.8930	0.8919	0.8907	0.8895	0.8884	0.8872	0.8860	0.8849
24	0.8837	0.8826	0.8814	0.8802	0.8791	0.8779	0.8767	0.8766	0.8744	0.8733
25	0.8721	0.8709	0.8698	0.8686	0.8674	0.8663	0.8651	0.8640	0.8626	0.8616
26	0.8605	0.8593	0.8581	0.8570	0.8558	0.8547	0.8535	0.8523	0.8512	0.8500
27	0.8488	0.8477	0.8465	0.8453	0.8442	0.8430	0.8418	0.8407	0.8395	0.8384
28	0.8372	0.8360	0.8349	0.8337	0.8326	0.8314	0.8302	0.8291	0.8279	0.8267
29	0.8256	0.8244	0.8233	0.8221	0.8209	0.8198	0.8186	0.8174	0.8163	0.8151
30	0.8140	0.8128	0.8116	0.8105	0.8093	0.8081	0.8070	0.8058	0.8047	0.8035
31	0.8023	0.8012	0.8000	0.7988	0.7977	0.7665	0.7953	0.7942	0.7930	0.7919
32	0.7907	0.7895	0.7884	0.7872	0.7860	0.7849	0.7837	0.7826	0.7814	0.7802

Source: Toquero 1981

The published methods for assessing processing losses were examples intended to guide workers studying similar operations. Many of the methods were untested and were therefore little more than suggestions. There appear to have been few studies of losses in processing and many of the procedures are still untried.

The losses which occur during harvesting are strictly post-production rather than post-harvest losses and for this reason they were considered beyond the scope of the publication *Post-harvest grain loss assessment methods*. However, some workers, (e.g. Huq and Greeley, 1980) combined studies of harvesting losses with studies of threshing loss and others, (e.g. Toquero, 1981) clearly consider that post-harvest loss assessment studies should embrace harvesting. Little experimental work appears to have been undertaken to develop methods of estimating losses at harvesting and threshing. Certainly Huq and Greeley (1980) and Qureshi (1980) reported that they were unable to trace information in the literature that could guide the selection of a suitable method. It therefore seems appropriate to mention harvesting losses in this review, if only to indicate that further development of methodology is required.

HARVESTING LOSSES

There is an optimum time for harvesting when immature grains, shedding/shattering losses and weather damage will be minimal. At the appointed time of harvest the method used and the skill of the harvester will affect the yield of grain. Thus, the amount of loss needs to be measured in relation to both the stage at which it is harvested and the methods employed.

The damage which grain suffers during harvesting may directly affect the losses which arise later in the system. If the crop is harvested too early, there will be a high proportion of immature grains which, because of their high moisture content, will deteriorate rapidly in store. If harvesting is delayed, mature grains may suffer attacks of insects, micro-organisms, etc. and may be physically damaged through repeated wetting and drying, for example, by rain or dew followed by hot sun. Damage of this kind may be serious for paddy.

In the following pages methods for assessing shattering and shedding losses are discussed. The basic approach is to measure the potential yield of the crop under study and the actual yield achieved by the farmer (sometimes referred to as the obtained yield). The approach is the same whether the crop is harvested by hand or machine. However, there has been some debate about how the potential yield should be calculated. The potential yield is the yield which might have been achieved if there had been no losses of any kind. It may be determined in two ways:

(i) by performing all the operations from a sample area of the field under careful supervision to avoid any shattering loss, and

(ii) by collecting all the grain lost at each stage during the farmer's own operations, e.g. gleaning of the field, etc., and adding this to his actual yield.

Method I provides a potential yield measurement based on the removal of all grains from the straw or panicle at the time of harvesting, but Johnson (1978) warns that the yield patterns in most fields are very pronounced, and to detect the 2–10% losses one might expect with harvesting, hundreds of samples would have to be taken. The potential yield can be estimated by sampling the crop for tillers per square metre and grains per tiller, and either assuming or measuring a 1,000 grain weight, but again this requires a large number of samples to obtain an accurate estimate of the yield.

Huq and Greeley (1980) calculated the potential yield by cutting sample plots under controlled conditions and weighing the farmer's grain after threshing to obtain the actual yield. The yield difference, as a percentage of the potential yield is then equal to the loss incurred in the operations from cutting to threshing. The disadvantage here is that the method does not distinguish the incidence of loss by operation from harvesting through to threshing. Huq and Greeley undertook a study of the efficiency of the method, which is essentially based upon crop cutting techniques for estimating yields in variety trials, and demonstrated the practical difficulties of obtaining accurate measurements of potential yield from small plot areas. They reported that high inter-plot variation prevented the use of comparative yield estimates (potential and actual) from different plots even within the same field, and therefore the potential yield estimate must be based upon a sample crop cut from the plot being used to estimate the farmer's actual yield. Randomizing the selection of sample cuts and choosing small plots of visibly uniform yield—avoiding edge effects, soil fertility gradients and localized pest damage—reduced the possibilities of intra-plot variation which would invalidate or reduce the significance of results. Measurements of area in these small crop-cut-estimating procedures introduces another form of bias leading to over-estimates of yield. There is an inverse relationship between the size of crop cut and the degree of error in estimating. The problem is that the smaller the area the larger the edges are in relation to the total size of cut, and therefore any inaccuracy in measurement will cause a higher degree of error in smaller crop cuts; yet to obtain a series of random sample cuts from a small total plot area requires use of a small sample cut. The difficulties in obtaining accurate measurements of potential yield from small plot areas are well known. It has been demonstrated that estimates of yields from a small plot one foot square can be up to four times greater than estimates obtained using a sample plot l6 feet square (Mahalanobis, l96l).

Huq and Greeley's final conclusion, after using the sample yield approach to measuring potential yield over two seasons' studies, was that the results were too variable for the technique to be adopted as a suitable method for assessing losses.

The second method, i.e. gleaning of the field after harvesting, was discussed by Johnson (l978) who drew attention to the disadvantages:

(i) it is tedious, time consuming and labour consuming if done accurately,

(ii) grains may be so small or so coloured as to be difficult to find,

(iii) in dry soils seeds may be lost in cracks,

(iv) in wet, muddy soils seeds may be buried under the feet of workers, and.

(v) in special cases (e.g. rice) seeds may be lost in water remaining on the field.

He further considered that, from the point of view of loss assessment, harvesting losses fall into two main categories—uniformly distributed and concentrated. The uniformly distributed losses include pre-harvest shedding and scattering during cutting and are said to be relatively easy to assess. Concentrated losses occur when grain is stooked or stacked in the field or when it is loaded on to transport for removal from the field.

The procedures for assessing uniformly distributed and concentrated categories of loss are essentially the same, but the latter requires many more samples. The descriptions of the methods given below are taken from Johnson (l978).

(a) Uniformly distributed losses

Areas of 0.l-l m^2 are selected at random in a field and all grains, panicles, etc. found within that area counted. Some idea of the magnitude of this sort of loss assessment is given by FAO (UN:FAO, l968) in a report on paddy losses in Thailand. One square metre sampling areas were used, each one taking up to an hour to sample. When the statistical analysis was made, it was estimated that 30 samples per field would be necessary to be able to say with 90% probability that the true loss was within 20% of the average found and l00 samples if the range was to be reduced to l0. The average field size was 0.l hectare. Having determined the average loss per square metre, the loss in kilograms per hectare can be quickly calculated. It is normal when making this type of loss assessment to count the grains rather than weigh them, and, using the 1,000 grain weight for that crop, estimate the loss per hectare direct. (For casual checking of field losses, the 1 m^2 sampling area is too slow and cumbersome. A much simpler system is a 0.1 m^2 square or circular frame of wire that can be thrown at random in a field. These frames can normally be sampled in 2-5 minutes).

(b) Concentrated losses

More samples are required when assessing concentrated losses because of wide variation in counts between areas with and without concentrated losses. In some cases the areas where concentrated losses might occur can be isolated and sampled separately. For example, where grain has been stooked to dry (*see* p.28), the sites of the stooks can be marked and sampled after carting the grain off. The average loss per stook can then be multiplied by the number of stooks in a hectare to give the drying loss. Another form of concentrated loss that can distort statistics is the occasional complete panicle with up to 300 seeds in the sampling area. This can sometimes be overcome by differentiating between shattering losses (individual grains), and loss of grains on the panicles which might arise especially during mechanized harvesting (cutterbar losses). The shedding losses can be assumed to be uniformly distributed over the field while the 'cutterbar' (panicle) losses would be calculated on the basis of the percentage of samples in which complete panicles occurred and the average size of the panicle.

Huq and Greeley (1980) obtained estimates of cutting losses based on five 2 m^2 areas randomly selected within a farmer's field. The field itself was measured and the loss estimate was obtained by standardizing the yield of gleaned grain and the farmer's yield at 14% moisture content and expressing the gleaned grain yield as a percentage of farmer's yield plus gleaned grain. However, this method is likely to include not only the grains lost from the straw or panicle at the moment of cutting (i.e. shattering loss), but also grains which might have been dislodged from the plant—for example by the wind—some time before cutting (shedding loss). During the gleaning process it would not be possible to distinguish between the two types of loss.

Some workers refer to the loss due to shedding as the 'before-harvest loss' (Toquero, 1981) and recommend that allowance be made for this in loss assessment studies. It could, however, be argued that there is no need to estimate this 'before-harvest loss' since very little can be done to reduce it, but it is recognized that it would be useful to measure it to be able to distinguish the true shattering loss, which depends upon the method of harvesting and can perhaps be reduced.

It is difficult to see how this before-harvesting loss can be reasonably estimated, since it seems impossible to glean grains from the soil surface within a field before harvesting without dislodging more grains from the standing crop. Nevertheless, Toquero (1981) recommends that this in fact should be done for selected plots within a field, before the measurement of loss during cutting is undertaken. An alternative approach might be to obtain an estimate of the before-harvest loss based on a number of sub-plots just before the harvesting begins and then to estimate the total shattering and shedding loss from another series of sub-plots and to obtain a measure of the shattering loss from the difference between the two results (Aggarwal, 1981).

To achieve this practically in the field the following method has been suggested:

> A randomly selected 50 m^2 plot (5 m × 10 m) is used for the harvesting loss study and a single sub-plot 1 m deep (1 × 5 m) is used to assess the before-harvest loss. This 1 m strip must be the first metre on the side of the plot where harvesting will begin and should be gleaned carefully before harvesting begins. A second 1 × 5 m strip is then selected at random from the remaining 9 m for gleaning after harvest to obtain a measurement of the shedding plus shattering loss. The values should be multiplied by 10 and the shattering loss

obtained by subtracting the first 'loss' from the second. It remains to be seen whether the method, proposed by Toquero (1981) and refined by Aggarwal (1981) will produce reliable results under practical field conditions.

There has been some disagreement about the way in which the harvesting loss is expressed. Huq and Greeley (1980) expressed the loss (i.e. the difference between the actual and potential yield) as a percentage of the potential yield, but others (Toquero, 1981) recommend that the loss be expressed as a percentage of the actual yield. Clearly this is a situation where some standardization is needed, particularly if results of different studies are to be comparable. It would seem appropriate to express the loss in terms of the amount of food grain available at harvest and so expression of the loss as a percentage of the actual yield is perhaps justified. It must, however, always be made quite clear how the potential yield has been calculated and whether this yield includes grain which should be described as the 'before-harvest loss'.

The 'before-harvest loss' and shattering loss which occurs during harvesting have been combined and described by Elder (1980) as the 'standing crop loss'. This term has also been used by Toquero (1981) but to describe an entirely different loss—i.e. 'the loss of sound and mature grains left on the standing plant during the harvesting operation as a result of oversight, carelessness, haste in completing the operation, etc.' This is common for border-line plants where tall grasses or weeds grow side by side with the rice plant. Toquero also introduced the concept of a 'lodging loss' defined as 'sound and mature grains that are left on plants that have lodged or are lying flat on the ground due to varietal characteristics or environmental conditions'. As far as can be determined neither of these losses has been considered by other workers.

Most studies of harvesting losses have concentrated upon losses due to shedding or shattering, but Johnson (1978) suggests that the term 'harvesting loss' should include all losses due to damage caused in the period between grain maturity and the time of storing, since many of the harvesting operations are interdependent. Harvesting losses are related to the state of maturity of the crop and since it is impossible to harvest and store a crop at the optimum time, some loss is inevitable. The timing of the various operations must be such that a compromise to give the lowest possible loss (or sometimes lowest cost) with the resources available, must be reached. For example, in some circumstances it may be appropriate to begin to harvest (cut) early when a high proportion of the crop is immature, and to tolerate the loss in drying, etc. in order to avoid a high field shattering loss, or even more serious loss if heavy storms are likely to occur towards the end of a harvesting period.

As the grain in the field matures the risk of loss to birds increases, and the longer the crop remains on the field the greater the risk.

Mature grains removed by birds can be considered a harvesting loss and can be estimated by counting damaged ears and recording the number of grains lost per ear (*see* also *Losses due to birds* p.49). However, bird damage in a mature crop is likely to be accompanied by grain shedding and it may be difficult to differentiate loss due to birds (grain consumed) and grain lost through shedding as a result of their activities.

Loss of quality arising from deficiencies in the operations between cutting and storage (e g. damage resulting from delays in drying when grain is harvested at high moisture content in order to speed up harvesting operations) should be classified as harvesting loss. With some crops, especially rice, the extent of harvesting loss cannot be determined until the grain has been processed (milled) and the quality of the final product assessed.

LOSSES DURING STOOKING AND STACKING

After harvest, grain may be stooked in the field to dry or placed in a stack where it may remain for a few days or perhaps for several months.

Losses which occur during stooking/stacking are largely due to shedding or scattering. It has been suggested that these losses can be measured if the operation is carried out normally except that the stooks or stacks are built on a plastic sheet or tarpaulin to collect all the scattered grains when the bundles of panicles are removed. The 'lost' grain is calculated as a percentage of the grain removed by threshing, adjusting grain weights to a standard moisture content (Toquero, 1981).

One problem with this approach is that the mere presence of the investigators and the sheet or tarpaulin laid on the ground means that the situation is not normal. The labourers may handle the bundles of panicles in such a way that 'losses' may be lower (handled carefully) or higher (handled roughly) than in the normal procedure.

Some loss of quality may occur when newly harvested grain is stacked prior to threshing especially during a wet season (common with rice in SE Asia). Threshing may be delayed due to wet weather or shortage of manpower, etc. and unthreshed grain may remain in a stack for several days. If the moisture content of the grain is high, some heating may occur, grains may become mouldy and some may even germinate. Discolouration of rice grains is also a problem.

If the deterioration is so severe as to lead to rejection of the grain as unfit for consumption, this reduction in quality may be expressed on a quantitative basis. However if the grain is not rejected, some estimate of the reduction in quality may be obtained by comparing the condition of a carefully processed sample of grain from a stack at threshing time with that of a sample drawn at the time of stacking. For example, deterioration of rice quality could be checked by carefully drying and milling samples of paddy collected on the two occasions and examining the rice for discoloured and broken grains, etc. Further details of the type of laboratory procedure used are discussed below in the section relating to losses in drying.

When grain remains in stacks for several months, the stack can be regarded as a means of storage during which loss due to rodents, birds and insects as well as micro-organisms may occur. It may be difficult to estimate the losses due to rodents and birds, but the standard techniques for measuring losses due to insects in storage can still be applied (*see* Section 5). Samples of grain collected at stacking and again immediately before threshing should be carefully threshed and the grains analysed for insect loss. However, there appear to be no reports of such a technique being used.

LOSSES DURING THRESHING

Losses during threshing may arise because of incomplete threshing, (i.e. grain remaining on the straw), through damage to the grain itself, or through scattering and spillage during the operation.

(a) Incomplete threshing

The loss of grain which remains on the straw has been measured satisfactorily in studies of both hand and machine threshing (Calverley *et al.*, 1977; Huq and Greeley, 1980). The procedure described by Dendy and Harris (1978), which relates primarily to paddy, has been adapted by some (Qureshi, 1981; Toquero, 1981) to suit local conditions.

Sample bundles of harvested grain are selected at random and threshed in the traditional way and the threshed grain and straw retained (Sample I). The grain remaining on the straw is then carefully hand stripped and collected (Sample 2). The two samples must be winnowed and cleaned to ensure that the grain is of the same quality. The good grain in both samples is weighed and the weights corrected to a standard moisture content.

Representative samples of each lot should be examined to estimate as accurately as possible (e.g. by hand sorting) the proportion of useful quality grain. The weight of unfilled, immature or green grains that would be rejected during subsequent processing should be noted. Then the total of these, plus extraneous matter, should be determined and the estimated total weight subtracted respectively from the main threshed sample and the hand-stripped material. The good hand-stripped grain would normally be lost, and the loss is the percentage ratio of this to the total good grain (hand-stripped plus normally threshed).

When the traditional method of threshing is by trampling using cattle, grains may be trodden into the soil and lost. This loss would be extremely difficult to measure and, furthermore, in calculating the loss of grain remaining on the straw as a percentage of grain removed, no account can be taken of grains trodden into the soil.

Experience of such cases is limited, but Huq and Greeley (1980) reported that in Bangladesh loss of grain (paddy) in the soil was negligible, since it was observed that generally great care was taken in preparing the threshing floor. Cases of carelessness and cases where muddy floors had to be used because of constraints of labour and/or cattle availability did occur, but under usual farm management practices losses are minimal. This perhaps serves to emphasize the need for careful observation of traditional practices before beginning the actual measurements of loss.

(b) Damage to grain

The method of assessing damage during threshing is basically the same as that for any other processing stage; all the processing steps leading to the final product must be standardized, and the grain must be threshed by the normal method and by an optimal method which gives the maximum yield of undamaged grain.

Experience with this method has been obtained largely from studies of rice, since the presence of a high proportion of damaged grains in this product is considered undesirable. The steps in the method for assessing the grain damage are as follows:

(i) as in the estimate of incomplete threshing, random bundles of harvested grain are selected and randomly divided into two lots of approximately equal weight;

(ii) the first lot is threshed normally; this may include hand-stripping or a second threshing depending upon local practices. The threshed grain is then bulked and weighed;

(iii) the second lot is hand-stripped with care, bulked and weighed;

(iv) the two lots are sampled, and the samples processed separately using a method which gives the maximum recovery of undamaged grains;

(v) the products of each sample are then analysed for broken grains and damaged grains according to a predetermined standard, which may involve using local labour to perform the separation, and

(vi) the out-turn of the whole grain is calculated and the results from threshing by the normal method compared with those for hand-stripping.

Instead of sampling the batches of normally threshed and hand-stripped grain for laboratory processing, the whole batch of grain could be processed on a village mill.

(c) Losses due to scattering and spillage

Sound and mature grains may be lost through scattering and spillage during threshing, even though the techniques may include precautions against such loss. The published methods gave little guidance on ways in which these losses might be assessed, except to say that the scattered or spilled grain could be recovered from known or controlled amounts of threshed grain. Alternatively, it is suggested that the loss can be obtained by comparing the 'weigh-ins' and the 'weigh-outs.' No explanation of what constitutes a 'weigh-in' or 'weigh-out' was given, but the 'weigh-in' must relate to the unthreshed grain, and the 'weigh-out' to the total products (straw, grain, etc.), at the end of the operation.

Toquero (1981) suggested that a large sheet be spread on the threshing floor to catch all possible scattered grains, but experience has shown that the sheet would have to be very large, since grains are often scattered several metres from the point of threshing.

In a study of post-harvest losses of paddy in the Dominican Republic, scattering and spillage losses were estimated indirectly. Losses in the field were calculated by comparing the actual yields from traditionally harvested plots with potential yields from randomly selected plots which were carefully harvested by hand. The amount of grain remaining on the panicles threshed by farmers was calculated and subtracted from the potential yield. The difference represented the loss due to other causes including grain shedding during harvesting and handling and scattering during threshing. No further separation of these losses was attempted (La Gra *et al.*, 1982). Unless there is a good possibility of reducing the scattering loss there seems to be little point in measuring it, except as an academic exercise. The traditional methods of threshing, as already mentioned, often include some precautions against loss due to scattering (e.g. screens around the threshing point) and usually the threshing floor is thoroughly cleaned at the end of the day, thus minimizing the loss.

MAIZE SHELLING

Losses during maize shelling may be due to grains remaining on the cob or damage caused to the grain by the method of shelling. The method for assessing loss of maize on the cob is essentially the same as for threshing losses described above. The steps are as follows:

(i) a random selection of sample cobs is first shelled by the method under examination, and the grain weighed;

(ii) the grains remaining on the cob are then removed by hand and weighed. These grains would normally be discarded and therefore represent the loss; and

(iii) the moisture content of the two samples must be measured and the weights adjusted to a standard moisture content before the loss is calculated.

It is usual to express the loss as a percentage of the total weight of grains, but some workers prefer to express the loss as a percentage of the weight of shelled grain (actual yield, rather than potential yield).

The shelled maize should also be examined for grain damage caused by the sheller. This gives an indication of the efficiency of the sheller, rather than an estimate of food loss. However, the damage caused by the machine may render the grain more susceptible to attack by insects or micro-organisms, leading to loss during storage, and is therefore important.

To assess the damage caused by the sheller, the shelled grain should be divided to give a representative sample of at least 200 grains. These should be examined for cracks and scratches and the number of damaged grains expressed as a percentage. Insect and mould-damaged grains are not counted with the sheller-damaged grains. A second sample of cobs should then be hand-stripped and a sample of at least 200 grains examined as before to serve as a check on the sheller damage.

LOSSES DURING DRYING

Losses during field drying of maize

In parts of Latin America, maize is sometimes left in the field for long periods to dry. For example, in Honduras and Mexico, mature maize stalks may be bent over, or 'doubled', just below the first cob so that the tips point downwards. The crop remains in this position for up to four months, during which period losses due to birds, moulds and insects occur. Sometimes the crop may be cut and stacked in the field and this period can be regarded as a temporary drying/storage phase.

The procedure outlined below and described more fully in Appendix VI was developed as the basis for estimating total losses during the drying/storage phase and to quantify loss by cause. It was designed for a specific study but could be adapted and used elsewhere (de Breve *et al.*, 1982).

Approximately 50 cobs were chosen at random and segregated into undamaged and damaged lots. The loss of grain was calculated by subtracting the actual yield of shelled grain from 50 cobs from the potential yield, which was based upon the weight of grain obtained from a known number of undamged cobs.

The damaged fraction was examined and grain which was obviously unfit for consumption was separated and counted as an additional loss.

Losses during yard drying and in grain dryers

Losses during drying may occur if grain is physically removed from the process or if the method of drying results in a lower-grade product, in which case the efficiency of the operator may be a significant factor. The loss of moisture is not regarded as a post-harvest loss.

To measure physical loss of grain from the drying process, the amount of grain entering and leaving this part of the system might be measured. For example, grain may be weighed before and after sun drying on the floor and the difference (after correcting to a standard moisture content) would be the loss due to spillage, scattering, removal by birds, wind, etc. The actual cause of loss would be identified by careful observation of the process.

The principal quality loss factor during drying is that of kernel damage or cracking of grains and so the measurement of loss by reference to grain damage can only realistically be applied to those grains which are consumed whole. In the majority of cases this will relate to rice. Usually the greatest damage occurs when the grain is subjected to rewetting, for example in sudden rain showers during sun drying or when grains of widely differing moisture contents are mixed in a dryer. The damage to rice results in an increase in the broken grain content during the milling process and more especially during polishing. Although the physical volume of the total rice produced may not be seriously affected, the loss in quality may be significant when measured in terms of a lower-grade product or as a loss of solids (nutrients) during cooking.

The methodology for assessing losses during drying described by Dendy and Harris (1978) relates to raw paddy and is based upon experiences of a team which investigated losses in Malaysia (Calverley *et al.*, 1977). It is suggested that the methodology can be applied in principle, if not in detail, to parboiled paddy and other grains.

Three methods of paddy drying were identified, namely yard (sun), batch and continuous drying. To obtain a measurement of the loss during drying (i.e. the efficiency of the technique) the quality of milled rice from the system under study is compared with that obtained by carefully drying and milling a sample of grain in the laboratory. In each case, samples of undried paddy are collected as the grain is received at the drying site and a composite sample is submitted for laboratory analysis. At the end of the drying process a similar size sample is collected and also submitted for laboratory analysis.

The first sample should be carefully dried in the laboratory and both samples should then be milled on a standard laboratory rice mill. A comparison of the quality of the final product (percentage of broken grains) provides the basis for an assessment of loss. It has been suggested that a small commercial rice mill can be used in the absence of a laboratory mill, but clearly much larger samples would be required (Dendy and Harris, 1978). The practical difficulties of using a commercial rather than a laboratory mill are unknown, since it appears that laboratory mills have always been used in loss assessment studies.

Full details of the procedure outlined above are given in Appendix VI.

Batch drying

When studying losses during batch drying, samples must be taken to investigate the differences in the percentage of broken grains in different parts of the drier bin. If the drier is filled with paddy which is thoroughly mixed and blended, then a single sample will suffice, but usually samples will have to be taken from a number of points both near the top and the bottom of the bin. This can be achieved by collecting samples as the paddy is loaded into the drier and just before the bin is fully charged. Samples should be collected as nearly as possible from about the same points as the bin is emptied and should be carefully dried and milled as described above. Analysis of the samples will reveal the damage at different points of the bin, for example, grain at the bottom of the drier is likely to be overdried and that at the top rewetted as moisture is transferred from below, resulting in increased breakage during milling of the latter portion.

A measure of the average damage caused by the drying process is obtained by comparing the percentage of broken grains of milled rice after drying with the percentage of broken grains from a sample collected before drying. The differences between the percentage of broken grains in samples collected from different parts of the drier will provide a measure of the efficiency of operation; the smaller the difference, the more efficient the operation.

La Gra *et al.* (1982) describe a method of sampling large-scale batch (tower and rotary) driers in which grain is continually mixed and blended during the operation. Samples of approximately 1 kg were collected prior to drying at 15 minute intervals as the drier was being loaded. The samples were then blended to provide a bulk sample, which was subsequently divided to provide replicate laboratory samples. At the end of the drying period, samples were collected at similar intervals throughout the unloading and another bulk sample obtained. Samples were dried in a laboratory drier and allowed to cool and stabilize for 48 hours before milling in the laboratory. This study which related to commercial level drying and processing of rice, serves to illustrate the need for careful planning in loss assessment studies. The procedure for sampling grain driers was based upon the methods published by Harris and Lindblad (1978). However, a preliminary investigation demonstrated that sampling of driers would be very time consuming. This was due in part to the inability of millers to indicate accurately times at which particular driers would be filled or emptied. Drying times were said to vary between 8 and 10 hours, but experience showed that the time could extend considerably over this period. Allowing for filling and emptying time, the full cycle could be up to 18 hours. It was established that drying of paddy was usually in two stages—initial drying to a safe holding moisture content, followed several days later by a second drying immediately before milling. However, because of shortage of storage capacity, drying was sometimes completed in one stage. Such changes to procedure interfere with set sampling patterns and can lead to confusion and lost time. This, coupled with malfunction of equipment and unexpected changes in drying time, can well lead to loss of samples and extend sampling times by 24 hours. However, careful sampling of this kind is essential if accurate measurements of loss are to be obtained.

Continuous drying

The procedure for sampling continuous driers is similar to that for batch driers. Samples of paddy of approximately l kg should be collected at intervals of about l5 minutes over a period of about l.5 hours at the input and output sides of the drier. After careful laboratory drying the samples should be milled in the laboratory. The measure of the damage caused in drying will be obtained from the difference between the input and output samples.

LOSSES DURING GRAIN PROCESSING

The term grain processing here refers to dehusking, milling and grinding and includes traditional hand-processing as well as mechanical processing. The losses which occur at this stage of the post-harvest system largely result from breakage caused by maladjusted or maloperated machinery and poor pretreatment of the grain (for example, paddy which is subjected to repeated wetting and drying during the drying phase is likely to yield rice with a high proportion of broken grains). There may be some physical loss of grain, through spillage, etc., but the loss in processing is usually expressed as a reduction in quality of the finished product. This may reflect the 'loss' or inefficiency of the process or the processor.

Grain may be processed in a continuous operation, as in large-scale, commercial mills, or in small batches, for example, hand pounding, using querns or village custom mills. Loss assessment studies at the farm level are more likely to be concerned with the latter operations and so it should be possible to weigh the grain before processing, and the resulting product(s), to obtain a measure of physical loss. Comparison of the product(s) with that of a sample of grain carefully processed in the laboratory will give an indication of the loss of quality or the inefficiency of the process.

Dendy and Harris (l978) describe a simple procedure for studying rice milling losses. It is suggested that a sample of about 0.5 kg of paddy should be collected for laboratory analysis. The batch from which the sample was collected is weighed, milled and the product sampled. Sub-samples of the paddy collected before processing are milled in the laboratory and the product separated into husk, bran and rice and the rice separated into the whole grains, halves, brokens, etc. The relative proportions of whole grains and total grain are compared in the laboratory sample and the sample from the commercial process and the relative quality loss calculated.

Further elaboration of the technique is discussed by Dendy and Harris in relation to studying losses in continuous and two-stage rice processing systems, but these are not farm/village systems.

There is little available information about studies of rice processing loss at the farm/village level, although the published techniques were adapted satisfactorily for a study of commercial rice milling losses in the Dominican Republic (La Gra *et al.* l982).

The method described above was used in a study of losses in traditional and village custom-mill processing in Bangladesh (Greeley, l982). Few details are given, but in this study the dheki (a foot-operated pestle and mortar system of dehusking paddy) was compared with the Engleberg-type huller. A batch of paddy was divided equally and processed by each method. A sample of paddy collected before processing was milled in a laboratory system which was taken as representative of a 'modern rice mill'. The total yield of rice and the proportion of broken grains in samples from each process were compared to obtain an estimate of quality loss. (Copies of the data sheets used in this study are given in Appendix III).

Loss during grinding is considered by Dendy and Harris (1978) in terms of the removal of bran; the more bran in the finished product (flour), the lower the quality. The optimum process will remove all the bran leaving pure endosperm (flour), but this can only be achieved in sophisticated commercial systems. At the farm/village level the process will yield a wholemeal flour and so bran content is not a factor which can be considered in assessing losses. Measurements might be made of the milling yield to compare grain varieties, operator efficiency or efficiency of different mills. The procedures described by Dendy and Harris (1978) are outlined below.

When comparing the milling yield of different varieties of grain it is proposed that a portion of each grain variety is given to each of a number of operators who then process a known weight of grain in the same way (for example, all using querns). The milled products are then sieved and winnowed until the operator considers that the flour is of the locally acceptable standard, and the flour and bran weighed. After determining moisture contents and correcting weights to a standard moisture content the milling yield can be calculated from the formula

$$\frac{\text{Weight of flour at m.c.}x}{\text{Weight of grain at m.c.}x} = \text{Milling yield}$$

and the average yields for each variety calculated. This figure would be used as the standard or attainable yield by the method used, to which later measurements can be compared.

The same procedure might be used for one variety of grain for a number of operators to investigate operator efficiency. It is suggested that if all the products were acceptable locally then the operator attaining the highest yield might set the standard. A comparison of mills could be made using the same procedure. The yield of one variety of grain in a number of mills could be compared, in which case the mill with the highest yield would set the standard.

There are no records of these methods being used in loss assessment studies, but it is worthwhile noting the general principles, since a similar technique could be used to provide a better indication of food loss during, say, storage. A comparison of the yields of damaged and undamaged grain would perhaps give a better indication of food loss than a simple measurement of grain weight loss.

LOSSES DURING COOKING

It is widely recognised that loss of food material and nutrients is likely to occur during the preparation and cooking of rice, particularly if there is a high proportion of broken grains. Cheigh *et al.* (1978) demonstrated by experiment the loss of solids and certain nutrients (protein, amino acids and vitamins) during washing and cooking. Their techniques were adapted in a farm-level study of post-harvest losses in Bangladesh (Dawlatana, 1980). In this case the technique was used to compare the loss of food (solids and nutrients) during cooking using rice from the traditional foot-operated dehusking machine (dheki) and the village custom mill (Engleberg-type huller).

The two methods of dehusking result in a high proportion of broken grains (25-30%) and to estimate the loss of solids during cooking, controlled cooking trials were conducted using rice from both sources and also samples which had been screened to remove brokens.

The trial was conducted in the laboratory but was designed to simulate village practices. The moisture content of the rice samples was determined at the beginning of the study and 100 g of rice of each type was washed and cooked using 500 ml of water at 100°C. After cooking, the surplus liquid was drained off, and the moisture content of the rice determined.

The loss of food (solids) was calculated as follows:

$$\frac{\text{Dry weight of rice at start} - \text{dry weight of rice at finish}}{\text{Dry weight of rice at start}} \times 100 = \%\ \text{loss of solids}$$

Samples of the liquid and rice were then submitted for nutritional analysis. The loss of solids would of course be low in those countries where the rice is cooked without a surplus of water.

It is unlikely that the methods outlined above would be used in a farm-level loss assessment study other than as part of a research project. Nevertheless, it is useful to record them here if only as a reminder that a reduction of weight losses will result in greater benefits than a simple increase in the weight of available unprocessed foodstuffs.

Section 5

Losses during storage

The principal agents causing loss of foodgrains during storage are insects, micro-organisms and vertebrate pests (rodents and birds). In this section the methods of measuring loss caused by these agents are discussed. The techniques described by Harris and Lindblad (1978) which essentially relate to the assessment of straightforward loss in weight are reviewed and consideration is given to measurement of the total loss (of food material) due to those principal agents.

It has already been mentioned that when conducting a study of losses it is important to measure the losses from the point of view of the person or persons suffering them. A relatively small loss in weight in a sample of grain due, say, to insect infestation, may result in a quite substantial loss of food material if the level of insect attack is such that it leads to total rejection of a batch of grain by the consumer. It is this final weight of rejected grain which is the true loss of foodstuff. Insects are generally regarded as the most important cause of loss in farm storage and it is not surprising therefore to find that methods of assessing losses due to insects have received a great deal of attention. The same techniques can be used to measure weight losses due to mould; however, when assessing mould loss it is usually more appropriate to weigh the grain rejected as unfit for consumption, rather than regard the proportion of mouldy grains as simply the weight loss.

The methods for assessing losses due to rodents and birds are not well developed, but here again measurements of loss must include not only the quantity of grain consumed by the pests, but also the quantity which may be rejected because of contamination or fouling.

LOSSES CAUSED BY INSECTS

Insects are a major cause of post-harvest grain losses. By boring within the kernels and feeding on the surfaces they remove food material (sometimes selecting highly nutritive fractions), and encourage both higher moisture in the grain and the development of micro-organisms. However, the methods generally used to assess losses caused by insects focus upon a loss in weight. The methods have arisen largely from a basic research study of farm-level storage losses carried out by Adams and Harman (1977) in Zambia, and relate specifically to losses in weight caused by grain-boring insects rather than by surface-feeding insects. Harris and Lindblad (1978a) briefly discussed the problem of the presence of insect infestation within individual grains (internal infestation) in relation to assessment of weight loss. Loss assessment studies are concerned with the removal of foodgrain material from the direct human food chain. Where a grain is attacked by a grain-boring insect, that grain will be shown to have lost weight if it is weighed before and after attack. If the grain contains an insect larva, pupa or an adult at the time it is weighed, a lower level of weight loss will be recorded than if the insect had been removed. The importance of such an insect depends upon its fate. If it is removed before the grain is eaten its weight is a loss; if it remains in the grain it is weighed as food. The problem of internal infestation is discussed again below.

Determination of losses in a sample of grain

Adams and Schulten (1978) suggest three methods of determining losses in grain:

1. Determination of the weight of a measured volume of grain. In this case the loss in weight in samples taken over a period of time is taken as a reflection of losses caused not only by insects but also by micro-organisms and other factors (*see* below). The method is called the volumetric, bulk density or standard volume weight (SVW) method.
2. Separation of damaged and apparently healthy or sound grains and a comparison of their weights calculated as a percentage of the whole sample. This is referred to as the gravimetric method or the count and weigh method.
3. Determination of the percentage insect-damaged grain in a sample and its conversion to a weight loss using a predetermined factor; sometimes called the converted percentage damage method.

The principle of the first method is to establish the condition of the grain at the beginning of the storage season and to compare the condition of grain samples collected throughout the season with this baseline condition. The weight of grain occupying a standard volume container, determined from a sample collected at the time of storing, represents the baseline. Losses are recorded by following changes in the weight of grain occupying the same standard volume on subsequent occasions. In the second method, a sample containing damaged grains, collected at any time during the storage period, is analysed for damage and the weight of the sample compared to a mathematically calculated baseline weight of a theoretical sample which contains only undamaged grains.

The third method was proposed as a way of obtaining a quick appraisal of losses without the need for equipment. A laboratory experiment must first be conducted to determine the relationship between the percentage damage and weight loss. The results of the experiment are then applied to field samples of the same variety infested by the same insect pest.

Weight losses may be misinterpreted when comparing grain samples unless allowance is made for the differences in the amounts of non-edible material, and in the case of the first method, differences in the moisture contents. Before analysis it is therefore necessary to sieve and/or winnow the samples to remove stones, dust, insects, etc., and to hand-sort further if necessary, to remove all other foreign matter. It is also necessary to express all grain weights in terms of a constant moisture content - usually the dry weight - when comparing samples collected on different occasions. In the second method, moisture content adjustments are not needed since it is assumed that the sample and undamaged fraction extracted from it have the same moisture content.

Although the weight of dust and number of insects removed from grain samples are not useful indicators of loss in themselves (Adams and Harman, 1977), it is usual to record this information during the course of loss assessment studies, as it should help in judging the quality for sale. Counts of insects may also be useful in establishing a broad pattern of the changes in the level of infestation throughout a storage period.

The volumetric method

The volumetric method using bulk density apparatus was proposed by Adams (1976), but this was by no means the first occasion that a volumetric method of measuring losses caused by insects had been used. The idea that a weight loss can be measured by comparing the weights of standard volumes of damaged and undamaged grain has been used by many workers. Rawnsley (1969), working in Ghana, developed a method that involved collecting a sample of cobs, (usually 200) and shelling and separating the grains into damaged and undamaged fractions. After measuring the weight and volume occupied by each fraction, the litre weight of each was calculated. The percentage weight loss was then calculated using the following formula:

$$\frac{(Wa - Wb)}{Wa} \times \frac{100 \times Lb}{La \times La} = \%\ \text{weight loss}$$

Where Wa = litre weight of undamaged grains
Wb = litre weight of damaged grains
La = volume (litres) of undamaged grains
Lb = volume (litres) of damaged grains

No allowance was made for differences in moisture content, since both fractions were obtained from the same sample.

A similar method was used by Schulten (1972). A random sample of 20-30 cobs was shelled and well mixed. The weight of grain filling a standard container (capacity 2.7 litres) was determined and the procedure repeated using 20-30 visibly undamaged cobs. The difference between the two weighings was taken as the weight loss. The determination of loss of weight in the field was reported to be unsatisfactory since it was found that the sample of damaged grain frequently weighed more than the undamaged grain.

Furthermore, despite strict standardization of procedures, different operators obtained different results when filling the same container, especially under field conditions. The method was considered cumbersome and time consuming. However, Coyne (1971) used a similar method satisfactorily in Kenya. He compared the weight of a standard 4-gallon kerosene tin of maize with the weight of a similar volume of undamaged maize. The better results which he obtained may be due to the larger sample size used, better weighing facilities and possibly the higher losses experienced. It would seem that the recommendation to use bulk density apparatus for determining weight losses in samples of grains arose naturally from these earlier volumetric methods. It was considered that some of the problems encountered with the earlier methods would be overcome if a standard piece of equipment and a well-defined procedure designed to eliminate errors or operator bias was used. In 1973 a GASGA seminar on the methodology for evaluating grain losses recommended that loss in weight should be assessed on the basis of bulk density using apparatus specially designed for the purpose and using a strictly defined procedure. Full details are given in Appendix VII.

When using this method in loss assessment studies, it should be remembered that the apparatus strictly records changes in the bulk density of a sample of grain and not changes in weight. Nevertheless, the change in weight of the grain contained in a given volume (weighing bucket) at different times has been taken to reflect the loss due to damage caused by grain-boring insects. It is assumed that when grains are dropped into the weighing bucket the volume occupied by the same number of undamaged and insect damaged (in this case *hollowed*) grains will be the same, but the weight of the latter will be less. However, the very fact that some grains in a sample are damaged (hollowed) will mean that a particular sample may fall and pack into the weighing bucket in an entirely different manner from that of a sample of undamaged grain, and this will affect the number of grains required to fill the container. Certainly, where excessive insect damage has occurred, grains may become squashed when dropped into the weighing bucket, and so pack more closely than undamaged grains. This factor was recognized but not considered to be a problem by Adams and Harman (1977) working with maize in Zambia; damaged grains retained their shape and it was considered that the measurement of the weight of grain contained in the weighing bucket at different periods compared with the original weight of grain in the same container gave a realistic estimate of weight loss with time after allowing for changes in moisture content. Boxall *et al.* (1978) working with paddy in India used the same approach and found that this grain retained its shape at the levels of insect infestation and the usual range of moisture content (10-15%) encountered.

Moisture content changes in grain samples collected at different times will affect the weight of grain contained in a standard volume container but can be excluded by expressing all weight measurements in terms of a constant moisture content—

usually the dry weight. However, changes in moisture content also affect the volume and frictional properties of grain. Generally speaking, an increase in moisture content will increase the volume of the grain and cause it to pack loosely, leading to a decrease in the weight of a given volume. The effects of moisture on the bulk density may be extremely variable and have been discussed by Browne (1962) and Hall (1972). To allow for the effect of moisture on the volume of the grain, it is necessary to calculate by experiment the dry weight of a standard volume of a reference sample of grain at different levels of moisture content. The dry weight of grain filling the standard volume container for subsequent samples taken at the prevailing moisture content, can then be related to the dry weight of the reference sample at the same moisture content, by reference to a specially prepared graph or chart. The procedure, which is described in full in Appendix VII, requires a great deal of care and time and an adequately equipped laboratory.

Another factor which affects the weight of a standard volume of grain is the addition of insecticidal dust. The dust adheres to the surface of the grains, causing an increase in volume and a change in their frictional properties. Sieving of the grain sample is unlikely to remove all the dust; where insecticides have been applied, therefore, the volumetric method is less useful since it will tend to lead to over-estimates of loss.

Clearly the volumetric method is beset with more difficulties than was first apparent and it would seem appropriate to recommend that if the method is to be used then it is essential to carry out an investigation of the relationship between bulk density and moisture content. If the differences between the readings of standard volume weight over the range of moisture content expected under field conditions are small, that is, the likely error is acceptably low, then it may be possible simply to compare the dry weights of samples of grain occupying a standard volume container collected at different times during the storage period, otherwise a graph or chart will have to be prepared. However, the assumption has been made that the use of the graph will always account for the effect of moisture content on the standard volume weight and that this will enable a measurement of true weight loss, rather than a change in bulk density. As far as can be determined, no work has been undertaken to establish this relationship and clearly this must be done if the volumetric method is to be recommended in future as a method for assessing losses due to insects.

From the information available it would appear that for a given sample of grain, the bulk density/moisture content relationships at any moisture content are likely to differ depending on whether the grain is wetting or drying. Furthermore, it is known that although for most grains the bulk density decreases with an increase in moisture content, in some grains, for example rice, an increase in bulk density may accompany an increase in the moisture content (Lorenzen, 1958).

The outcome of any investigational work on bulk density/moisture content relationships is therefore likely to suggest that the volumetric method may not be the most appropriate method for assessing losses due to insects. Even if the bulk density/moisture content relationships can be satisfactorily explained and allowed for, the method will undoubtedly demand such a considerable amount of preparatory work as to make it tedious and impracticable.

Using the volumetric method when baseline samples cannot be obtained
The volumetric method was described by Adams and Schulten (1978) as the most reliable method for loss determination at the time. However, it was recognized that there would be occasions when the method could not be used without modification. For example, in the field it may be difficult to obtain reliable moisture content determinations, or it may be necessary to make loss estimates in the middle of a storage period when no baseline has been previously determined. It was suggested that the volumetric method could still be used, but with an artificial

baseline prepared using undamaged samples of grain present in the store at the time of the loss determination. This would not be practicable if further samples were to be taken during the season, since the inference is that undamaged grain should be collected from any part of the store. This procedure would disrupt the distribution of an insect infestation and lead to erroneous results. To overcome the problem it was proposed that the undamaged grain should be drawn from the actual sample collected. In effect, this would mean withdrawing a sample much larger than the usual 1-1.5 kg to ensure that sufficient undamaged grain to fill a standard volume container was collected. The weight of the standard volume of the sample should be determined first and then the visibly undamaged fraction separated and its standard volume weight determined. The loss would be simply the difference between the two weights. Conversion to a dry weight or standard moisture content was seen to be unnecessary since it was assumed that the moisture content of the undamaged grain would be approximately the same as that of the whole sample. Whilst this approach seems satisfactory in theory it may be difficult to separate sufficient undamaged grain to fill the standard volume container, particularly at high levels of infestation and even then the 'undamaged' grain could contain some internal infestation. Furthermore, the separation of undamaged grain would be a laborious procedure even with the larger grains such as maize and it would seem more appropriate to use a simpler technique such as the count and weigh method (which is discussed later) because this involves a smaller sample. However, this method is known to give unreliable results especially at high levels of infestation.

An alternative might be to use a miniature standard volume container. With a sample size of about 1-1.5 kg it should be possible to select sufficient undamaged grain to fill the container to achieve a baseline. The method could be used at any time during the storage season and might overcome the problem of moisture content differences between samples collected at different times. Early work by Swanson (1942) and Harris and Sibbit (1942) demonstrated that micro-methods of determining bushel weight were satisfactory. Work at TDRI with small and large bulk density containers and using four different types of grain, and four different species of insect at various levels of infestation, has demonstrated that it would be possible to predict the number of replicates of a given container size, necessary to maintain confidence intervals below a pre-determined level.

The repeatability of results obtained using a particular container may vary when used for different types of grain under different conditions. If repeatability is poor, then it will be necessary to take a large number of replicate readings. It is, therefore, recommended that before embarking upon a programme of work involving the bulk density apparatus, it is advisable to calibrate the instrument in order to determine the number of replicate readings to be made. Calibration involves making a large number of measurements using the bulk density apparatus and measuring the variability of the data obtained (Andrews, personal communication).

The gravimetric (count and weigh) method

The count and weigh method provides an estimate of loss where a baseline cannot be determined at the beginning of the storage period and uses only minimal equipment. The method, which is applied to a single sample, requires the calculation of (i) the proportion by weight of grains damaged by insects, and (ii) the percentage of damaged grains. The proportion of damaged grains is calculated from the mean grain weights of undamaged and damaged grains:

$$\frac{\text{Mean weight of undamaged grain} - \text{mean weight of damaged grain}}{\text{Mean weight of undamaged grain}}$$

This proportion, i.e. the average weight loss per damaged grain, is then multiplied by the percentage of damaged grains in the sample to obtain the weight loss. This can be expressed in the formula:

$$\frac{\left[\frac{U}{Nu}-\frac{D}{Nd}\right]}{[{}^{U}/_{Nu}]}\times\frac{Nd}{Nu+Nd}\times 100 = \%\ \text{weight loss}$$

Where U = weight of undamaged grains
D = weight of damaged grains
Nu = Number of undamaged grains
Nd = Number of damaged grains

From this it can be seen that the estimate will only be valid if the damaged and undamaged sub-samples are closely comparable in original size of grains. If the insects preferentially attack larger grains, the mean weight of damaged grains could exceed that of undamaged grains, resulting in a negative value, which is clearly absurd.

The formula above is similar to that proposed by De Luca (1969):

$$\frac{Ua-Da}{UaN}\times Nd\times 100 = \%\ \text{weight loss}$$

Where N = total number of grains
Nd = number of damaged grains
Ua = the average weight of an undamaged grain
Da = the average weight of a damaged grain

The Commission for Evaluation of Losses published a modification of the basic formula which incorporated the calculation of the reduction in average grain weight due to insect attack, and the percentage of damaged grains. (Anon., 1969):

$$\frac{UNd-DNu}{UN}\times 100 = \%\ \text{weight loss}$$

Where U and D are as in the first formula, Nu and Nd are the numbers of undamaged and damaged grains respectively and N is the total number of grains (Nu + Nd).

This is the formula described by Adams and Schulten (1978) as the count and weigh method except that N was expressed in the expanded form (Nu + Nd).

Adams and Harman (1977) used the method in Zambia and noted the problems of variation in grain size, variation in average grain weight for damaged grain at high levels of infestation and of counting grains with internal infestation as undamaged.

They concluded that in their project the method could not be used, but suggested that it might be of use in single visit surveys, especially with smaller grains of more uniform size which are not liable to multiple infestation, and perhaps for situations where the infesting insect species feed entirely on the surface of the grain.

Since the method involves a single sample it is considered unnecessary to determine the moisture content of the separate fractions, since the differences are likely to be small. It would appear, however, that no investigation has been conducted to determine how widely the moisture content of damaged and undamaged fractions in a sample may vary and what effect any variation would have on the final figure for weight loss.

Despite the disadvantages and lack of experience with the method it has been offered as a standard technique for situations where no baseline could be obtained.

Adams and Schulten (1978) recommended that a sample of 100-1,000 grains should be used, but no guidance was given on how these grains should be taken. The common tendency, simply to count out the required number of grains, undoubtedly leads to a bias in the result. The sample should be obtained from the main sample by a standardized method of sample reduction. The smallest sample size (100 grains) recommended is too small. Little work has been undertaken to determine the actual number of grains required for a given level of accuracy, but from field experience it is considered that the sample size should not be less than 500 grains and that at least three replicates should be used. However, there seems to be no experimental basis for adopting this procedure. The method, or variations of it, have been widely used in loss assessment projects conducted under the FAO Prevention of Food Losses Programme but little information about the reliability of results is available (Schulten 1982). Golob (1981) used the method for maize and compared the results with those obtained with a standard volume weight method using the same samples of grain and found that the count and weigh method gave consistently lower losses.

He indicated that further investigation of the method was needed, but suggested that in future loss assessment studies both the count and weigh and the volumetric method should be used and both results stated.

The method has been used as a second approach to determining weight losses in paddy rice and achieved very variable results compared with the standard volume method. The difficulty in this case was not so much the disadvantages of the method described above but practical problems in the laboratory. The task of sorting damaged and undamaged fractions from a sample of about 1,000 grains is a somewhat tedious task particularly when a large number of samples is awaiting processing, each requiring three replicates of the count and weigh technique. The shape of the paddy grain is such that grains do not roll and each grain has to be handled to determine the presence of damage. Some consistent results were achieved but usually only where laboratory staff were truly conscientious or where constant supervision was exercised. Very often it was found that grains were categorized wrongly or staff attempted to use smaller samples than those demanded (Boxall *et al.*, 1979).[7]

The converted percentage damage method

Weight losses have frequently been obtained by reference to the percentage of damaged grain in a sample. The obvious simplicity of the technique probably accounts for its wide use. Parkin (1956) recommended that in order to achieve an assessment of losses, laboratory studies should first be undertaken to determine the relationship between damage and weight loss, including a correction for hidden infestation. Tables could then be constructed for use in the field. Other workers, (for example, Schulten (1969)) used the relationship between percentage damage and weight loss to obtain estimates of storage losses. These techniques now referred to under the general heading of the converted percentage damage method (Adams and Schulten, 1978), are considered suitable where a quick assessment of loss caused by grain-boring insects is required without the need for equipment, for example during a rapid field appraisal.

Once the relationship between percentage damage has been established by laboratory experiment, a conversion factor can be calculated and subsequently used to determine weight losses in other samples of the same type of grain. It is recommended by Adams and Schulten (1978) that the percentage damage: weight loss relationship be established from the count and weigh method. It is therefore obvious that this method is subject to the same sources of error.

The conversion factor is calculated from the formula:

$$\frac{\%\ \text{damaged grain}}{\%\ \text{weight loss}} = \text{conversion factor}$$

using the figures from the count and weigh technique. (An example is given in Appendix VIII).

In order to avoid some of the sources of error it is recommended that a sample of grain with 10% or more damaged grains is used in this first step, because the count and weigh method tends to underestimate loss at low levels of infestation. When a subseqent sample of the grain is collected, the number of insect-damaged grains in a sub-sample of 500-1,000 grains is counted and expressed as a percentage of the total number of grains. This figure is converted to a weight loss using the predetermined conversion factor. When obtaining the sample of 500-1,000 grains it must be remembered that the grains should not be counted out, but the sample reduced using a standard sample-dividing technique to obtain a sub-sample which contains approximately the required number of grains. When grains are heavily infested, feeding by secondary pests and multiple infestation may occur and this will disturb the exit hole/weight loss relationship and so lead to an underestimate.

Some conversion factors have been established and were quoted by Adams and Schulten (1978). They all relate to cases where larval stages of insects develop within grains, for example *Sitophilus* sp. and *Sitotroga cerealella* infestations (*see* Table 4).

Table 4

Conversion factors for a selection of crops

Maize (stored as shelled maize or as ears without husks)	% bored grains ÷ 8
Maize (stored as ears with husks)	% bored grains ÷ 4.5
Wheat	% bored grains ÷ 2
Sorghum	% bored grains ÷ 4
Paddy	% bored grains ÷ 2
Rice	% bored grains ÷ 2

Source: Adams and Schulten (1978) LGB =

These conversion factors have been suggested with very little practical experience and should be regarded as very rough guides only. It would perhaps be better to determine a conversion factor for the particular grain being studied on each occasion. However, it has often been found that when this is done the factor agrees closely with the published one (Huq and Greeley, 1980).

The method proved useful for assessing losses of maize in Nepal where the difficult terrain and remoteness of the field study areas precluded regular transfer of many samples to a central laboratory for analysis and the use of all but the simplest of field equipment (Boxall and Gillett, 1982). A laboratory investigation to establish the relationship between percentage damage and weight loss was performed during the study on grain samples with 10-20% visible damage. These were collected from 50 farmers' stores, 10 stores in each of 5 study areas.

The results for each store, and for each study area, agreed so closely that a single mean figure was used as the conversion factor throughout the study. Samples from the 50 farm stores collected on a monthly basis were also subjected to a standard volume weight analysis and the results compared with those using the converted percentage damage. The figures for loss calculated by the two methods agreed closely although estimates obtained by the standard volume weight method were slightly higher. It was noted that with the converted percentage damage method, misleading results may occur at high levels of insect infestation, especially in large grains. In an attempt to overcome the errors which result from this multiple infestation, the number of insect emergence holes, rather than the number of damaged grains, were counted. In practice, multiple infestation was rare, but this is not the case with pulses, where several, well defined exit holes are commonly found in one pea or bean. In such cases Adams and Schulten (1978) recommended that the number of exit holes should be counted and not simply the number of damaged grains, since it is assumed that each beetle infesting a sample of peas or beans will consume about the same amount of food material. When calculating the conversion factor for pulses, the same procedure as for cereal grains is followed, but the damaged sample should consist of beans/peas with one exit hole only. The conversion factor then indicates the number of exit holes which equals a weight loss of 1%. In the field sample the number of exit holes in a sub- sample of 500-1,000 beans/peas is expressed as a percentage of the number of beans/peas and divided by the conversion factor to obtain the weight loss.

The method of determining the conversion factor described above uses the count and weigh technique to establish the percentage damage: weight loss relationship. However, there is no reason why other methods should not be used. For example, weight loss could be determined by the standard volume method and the percentage damage calculated using the damaged sample. The advantage of using the count and weigh method is that it is less laborious, since all the information needed to calculate the conversion factor is derived in one operation.

Discussion of the published methods of assessing losses caused by insects

When the three methods described above for assessing losses caused by insects were first published as recommended procedures, it was recognized that they were largely untried. Since then, they have been used widely and as a result of this valuable field experience it is now possible to understand more fully their shortcomings and to propose solutions or alternatives. However, they can still be used more or less as originally published if all that is required is a measure of the approximate losses rather than more precise figures.

The volumetric method does not measure changes in weight (loss) but changes in the weight per unit volume (bulk density), unless laboratory work to establish the effect of moisture content on the dry weight of a standard volume of grain is undertaken. The method is useful only where the grain is attacked by grain-boring, internal feeding insects and at fairly low levels of infestation, where the grains are not hollowed to the extent that they collapse under the pressure of other grains in the standard volume container. However, further laboratory investigation is required to confirm that, even after allowing for the effects of moisture content on the dry weight of grain in a standard volume, the method does indeed measure true weight losses. A major problem of the volumetric method is that reliable results will only be obtained when a baseline (reference) sample can be collected at the beginning of the season. Experience has shown that it is often difficult to obtain such a sample and that a method which can be used at any time within the first few months of the storage season is needed. The preparation of an artificial baseline for the volumetric method, by selecting visibly undamaged grains from a sample, does not appear to be practicable because of the need for large initial samples and the difficulty of sorting damaged and undamaged grains.

A method which uses a smaller sample would be better and, although the use of small-scale standard volume vessels cannot be dismissed entirely, the count and weigh method would appear more suitable in this respect. However, this method is known to be unreliable because (i) it assumes that insects attack the grains at random, which is often not the case, (ii) it does not account for hidden infestation, which may be counted as undamaged, and (iii) at high levels of damage there are often multiple infestations especially in the larger grains such as maize.

The extent of the problem of insects selectively attacking the larger (or smaller) grains in a sample has not been investigated thoroughly. However, if it is considered serious, then some allowance might be made for non-random insect attack by modifying the procedure.

For example, before separating the damaged and undamaged fractions, grains could be divided into large and small categories (or as many size categories as seem necessary) using a suitable set of sieves.

After counting and weighing grains in each fraction size category, the weight loss can be calculated as follows:

Weight of 'undamaged' reference sample (weight UN) =

$$\left[\frac{\text{weight undamaged large grains}}{\text{number undamaged large grains}} \times \text{total large grains}\right] + \left[\frac{\text{weight undamaged small grains}}{\text{number undamaged small grains}} \times \text{total small grains}\right]$$

$$\%\ \text{Weight loss in sample} = \frac{\text{weight UN} - \text{weight sample}}{\text{weight UN}} \times 100$$

This approach is as yet untested, but in principle it should improve the figure for weight loss obtained by this method, and overcome the absurdity of negative values for percentage weight loss. Little can be done about the presence of hidden infestation, although Pointel and Coquard (1975) suggested that grains with internal infestation could be identified by flotation, dyeing or X-ray techniques. They did not, however, consider the additional time and equipment needed nor that the grain weight would be affected by some of the techniques.

The thousand grain mass method—a new technique for assessing insect losses

Work at TDRI has led to the development of a new method which overcomes the problems encountered with both the volumetric and the count and weigh methods. The technique is modified from a standard procedure of determining the weight of one thousand grains and is known as the thousand grain mass (TGM) method. A refinement,—the multiple TGM technique—has been proposed to take account of variations in grain size and difficulties in obtaining representative samples (Proctor and Rowley, 1983).

The TGM is the mean grain weight multiplied by 1,000 and corrected to a dry weight, and is calculated by counting and weighing the number of grains in a working sample. The sample is not adjusted to a specific weight or number of grains and therefore avoids a source of error or bias. The method involves the determination of a reference TGM from a sample of grain collected in a representative manner at the beginning of the storage season and comparison with subsequent measurements throughout the season. The weight loss in a sample of grain is given by the formula:

$$\frac{\text{Initial TGM} - \text{sample TGM}}{\text{Initial TGM}} \times 100$$

If all the calculations of TGM are routinely done on a dry basis, then the dry weight TGM can be obtained directly using the formula:

$$\frac{10m\ (100 - H)}{N} = M_D$$

where m = mass (weight) of grains in sample
N = number of grains in sample
H = moisture content of sample
M_D = TGM (dry basis)

In a farm-level loss assessment study the sample of grain collected at the beginning of the season must be representative of the entire quantity of grain stored (*see* Section 5). The subsequent samples are collected from the quantities of grain removed for consumption and are therefore representative of those quantities alone. The regular samples collected throughout the season are therefore not strictly comparable to the baseline and there may be wide differences in the composition of the sample. For example, the proportion of large to small grains may be so different between samplings that widely differing thousand grain masses will be recorded. Under these circumstances it would be possible to record apparent weight losses, even in the absence of insect damage, if samples collected later than the baseline sample contained a greater proportion of smaller grains. Conversely, apparent weight gains might be recorded if the sample contained a greater proportion of larger grains than the initial sample. It is not known to what extent this might be a problem in applying the thousand grain mass method in a practical field study and further investigation is needed.

Meanwhile, it is proposed that in using the thousand grain mass method the proportion of grains of different sizes should be taken into consideration (multiple TGM method). It will involve some additional work but will improve the reliability of the method. When the initial sample is collected and before counting and weighing grains to calculate a TGM, the sample should be separated on the basis of grain size into as many size groups as seems necessary. For most grains, this can be done quite conveniently by using an appropriate range of sieves. Once suitable sieves have been found for the required grain sizes the same set should be used throughout the study.

After separating into size groups, the grains in each group should be counted and weighed and the TGM calculated for each group. For example, grains in an initial sample might be categorized as 'large' or 'small', and their TGMs calculated. By recording corresponding TGMs from subsequent samples, sample weights can be 'corrected' before calculation of the weight loss. After determining the TGM for each size group in subsequent samples the potential weight of each size group is calculated as follows:

$$\frac{M_1}{M_x} \times W_x = W_p$$

Where M_1 = initial TGM
M_x = sample TGM for a grain size group
W_x = weight of that grain size group
W_p = potential weight.

The percentage loss is then calculated from the formula:

$$\frac{W_p(\text{large}) + W_p(\text{small}) - W_x(\text{large}) + W_x(\text{small})}{W_p(\text{large}) + W_p(\text{small})} \times 100$$

or simply:

$$\frac{\text{Potential sample weight} - \text{actual sample weight}}{\text{Potential sample weight}} \times 100$$

The development of the TGM method has been from laboratory studies and field testing is only just beginning (Proctor, 1982). Nevertheless it appears to be a useful technique, requiring a modest amount of equipment, and one in which most of the disadvantages of methods used hitherto are overcome.

LOSSES CAUSED BY MICRO-ORGANISMS (MOULDS)

The growth of micro-organisms, particularly moulds, in stored grains is always at the expense of the dry matter of the grain itself, consequently each infected grain will lose weight. The rate of loss depends upon the grain moisture content, temperature and the amount of physical damage to the grain. There appears to have been little work done on the quantification of losses due to moulds at the farm level, perhaps because they are rarely a serious problem in the truly traditional system. The methods of assessing weight losses caused by insects can be used for assessing losses due to mould, and inevitably, the estimates of losses due to insects often include an element of loss due to mould. The loss in weight caused by moulds in a sample of grain can be calculated by a comparison of the damaged (infected) sample with a baseline (undamaged) sample. As in the case of assessing insect losses, the baseline sample should ideally be collected at the time the grain is stored.

Alternatively, an artificial baseline might be prepared by selecting visibly undamaged grains from a sample of grain collected at any time, or the count and weigh method can be used. The problems associated with these procedures have been discussed above. If either of these approaches is used for assessing weight losses due to moulds, then an allowance must be made for differences in moisture content between damaged and undamaged grains, since the mould-infested grains will generally have a moisture content higher than the undamaged fraction.

Measurement of the weight loss in a sample of mould-damaged grain is unlikely to give an indication of the real loss. Some internally infected grains which show no outward signs of mould damage may be counted as undamaged. More importantly, the presence of mould invariably leads to rejection of large quantities of foodgrains, some of which may not actually be infected. When dealing with significant mould damage, local practices must be considered. The extent to which mould-infected grain is consumed or rejected by the local population will depend upon many factors. For example, in times of shortage, years of poor yield, or at the end of a storage period, consumers may have little choice but to consume some mouldy grains and in this case, the measured loss of food material may simply be the loss of dry matter in the damaged grain. Nevertheless the consequences of consuming mouldy grain can be serious, especially if the presence of mould leads to the production of mycotoxins. At present these consequences cannot be quantified. The method of assessing loss due to mould is simply on the basis of dry weight loss plus the amount of grain rejected. In those cases where some mouldy grain is consumed, the method, whilst giving an estimate of the loss of food material, underestimates the seriousness of the problem. Occasionally figures for loss are qualified in reports to the effect that the results present the minimum level of loss. The benefits of reducing such a loss are likely to be much greater than simply an increase in food availability, since the food grain will be of better quality.

Saul and Harris (1978) suggest that the approach to the assessment of losses due to moulds should be to determine what is acceptable as food material, but they go on to warn that the measurement of loss will depend upon subjective measurements which will vary with time, place and degree of hunger. They also discuss, briefly, the possibility of adopting a standardized grading for assessing such loss and suggest that an experienced grain grader in the country concerned might establish the grading system. He would need to survey local conditions and the level of acceptability of mould-infected grain at different times of the season. An estimate of loss could then be based upon an 'average' level of acceptability. This might give a better indication of the actual loss being suffered compared with a subjective survey of individual consumers. Nevertheless, the standard at which grain would be accepted or rejected might actually be lower than an international standard of acceptability. Therefore by international standards some consumers might still be suffering a loss.

There appears to be a need to revise the procedures for assessing loss due to mould to reflect more clearly the advantages of reducing such a loss. Most workers agree that simply measuring the dry weight loss is not enough; the amount of grain rejected as unfit for consumption must be considered. The standardized grading with an 'average' level of acceptability is a better approach but perhaps a nil tolerance in any given sample should be introduced for loss assessment studies. This could be justified on the grounds that with good post-harvest practices, deterioration in store due to mould growth can be prevented and that the consumption of mouldy grain under any circumstances is undesirable.

LOSSES DUE TO VERTEBRATE PESTS

Rodents

A review of the literature on pre- and post-harvest food losses caused by rodents indicated a lack of adequate data and appropriate survey and sampling techniques which precluded satisfactory estimates (Jackson, 1977). Surveys have shown a wide range of post-harvest losses caused by rodents and estimates for India alone range from 2.5% (Huysmans, 1970) to 5.9% (Deoras, 1975) and even 25-30% (Girish *et al.*, 1974). The range in estimates perhaps reflects the problems of methodology and in practice these estimates are of little use in evaluating losses.

Grain stored on the cob or head

Jackson and Temme (1978) proposed that in order to measure loss of grain from cobs or heads, the percentage of grain removed should first be estimated. Undamaged cobs or heads of the same size as the damaged ones should be shelled or threshed and the grain weighed. The loss is calculated by multiplying the weight by the percentage of grain removed. Apart from warning of the need for representative sampling, no further information is provided on how the method should be used. It would, at first, seem unnecessary to shell or thresh a number of undamaged cobs or heads, since it could be claimed that the estimate of percentage grain removed equals the weight loss. However, this assumes that the grains were of equal size and weight, whereas the grains actually removed may have been significantly smaller. For example, grains at the tip of a maize cob are smaller than those in the middle of the cob.

Estimates of the percentage of grain removed by rodents from maize cobs are likely to be easier to obtain than estimates of grain removed from loose grain-heads such as sorghum. Boxall and Gillett (1982), working in Nepal, estimated rodent losses in stored maize cobs by reference to the percentage damage in a sample of cobs. Samples of 10 cobs were collected each month and the percentage of grain damaged or removed by rodents was estimated and the average taken as the weight loss in the sample. This weight loss was applied to the quantity of grain removed to obtain the monthly loss figure. It was assumed that the percentage of grain damaged and removed was equal to the weight loss since gnawed grains which remained on the cob would be discarded when the cobs were shelled.

It was recognized that this method would result in an over- or underestimate of weight loss, depending upon the part of the cob which was damaged, since it was assumed that all grains were of equal weight. It was impossible to use the weight of grain shelled from cobs of similar size because of the high incidence of rodent damage and because of the variation in size of maize cobs. The method was found to be subject to errors in estimating percentage damage and so an investigation to determine the likely error was conducted. Rodent damage was simulated in a number of maize cobs by removing grains and field investigators were asked to assess the percentage damage (= weight loss). The results, when compared with the 'true' weight loss obtained by weighing 'damaged' (removed) grains and the total quantity shelled, revealed that the percentage damage per sample was on average underestimated by 2.5% and field results were corrected by this factor. The effect on the total recorded loss due to rodents was, however, small—an increase of 0.4%.

Threshed grain

Losses of threshed grain to rodents can be estimated by comparing weights of grain stored and removed. However, allowance must be made for other losses, for example, losses due to insects. Experience has shown that in farm-level studies this may be impossible, except in experimental studies, because of the difficulty of monitoring all grain movements in and out of store.

Attempts have been made to quantify losses using population studies and food consumption data from feeding trials (*see* Appendix IX) but these techniques are difficult to apply and have only limited accuracy. Rodents utilize stored food as part of their diet only and allowance must be made for situations in which the store is not the only source of food. Allowance must also be made for the difference between the unlimited food supply in the feeding trials and the foraging habits in the field. Further problems arise in the interpretation of population/consumption data due to changes in population structure and densities, ages of individuals and food hoarding habits.

Nevertheless, it was considered that the approach could be adapted for use in fields immediately after harvesting, in threshing yards (except where grain on the straw is in large, compact stacks), and perhaps in farm stores. It was felt that the methods would 'enable the ordinary competent biologist with little specialised training to derive loss estimates which, though indirect, will be based on objective data and, though approximate, will generally be of the correct order of magnitude'. The stated aim of the methods is to estimate the weight of grain consumed by rodents. As far as can be determined, no specific farm-level rodent loss-assessment studies have been carried out and even in those projects where consideration has been given to rodent losses, the published methods involving population estimates have not been used.

The need for actual figures for loss caused by rodents might, however, be questionable. If it can be established from a general survey of rodent activity that a rodent problem exists and is rated important by the community, then this may be enough to justify the introduction of a control programme. Losses of food material due to rodents may be relatively insignificant when compared to the loss and damage to personal property, buildings, etc. and the potential health risks. Nevertheless, it must be remembered that almost all communities in developing countries have a low endemic rat population which is not a major problem. This may become a serious problem when circumstances change which favour the rodent population. A joint FAO/WHO/EPPO Conference has recommended that rodent depredations on crops and stored food should not be considered solely as an agricultural problem, as severe public health implications may be involved (UN:WHO, 1976).

Birds

Losses caused by birds after harvest have rarely been quantified; indeed, Jackson (1977) reported that he could find no estimates of loss for developing countries. He further added that there seemed to be little concern about the losses that were occurring. It is not surprising therefore to find that there is no generally accepted methodology for assessing bird losses.

Losses before harvest are recognised to be serious; Harris (1978) quotes examples of losses to the maturing or drying crop caused by *Quelea* sp., parakeets and blackbirds. The same birds, and others, will cause losses in the newly harvested crop when it is stacked on the field or at the threshing point, but it is questionable whether quantification of this loss should be attempted, since it may be difficult to prevent.

Little guidance has been offered on the assessment of post-harvest losses to birds. Indeed, the published methods have concentrated upon estimates of field losses. The techniques are based upon work by Jackson (1977) and do not appear to have been used in any post-harvest loss assessment study.

Estimates of the losses caused by birds may be possible at some stages of the post-harvest system by comparing weights of grain entering and leaving the stage under study. Huq and Greeley (1980), for example, measured losses of paddy spread out in the sun to dry, by weighing the amount of grain placed onto and subsequently removed from the drying floor, after correcting weights to a standard moisture content. Losses caused by birds during storage are more difficult to assess. In some loss assessment studies vertebrate pests have been blamed for the remaining losses after accounting for those due to insects and moulds (e.g. *see* Boxall *et al.*, 1978), but to apportion the loss between rodents and birds is often impossible. Birds seem to be more readily accepted as part of the storage environment and the actual amount of grain lost to birds may be insignificant compared with losses due to other factors and preharvest bird losses.

For example, it is estimated that feral pigeons will consume 30 g of food grain per day, and sparrows 25 g of food grain per day. Where the pigeon population is high, for example in grain warehouses, a flock of 100 birds could be expected to consume about 3 kg of grain per day, or 1,000 kg annually, which may be insignificant in terms of total grain stored (0.1% if the storage capacity is 1,000 tonnes). It is assumed that the 100 birds feed exclusively on the grain and do not supplement their feeding from elsewhere; were this not the case, the loss would be less. Furthermore, the birds may be attracted to and feed on the easily accessible spillage which may be lost anyway, rather than feeding on the main bulk of grain in store. Although the loss of grain through direct feeding may be insignificant, it must be remembered that larger quantities of grain may actually be lost if, for example, grain fouled by birds is rejected or downgraded. These examples, however, relate to losses in commercial warehouses rather than farm-level storage where losses to birds are likely to be less.

Section 6

Sampling grain in store

The assessment of storage losses involves the observation of the general condition of the grain at specific points in time or over a long period. It is physically impossible to examine every grain in the store and therefore the condition of the whole batch has to be determined from an examination of a sample. The sample must be representative of the batch from which it is drawn and to ensure that this is so a strict procedure must be adhered to. A sample of any size could be drawn from any part of the batch of grain in store if all the characteristics (damaged grains, discoloured grains, foreign matter, etc.) which determine the condition of the grain were evenly distributed throughout the batch. However, grain is rarely, if ever, of such a uniform composition and in order to obtain a sample which is truly representative it is essential that all the parts of the batch should have an equal opportunity of being sampled. For example, when a stack of grain in bags is to be sampled, only the bags at the top and sides of the stack will be immediately available for sampling. If every bag is to have an equal opportunity of being sampled the bags must be moved. If a sample were taken from the exposed bags in a stack then that sample would be representative only of the exposed bags and not of the entire stack.

The way in which a representative sample is collected from a grain store will depend upon the approach to the loss assessment study, the size of the individual store and whether the grain is stored in bulk or in bags (or other small units). If the purpose is to estimate the loss in all the produce at one particular time then sampling must be carried out on all the produce in store. This approach may be adopted when loss estimates are based upon one or two visits during the season. However, more usually a regular sampling programme is undertaken over a storage season and a sample must then be taken from produce being consumed between sampling occasions. To remove produce from elsewhere in the store could disturb the natural progress of loss. When the grain is removed at intervals during the storage period, each quantity will have been exposed to deterioration for a different length of time and will have suffered a different degree of loss. The size of the sample depends on whether or not it is to be returned to a laboratory for analysis, but a sample of l-l.5 kg is usually sufficient. All samples must be labelled with the date of collection, exact location where obtained, method of collection, grain type and variety. A brief history of the sample up to the point of collection should also be recorded, if this information is necessary for the interpretation of analytical results.

SAMPLING ON ONE OCCASION ONLY

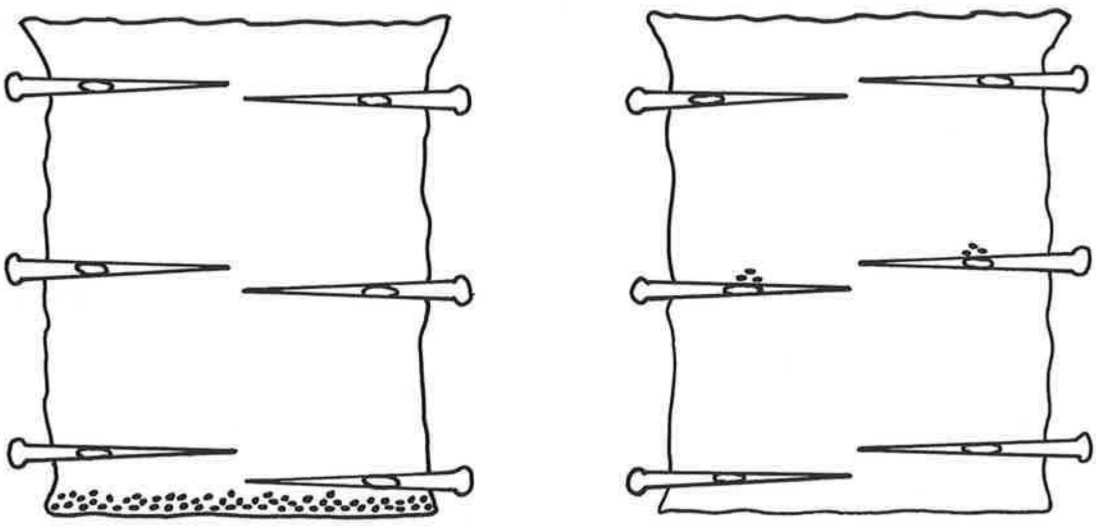
Small containers—bags, baskets, pots, tins, etc.

Grain stored in small units at the farm level is usually relatively easy to sample. The quantity stored is often small and the storage units easily accessible. Grain can be collected from the storage unit with a sampling spear or probe but it must be remembered that spear sampling does not conform to the principles of representative sampling. The disadvantage of spear sampling is illustrated in Figure 2.

Figure 2

Sampling bags using a simple spear

Samples taken with spears are not always representative. The shaded areas represent concentrations of foreign material, insects or defective grains.



A—Excessive amounts can be missed

B—Small amounts can give over-estimations of what is actually present

A double-tube sampling spear may also be used for sampling small storage units. This is better than the simple bag spear since it collects samples from several points within the bag, but it is still a rather haphazard method of sampling (*see* Figure 3).

The only way in which a truly representative sample can be obtained from a small storage unit is to remove the contents so that every grain has an equal opportunity of being sampled. When relatively small quantities are involved, for example, at the farm level, it may be possible to do just this. The grain can then be divided to obtain a sample of the required size by coning and quartering (*see* Appendix X).

It is important to ensure that samples are collected from a sufficient number of units (primary sampling units) in order to obtain a good representative sample. The number of primary units to be sampled will be determined to some extent by the availability of manpower and the time available for sample analysis. Nevertheless, a scheme for selecting the number of primary units must be established. The minimum number of primary units needed to represent a batch can be determined statistically and depends upon the total number of units in the batch. Table 5 below, is based upon the recommendation of the International Organization for Standardization (ISO) and indicates the number of units to be sampled in batches of different sizes.

Table 5

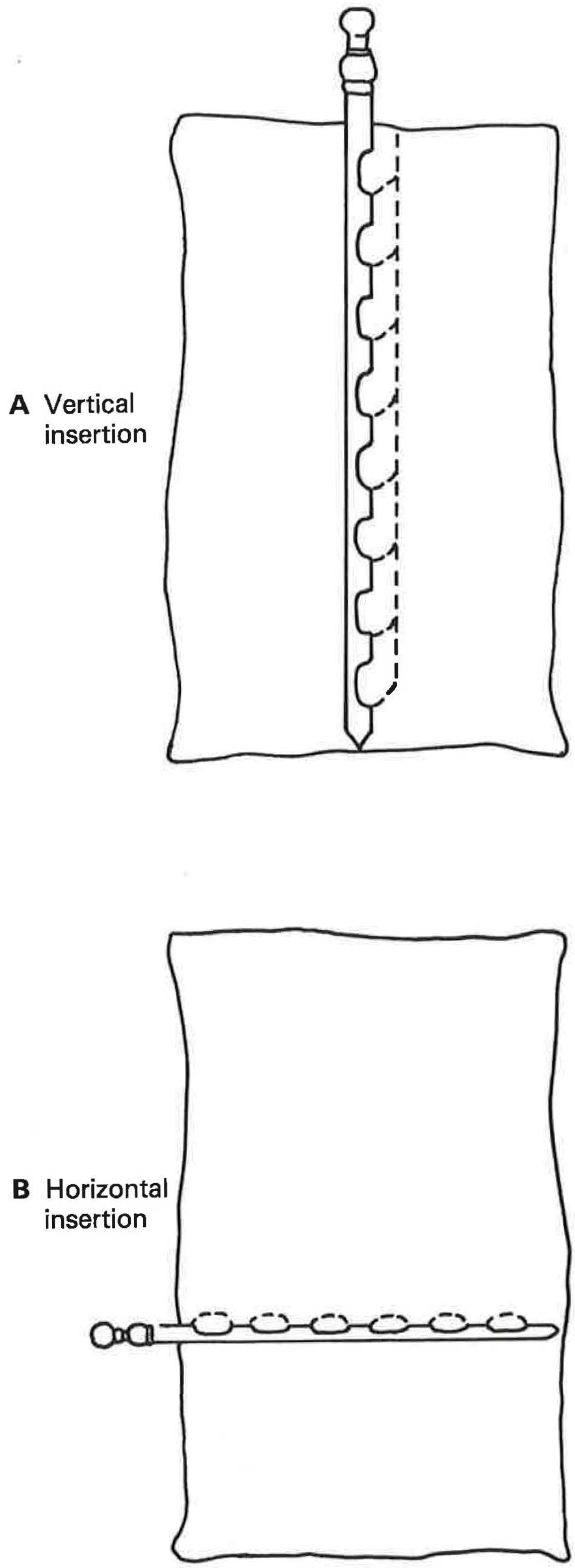
Numbers of units to be sampled from batches of different sizes

No. in batch	No. to be sampled
Up to 10	Every unit
11 to 100	10 drawn at random
More than 100	Square root, (approximately) of the total number of units drawn at random according to a suitable scheme

Figure 3

Sampling bags using a double tube spear

(Area of grain sampled when a double tube spear is inserted into a bag shown by dotted lines).



Once the required number of primary sampling units has been determined, the actual units must be selected at random using a table of random numbers (*see* Appendix IV). A regular pattern of selection, for example, taking every tenth unit, must not be adopted, since this does not conform to the principles of representative sampling.

The primary samples should be combined and thoroughly mixed to form a bulk sample. This bulk sample will, in most instances, be too large for the purposes of the loss assessment analysis and will have to be reduced and a submitted sample extracted. In the laboratory, further division may be necessary to provide a number of working samples. Throughout the process from primary to working sample, the representative nature of the sample must be maintained, otherwise the validity of the analytical results will be questionable. This means that the sample must be reduced in such a way that all the grain in the larger sample has an equal opportunity of being included in the reduced sample. Details of suitable methods of sample division are given in Appendix X.

Grain stored on the head, ear or cob

If the grain stored in the small containers is in the form of heads, ears or cobs the procedure outlined above should be followed, but before the sample is taken the grain in each selected container should be shelled or threshed. In practice this may be impracticable because of objections from the owner of the grain, or the containers may hold more grain than can conveniently be shelled or threshed within the sampling programme. As an alternative, a sample of 10-15 cobs or heads of sorghum—sufficient to yield approximately 1 kg of shelled grain, could be chosen at random from each selected container.

Sampling bags in a stack

When samples of grain have to be withdrawn from bags contained in a stack which cannot be broken down, only the exposed or readily accessible bags can be sampled. It must be remembered that the sample obtained is then only representative of those bags and not of the stack as a whole. Whenever this approach has to be adopted the conditions under which the sample was drawn should be clearly stated so that people can draw their own conclusions about the validity of any sample analysis results.

Grain stored in bulk

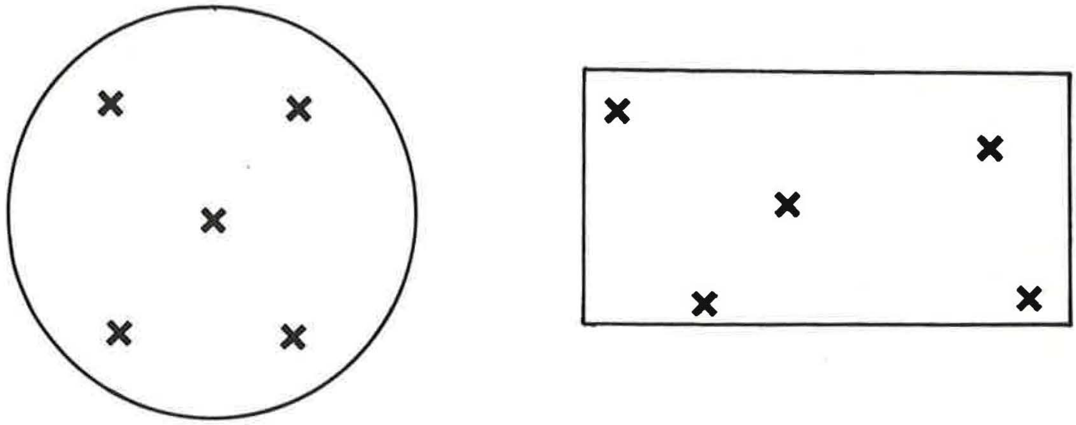
At the farm level, grain stored in containers with a capacity of 500 kg or more is usually regarded as being stored in bulk. To achieve an estimate of loss within a store at a given point in time it is necessary to sample the entire contents of a store. Ideally, the store should be emptied and the grain transferred to another container in such a way that samples could be drawn from the grain as it passes from one container to the other. For example, the grain might be transferred from the storage container to a number of smaller containers. This method is time-consuming, but it does ensure that the sample is truly representative of the bulk.

There will be occasions when sampling whilst unloading a store cannot be carried out and the bulk must be sampled using a probe. The unrepresentative nature of probe sampling is well known and so whenever the method is used it should be clearly noted in the report of the loss assessment study. When probing a bulk of grain, an effort should be made to reach every part of the storage container. A large sample should be taken and then reduced (for example, by coning and quartering, *see* Appendix X) to obtain a submitted sample of 1-1.5 kg. Samples collected with a probe from bulk should be taken from at least the positions shown in Figure 4. A compartmental probe that samples at all levels should be used.

Probe sampling may sometimes be restricted, because of limited headroom in the store. For example, some farm grain stores are filled through a small trap door,

Figure 4

Probe sampling grain stored in bulk. Minimum number of sampling positions



which when opened, exposes only a fraction of the bulk surface. In many parts of the world, storage containers (bins, baskets, etc.) are kept inside the house and the top of the container may be so close to the roof that insertion of a probe is impossible. Under these circumstances a representative sample can be collected only by emptying the whole store, but clearly this is impossible with very large bulks.

De Lima (1978) used the total store technique of sampling (either probing or emptying the contents) in his studies of farm-level storage losses in Kenya and found them convenient. However, before adopting this method, careful consideration must be given to the types of store to be sampled to decide whether it will indeed be practicable, with the time and manpower available, to empty a store completely if probe sampling cannot be used.

SEQUENTIAL SAMPLING

In a study of farm-level storage losses, the estimate of the total loss suffered by farmers is of more interest than an estimate of loss on one occasion, and so a number of stores must be studied and sampled intensively over a full season. This is the sequential sampling, or chronological, approach, recommended by Adams (1978). Many workers have followed this recommendation (e.g. Boxall *et al.*, 1978; Huq and Greeley, 1980; Golob, 1981). A representative sample of the stored grain is obtained at the beginning of the season (using the principles of representative sampling of small lots of grain as the store is filled). This sample provides the reference point against which subsequent samples will be compared. As the objective is to know what the farmer actually loses, samples must be taken at frequent intervals throughout the storage season and ideally the samples should be collected from each quantity of grain removed. The quantity removed can be regarded as the bulk sample. It is usually of a manageable size to allow immediate reduction by coning and quartering to obtain a submitted sample. If this procedure is repeated until the end of the season, i.e. until the last grain is removed, the total loss of grain to insects or mould can be calculated by summing the individual losses. Furthermore, by subtracting the sum of the quantities of grain actually removed from the weight of grain initially stored, an estimate of the total loss can be obtained.

If a very large quantity of grain is removed and cannot conveniently be divided by coning and quartering, the quantity should be divided into a number of primary sampling units. A representative bulk sample can then be obtained from a random selection of primary units according to general principles described above.

Such an intensive sampling programme can rarely be achieved and it is more usual to establish a regular (monthly) sampling programme and to record the pattern of grain removed from the store between the sampling dates. The loss estimate for each sample is then applied to the quantity of grain removed in the two-week period either side of the sampling date, in the case of a monthly (four-weekly) sampling programme (Adams, 1976).

A shorter or longer sampling cycle may be more appropriate. At periods of low insect activity (during a cold winter period) the sampling cycle might conveniently be extended to 6 weeks or more, whereas at times of high insect activity or when grain is being removed very frequently from store, the cycle might be shortened to two weeks.

Small containers—bags, baskets, pots, tins, etc.

When grain stored in a number of small units is to be sampled sequentially, the investigator will need to establish the unit or units from which the farmer is drawing grain for consumption, and the approximate rate of consumption. These units can then be withdrawn and sampled, preferably by emptying the whole contents of each one. For the average farm-household and with a monthly sampling routine, the number of units to be sampled is unlikely to be more than 2 or 3, unless a quantity of grain is to be sold, so sampling will be relatively simple.

Grain stored on the head, ear or cob

When grain is stored as unthreshed heads, ears or unshelled cobs, a large quantity should be removed from store, and the grain threshed or shelled before collecting a sample. It will be necessary to establish the position from which the grain is normally withdrawn for consumption and to sample at that point. Boxall and Gillet (1982) used this procedure in Nepal but because of the reluctance of some householders to remove large quantities of maize cobs the bulk sample was rather small (10-15 maize cobs) but nevertheless, still satisfactory.

Sampling bags in a stack

When the investigator is faced with a stack of bags he must establish the point from which the farmer is withdrawing bags of grain for consumption and the approximate rate of consumption. He can then select an appropriate number of bags for sampling, preferably emptying each one and obtaining a bulk sample from which a submitted sample can be extracted.

Grain stored in bulk

Ideally a sample of grain should be collected from the quantity actually removed from the bulk by the owner. However, this may be rather difficult to arrange and so the bulk itself must be sampled. In this case it must be remembered that the sample should be withdrawn from the point at which grain is normally removed. If the regular practice is to take grain from a small door at the base of the store then this is the sampling point, even though it may be more convenient to lift the store roof or lid and sample from the top of the bulk. A large sample should be collected from the stream of grain as it flows from the outlet. If grain is usually removed from the top of the bulk, an amount of grain in excess of the quantity required should be collected from this point. In both cases the collected sample (bulk sample) should be reduced to obtain a submitted sample of 1-1.5 kg. The balance of the bulk sample should not be returned to the store.

PAYMENT FOR SAMPLES

Payment for grain samples should always be made either in cash or in kind. The method of payment will depend upon local circumstances. Payment in cash, perhaps at slightly above the market rate, is convenient, avoiding the need to arrange for a supply of grain to trade for samples, and is likely to be quite acceptable to many farmers. However, payment in kind may be more appropriate when household and food storage management responsibilities are taken into consideration. For example, the farmer himself may readily accept the cash, but his wife may not be so happy with the arrangement. If she has responsibility for managing the household food supply she may have to cope with a monthly shortage of about 1.5 kg (the usual sample size) unless the cash is made available for her to replenish the grain removed. Payment could, of course, be made directly to the wife but this may be a cause of conflict if family finances are strictly controlled by the male members of the household. Replacement of grain samples with a similar quantity of similar grain is therefore perhaps to be encouraged and this procedure has been used in a number of loss assessment studies. If the grain offered in exchange is of good quality and undamaged throughout the storage season it may serve as a useful demonstration that grain can be stored without damage. Grain offered in exchange for samples should never be put into the selected sample store. When maize is traditionally stored on the cob and shelled grain is offered in exchange, the problem does not arise, but when loose grain is sampled there is a risk that replacement grain will be put into the store. It would, therefore, be advisable to offer a different, but nonetheless acceptable, food grain. The simplest situation is when paddy is being sampled, since this can be replaced by milled rice, but where an entirely different grain is to be exchanged a knowledge of local food-grain preferences is essential.

Boxall and Gillett (1982) sampling maize, paddy and wheat in the hills of Nepal gave rice in exchange and found that this arrangement was highly acceptable to the farmers, since rice is a prized commodity in the hills.

Golob (1981) sampling maize cobs and sorghum in Malawi successfully exchanged shelled maize, but found that a few farmers would have preferred to have had sorghum replaced by sorghum. Golob also demonstrated the value of offering good quality maize in exchange since many farmers retained at least some of the grain for seed.

A final advantage of payment in kind is that in some circumstances it may be possible to use the samples themselves after analysis, thereby reducing costs. For example, in a study of paddy storage, the samples could be milled and the rice exchanged for paddy in a further round of sampling.

PACKAGING, LABELLING, TRANSPORTATION AND STORAGE OF SAMPLES

Whenever any sample is to be transported to a laboratory for examination or has to be stored for some time before being examined, it should be packed to suit the purpose for which it has been collected, and in a way that minimizes changes in its condition.

Packaging

Samples for moisture-content determination

Samples for moisture-content determination should be packed in moisture-tight and airtight containers. Glass jars with screw caps and rubber seals may be used but unbreakable containers are preferable; for example, screwcap polythene bottles, polythene bags, or screw-cap metal containers. The container should, whenever possible, be filled completely to minimize the risk of interchange of moisture between the commodity and the air in the free space and to prevent damage to the sample caused by movement during transportation.

Samples for weight loss and quality determination

If grain moisture content is measured on the spot then preventing moisture loss is not important, but ventilation is. In this case samples may be packed in closely woven bags made of unglazed, unbleached cotton or similar material. Where there is a risk that such bags may be infested before use they should first be treated, preferably by heat sterilization. If there are several samples to be transported some distance from the sampling site then some additional packaging to protect the sample material and the primary packaging will be required.

Labelling

Samples collected in the field and which are to be submitted for laboratory examination must be carefully labelled at the time of packaging so that they can be readily identified whenever they are subsequently handled. The system of labelling will be decided by the individuals conducting the loss assessment studies, but it may consist of a series of reference numbers or letters which refer to more comprehensive information contained in an accompanying document, or all the required information may be recorded on the label itself.

Whichever method is used the following information should always be recorded:

—the nature of the sample

—the origin of the sample

—how, when and where it was collected

—the purpose for which the sample was collected.

Labelling of samples may be done in various ways. If possible and permitted, the required information may be written indelibly on the fabric of the sample container. Usually this method is restricted to disposable containers only. Alternatively, adhesive or tie-on labels may be used, although such labels need to be strong and very securely fixed in position.

The safest method is to place a duplicate label, enclosed in a sealed polyethylene bag, inside the container with the sample material. If the sample container happens to be transparent, the internal label can be arranged to display its information through the outer covering.

Transportation

During transportation, indivdual samples should be separated from one another with suitable packing/insulating/shock-absorbing material. A strong, compartmented, cardboard or wooden box should be used. Samples of different commodities should not be packed in the same container in order to avoid cross-contamination or cross-infestation. All cartons or boxes containing samples should be well secured and protected from exposure to direct sunshine, sources of extreme heat (for example, vehicle engines) and any form of wetting.

Storage at the laboratory

Samples awaiting examination need to be stored under equable conditions best suited to the commodity concerned and the purpose for which they were obtained. If, for example, the analysis included an examination of microflora, the samples could be stored in a refrigerator or deep-freeze unit. However, for most loss assessment studies a well-ventilated, darkened room with shelving for samples will be perfectly adequate. The room should, of course, be proofed against vertebrate pests, and insect control facilities should be available. Samples which are known to be infested by insects at point of collection should be fumigated if there is likely to be a delay of more than a day or so before analysis. Batches of samples can be fumigated quite conveniently using a phosphine-producing compound such as 'Phostoxin' or 'Celphos' in a gastight drum. Fumigation will normally be carried out at the laboratory but it may sometimes be necessary to arrange for fumigation to be carried out before samples are dispatched from a field station.

Section 7

Calculation of total storage loss

GENERAL PRINCIPLES

When making assessments of total storage losses at the farm level it is important to relate losses calculated from samples to the quantities of grain originally stored and the pattern of consumption. Ideally, grain would be weighed into and out of store and the total loss calculated from the difference between these weights, after allowing for changes in grain moisture content. From an analysis of samples collected from the different quantities of grain removed, the loss caused by different agents (insects, moulds, etc.) can be determined.

In the simplest case where grain is left untouched throughout the season but is attacked by insects alone, the loss due to insects, obtained by comparing representative samples of grain collected at the beginning and the end of the season, would be confirmed by comparison of the total weights of grain stored and removed. Such a simple case rarely occurs, except perhaps where seed grain is stored throughout a season. Grain is removed from most stores at intervals during the season and if this store of grain is infested by insects, then each successive quantity removed will have suffered a different, probably greater, degree of loss, since it will have been exposed to the insect infestation for a longer time. Consider the hypothetical situation where an insect infestation is more or less evenly distributed throughout the grain in a farmer's store and the infestation increases with time. At the beginning of the season both the insect infestation and the percentage loss will be low. As the storage season progresses, the insect numbers and consequently the percentage loss will increase, until at the end of the season a high percentage loss will be recorded. However, if the grain has been withdrawn for consumption at regular intervals during the season, the highest percentage loss will only apply to the small quantity of grain remaining.

The total loss due to insects is considerably less than it would appear to be from looking at the condition of the stored grain at the end of the season. It can be determined by calculating the loss in each quantity of grain removed by comparing samples of grain collected from these removals with a sample collected at the beginning of the season.

The two situations are shown in Figures 5a and 5b taken from Adams (1978). In both it is assumed that the pattern of insect attack is the same and the final recorded weight loss in a sample is 10%.

In Figure 5a, line A represents grain that is held for the full storage period and then removed and line B represents grain that is removed at intervals (in this example the lines represent the volume of grain in store rather than the actual weight of grain).

In Figure 5b, line A represents the cumulative weight loss where grain is held for the full 6 months (i.e. 10% loss at the end of the season) and line B the cumulative weight loss when grain exposed to the same pattern of insect attack is removed

Figure 5

Effect of rate of consumption on cumulative weight loss

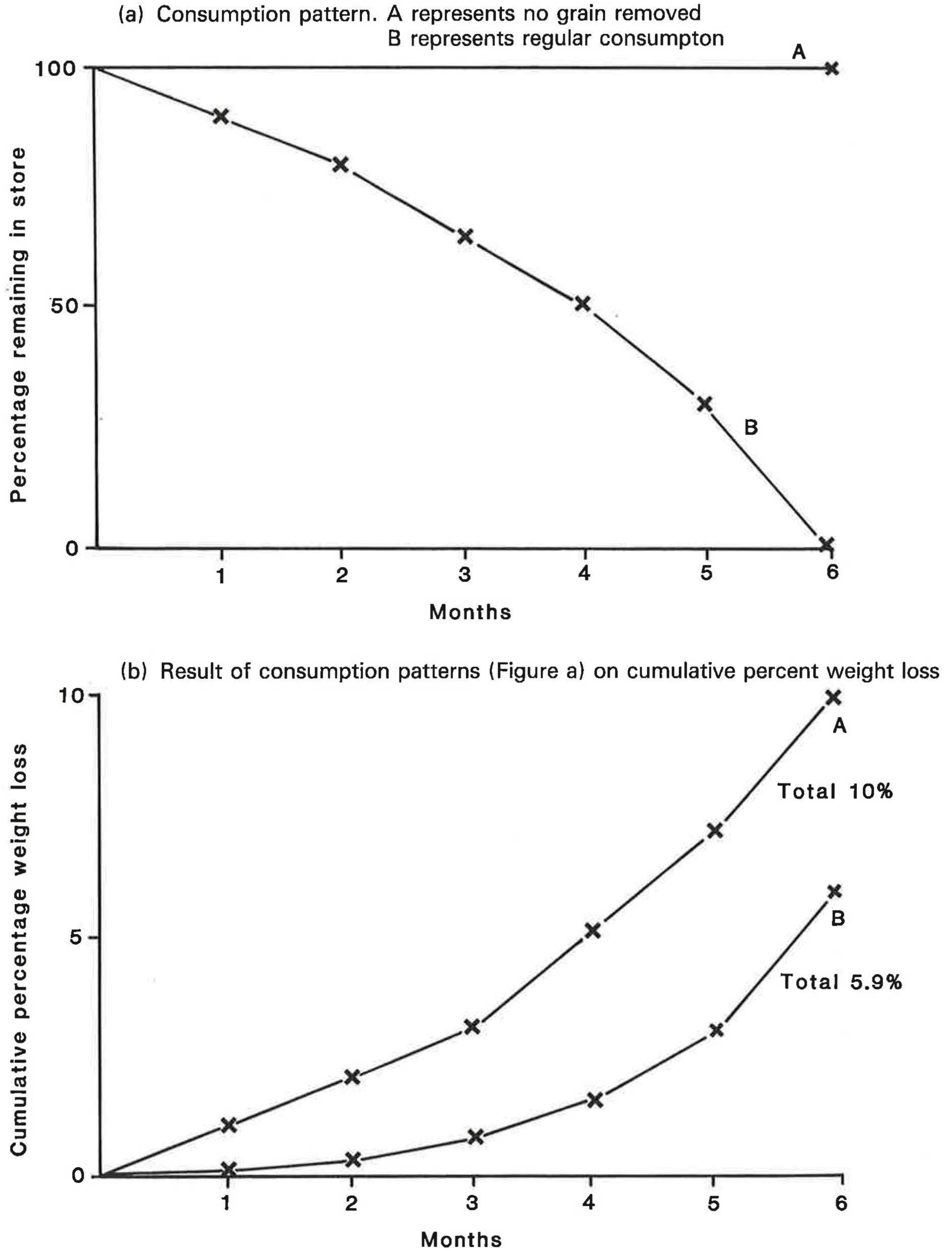


Table 6

Relationship between weight loss and grain consumption

	Months during which grain is removed					
	1	2	3	4	5	6
Quantity (volume) of grain removed (%)	10	10	15	15	20	30
Weight loss in sample (%)	1	2	3	5	7	10
Weight loss (as percentage of total stored)	0.1	0.2	0.45	0.75	1.4	3.0
Cumulative weight loss (as percentage of total stored)	0.1	0.3	0.75	1.5	2.9	5.9

for consumption at regular intervals. The derivation of the lower total loss figure is shown in Table 6.

These examples are useful in that they demonstrate the principle of interpreting insect weight loss measurements in relation to grain consumption patterns. However, they do perhaps oversimplify the matter, since they relate to volumes of grain removed so that in the graph the amount removed is the same as the amount stored, despite the loss caused by insects. Some further examples are discussed in Appendix XI.

ESTIMATION OF QUANTITIES OF GRAIN IN STORE

Under ideal conditions quantities of grain put into and removed from store will be weighed, but this approach can rarely be achieved except perhaps in research projects. In the field, although some weighing of grain into and out of the store might be done, in the main, estimates of grain quantities have to be made.

In a study of losses in Malawi the first visits to farmers' stores were often some weeks after the maize cobs and sorghum heads had been put into store and estimates of the total quantities stored had to be made by questioning farmers during the early part of the survey (Golob, 1981). When asked how much grain they had harvested and stored some farmers were able to give an estimate of quantities in terms of numbers of baskets but many did not know. Golob (1981) points out that it is important to know the amount of grain stored, not the actual harvest; so it was necessary to measure the volume occupied by the produce in store and to convert this to a standard weight using a previously determined factor.

The dimensions of the store occupied by the produce were measured. In the case of the cylindrical basket store, this was the diameter of the basket and the height of the produce in store, and in the case of platforms it was the height, length and width of produce stored. The volume was converted to a number of 'standard bags of maize, cobs or sorghum panicles' by dividing by a factor of 4.5. (It had previously been calculated that a 91 kg (200 lb) hessian sack when full occupies 4.5 cu. ft). To convert this to a weight of grain it was then necessary to multiply by the approximate weight of grain contained in a full bag. In the case of maize cobs this was 45 kg, which shelled out to about 35 kg of loose grain, and in the case of sorghum heads, 40 kg, which produced 26 kg of loose grain.

The quantities of grain removed were calculated by reference to standard baskets. When produce is removed from store it is placed in a basket, so that with a prior knowledge of the dimensions of the baskets used at each site, the volume and weight of grain removed could be calculated, (Golob, 1981).

A similar procedure for determining grain quantities was attempted in a pilot study of storage losses of paddy in India (Cook—personal communication) but here a check was made of the accuracy of the estimates. The grain in some stores was actually weighed in and so it was possible to compare the weight with an estimate obtained from a measurement of the volume of the store and the weight of grain per unit volume. It was found that the estimates were grossly inaccurate, with up to 39.5% variation from the actual weight, largely due to the irregular shape of the stores and difficulties in measuring the thickness of store walls.

Estimates of quantities of grain removed from store using standard local volume measures were, however, more reliable, but some preliminary investigation was necessary to determine the weight of grain of different varieties which occupied the standard volume measure.

In Nepal, Boxall and Gillett (1982) had to rely heavily upon the use of local volume measures to obtain estimates of quantities of grain stored and removed. All grain quantities were expressed in terms of the local standard volumetric measure used for measuring most commodities in the region and understood both by farmers and field investigators. Quantities of grain in store were also assessed by eye and by asking farmers how much grain had been stored, how much had been removed between sampling visits, and how much remained. The figures reported were compared with the records from previous visits and any discrepancies questioned. This procedure worked satisfactorily, largely because of the skill of both farmers and field investigators in being able to assess quantities of grain reasonably accurately.

Adams (1978) recognised that in storage loss assessment studies, it is sometimes difficult to obtain accurate measurements of the weight of grain stored and removed. He proposed that, where removals of grain are roughly estimated, the loss may be obtained by applying the percentage loss from a sample to the amount removed expressed as a percentage of the total quantities stored.

THE USE OF EXPERIMENTAL STORES IN LOSS ASSESSMENT STUDIES

A feature of some farm-level storage loss assessment surveys has been the establishment of experimental stores which are studied concurrently with the farmers' own stores. Indeed it has been suggested that experimental stores should be used as an integral part of a storage loss-assessment project, to compare the performance of local storage designs with improved structures (Anon., 1978). These experimental stores, which must be under the control of the loss assessment project team, should contain grain of the same variety and same quality as used by the farmers and the farmers' pattern of consumption should be simulated throughout the study.

It is sometimes difficult to decide where best to site experimental stores. Agricultural research stations provide useful sites but conditions may differ significantly from those prevailing in the field. Adams and Harman (1977) sited their experimental stores at a research station and tested a simple improved method of storage recommended by the local Ministry of Rural Development. The improvement could not be tested in the field because, at the time, it had been adopted by only a few of the farmers in the survey area.

When stores are located at a research station they can be monitored more closely than if they are located in the field, but this does not necessarily mean that the degree of storage management provided by the project team would match that of the farmer. Boxall *et al.* (1978) introduced experimental stores in the field in a study of storage losses in India. A number of selected farmers agreed to put their traditional grain stores and their grain at the disposal of the project team and movements of grain into and out of the stores were strictly monitored. The aim was to have representative examples of the most important types of stores in the area which could provide the 'ideal' situation for a study of storage losses, i.e. grain could be weighed into and out of store, sampling coinciding with grain removals. The value of having the stores under the complete control of the project team was, however, questionable, because in some instances losses were higher than expected and higher than in the farmers' neighbouring stores of similar design and containing similar grain. The team concluded that it could not provide the same degree of store management as that provided by the farmer. The farmer keeps a careful check on the condition of his stored grain and the decision on when and from where grain should be removed may be influenced by its conditon. For example, a patch of infested grain or grain with an obviously higher moisture content might be detected and removed at a routine inspection, or the suspect grain may be removed in preference to other grain during a regular removal for consumption. These decisions would not necessarily be made by a member of a project team who would be interested mainly in ensuring that a given quantity of grain, irrespective of condition, was removed at a given time. A compromise might be made by asking a farmer to withdraw grain at the allotted time but this would still not take account of the need for additional removal of grain when a problem was detected in store. Boxall *et al.* (1978) also introduced a range of 'experimental' improved storage structures in the second year of the project. All were sited on farms in the project area and, in the light of experience with the 'experimental' traditional stores in the first year, all improvements were treated in the same manner as all other sample stores, that is, used normally by the farmers but closely monitored by members of the project team living in the same village.

The advantage of this approach was that the improvements could be evaluated under field conditions. As well as studying the extent of loss, assessments of the acceptability and problems in management could be identified. Furthermore, since the improved stores were constructed from locally obtained materials, by local artisans working under the supervision of the project team, a true estimate of the costs of construction at different locations could be obtained. This would have been difficult, if not impossible, if the improved stores had been built at a research station.

It is often stated that improvements to reduce losses should not be introduced until an assessment of the extent of loss has been made and the need for the improvements justified. Whilst this is certainly true in some circumstances, as far as farm-level storage is concerned it is usually possible to identify at an early stage (e.g. during a preliminary survey) simple improvements which might be made in storage design or storage practices. These could be introduced and evaluated, perhaps on a limited scale, during the loss assessment survey. Often the local extension service is promoting improvements and it would of course be appropriate to include an evaluation of these in the loss assessment survey. A survey which provides information on the extent of loss under existing conditions, an indication of how the loss might be reduced by introducing improved practices, together with an evaluation of the acceptability of the new measures, is likely to be of greater benefit than one which simply provides figures for loss alone.

ESTIMATES OF FOOD LOSS

Post-harvest losses are usually expressed as the weight of food grain lost (storage loss caused by insect feeding) or as a reduction in quality (broken grains during rice milling) and for most purposes this will be sufficient. However, some workers have taken their investigations a step further and defined the post-harvest loss as a loss of food material or nutrients.

Estimates of weight loss due to insects are often taken as being equal to the weight of food material loss. However, this is not strictly true. Except where the whole grain is consumed, the weight loss of food material will be under-estimated if the damage largely affects the kernel of the grain. With milled rice, for example, a weight loss due to insect attack is indeed a measure of the loss of food material. This is not so in the case of paddy (unmilled rice) since the husk and usually part of the bran are removed before consumption. When the paddy grain is attacked by insects there is little loss of husk (and bran), but much of the kernel will be damaged. Huq (1980) proposed that the physical loss of paddy during storage should be converted to a true food loss by taking account of milling yield and the husk/bran content of the grain. It was established that the yield from milling by traditional methods in Bangladesh was 72%, and so the initial weight of paddy could be converted to its rice-kernel weight when milled by multiplying by 72/100. It was shown from experiments that the proportions of weight loss of paddy husk and kernel due to insect attack were 10% and 90% respectively. The loss in kernel weight can therefore be expressed as a percentage of the calculated weight of milled rice. To convert a weight loss of paddy to a weight loss of food material (rice) the paddy loss must be multiplied by a factor of:

$$\frac{90 \text{ (proportion of kernel loss)}}{72 \text{ (milled rice percentage)}} \text{ or } 1.25$$

Example:

Weight loss in paddy	=5%
Proportion of kernel loss	= 5×90% =4.5
expressed as percentage of calculated weight of milled rice	$=\frac{4.5 \times 100}{72}=6.25$
OR 5%×1.25 (conversion factor)	=6.25

Thus, the 'value' of taking into account this factor would be 1.25%; or, the real loss (of food material) is 1.25% more than the apparent loss.

The conversion factor would be greater when the milling yield is less, for example, paddy processed in a village mill might yield only 65% rice so the real loss would be 90/65 or 1.39% more than the apparent loss.

The expression of a post-harvest (storage) loss in terms of a loss of food value is not a recent development. Oxley (1950) determined the apparent loss caused by insects to Kenyan maize, and demonstrated that the real losses, including loss of food value, would be higher. He estimated that the maize grains consisted of about 15% bran (pericarp) and judged by eye that between 0.5% and 5% of the bran area was lost to insect attack. As the loss was usually nearer the lower figure an estimate of 2% was taken. The loss of bran was therefore:

$$\frac{15}{100} \times \frac{2}{100} = 0.3\%$$

The loss of endosperm and embryo, (i.e. the nutritious parts of the grain) is therefore equal to the calculated percentage loss of weight minus the percentage loss in the bran (0.3%).

But this figure related to 85% of the grain and so the real loss of food value is calculated from:

$$\frac{(L_A - 0.3)}{85} \times 100 = L_{Fv}$$

where L_A = the apparent loss
L_{Fv} = the loss of food value

Example:

Apparent loss in weight (L_A)
(foreign-matter free and on dry weight basis) = 12.0%

Loss of food value (L_{Fv}) =

$$\frac{12.0 - 0.3}{85} \times 100 = 13.8\%$$

Section 8

Interpretation of loss

LOSS ASSESSMENT AS PART OF LOSS REDUCTION

Loss assessment forms an important part of any loss reduction programme; it serves as a means of evaluating proposed methods to reduce losses. The few studies which have included an evaluation of loss have been at the small-farmer level and this section reflects this emphasis.

In the past, improvements intended to reduce losses have often been introduced in ignorance of the nature, type, size and true cause of loss or of the acceptability of the new measures. Furthermore, they have sometimes been introduced either at the most prominent or the most readily accessible point of the system. This has often been because of an outside pressure such as the availability of a particular input, of funds to provide the input, or because of the need to have a project completed within a limited time scale, or simply local politics. Sometimes, only concurrent with, or even after, the introduction of the loss-reducing procedures has an evaluation been carried out. Frequently schemes have subsequently been shown to be unviable and/or unacceptable, making little contribution to the reduction of loss in the short term and none in the long term.

With prior knowledge obtained from an assessment of losses in the whole post-harvest system, such disasters can be avoided. For example, with subsistence farmers having limited resources and ability, only extremely modest measures for reducing losses are suitable. These might be: encouraging the wider use of simple modifications to traditional storage structures to incorporate design features already found to be beneficial in some stores (in humid areas particularly to aid drying); encouraging the use of effective traditional pest control methods, and improving store hygiene (thereby reducing risk of cross-infestation). Where such simple modifications and improvements can yield an adequate reduction in loss, that is, one which satisfies the farmer, then these should always be tried first, even in areas where more complicated techniques and greater changes might reduce losses even further.

Where the traditional farming pattern has been disturbed and the farmer has demonstrated an ability to accept new ideas, for example, the introduction of new crop varieties and associated improved cultivation practices, some modification of the storage procedure may be essential if losses are to be minimized. The farmer who has adopted better cultural methods may more readily appreciate the benefits of improving storage. For example, it may be considered desirable to improve the basic design of a store and to incorporate modern building materials or to introduce synthetic pesticides. In order to do this satisfactorily the shortcomings of the existing system in relation to the development of loss must be determined and the appropriateness of chosen improvements obtained.

However, the measures taken by farmers to reduce loss may involve drastic changes away from the traditional home storage practice, for example, the grain (and hence the risk of losses) may be passed immediately after harvest by the farmer to some form of centralized storage organization.

Countries that have constant buying and selling prices throughout the year are, as it happens, indirectly encouraging farmers to use this method of reducing losses. Elsewhere, the incentive to pass on potential losses is reduced, since the higher purchase price later in the storage season may cancel out the benefit obtained by passing on the potential loss.

When a loss reduction method is introduced, it is accepted that the loss cannot sensibly be eliminated entirely. To strive to achieve this ideal of nil loss would be extremely costly since it would require commitment of resources to guard against every conceivable eventuality likely to result in loss. Loss therefore has to be reduced to a realistic or acceptable level, but the amount of loss which is considered acceptable is not really quantifiable in precise figures. The level of loss a reduction programme should aim for is the minimum which the more enlightened small farmers are capable of achieving. Traditionally, containment of loss has been achieved by trial and error and by natural selection of varieties of grains which are best suited to the handling, storage and processing procedures used over many centuries. Where the new high-yielding varieties of cereals have been introduced it has been found that the post-harvest characteristics of the grain are often inferior and consequently the potential for loss is much higher.

No single approach to loss reduction can be recommended; rather the nature of any acceptable loss reduction programme must reflect cultivation practices and socio-economic factors. The discussion which follows is not a thorough review of socio-economic considerations in loss assessment studies; rather it is intended to draw attention to their importance. However, some guidance is given on the approach to the economic interpretation of physical loss and to the evaluation of loss reduction methods. It should be emphasised that the advice of an economist should be sought at an early stage in the planning of a loss assessment study, so that arrangements can be made to collect the necessary information to enable full evaluation of losses and loss reduction programmes to be made.

EVALUATION OF LOSS REDUCTION MEASURES

Before introducing measures designed to reduce losses, four important questions need to be answered:

(i) are losses high enough to justify action?

(ii) is the loss reduction measure proposed both practical and acceptable?

(iii) do those suffering loss have sufficient motivation to take the necessary action to reduce losses?

(iv) where, when and how, exactly, in the system should action be taken?

Are losses high enough to justify action?

The reduction of post-harvest losses will require the use of various resources, some of which may already be scarce. In order to decide whether available resources should be used to reduce losses and the extent to which these resources should be used, their cost must be compared to the value of losses saved, that is, the benefits. For a programme to be accepted, benefits should exceed costs.

Even when a positive return is obtained, it is necessary to ask whether this is sufficiently large to encourage adoption. A loss reduction technique may be technically sound and financially viable but its ultimate acceptance by farmers will include other socio-economic considerations, risk, the degree of change needed in traditional handling and storage patterns, and availability of credit.

When evaluating a loss reduction programme the costs and benefits may have different consequences for different groups of individuals, for example, farmers, consumers, traders and even for the country as a whole. It is therefore essential to define from whose viewpoint the assessment is being made.

To a farmer, lost food is lost income and the size of the loss will depend on the replacement cost of the lost grain. The importance of that lost income will vary according to the farmers' individual economic status. For example, a poor farmer would tend to sacrifice more labour and perhaps other resources to prevent a given loss than would a larger farmer, because the loss represents a larger proportion of his total income. Even the same percentage loss is proportionally more valuable to a small farmer than to a richer one.

The sacrifice borne by the country is different again. In this instance the implications for the country as a whole are considered; for exmple, will imports need to be increased to replace the loss, are exports lower, what changes are needed in the allocation of resources between different sectors and different industries?

Valuation of costs and benefits

Costs The cost of a proposed improvement is normally the associated monetary value but, in particular at the small-farmer level, important inputs, such as family labour, may be used and no cash payment made. Nevertheless, these cash-free inputs have a value, sometimes a high value, and should not be ignored. A cost can be attributed by calculating the time input and an 'imputed' wage rate reflecting the value of the time as if it had been used in some alternative way.

When evaluating projects from the country viewpoint, the procedure is to treat as many of the inputs as possible as if they were internationally traded commodities and to apply border prices. A border price is the import price for imported commodities (c.i.f.), and the export price for commodities exported (f.o.b.). Any non-tradeable commodity is valued at its opportunity cost; the opportunity cost of a factor is the value of its output in its next most remunerative use. An important aspect of this procedure of evaluation is that any influence of subsidies or taxes on the resources is removed; taxes and subsidies redistribute money between different sectors of the economy, but do not make the country as a whole better or worse off.

Benefits Losses may be either quantitative or qualitative. Commonly most studies have taken the level of loss to be simply the percentage of physical loss. In an evaluation of food-grain loss, quantitative losses present fewer difficulties in interpretation into a monetary value. The monetary value is obtained by pricing the weight loss according to the price ruling at the time the loss is replaced and according to the use to which the lost produce would have been put.

This is usually simple to understand and value, but difficulties may arise when damaged food grain is not entirely discarded, but is used for a secondary purpose such as animal feed or for brewing alcoholic drinks. In the case of damaged seed grain, an entire batch of grain may be 'lost' (as seed), but it may have a secondary use as a food grain and therefore still has a value. To arrive at an accurate assessment of loss, the value of the produce in its secondary use should be deducted from the gross value of the loss incurred. An assessment of net loss should also take into consideration any costs additional to the produce itself that may be incurred when a loss occurs, for example, cost of cleaning or reprocessing damaged grain, additional handling/rebagging costs, etc.

Sometimes, secondary uses of grain intended for consumption have been unaccounted for by defining as loss anything which is no longer consumed. For small farmers, however, this definition may be inadequate because the secondary uses have an economic value to them. For example, traditional threshing, drying and processing techniques may result in spillage which is left for chickens or cattle to eat. In practice it would be difficult to calculate with any degree of accuracy a value for this secondary use of grain as animal feed. Therefore, while accepting that a monetary value cannot be ascribed to the grain and must therefore be excluded from a financial cost/benefit analysis, nevertheless this secondary use is important and must not be totally ignored. It should be mentioned descriptively.

Qualitative losses are more difficult to value. They may consist, for example, of changes in the physical appearance of the produce, nutritional deterioration, or the development of mycotoxins. These factors may be measured in a wide variety of ways and to obtain a single index of qualitative loss may be virtually impossible. It is usual, however, to consider the changes in the physical appearance of the produce (i.e. the consumer-preferred characteristics), and a quality loss is deemed to have occurred if a change in the physical appearance results in a lower price. Conveniently many countries have quality standards and these are used as a guide in calculating quality losses. Where standards are not available, then the more time consuming approach of establishing consumer-preferred characteristics and relating these to prices is required.

A reduction in the nutritional content of produce does not reduce its monetary value and therefore, in the short term, no financial cost is borne. In the long term however, this reduction may have a significant, dietary impact and affect labour, productivity or health.

Comparisons of costs and benefits A number of methods exist which compare costs and benefits, but whichever method is chosen it must be readily understood by the audience. The main method that has been used in loss assessment is the cost/benefit ratio but others have included the internal rate of return and net present value. These methods, which are no doubt easily comprehended by loss assessors, are likely to be unintelligible to the small farmer, the very person who needs to understand the benefits of loss reduction. For the small farmer, other more meaningful means of expressing the finding are required and one option is to express the savings as net benefits, either expressed in money or converted into grain saved. Whichever method is chosen, as costs and benefits occur over a period of years, account must be taken of time. The procedure is to discount all cash flows using a suitable interest rate.

If the value of the loss is low, then expenditure of appreciable resources on loss reduction may be unjustifiable. This does not mean that low losses (for example, measured on a weight basis) are not worth worrying about. A low physical loss may have an economic value which will justify some form of loss reduction. However, the method may have to be selected with care, particularly if the choice is between simple improvements to a traditional system and the introduction of a new concept.

Loss reduction does not inherently make the best use of resources, and even when storage losses are high the advantages of reducing losses as against making an alternative investment must be considered. For example, where the overall aim is to increase the quantity and quality of food, it may be advantageous for a country to spend resources on fertilizers to increase production, or to change the marketing arrangements to encourage farmers to store less, so as to provide them with a good supply of food grain at a guaranteed price throughout the year.

Is the loss reduction method proposed both practical and acceptable?

Loss assessment studies may indicate ways in which losses can be reduced, but before technical improvements can be recommended they must be considered in the social and economic context within which they are to be applied. The technically ideal may be quite different from that which is practicable and feasible within the existing socio-economic environment. It is a relatively simple matter to demonstrate that, say, 5% of farmers' grain is lost in a period of 9 months and a financially viable method exists that will reduce this loss to about l%. However, it is more difficult to convey the message to farmers, especially to those who are perhaps conditioned to accept a certain level of loss. Even when the financial benefits of a new technique are equally clear to the loss assessor and the farmer, the loss assessor should be aware that the farmer will consider other factors as well before accepting the improvement. The farmer will not only have to understand the technique being offered, but also believe that it is right for his particular circumstances. He may be reluctant to accept the improvement if its adoption involves a substantial change in his traditions or habits to the extent that he is ridiculed by fellow members of the community. Furthermore, he will look closely at the financial implications, taking account of both the initial cost and the likely costs of maintenance, spare parts, and additional materials.

It is often stated that losses of food grain arise because of the traditional attitudes and beliefs regarding the management of the post-harvest system and that farmers, especially small farmers, are reluctant to change. The evidence from farm-level loss assessment studies, however, demonstrates that the traditional post-harvest system has evolved according to local customs and social and economic conditions. Over several generations, the farmer's capability has become finely adapted to the point that he has become an efficient conserver of grains. The well-established, efficient, traditional practices are unlikely to be abandoned unless the farmer can see that the new techniques will be effective and will not result in a strain on social structures, income levels, etc.

At the national level, agricultural planners will have to be provided with a full evaluation programme to allow a decision to be made on the scope of any intervention thought necessary. This means that before a decision is taken, economic, sociological and perhaps political implications of the figures provided by the scientist will be sought.

Do those suffering loss have sufficient motivation to take the necessary action to reduce losses?

It is apparent from farm-level studies that the level of losses and the capacity of individuals to invest in loss reduction/prevention methods are related to economic status. Similarly, the response to loss reduction programmes is, therefore, closely related to economic status, and this in turn is largely dependent upon farm size. When a decision is made to introduce improvements it is essential that the improvements be tested by those who are to use them. Only then can it be known whether or not the people are sufficiently motivated to make changes and adopt the improvements.

Change is, however, inevitable. New agricultural practices or crops will ultimately lead to possibilities for increased levels of loss at all stages of the post-harvest system and if these losses are to be minimized, changes in post-harvest practices must follow. If these changes are to be introduced successfully, the target group for the loss reduction programme must be correctly identified. It is often assumed that the efforts of the extension service should be directed towards the farmer himself, yet it is clear that in many countries the women are responsible for post-harvest operations, particularly storage management. Myntti (1981) drew attention to this problem and pointed out that although this was the case in three countries that she had visited, the men were still the decision-makers, particularly in matters relating to agricultural improvement. She considers that the entire population should be given access to information which might result in a better standard of living, but acknowledges that women, particularly in rural communities, are often more difficult to reach than men. Loss reduction programmes must recognize the contribution made by women in the post-harvest sector and respond to their needs.

Once the target group has been identified, consideration must be given to the likely consequences of a loss reduction programme. In addition to the target group which will benefit from a reduction in loss, this loss reduction may have other social and economic consequences. For example, improved techniques to reduce storage loss would only be implemented if the store owner anticipated an increase in net income. However, should the improvement be widely adopted, the naturally occurring rise in prices during the storage period may be modified because of improved grain supplies, and in this instance the consumer clearly also benefits from the reduced storage losses.

Where, when and how, exactly, in the system should action be taken?

It is important that development planners should appreciate the likely sociological and economic impact of a loss-reduction programme as well as the purely financial benefits. The loss assessor can make a valuable contribution here because he will have acquired an intimate knowledge of post-harvest practices and how the community in which he has been working functions. Much of the information about the community will be obtained during the preliminary stages of the loss assessment survey and this will be supplemented by occasional questionnaires conducted at different times during the survey (*see* p.16) In particular, he will be able to advise on the type(s) of improvements to introduce, how they might be introduced and the possibile effects of these improvements. The loss assessor will be able to advise on other post-harvest changes that may be working in opposition to the objective of reducing losses. In Bangladesh and Indonesia mechanical hullers for rice are replacing the traditional method of pounding rice. Greeley (l982) considers the produce to be inferior, with a higher percentage of brokens and a lower milling yield, compared to that of the traditional system. Nevertheless the uptake of these mechanical hullers clearly shows that mechanical hullers are more acceptable to farmers despite the increase in processing losses.

Section 9

Discussion and conclusions

PLANNING AND OBJECTIVITY OF LOSS ASSESSMENT STUDIES

It has long been recognized that some form of loss assessment study is often required to justify a loss reduction activity, but a criticism of early surveys is that objectivity was lacking. Before embarking on a loss assessment study it is important to ensure that the objectives are clearly defined and the use to which the results will be put are carefully considered.

Where losses are obvious, little more than a rapid appraisal to establish the priority action is needed. Crude measurements alone suffice, providing the reference point from which improvements can be judged. Where losses are less obvious, more detailed measurements are required. These might be obtained in two ways. Firstly, the small-scale, virtually experimental study which will produce relatively precise data, but uses only a very small area and so cannot be related to national or regional efforts. A more practical approach is a large-scale study which covers a wide area and many farmers. The accuracy of individual assessments will not be as precise as in the first approach, but will nevertheless provide reasonable figures at minimum cost. Crucial to planning is timing of the study in relation to the state of the season, the time required to train staff and the period needed to develop the methodology. Ideally a dummy run prior to the main study is required. This serves to check the methodology (especially data collection and sample analysis) and permits training of local staff, which is essential.

STAFFING, OPERATION AND FUNDING

The small-scale, experimental study is a full-time occupation for an expert with few local support staff, and is more suitable for developing methodologies of loss assessment, whereas in the more practical, large-scale study many local staff can be used, mostly at a fairly low level of education, each carrying out simple tasks. The extent and type of supervision required will be determined by the calibre of the staff, but experience has shown that full-time supervision rather than a series of short supervisory visits at predetermined intervals is highly desirable. There are few reports of full multidisciplinary teams being involved in post-harvest loss assessment studies, except perhaps at the rapid appraisal stage. This may be a reflection of the difficulty in fielding and/or managing such teams. Specialist interests may tend to lead the work away from the overall objectives of a study. Good results can be obtained when the study is supervised by an individual (specialist or generalist) who understands the complexities of the post- harvest system and is supported by specialists of other disciplines at appropriate times.

Operation is invariably restricted by practical constraints, such as difficulty with transport or lack of equipment. Funding can also be a problem where a budget is split between donor or local sources. It is therefore important that there is a true national commitment to the identification and reduction of post-harvest losses. A suitable local organization must be charged with the responsibility for the work and provided with adequate funds to carry it out.

UTILIZATION OF DATA

Very often more data tends to be collected than is really necessary. There may be a considerable difference between the amount of data needed on which to base a decision on loss reduction and that required to convince a politician or to publish a comprehensive account of the work. Only that information which is relevant to the objectives of the study should be collected.

Loss assessment studies should not be confined to the traditional, unimproved system, but should include an evaluation of loss reduction techniques. The rapid appraisal will identify those loss reduction techniques already in use and possible additional improvements. These should be introduced at an early stage so that the results of the study provide not simply an estimate of loss, but guidance on how the loss might be reduced.

METHODS OF ASSESSING POST-HARVEST LOSSES

In the mid-1970s there was widespread agreement that a standardized approach to the assessment of post-harvest losses was needed as a first step towards the introduction of appropriate loss reduction programmes. The publication *Post-harvest grain loss assessment methods* compiled by Harris and Lindblad (1978) was seen as an attempt at describing, for the first time, such a standardized approach. In order to develop the approach as objectively as possible, loss assessment studies largely concentrated upon the measurement of weight losses, since it was felt to be the simplest factor which could be quantitatively expressed. Since then there have been few, if any, specific attempts to test the methodology; rather this publication has served as the basis on which a methodology to suit local conditions has been developed.

Experience has demonstrated that the methods are not universally applicable in the field. There can be no single best method for assessing losses; the methodology must be prescribed for each situation to meet local constraints.

The limitations of the methods are now more fully understood and it is clear that further investigation of some techniques, particularly laboratory techniques related to storage loss assessment, is required. However in pursuing these investigations one must guard against becoming overconcerned about the degree of reliability of the techniques and losing sight of the ultimate objective. What is required is a reasonable estimate of loss on which decisions can be made about the scope of a loss reduction programme. The point at which by far the larger errors occur is not at the sample analysis stage, but at sampling in the field unless, of course, a truly experimental approach is being followed. The experimental approach adopted in the early stages of methodology development was entirely correct, but what is needed now is an approach which will provide reasonable figures at minimal cost; loss assessment studies must not become so refined that they become more costly than the action needed to reduce the loss.

Losses at harvesting

The losses which occur at harvesting are strictly post-production rather than post-harvest losses and, as such, were not considered by Harris and Lindblad (1978). Nevertheless, there has been considerable interest in assessing harvesting losses using methods based upon standard crop-cutting techniques to assess yields. Various approaches have been used but no single methodology can be described as ideal. Further investigation is needed and a comparison of the various techniques used should be undertaken to establish whether a standardized methodology for assessing harvesting losses can in fact be recommended. The difficulties of obtaining accurate measurements, of crop yields are well known (Yates 1981) and so whenever these techniques are used for loss assessment each situation must be carefully assessed. Before attempting any measurements, the precautions needed to reduce the possible bias of the results must be understood. It is likely that errors in the technique will be greater than the actual loss and that the measures needed to reduce the error will involve an unacceptably high work load.

Losses during stooking and stacking

There are few reports of studies of losses during stooking or stacking but the methodology which has been adopted appears to be satisfactory. Emphasis has been placed upon measurement of the physical loss of grain through shedding or scattering, although some workers have considered the qualitative loss caused by damp grain heating. Losses caused by insect infestation whilst grain remains in a stack can be measured using any of the standard techniques for assessing insect loss in storage (*see* below).

Losses during threshing

Losses during threshing may arise because of (a) incomplete threshing (grain on the straw), (b) damage to the grain itself and (c) scattering and spillage. The techniques, described by Harris and Lindblad (1978), for the assessment of losses of grain on the straw and losses due to damage to the grain itself have been used or adapted satisfactorily. Estimates of loss through scattering are more difficult to achieve, but unless there is a good possibility of reducing this loss there is little point in measuring it, except as an academic exercise.

Losses during drying

Field drying of maize: The procedure developed in Honduras for assessing the loss in maize cobs left on the field to dry is worthy of further investigation. There is a need to establish guidelines on the size of samples required and how they should be selected in order to achieve a reliable estimate of loss.

Losses in yard drying and in grain dryers: The principles for assessing losses during drying are sound. The physical loss of grain from the drying site is relatively easy to measure by checking the weight of grain entering and leaving the system. More difficult is the assessment of the loss of quality during the drying process. Practical experience is limited to studies of paddy and although standard laboratory rice milling, drying and grading procedures have been used satisfactorily to assess quality loss during drying there is no similar experience with other crops such as maize, sorghum or wheat.

Losses during grain processing

The standard procedures for measurement of the efficiency of rice milling equipment are well developed. They have been used successfully in studies of losses occurring during rice processing mainly at the farm and village level, but have also been adopted on at least one occasion to study losses in a larger commercial system. The published methodology can therefore be regarded as adequate, although some modification may be required to suit local conditions. A procedure for the assessment of loss during grinding (of maize, sorghum, wheat, etc.) has been described but there are no records of this being used in a loss assessment study. A field study is required to confirm that the procedure is indeed acceptable.

Losses during cooking

A laboratory procedure to assess the loss of solids and certain nutrients of rice during cooking has been described but this is largely of academic interest. It is most unlikely that the technique would be used in a study of farm-level losses.

Losses in storage

Insects

When the three techniques for determining losses caused by insects in storage were first recommended in *Post-harvest grain loss assessment methods* the various problems affecting their reliability were, to some extent, understood and accepted. They were, perhaps, even regarded as unimportant in relation to the overall figure for loss obtained at the end of the study. What was considered important was the need to begin detailed studies of storage losses using an accepted methodology to produce figures, which although still open to question, were regarded as being more reliable than those available hitherto. Application of the techniques in the field and laboratory investigations have led to a better understanding of their limitations and a new technique has been proposed (the thousand grain mass (TGM) method). Preliminary results from laboratory studies of this method are encouraging, but field application is only just beginning and it remains to be seen whether in fact this technique is better than those previously used.

There are still few comparative data on the reliability of the different techniques and it would be unwise at this stage to rely upon a single technique in a study of storage losses caused by insects.

A practical difficulty in using both the volumetric and TGM methods is the need for a baseline (reference) sample collected at the beginning of the storage season. Unless the loss assessment study is a small-scale, experimental one, it will be difficult to obtain such a sample from every store. A technique which can be used at any time, usually within the first 4-6 weeks of putting the grain into store, and which does not require a baseline sample, would be more appropriate. The improved count and weigh technique, which takes account of the variation in size of grains within a sample, would appear to be suitable in this respect. However, experience with this technique is even more limited than with the TGM method and further investigations both in the laboratory and in the field are urgently required.

Moulds

The assessment of losses due to mould must take account of the quantities of grain which are unfit for consumption. A measurement of a simple weight loss alone is not sufficient. The farmer's view of what is, or is not, acceptable may not always provide a useful indicator of the true loss. The amount of grain lost to the individual will depend upon, for example, the crop yield, the degree of hunger or the degree of affluence of that individual. A better indication of loss would be achieved by adopting a standardized grading technique which reflects the average level of acceptability of mould-infected grain.

Vertebrate pests

Rodents A methodology for assessing storage losses caused by rodents was described in great detail by Jackson and Temme (1978) and Greaves (1978), but there is little evidence that it has been used in storage loss assessment studies, probably because it is more suitable for use in warehouses rather than at the farm and village level.

Even if the methodology, which is based upon population estimates and feeding trial data, could be used at the farm/village level, the information on the amount of food consumed by rodents is likely to be of less relevance to the justification of a rodent control programme than a simple demonstration that a rodent problem exists and is considered important by the local community.

Birds As far as can be determined there have been no attempts to measure the loss of stored grain caused by birds. Little guidance can be offered, except that, as in the case of rodents, the need for figures for loss caused by birds at the farm level is considered minimal.

Estimation of total loss

Estimates of farm storage losses recorded at one period during the storage season will not give an indication of overall losses throughout the year. If the objective is to know what losses farmers are suffering then a study over the whole storage season is vital. Losses in a sample must be related to the pattern of consumption.

FUTURE APPROACH TO ASSESSMENT OF POST-HARVEST LOSSES

There has been a somewhat piecemeal approach to post-harvest loss assessment. Studies of discrete parts of the post-harvest system have been undertaken, but rarely have losses at the different stages been considered in relation to each other. Much of the available data on losses relates to small farms with unimproved traditional systems, particularly of storage. Moreover, the information has been derived from studies of a limited range of crops and only under a limited range of climatic conditions. There is a need to undertake field studies aimed at filling the gaps in the present knowledge, for example, in relation to storage and processing of pulses and groundnuts and storage of maize in hot, wet climates.

The methodology developed for farm-level studies cannot be applied to commercial systems. Although loss may be attributable directly to physical, chemical or biological factors the root cause may be shortcomings of management and an approach which takes account of such factors is required.

The piecemeal approach to post-harvest loss assessment is therefore likely to continue. Nevertheless, greater consideration must be given to the post-harvest sector as a whole and losses which occur in systems embracing harvesting (as a precursor to other losses), threshing, handling, processing, marketing, storage and transport. Within the post-harvest system there is a complex interaction of factors which frequently results in a loss, be it of food, money, effort, or efficiency. Methods of qualifying or quantifying these factors (for example, social, economic, political, technical) must be developed in order to measure the efficiency of the post-harvest system, rather than weight losses alone. The object is to achieve greater efficiency in conserving both quality and quantity of foodgrain passing through the post-harvest system. By application of a systems approach, it will be possible to determine the resources required for the attainment of acceptable, minimum levels of loss for any archetypal agricultural system.

Appendices

APPENDIX IA SOURCES OF INFORMATION LIKELY TO BE USEFUL DURING PLANNING OF A POST-HARVEST LOSS ASSESSMENT PROJECT

1 Records of population censuses

2 Lists of villages with population statistics

3 Large-scale maps and an indication of their reliability

4 Aerial photographs, serial or individual with indication of location, and dated

5 Maps—of vegetation, soil type, tribal areas, etc.

6 Geological survey data

7 Meteorological data

8 Production and marketing data, giving quantities, handlers, etc.

9 Farmers calendar

10 Agricultural Department organization—maps showing location of offices, staff lists, experimental farms, observational areas, etc.

APPENDIX IB QUESTIONS ON POST-HARVEST OPERATIONS AT THE FARM LEVEL

The following questions are a check list for use by those investigating a known or suspected post-harvest problem. So many factors affect post-harvest losses that it can be most misleading to suggest specific remedies or control methods until the more important of these factors are known.

However, it is important to remember that it may be possible and indeed desirable to begin loss reduction activities before, or instead of, a loss assessment study.

The first questions to ask are therefore:

1 What can be done locally now?

2 What can be done in time for the next crop season?

3 What outside help is needed and who can provide it?

It may be decided that a loss assessment study is needed, but the following questions should first be asked in the following categories:

A AREA OF PROBLEM

B CROP

C WEATHER

D POST-HARVEST OPERATIONS AT FARM LEVEL

E MARKETING

F STORAGE STRUCTURE OR CONTAINER

G PESTS AND CONTROL

H ADVICE AVAILABLE

I LOSSES

It is fully appreciated that it is rarely possible to obtain all the answers. Even so, a partially completed list will usually enable the preparation of guidelines for action and further investigation. Separate lists of answers should be prepared for each crop and for each major post-harvest operation.

A Area of problem

How widespread are the suspected losses? i.e. does the problem relate to a few villages, to a district, a region, or to the whole country?

B Crop

1 What crops are concerned? Mention varieties if any, such as local hybrid maizes, paddy and hill rice, hybrid and locally grown sorghums, etc.

2 Have losses in this crop been estimated or 'guestimated' already? If so, what was the estimate? (more details in Section I Losses).

C Weather

1 What is the *average* monthly temperature and rainfall during the full crop season?

2 What is the average monthly temperature and rainfall in the present, or immediately past, crop season?

D Post-harvest operations at farm level

1 In what month (or months) is the main crop harvested? Where there is more than one harvest, give all dates, indicating which is the main crop.

2 What method of harvesting is used? Who does the work? e.g. farm family, hired labour?

3 If any portion is husked, shelled, threshed or treated in any way before storage, at what time is it done? e.g. straight after harvest or intermittently to meet household and sale needs.

4 What method of husking, shelling, threshing is used? Who is responsible for this task?

5 How and at what stage is the crop cleaned? Who is responsible for this task?

6 By what method is the crop dried?

7 How does the farmer know when the crop is dry enough to store?

8 How near are the stores to the fields where the stored crop is grown?

9 How is the crop transported from the field?

10 For how many months is the crop normally stored on the farm?

11 In what form is the crop stored? i.e. if maize, is it on the cob,with sheath intact, cob alone, or shelled?

12 Is the crop stored at more than one location, e.g. near or in the house; on fields far from the house; village centre?

13 Is the storage carried out by each farmer, by an extended family, a tribe, village, a co-operative, small traders, or absentee owners or a combination of these?

14 If the storage is by individual farmers, how is the work of storage divided between husband and wife? e.g. Husband does all the work up to storing; wife is responsible for taking grain out of store and also maintenance of store?

15 Concerning the family subsistence crop, how frequently is it drawn upon from store? i.e. every day, each week, each month, or irregularly?

16 Is the crop processed (milled/pounded) on the farm or at a local mill? If on the farm who is responsible for this task?

E Marketing

1 What proportion of the crop is sold off the farm?

2 If a proportion is sold, at what time or times (in relation to harvest) is it sold?

3 Does a Government Marketing Board or large co-operative buy all or most of the cash crop, or is the trade in private hands?

4 Are there commodity price increases as the storage season advances?

5 Would farmers store more, either for food or for sale, if storage losses were less?

6 If not, are there other factors which limit the amount a farmer stores, e.g. lack of markets or roads; shortage of materials, of crop, or labour; some crop pledged to a trader?

7 Do farmers sell as much as they can as soon as possible and risk buying back later in the season? If so, is this due to heavy storage losses, or to shortage of capital, or some other reason?

8 Is there a price/grade structure available to farmers or traders or both, or are higher prices, later in the season, due solely to scarcity?

F Storage structure or container

1 What are the most common kinds of structures or containers for storing this crop? A sketch showing rough dimensions and capacities should be prepared.

2 What materials are used to build these structures? Are they readily obtainable locally?

3 What is the estimated length of life of these structures?

4 What is the estimated cost of building these structures, in materials and labour (money and man/days)?

5 Is the general standard of construction good, average or poor?

6 Are craftsmen employed to build the store? How are they paid?

G Pests and control

1 What pests attack the crop in store? Identify them as specifically as possible, particularly the insect pests. Group pests under rodents, moulds, insects, others.

2 What is the relative importance of these pests?

3 At what time(s) of the year is the pest attack worst? i.e. is the damage seasonal, and if so, when does it begin, and for how long is it serious? If possible, this information should be recorded separately for specific pests.

4 Are any of the storage pests also found on the growing crop, on adjacent different crops or plants, or in neighbouring stores and buildings?

5 Are traditional pest control measures presently used? If so, how well do they work? e.g. sweeping out empty stores and burning sweepings, raising store on legs against rats, mixing grain with wood ash, exposing to hot sun to drive off insects, storing in smoke over fire, sealing grain in pots or drums, etc.

6 Are general agricultural pesticides locally available? (list type and prices).

7 If pesticides are used at all against storage pests, state their kind, dosage rate, and frequency of use. How widespread is their use?

H Advice available

1 What kind and extent (quality and quantity) of advice is available to farmers/traders on post-harvest problems from the local agricultural extension service?

2 What agricultural research stations, or laboratories are there available in the area?

3 Are pest control companies operating in the area?

4 What advice is obtainable from other sources, e.g. marketing boards, co-operatives, commercial firms?

5 Are there farmer training centres which do, or could, run courses on or including storage?

I Losses

If an assessment of losses has been made:

1 Who made it?

2 In what year(s) was it made?

3 In what month(s) was it made?

4 Is the record published or otherwise available?

5 To how large an area was this assessment thought to apply?

6 What method of assessment was used? Has it been published?

7 Were crop yields that year above, below, or on the average?

8 Were the temperature and rainfall that year above, below, or on the average?

APPENDIX II EQUIPMENT FOR MEASUREMENT OF POST-HARVEST GRAIN LOSSES

The items of equipment listed are those most likely to be required in post- harvest loss assessment studies. The final choice of items will be governed by several factors, for example, the scope and scale of the exercise to be undertaken and the financial resources available. Descriptive notes are included to aid selection of items and a list of suppliers' names and addresses is given. It is intended that this should be used as a check list by those planning a loss assessment study. It is not exhaustive nor is it complete in its coverage. The items included are generally those which have been found to be suitable; other equipment may serve equally well. No discrimination is intended against any manufacturer whose equipment is not included. Where prices are given (in US dollars) they should only be taken as an approximate guide; they were believed to be current in early 1984.

SECTION I Sampling grain in bags and bulk

SECTION 2 Sample reduction

SECTION 3 Moisture measurement

SECTION 4 Harvesting and threshing

SECTION 5 Processing

SECTION 6 Insects, mites and micro-organisms

SECTION 7 Rodents

SECTION 8 General equipment

SECTION 9 Names and addresses of suppliers

Section I Sampling grain in bags and bulk

Sampling bagged grain

Spear sampling does not conform to basic principles of representative sampling due to the haphazard nature of the sampling.

(i) Simple bag spear (sampler, sack trier or probe) (*See* Figure A)

Shape, size, position of aperture, etc. are variable, but a cylindrical or tapered type having a penetration of 40-45 cm is preferred. Shorter spears do not allow sampling of material deep inside a bag.

External diameter should be 12 mm for small grains such as wheat or rice and 25 mm for larger grains.

Suppliers: Cambridge Repetition, Rudebeck, Seedburo, Tripette
Price range: US$15-20

(ii) Double tube bag spear (*see* Figure B)

This consists of two tubes, one fitting closely inside the other, each with a line of slots corresponding to similar slots in the other tube. The inner tube can be rotated to close the slots. Spear length may vary from 45 cm upwards and diameter may vary from 12 mm to 50 mm. A length of approximately 45 cm is required for bag sampling.

Sample material can be removed from the spear either by pouring it from the open handle or by holding the spear horizontally with the slots downwards to deposit the material in small heaps corresponding to the original sampling positions:

Suppliers: Rudebeck, Seedburo, Tripette
Price range: US$130-150

(iii) Produce flow sampler

Capable of extracting a truly representative sample from a whole bag of grain. Very large size, so it is not readily portable. Originally designed for sampling bags as they are off-loaded from a truck.

Figure A

Simple bag sampling spears

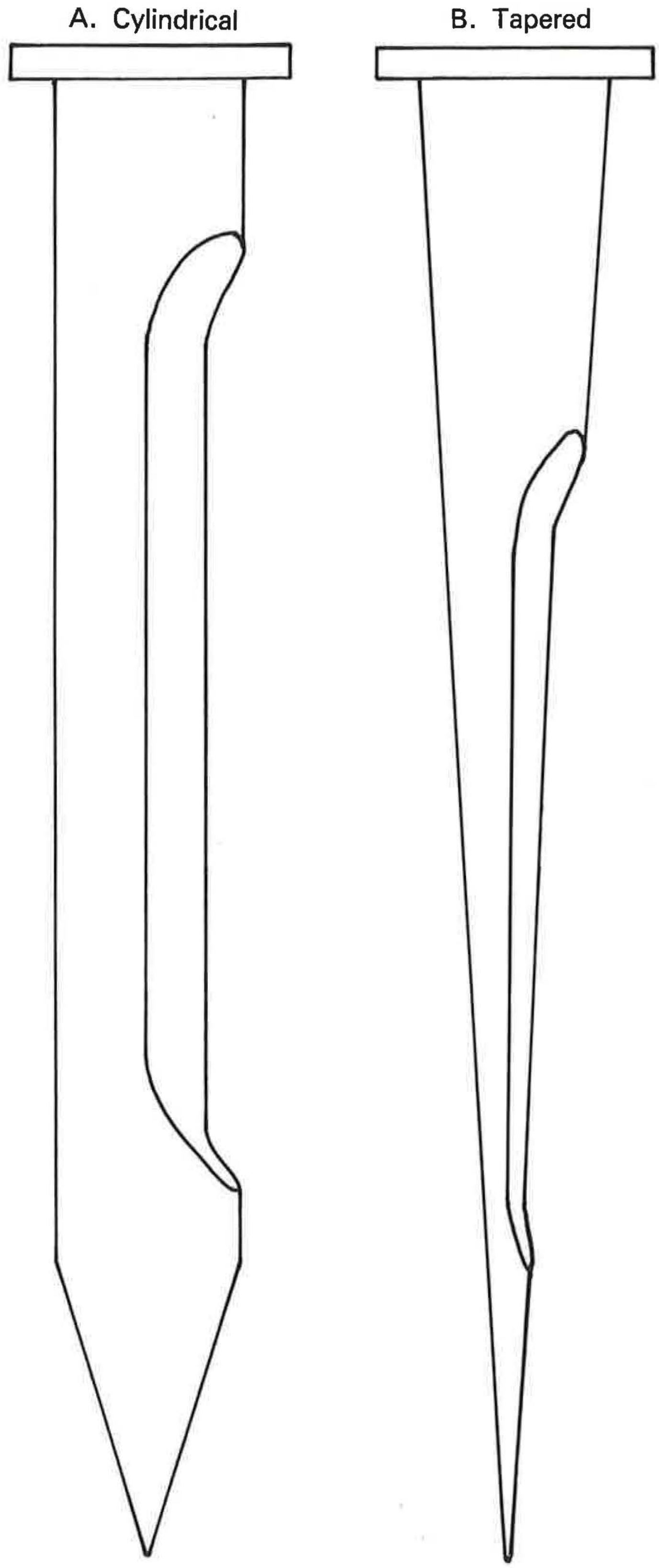
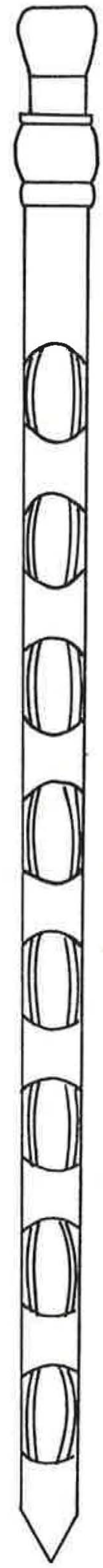


Figure B

Double tube sampling spear



Sampling of 100 kg bag completed within 20 seconds.

Supplier: Advanced Industrial Mouldings

N.B. Currently out of production, but will be produced if sufficient demand—price likely to be in excess of US$900

(iv) Cargo divider

Divider designed to reduce bulk samples, but can be used in the same way as the produce flow sampler (*see* (iii) above) but for smaller quantities of grain.

Supplier: Seedburo
Price: US$600

Sampling bulk grain

(i) Double tube sampling spear

As (ii) above but the inner tube should be compartmentalized. Length up to 3.5 m, width 12-50 mm, but a spear 1.8 m long and 35 mm wide will generally be acceptable. Grain can be withdrawn from several identifiable positions along the line of penetration.

Suppliers: Rudebeck, Seedburo, Tripette
Price range: US$100-200

(ii) Deep bin probe or cargo sampler

This consists of tapered, hollow spear head which serves as a sampling cup, with a spring loaded cap attached to a wooden or metal rod. A series of extension rods may be added as the probe is inserted into the bulk.

Maximum expected depth of penetration (with considerable physical effort) is about 5 m.

A single probe yields up to 300 g of sample material.

Suppliers: Seedburo, Tripette
Price range: US$150-200

Section 2 Sample reduction—(*see* also Appendix X)

(i) Box divider (the riffle or multiple slot divider)

Simplest of sample dividers, recommended by the International Organization for Standardization. Compact and portable. Two models available:

$\frac{1}{2}$ inch (12.7 mm) slots for dividing samples of large grains, for example, maize
$\frac{1}{4}$ inch (6.4 mm) slots for dividing samples of small grains such as wheat.

Suppliers: Endecotts, Scientific Supplies, Seedburo, Tripette
Price range: US$125-160

(ii) Boerner divider

Produces reduced samples of equal quality and quantity and is recommended by the International Organization for Standardization.

Its large size restricts use to laboratory research.

Suppliers: Satake, Seedburo, Tripette
Price range: US$600-700

Section 3 Moisture measurement

Field use

Moisture meters for field use must be portable, battery operated, quick and simple to use. It is unreasonable to expect most meters for field use to be capable of measuring to an accuracy of less than 0.5%. The meter selected should cover the expected range of moisture contents. Final selection will also depend upon the commodity being measured and the availability of spare parts, including batteries, etc.

The following are considered suitable:

(i) Models using a ground sample

—Protimeter grain-mini

Calibrations are available for most commodities.

Supplier: Protimeter
Price: US$140-210

—Marconi TF 933C

A grinder (e.g. coffee grinder) is needed for use with this meter. Calibrations are available for most commodities.

Suppliers: Bentall
Marconi Instruments (United Kingdom and USA)
Price: US$450-500

(ii) Models using whole sample

—Cera tester

Calibrations are available for most commodities.
A small balance is provided to weigh a sample of whole grain which is then poured into the cell. The moisture content (read off on a scale) is corrected for temperature from a thermometer incorporated in the body of the meter.

Supplier: A/SN. Foss.
Price: US$450-500

—Dole moisture meter

Calibrations available for most commodities.

A small sample is weighed on the balance provided with meter, and poured into the cell. The moisture content is corrected for temperature using a separate thermometer.

Suppliers: International Marketing, Seedburo
Price: US$220-260

—Dickey-John

Calibrations available for a wide range of commodities.

A sample is poured into the measuring cell and the moisture content corrected for temperature is read off from a digital display incorporated in the handle of the meter. A very similar meter is known as the 'Safecrop'.

Suppliers: Dickey-John, Robydome, Seedburo (Safecrop)
Price range: US$400-420

Laboratory use

Whilst the meters listed above may be equally suitable for laboratory use, a more sophisticated meter capable of measuring more accurately than ±0.5% may be required.

(i) Battery operated

Kett Grainmaster

Calibrations available for a wide range of commodities.

Supplier: Kett Electric
Price: US$650-800

(ii) Mains operated

Burrows Moisture Computer Model 700

Calibrations available for most commodities.

Suppliers: A/SN Foss, Nickerson, Seedburo
Price: US$1,700-2,000

Moisture meter calibration

(To International Organization for standardization Specification ISO-R-712 April 1968).

All equipment required to meet ISO Specification.

(i) Laboratory oven with fan assisted ventilation and safety stat

Suppliers: Astell Hearson, Seedburo
Price range: US$1,200-1,800

(ii) Analytical balance

Weighing to 0.0001 g.

(a) Precision beam balance

Suppliers: Gallenkamp, Sartorius, Seedburo
Range: US$3,000-3,500

(b) Top loading electronic balance

Suppliers: Mettler, Sartorius, Seedburo
Price range: US$1,000-2,000

(iii) Aluminium containers

Supplier: Astell Hearson
Price per 10: US$25

(iv) Desiccators

Scheilber Pattern, 20 cm diameter.

Suppliers: Astell Hearson, Gallenkamp, Scientific Supplies
Price range: US$35-45

(v) Grain Mill

Suppliers: Glen Creston, Regent Maskiner
Price range: US$450-600

Section 4 Harvesting and threshing

(i) Measuring tape

For measuring plot size. A 50 m woven cloth, 'reel-in' tape is preferred.

Suppliers: Gallenkamp, Seedburo
Price range: US$25-28

(ii) Moisture meter

Suitable for use in the field.

Refer to Section 3A, *Field use.*

(iii) Spring balance

For weighing samples of grain. It may be necessary to use several balances with varying capacities for the field situation under study. A range of balances is available: refer to Section 5.

(iv) Suspension spring balance

For weighing large samples of grain, or grain from crop cuts or threshing floor. Maximum capacity can be 65 kg if loss assessment survey is restricted to harvesting/threshing, but if survey includes storage, a larger capacity balance (e.g. 100 kg) should be obtained. Refer to Section 5.

(v) Sickle or scythe

Traditional implement for harvesting.
Purchase locally.

Section 5 Processing

Maize shelling

Simple hand held maize shellers are available to aid hand stripping.

Suppliers: *TPI Rural Technology Guide No 1 (Design for wooden hand-held maize sheller*). Similar from Seedburo, Hunts
Price range: US$8

Threshing

Small or single head threshers may be used to standardize laboratory threshing for comparative purposes.

Suppliers: Alvan Blanch, Seedburo
Price range: US$600-1,100

Wheat milling

(i) Laboratory-scale mills with stone grinding surfaces for the production of whole wheat flour may be used for comparative purposes.

Supplier: Samap
Price range: US$100-350

(ii) Production of extracted 'white' flour on a laboratory scale is achieved by using an experimental roller mill.

Suppliers: Buhler
Price range: US$22,000

Flour quality and test bakery

Specialized equipment for the assessment of flour, dough and bread quality is available.

Suppliers: Henry Simon, Brabender

Rice processing

For a fuller range of the equipment available for rice processing, reference should be made to Clarke (1978)

Rice hullers or dehuskers

Laboratory machines for the removal and separation of husk from paddy rice. There are three basic types:

(i) those with rubber coated rolls (the preferred type).

Suppliers: Colombini, Satake, Schule
Price range: US$1,000-1,600

(ii) those with disc hullers.

Suppliers: Colombini, Minghetti, Schule
Price range: US$700-2,000

(iii) those having one metal and one rubber roll.

Suppliers: Mercator, Seedburo
Price range: US$4,000

Rice Whitening

Laboratory machines for the removal and separation of bran and germ from dehusked rice. There are two basic types:

(i) those with abrasive coated cones or discs.

Suppliers: Colombini, Minghetti, Satake, Schule
Price range: US$2,200-5,000

(ii) those with metal rotors.

Suppliers: Mercator, Seedburo
Price range: US$1,600-4,700

Laboratory-scale complete milling systems incorporating dehusking, whitening and milled rice brokens separation are available.

Suppliers: Colombini, Schule
Price range: US$4,000-5,300

Separators

(i) Size separation. *See* under *Sieves* (Section 6).

(ii) Broken grain separation.

(a) Hand-held flat trays with appropriate indentations.

Suppliers: Colombini
Price range: US$40

(b) Mechanical devices, reciprocating or rotary.

Suppliers: Colombini, Schule, Seedburo
Price range: US$700-2,200

(iii) Aspirators.

Used to separate particles according to terminal velocity.

Suppliers: Mercator, Satake, Schule, Seedburo
Price range: US$900-3,800

Alternative machines having aspirators attached to hullers can be used.

Dryer

Small laboratory batch dryer.

Suppliers: Colombini, Satake, Schule
Price range: US$1,600-4,700

Parboiling

(a) Laboratory pressure cooker may be employed.

(b) Specialized equipment handling small (kilogramme) quantities of paddy.

Suppliers: Schule, Gariboldi
Price range: US$13,500-16,000

Grain quality determination (*see* also Sections 6 and 8)

(i) Analytical laboratory equipment and chemicals for the determination of the effects of the interactions of processing and grain quality may be available locally.

Alternative suppliers: Gallenkamp, Scientific Supplies

(ii) Assessment aids for visual and other physical inspection of grain may be required.

Suppliers: Gallenkamp, Satake, Scientific Supplies, Seedburo

Section 6 Insects, mites and micro-organisms

(i) Sieves

For grain quality assessment, including removal of free-living insect populations from samples, perforated metal plate sieves are preferred to woven wire cloth sieves. Specifications for the sieves used in loss assessment surveys should conform with local standards where these exist.

A wide range of screen specifications in aluminium frames (but not to metric sizes), suitable for situations where US-based (non-metric) standards are employed, e.g. USA and Philippines, available from: Seedburo.

A wide range of metric screen perforations to ISO standards, including test sieves, in strong brass or steel frames available from: Endecotts.

A comprehensive range of metric specifications, in brass or aluminium frames available from: Tripette.

(ii) Laboratory balances

For weighing samples of grain. Balance should be provided with scoop. Capacity 2 kg × 0.1 g.

Suppliers: Osi, Prolabo, Scientific Supplies, Seedburo, Testut
Price range: US$140-160

An electronic, top pan balance with similar capacity (2 kg × 0.1 g) may be more convenient and ensure speedy weighing, but is more expensive.

Suppliers: Mettler, Sartorius, Seedburo.
Price range: US$1,000-1,200

(iii) Bushel weight/hectolitre weight tester (chondrometer)

Used for assessing losses due to insects in samples of grain - (volumetric method)—*see* also Appendix VII. The complete apparatus consisting of weighing bucket, levelling stick, filling hopper and balance unit can be used, but more usually the balance unit is not required, the grain being weighed on a laboratory balance.

The simplest piece of apparatus consists of weighing bucket, funnel and strike-off stick.

Suppliers: Satake, Seedburo
Price range: US$350-650

An alternative type of tester consists of a standard weighing bucket with a filling tube, cut-off slide and plunger to ensure fixed drop height, steady dropping speed and accurate levelling. The complete apparatus includes a balance for weighing the full bucket.

Supplier: E.L.E., Tripette, Rudebeck
Price range: US$650-800

(iv) Spring balance

For weighing samples in the field. Various capacities available and choice will depend upon the operation under study. Suggested capacity 2 kg × 5 g.

Suppliers: Gallenkamp, Salter Abbey, Scientific Supplies, Testut
Price range: US$7-9

(v) Balance for weighing grain into and out of store

Balance should be robust and easily transportable.

Maximum capacity: 100-150 kg × 250/500 g according to local bag sizes. Suspension spring balance with dial will usually be found most convenient.

Suppliers: Gallenkamp, Salter Industrial, Seedburo, Testut
Price range: US$40-60

(vi) Magnifying lens

For examination of damaged grains, etc.
Lens should be mounted on a stand and preferably illuminated. If not illuminated a laboratory bench lamp will be required.

Suppliers: Satake, Scientific Supplies, Testut
Price range: US$20-25

(vii) Binocular microscope (stereoscopic)

For insect identification, variable magnification from × 5 to × 50. Microscope should preferably have inbuilt illumination, if not a laboratory bench lamp will be required.

Suppliers: Osi, Satake, Scientific Supplies, Tripette
Price range: US$1,050-$1,500

(viii) Seed counter

(a) Hand operation

Tally counter as an aid to hand counting grains.

Suppliers: Gallenkamp, Scientific Supplies, Seedburo
Price range: US$10-12

Grain counting trays for counting 100 or 500 grains

Supplier: Satake
Price range: US$20-40

(b) Electrical counter

Expensive item of equipment but may be useful where large numbers of seeds are to be counted accurately.

Suppliers: Seedburo, Tecator, Tripette
Price range: US$2,000-2,500

Section 7 Rodents

(i) Snap (or breakback) traps

Mouse size—striking bar 40-50 mm long
Rat size —striking bar 70-80 mm long
Suppliers: Lincoln, Procter, Rodent Control, Tomahawk, Woodstream

(ii) Live traps

For trapping for marking—size suitable for both mice and rats.

Suppliers: Longworth, Procter, Tomahawk, Woodstream, Youngs

(iii) Spring balance

Capacity 100 g × 1 g (for mice)
500 g × 5 g (for rats)

Suppliers: Salter Industrial, Stevens, Testut
Price range: US$7-9

(iv) Dissecting scissors, 125 mm

Suppliers: Gallenkamp, Scientific Supplies
Price range: US$7-10

Section 8 General equipment

Whirling hygrometer, for recording relative humidity in air spaces.
Suppliers: Gallenkamp, Osi, Prolabo, Scientific Supplies, Seedburo

Dust mask—paper disposable type for use when sieving dusty samples.
Suppliers: Seedburo, Tripette, or available locally

Electric torch or flashlight—available locally

Polythene sheets—approximately 1.5 m square to provide working surface for examination of samples in the field. Available locally.

Overalls or protective clothing as required. Available locally.

White trays—enamel or static-free plastic, approximately 50 × 25 cm for sample examinations.

Supplier: Scientific Supplies, or available locally

Sample pans—triangular, heavy tin, enamelled, approximately 25 cm × 25 cm × 25 cm × 6 cm deep.

Supplier: Seedburo

Jars or wide mouth bottles, glass or clear plastic with tight-fitting lids for retention of samples.

Suppliers: Osi, Prolabo, Scientific Supplies, Seedburo or available locally

Sample bags (cotton) 20 cm × 30 cm for temporary storage of samples.
Suppliers: Seedburo, Tripette, or can be made locally

Sample bags (polythene) 20 cm × 30 cm for sample collection and storage.
Suppliers: Burrows, Scientific Supplies, Seedburo, Tripette or available locally

Specimen tubes—polythene, hinged push-in lids approximately 16 × 64 cm.
Suppliers: Gallenkamp, Scientific Supplies

Forceps, fine point and blunt point for seed handling.
Suppliers: Osi, Prolabo, Scientific Supplies, Seedburo

Brushes, paint brushes and artists brushes for sweeping and handling grains—available locally.

Petri dishes, plastic 75 mm diameter approximately
Suppliers: Gallenkamp, Osi, Prolabo, Scientific Supplies, Seedburo

Plastic scoops—assorted sizes for handling grain.
Suppliers: Gallenkamp, Prolabo, Scientific Supplies, Seedburo

Calculator, pocket type with simple functions, to facilitate calculations.

Dictating machine: pocket-type for field use to facilitate rapid recording of observations and survey data.

Camera: 35 mm single lens reflex with flash accessories to record store types and details of situations encountered.

Section 9 Names and addresses of suppliers

Advanced Industrial Mouldings (Brackley) Ltd
Unit 6
Farm Road
Brackley Industrial Estate
Brackley NNI3 5EA
Northamptonshire
United Kingdom

Alvan Blanch Development Co.
Malmsbury
Wiltshire
SNI6 9SG
United Kingdom

Astell-Hearson
I72 Brownhill Road
Catford
London SE6 2DC
United Kingdom

E H Bentall & Co. Ltd
Malden
Essex
United Kingdom

Brabender OHG
Kulturstrasse 5I-55
D4I00 Duisberg
Federal Republic of Germany

Buhler Bros. Ltd
9240 Uzwil
Switzerland

Cambridge Repetition Engineers
Greens Road
Cambridge CB4 3BQ
United Kingdom

Colombini and C snc
via Cadorna 9
2008I Abbiategrasso
Milano
Italy

Dickey-John Corporation
PO Box I0
Auburn
Illinois 626I5
USA

ELE International Ltd
Eastman Way
Hemel Hempstead
Hertfordshire HP2 7HB
United Kingdom

Endecotts Ltd
Lombard Road
Morden Factory Estate
London SWI9 3UP
United Kingdom

A/S N Foss Electric
SlangerUpgade 69
DK 3400 Hillerød
Denmark

A Gallenkamp & Co. Ltd
PO Box 290
Technico House
Christopher Street
London EC2P 2ER
United Kingdom
(Supplier of a comprehensive range of laboratory equipment)

Gariboldi S A S
via Pienza 20
20142 Milan
Italy

Glen Creston Instruments Ltd
16 Dalston Gardens
Stanmore
Middlesex
HA7 IDA
United Kingdom

R Hunt & Co.
Atlas Works
Earl Colne
Essex
CO6 2EP
United Kingdom

International Marketing and Exporting (USA) Ltd
Dane John Works
Gordon Road
Canterbury
Kent CTI 3PP
United Kingdom

Kett Electric Laboratory
No 8-I, I-Chome
Minamimagome
Ota-Ku
Tokyo
Japan

Lincoln Bros. Ltd
60 Vyner Street
London E2 9DQ
United Kingdom

Longworth Scientific Instrument Co.
Abingdon
Berkshire
United Kingdom

Marconi Instruments Ltd
100 Stonehurst Court
Northvale NJ 08540
USA

Marconi Instruments Ltd
Longacre
St Albans
Hertfordshire
United Kingdom

Mercator Corporation
PO Box 142
Berkshire Towers
101 North Fifth Street
Reading
Pennsylvania 19603
USA

Mettler Instrument Corporation
Princeton Hightstown
Box 71
Hightstown NJ08520
USA

P Minghetti
via M Prestinari 132/134
Vercelli
Italy

Nickerson Ltd
Riverhead
Louth
Linconshire
United Kingdom

OSI
141-145 - Rue de Javel
75739
Paris Cedex 15
France

Procter Bros (Wireworks) Ltd
Pantglas Industrial Estate
Bedwas
Newport
Monmouthshire NP1 8XD
United Kingdom

Prolabo
11 Rue Pelec
BP 200
75011
Paris
France

Protimeter Ltd
Fieldhouse Lane
Marlow
Buckinghamshire SL7 1LS
United Kingdom

Regent Maskiner
Buryessinsvagen 59
Bromma
Sweden

Robydome Ltd
Croft Road
Sudbury
Suffolk CO10 6JB
United Kingdom

Rodent Control Ltd
70-78 Queens Road
Reading
Berkshire
United Kingdom

H Rudebeck & Co. Ltd
Mercantile House
39 Perrymount Road
Haywards Heath
Sussex RH16 3BN
United Kingdom

Samap s.a.
1 rue du Moulin
BP1
Andolsheim
68600 Neuf-Brisach
France

Salter Abbey Weighing Machines Ltd
St Botolphs Lane
Bury St Edmunds
Suffolk
United Kingdom

Salter Industrial Measurement Ltd
George Street
West Bromwich
Staffordshire B70 6AD
United Kingdom

Sartorius Instruments Ltd
18 Avenue Road
Belmont
Surrey
United Kingdom

Satake Engineering Co. Ltd
Ueno Hirokoji Building
Ueno 1-19-10
Taito-ku
Tokyo
Japan
(Suppliers of a comprehensive range of grain handling laboratory equipment)

F H Schule GmbH
PO Box 260620
D-2000 Hamburg 26
Federal Republic of Germany

Scientific Supplies Ltd
Scientific House
Vine Hill
London EC1R 5EB
United Kingdom
(Suppliers of a comprehensive range of laboratory equipment)

Seedburo International Equipment Co.
1022 W Jackson Boulevard
Chicago
Illinois 60607
USA
(Suppliers of a comprehensive range of grain-handling laboratory equipment)

C Stevens & Son (Weighing Machines) Ltd
287-289 Goswell Road
London EC1V 7LD
United Kingdom

Henry Simon Ltd
Special Products Division
P O Box 31
Stockport
Cheshire SK3 0RT
United Kingdom

Tecator Ltd
Cooper Road
Thornbury
Bristol BS12 2UP
United Kingdom

Testut-Aequitas
8 Rue Popincourt
75011 Paris
France

Tomahawk Live Trap Co
PO Box 323
Tomahawk
Wisconsin 54487
USA

Tripette and Renaud
ZI du Val-de-Seine-20
Av. Marcelin Berthelot
92390 Villeneuve-la-Garenne
France

Woodstream Corporation
LITITZ
Pennsylvania I 543
USA
and at
Niagara Falls
Ontario
Canada L2E 673

Youngs
Misterton
Devon
United Kingdom

APPENDIX III EXAMPLES OF DATA SHEETS AND QUESTIONNAIRES FOR VARIOUS TYPES OF LOSS ASSESSMENT SURVEYS

Recording information for the assessment of storage losses

In a study of farm-level storage losses, the following information should be collected for each selected farmer's store:
(a) Details of the storage structure, its construction, maintenance, etc.
(b) Baseline information about the commodity stored at the time that it was taken into store.
(c) Records of the quantity of grain stored, the quantities removed and methods of grain use.
(d) Estimation of the quantitative and, to whatever extent is feasible, qualitative losses, by analysis of grain samples.

A series of forms which might be used to facilitate the collection of these data is given in the following pages. The forms are based upon examples used in several different studies of post-harvest losses.

Form SI Description of storage structure

This type of form can be used to provide a full description of the selected sample store. Each section of the form should be completed as fully as possible. The dimensions of the store, construction materials, costs of construction, etc. should all be noted and if possible a simple sketch of the store on the reverse of the form should be included.

This form would be completed once during the first visit to the farmer at the beginning of the study, although it could also be used to record any modifications made to the store during the period of the study.

FORM SI

DESCRIPTION OF STORAGE STRUCTURE

REF. NO.: ____________
DATE: ____________

Farmer's name: ______________________ Village: ____________

Store type: ______________________

Capacity: ______________________ Age (approx.): ____________

CONSTRUCTION

Roof/lid

Walls

Floor

Platform

General condition

COST OF STRUCTURE: When built ____________ Now ____________

MAINTENANCE: Work done, frequency, by whom, etc.

PEST CONTROL:

COMMODITIES STORED:

AWARENESS OF LOSS: Farmer's estimate: ____________

Cause: ____________

GENERAL REMARKS:

Form SII Initial sample record

Like form SI, this form provides some background information, especially concerning the history of the grain under study. It also provides a record of field observations and measurements—e.g. grain condition, grain moisture content, weight of grain stored, at the time the first sample is collected. This form should be returned to the laboratory with the grain sample to which it refers.

FORM SII

INITIAL SAMPLE RECORD

REF. NO.: ____________

DATE: ____________

Farmer's name: ____________ Village: ____________

Store type: ____________

Commodity: ____________ Variety: ____________

DATE HARVESTED ____________

NO. OF DAYS STACKED ____________

DATE THRESHED ____________ METHOD ____________

NO. OF DAYS DRYING ____________ METHOD ____________

DATE PARBOILED ____________ METHOD ____________

NO. OF DAYS DRYING ____________ METHOD ____________

DATE DEHUSKED ____________ METHOD ____________

GRAIN CONDITION (evidence of damage, infestation, etc).

QUANTITY OF GRAIN STORED

How measured: ____________

SAMPLE

How collected: ____________

Weight ____________ Moisture content (i) ______ (ii) ______ (iii) ______

GENERAL REMARKS

Form SIII Sample record form

This form is similar to form SII and provides a record of store and grain conditions when subsequent samples are collected. Again, the form should be returned with the sample to the laboratory.

FORM SIII

SAMPLE RECORD

REF. NO.: ____________

DATE: ____________

Farmer's name: ____________________ Village: ____________

Store type: ____________________

Commodity: ____________________ Variety: ____________

STORE CONDITION (note repairs, damage, etc.)

GRAIN CONDITION (evidence of rodents, insects, etc.; details of any pest control treatments)

QUANTITY OF GRAIN REMOVED

(a) Since previous visit: ____________________ Use: ____________

(b) At this visit: ____________________ Use: ____________

(c) Grain discarded: ____________________ Use: ____________

SAMPLE

How collected

Weight: ________ Moisture content (i) ______ (ii) ______ (iii) ______

GENERAL REMARKS

Form SIV Storage loss sample analysis

This form really provides an abbreviated version of the laboratory procedure. As the sample passes through the various tests in the laboratory the corresponding sections of the form will be completed. The laboratory procedure should be strictly adhered to and by following this record form through step by step the technician will be reminded of that procedure. As the grain sample is received at the laboratory it should be noted in the laboratory log book and allotted a serial or identity number. This number should be entered on the form alongside the reference number which identifies the sample site. The sample collection data—farmer's name, village, store, commodity, date of collection should also be recorded on the form in case it becomes separated from the sample record form.

The sample is then weighed and the weight recorded. After sieving to remove insects, dust, foreign matter, etc. the sample is divided and submitted for the various analyses as listed on the form.

FORM SIV

STORAGE LOSS

REF. NO.: ____________________

DATE OF ANALYSIS: ________________

Farmer's name: ____________________________ Village: ____________________

Store type: ________________________________

Commodity: ______________________________ Variety: ____________________

Weight of submitted sample .... g.

Weight of foreign matter .... g. = ...%

INSECTS PRESENT:

Species	Alive		Dead		
	Adults	Larvae	Adults	Larvae	Pupae

Moisture content: (H) (i) .... (ii) .... (iii) ....(Av.) ....

Hectolitre weight: (i) .... (ii) .... (iii) .... (Av.) ....

WEIGHT LOSS DETERMINATION:

Weight of grains (M)	No. of grains (N)	$\frac{10M\ (100-H)}{N}$

Weight Loss $\frac{(M_l) - (M_x) \ \ldots\ldots}{(M_1) \ \ldots\ldots} \times 100$: ____________%

QUALITY DETERMINATION:

	Weight(g)	%	No. of grains	%
Sub-sample		100		100
Insect damage				
Rodent damage				
Broken/split grains				
Mouldy grains				

Foreign matter (%) ________

REMARKS:

Signature of analyst ....

Form SV Storage loss—summary sheet

This summary sheet is used to assemble all relevant data from field and laboratory observations for the calculation of the total weight loss. The sheet can be completed as and when the data are available; all weights should naturally be expressed at a standard moisture content or on a dry weight basis.

The total accounted loss will be obtained from the difference between the quantity stored and the quantity of grain removed (i.e. the sum of the quantities removed each month). The weight loss due to insects in any one month is calculated from the 'loss in sample' result and the quantity of grain removed on or about the same day. The monthly loss figures are then summed to obtain the cumulative weight loss due to insects. When this figure is subtracted from the total recorded loss (i.e. the difference between quantity stored and quantity removed) the loss due to other causes can be obtained. By reference to field observations this 'other' loss may be attributed to rodents, birds, mould, etc.

FORM SV

ASSESSMENT OF STORAGE LOSS—SUMMARY SHEET

Farmer's name: ______________________ Village: ______________________ Store type: __________ Ref. no. __________
Commodity: ______________________ Variety: ______________________ Dry weight of grain stored: __________

DATE
QUANTITY REMOVED (Dry weight)
QUANTITY DISCARDED (Dry weight)
BALANCE
DISCARDED QUANTITY
% QUANTITY STORED
LOSS IN SAMPLE
WEIGHT LOSS
WEIGHT LOSS (as % quantity stored)
CUMULATIVE LOSS

LOSS: Recorded weight loss = ________%
Loss due to insects = __________%
Loss due to other causes = _____%

DISCARDED GRAIN = ________%

Examples of other questionnaires for storage loss assessment surveys

Crop loss assessment survey—Shire Valley Agricultural Development Project—Malawi

Initial questionnaire This questionnaire was used to provide information on the types of storage structure used in the area under study and the type of grain stored.

Amounts of grain were to be recorded on the form but it was found that farmers were often unable to provide a definite indication of the amount of grain harvested and stored.

Quantities were described in terms of baskets, cartloads, etc. and to obtain a measurement of weight the volume of the different containers had to be calculated and multiplied by the weight of grain per unit volume (Golob, 1981).

INITIAL QUESTIONNAIRE—CROP LOSS ASSESSMENT SURVEY, SVADP, JUNE, 1978

1 Date of interview ....
2 Name of farmer ....
3 Village ....
   (a) Unit ....
   (b) Area ....
4 Do you grow maize? Sorghum?
5 What other crops do you grow? ....
6 How many people do you feed? ....
   (a) Adults ....
   (b) Children ....

MAIZE

7 When did you harvest your maize this year? ....
8 How much did you harvest? ....
   (a) Local ....
   (b) SV28 ....
   (c) Other ....
9 Where are you storing your maize? ....
   Cobs Shelled
10 Since filling your store how many times have you removed cobs (shelled grain) for consumption? ....
11 How many cobs (shelled grain) have you removed at each occasion?
....

SORGHUM

12 When did you harvest sorghum this year? ....
13 How much did you harvest?
   (a) Local ....
   (b) Other ....
14 Have you threshed your sorghum? .... if not when will you thresh it? ....
15 Where are you storing sorghum heads (panicles)? ....
16 Where will you store threshed sorghum? ....
17 Since harvest how many times have you taken sorghum for food? ....
....
18 How many heads (grain) have you taken on each occasion? ....
....

INSECTICIDE

19 Have you treated any of your produce with insecticide? ....
   If YES, specify ....

MEASUREMENTS OF RELEVANT STRUCTURE

I BASKET	Used for bringing produce to store or for taking produce for food preparation, etc. Length .... Width .... Height .... or Diameter ....Height ....
2 NKHOKWE	Diameter ....Height of cobs ....
3 CHETE	Area occupied by produce .... Length .... Width .... Height ....
4 CHIKWA	Diameter (approx. average) .... Height ....
5 PLATFORM	Area occupied by produce .... Length ....Width .... Height ....
6 OTHER STRUCTURE:	....
7 Volume of Produce :	....

Monthly Questionnaire The monthly questionnaire was completed for each sample farmer to record details of the amounts of grain removed from store and their use.

Because of time constraints the field investigators were not thoroughly trained in the use of questionnaires and the questionnaires themselves were not fully evaluated before the survey work and this led to some minor problems: e.g. field investigators had difficulty in differentiating between statements beginning 'How much ...' and 'How many times ...' (questions 4, 5, I0, II etc).

It was also considered that some of the questions were too long and that multipart questions caused confusion. It was found that the total of the quantities removed from store by use did not agree with the figure given for the total removed.

A general conclusion was that an attempt was made to collect more information than the field staff could assimilate. The capability of the staff was over- estimated and clearly a simpler design was needed (Golob I98I).

MONTHLY QUESTIONNAIRE FOR FARMERS. CROP LOSS ASSESSMENT SURVEY SVADP I978/79

I Date of interview ....
2 Name of farmer ....
3 Village ....(a) Unit ....
(b) Area ....

MAIZE

4 Since my last visit how much maize have you taken out of your store? ....
5 How many times did you take maize from the store? ....
6 Did you sell any of the maize?
(a)to ADMARC ....
(b)Locally ....
If YES, how much?
(a)to ADMARC ....
(b)Locally ....
7 Was any of the maize damaged? ....
How much did you (a) throw away? .... (b) use for beer? ....
(c) feed to animals? .... (d) use for food? ....

8 Was all the rest of the maize used for consumption? ....
If not, what did you do with it? ....
and how much did you use? ....

SORGHUM

9 Is your sorghum threshed or unthreshed? ....
10 If unthreshed (a) how many heads have you taken since my last visit for consumption, or any other reason? ....
(b) how many times have you taken heads since my last visit for consumption or any other reason? ....
11 If threshed (a) how much grain have you taken since my last visit for consumption or any other reason? ....
(b) how many times have you taken grain from your store since my last visit for consumption or any other reason? ....
12 Were any of the heads or the grains damaged? How much of the damaged grain did you
(a) throw away? .... (b) feed to animals? ....
(c) use for beer? .... (d) use for food? ....
13 Did you use any that was not damaged for beer making? ....
If YES, how much? ....
14 Did you sell any sorghum? .... If YES, where to? ....
and how much? ....
15 Did you do anything else with the sorghum (for example, pay labourers, use for gifts)? ....

ACTELLIC

16 Have you used Actellic on any of your produce? ....
17 What produce are you using it on? ....
18 How much are you using on your produce? ....

Pilot study of losses of wheat stored on farms in Central Anatolia, Turkey

Background information about storage practices, grain use patterns, pest control procedures, etc., was collected using three questionnaires, one completed at each of the first three visits to a farm.

Generally the questionnaires were completed well, but an analysis of the results highlighted difficulties which can arise when questions are literally translated from English. For example confusion arose over the term 'total capacity of store' (Information Sheet No. 1, question 9). Occasionally the total storage capacity of the farm was recorded, rather than that of the store under study. Furthermore the term 'for human consumption' (Information Sheet No. 2, question 9) was sometimes taken to mean food grain consumed on the farm (as intended) and sometimes included grain which had been sold as food grain (Boxall, 1983).

FAO/ANKARA PLANT PROTECTION RESEARCH INSTITUTE WHEAT STORAGE LOSS SURVEY

CORUM AND CANKIRI PROVINCES, CENTRAL ANATOLIA, TURKEY

INFORMATION SHEET NO. I Reference ..../..../..../....

To be filled in on first visit

1 Province .... 2 County ....
3 Village .... 4 Farmer ....
5 Location: Plain forest mountain
6 Type of store:
Wooden Mud brick Concrete
Other ....
Standing alone Inside another building
7 Age of store .... years
8 Approximate cost of construction, or } TL ....
Estimated replacement value }
9 Description of store:
Plan: Square Rectangular Round
Other: ....
Height .... metres Width .... metres
Length .... metres
Floor: Raised off ground .... metres *Not* raised off ground
Below ground level .... metres
Wooden Earth Cement
Ceiling No ceiling
Number of compartments ....
Compartments: All open at top
Some with lids or doors
All with lids or doors
How many outlets at bottom? ....
Any ventilators? If yes, describe ....
....
Roof: Attached directly to store Not attached to store
Other kind of roof ....
Total capacity of store .... tonnes

10 Description of structural defects of store (if any): ....
....
....
....
....

11. (a) Number of farmers in village considered for selection ....
(b) Number of farmers in village *not* considered for selection ....

Signature of surveyor: ....
Date: ..../..../....

FAO/ANKARA PLANT PROTECTION RESEARCH INSTITUTE WHEAT STORAGE LOSS SURVEY

CORUM AND CANKIRI PROVINCES, CENTRAL ANATOLIA, TURKEY

INFORMATION SHEET NO. 2 Reference ..../..../..../....

To be filled in on second visit

1 Province .... 2 County ....
3 Village .... 4 Farmer ....
5 Wheat in store (a) 1982 crop (b) older stock
For food .... tonnes .... tonnes
For animal feed .... tonnes .... tonnes
For seed .... tonnes .... tonnes
For sale .... tonnes .... tonnes
6 Method of harvesting wheat:
Sickle Scythe Combine
Other (describe) ....
7 Method of threshing (describe) ....
....
8 Storage begins (month) .... ends (month) ....
9 Pattern of removing wheat from store for human consumption:
Once a day Once a week Once a month
Other removal pattern (describe): ....
....
10 How much wheat is removed from store on each occasion? .... kg
If quantity removed varies:
Minimum quantity .... kg Maximum .... kg
Period .... Period ....
11 How is the quantity of wheat measured when either putting it into store or removing it? ....
Capacity of measure .... kg
12 Is the wheat cleaned with a sieve when removed from the store?
Yes No
13 If yes, what is done with the sievings? ....
....
....

14 Is the wheat milled
On the farm? In the same village?
Elsewhere? If elsewhere, how far away? .... kilometres
Where? ....
15 How is flour stored? ....
....
How long is the flour storage period?
Summer .... days .... weeks .... months
Winter .... days .... weeks .... months
16 Is wheat regularly removed from the food store for purposes other than for human consumption, for example, for feeding chickens?
Yes No Purpose ....
....
If yes, indicate frequency of removal:
Daily .... Weekly .... Monthly..........., and the quantity removed on each occasion: Measure .... kg. Number of measures ....
Total quantity .... kg

17 Other grain products stored near the wheat, in adjacent compartments, sacks, or other containers:

Barley	kg/tonnes	Chickpeas	kg/tonnes
Rye	kg/tonnes	Lentils	kg/tonnes
Rice	kg/tonnes	others	kg/tonnes

Signature of surveyor: ....
Date: ..../..../....

FAO/ANKARA PLANT PROTECTION RESEARCH INSTITUTE WHEAT STORAGE LOSS SURVEY

CORUM AND CANKIRI PROVINCES, CENTRAL ANATOLIA, TURKEY

INFORMATION SHEET NO. 3 Reference ..../..../..../....

To be filled in on third visit

1 Province .... 2 County ....
3 Village .... 4 Farmer ....
5 Does the farmer have problems with pests in his wheat store?
Insects Rats Mice Other
6 Do the pests appear at the beginning of the storage period? during storage? .... towards the end of storage? .... any other time? ....
....
7 To prevent or control insects, does the farmer use insecticide?
Yes No If yes, does he mix it with the grain? or treat the empty store? .... Is it effective? .... Yes No
What insecticide is used? Dosage .... Cost TL ....
Other method (describe): ....
8 To prevent or control rodents, does the farmer use traps? Yes No
Poison baits? Yes No If traps, what kind and where are they placed? ....
Are the traps effective? Yes No
If poison baits, what kind and where are they placed? ....
Are they effective? Yes No
Other method of rodent control (describe): ....
Is it effective? Yes No
9 Do you have problems with grain being spoiled by too much moisture?
Yes No If yes, in which part of the store does such spoilage occur? ....
....
At which time of the year is such spoilage most serious? ....
....

Signature of surveyor: ....
Date: ..../..../....

FORM Y

DHEKI SURVEY

Village: Respondent: Date: F.O. No.

PADDY PROCESSING Variety: 1st Husking		Laboratory analysis		
1 Wt of paddy 2 Moisture content 3 Wt of brown rice 4 Moisture content 5 Wt of husk 6 Wt of bran Remarks:	% %	Sample of No. 3	Gross wt	
		Wt of sample	MC	
		Wt of head rice	Wt of brokens	% brokens
		Remarks:		
2nd Husking		Laboratory analysis		
7 Wt of brown rice 8 Moisture content 9 Wt of white rice 10 Moisture content 11 Wt of husk 12 Wt of bran Remarks:	% %	Sample of No. 9	Gross wt	
		Wt of sample:	MC	
		Wt of head rice	Wt of brokens	% brokens
		Remarks:		
POLISHING		Laboratory analysis		
13 Wt of white rice 14 Moisture content 15 Wt of polished rice 16 Moisture content 17 Wt of bran	% %	Sample of No. 15	Gross wt	
		Wt of sample:	MC	
		Wt of head rice	Wt of brokens	% brokens
		Remarks:		

FARMERS CLEANING:

Wt of rice	MC	Wt of brokens	MC	% brokens	Wt of bran	MC

Recording information for the assessment of losses in rice processing

In a study of losses in village level rice processing in Bangladesh the traditional (*dheki**) system of processing practised at the homestead was compared with the village huller mill.

A batch of paddy was divided equally and processed by each method and a sample of paddy collected before processing was milled on a laboratory rice mill. An estimate of quality losses was obtained from an analysis of the yield of rice, proportion of broken rice grains, etc. in samples from each process.

Form X was used to record field and laboratory data relating to the huller mills and a similar form, Form Y was used for data relating to the *dheki*.

A summary form, Form Z, was used to collate the results of the study.

(Greeley, 1982).

FORM X

RICE MILL SURVEY

Village: Respondent: Date: F.O. No.

PADDY PROCESSING Variety:		Laboratory analysis		
1 Wt of paddy		Sample of No. 3	Gross wt=	
2 Moisture content	%			
3 Wt of rice out		Wt. of sample:	MC	
		Wt of head rice	Wt of brokens	% of brokens
4 Moisture content	%			
5 Wt of bran + husk				
6 Wt of bran		Remarks:		
7 Wt of husk				
Remarks:				

FARMERS CLEANING:

Wt of rice	MC	Wt of brokens	MC	% brokens	Wt of bran	MC

POLISHING		Laboratory analysis		
8 Wt of rice in		Sample of No. 10	Gross Wt	
9 Moisture content	%	Wt of sample:	MC	
		Wt of head rice	Wt of brokens	% of brokens
10 Wt of rice out				
11 Moisture content	%			
12 Wt of bran		Remarks:		
Remarks:				

FARMERS CLEANING:

Wt of rice	MC	Wt of brokens	MC	% brokens	Wt of bran	MC

**dheki*—a foot-operated pestle and mortar system for pounding paddy/rice.

FORM Z

MILL/DHEKI SURVEY SUMMARY SHEET

Village:	Respondent:	Date:	F.O.
Variety:	Experiment no:		No.

A. **Laboratory analysis of the sample paddy:**

Net weight of the sample:

Average moisture content:

Quantity taken for laboratory analysis

Product	Wt of Product	Percentage of product in respect of:			
		Paddy	Brown rice	Polished rice	Whole head rice
Brown rice					
Husk					
Polished rice					
Bran					
Whole heads					
Brokens					

Remarks:

B **Comparison chart:**

Product	Laboratory	Mill	Dheki
Brown rice			
Husk			
Bran			
Polished Rice: (a) Total			
(b) Brokens Actual			
(c) Brokens Farmer			

APPENDIX IV SELECTION OF SAMPLES USING RANDOM NUMBER TABLES

To ensure that a sample is truly representative it must be selected in a way which avoids all sources of systematic error or bias. The only way to avoid such bias is to select samples by means of randomization. A random sample means that every sample unit in the population, e.g. plots in a field, bags in a consignment, grain stores in a village, has an equal chance of being selected. Such a sample selection can only be achieved by using a table of random numbers.

Table A is composed of random numbers from I to I00. Figures I-9 are given as 0I-09 and I00 is shown as 00 to maintain a two-digit configuration throughout, and to facilitate reading of the table. The numbers are arranged in blocks of 25 for the same reason.

When reading random number tables it is permissable to start from any point in the table and to read off pairs of digits in any direction; from left to right across the page, up or down or diagonally; or the pair of digits in a certain position in each block may be taken. However, having decided upon how the table is to be read the user must always adhere to the method decided upon (at least until all possible number combinations obtainable from it have been exhausted) and must never start at any point in the table which has been used previously as a starting point.

Before sampling can begin a decision must be made on what will comprise a sampling unit and how many of these units are to be taken. The units must then be numbered starting at I and going as high as necessary.

Pairs of digits are then read off from the random number table and written down as they occur. Numbers that are repetitions or that are greater than the total number of units should be missed. When the required number of pairs of digits has been written down the last pair used should be circled to indicate that the next pair of digits will be the new starting point.

The selected random numbers should be rearranged in their proper order and the selected units sampled.

Examples of using random numbers

Selecting primary sampling units when there are II-I00 units

It is recommended that when there are II-I00 units, ten should be selected and this selection can be done using random number tables.

Example Refer to the table of random numbers (Table A).
Ten grain stores have to be sampled from a total of 53 in a village. The stores are first listed and each one given a number from I to 53. It has been decided that the random numbers in the table will be read horizontally from left to right, starting at the first line (from 73). The first ten numbers in the range 0I to 53 are: 47, 50, 37, 33, 23, 4I, I7, 52, I3 and I2. The number I2 in the table should be circled to indicate that it was the last number used and that the next number (22) is the next starting point.

Selecting primary sampling units when there are more than I00 units

It is recommended that when sampling within the range I0I-I0,000, the number of units to be sampled (n) should be approximately equal to the square root of the total number in the consignment (N). For example, when grain is stored in bags a random selection can be made by using the following procedure:
Bags arriving at the store should be arranged in groups, each group consisting of the approximate square root (n) of the total number of bags in the consignment (*see* table B).

Table A

Random number table

73 47 50 81 37	99 33 23 41 87	70 17 91 52 73	13 64 12 22 56	42 11 09 87 67
72 74 49 15 76	86 71 97 12 78	48 35 68 27 51	56 05 67 82 93	17 11 14 17 82
97 30 18 66 35	62 67 99 63 47	30 40 36 18 58	47 26 24 62 24	38 47 91 18 69
09 62 27 30 42	72 76 36 81 49	65 19 64 42 45	64 87 61 34 25	73 26 38 97 06
61 56 92 94 75	90 21 60 17 69	94 09 77 34 41	27 31 15 18 87	85 19 58 77 56
40 45 21 69 38	44 71 05 95 02	55 47 69 97 63	29 87 40 30 06	75 72 12 97 93
71 36 67 15 74	76 81 87 44 65	75 04 26 75 91	18 25 39 18 34	62 33 76 55 70
81 47 31 22 32	62 42 02 56 80	08 25 20 55 93	34 22 07 78 36	88 72 10 64 50
07 50 66 70 98	34 56 86 42 66	48 94 00 92 67	12 09 98 83 48	36 91 35 41 83
14 80 26 50 50	19 18 26 21 08	95 60 74 72 97	02 14 14 81 04	54 86 28 52 62
17 90 57 54 48	30 65 15 13 17	70 81 78 93 72	59 21 93 32 87	96 46 87 52 06
06 60 60 48 97	18 65 64 46 96	55 85 73 77 02	07 87 59 33 71	88 47 70 13 81
46 66 98 62 98	84 90 60 64 74	86 00 11 53 63	44 61 93 35 83	70 83 36 54 14
22 39 12 36 78	64 76 18 44 56	61 86 31 84 24	56 18 95 42 28	42 78 46 25 74
62 40 81 48 31	29 41 23 37 67	60 29 27 70 77	99 07 71 78 13	60 02 82 85 12
63 23 85 13 53	93 93 76 82 45	29 39 67 50 13	85 08 61 22 48	71 83 89 27 39
28 38 93 22 61	67 66 54 53 58	71 95 55 82 72	28 34 94 87 16	62 76 58 96 34
31 69 03 31 27	33 68 54 84 48	82 5- 75 05 28	09 06 27 21 76	36 95 11 89 82
92 17 82 54 42	66 84 27 52 68	48 25 35 92 25	19 45 11 86 96	70 15 67 03 71
72 23 78 50 85	84 19 57 98 57	27 27 18 37 11	81 29 92 12 36	35 95 66 87 59
33 90 61 20 23	01 73 37 75 91	39 78 16 86 66	69 60 21 77 56	32 33 36 11 19
77 20 63 33 26	38 19 94 69 65	84 24 08 88 50	21 31 41 64 53	30 85 55 62 99
44 41 90 90 34	36 46 14 15 51	61 45 87 72 01	31 54 00 42 57	16 74 68 43 22
23 30 15 89 06	63 33 88 49 96	29 34 71 00 32	93 77 02 97 84	63 08 36 86 50
87 11 78 24 39	77 14 29 71 38	85 11 82 35 46	46 00 74 48 79	26 03 46 70 70
76 82 02 80 57	35 98 02 63 11	79 20 15 38 19	89 14 20 47 11	06 00 41 38 50
39 87 83 58 72	35 75 75 81 55	48 80 73 84 95	52 52 37 06 22	78 76 03 26 92
33 38 10 49 42	28 12 27 13 75	30 29 96 17 96	06 46 75 75 21	08 87 87 85 07
24 64 16 87 72	15 91 76 71 83	21 13 66 51 64	06 78 19 88 96	64 78 27 21 16
13 77 53 95 17	14 96 12 68 55	21 30 57 97 71	09 23 57 55 04	77 26 52 07 53
24 84 24 46 77	11 83 83 19 27	22 38 50 63 67	04 15 12 34 01	95 14 72 48 26
62 08 91 79 38	69 21 23 90 93	13 27 34 58 64	14 45 29 02 53	06 57 92 57 71
51 02 66 99 85	20 43 65 67 69	82 06 04 51 89	94 80 67 70 58	65 15 87 21 70
55 63 95 22 96	24 10 25 73 19	52 84 04 51 89	82 15 55 45 76	62 20 14 14 34
84 36 50 90 24	30 54 77 92 84	36 50 04 87 00	62 85 18 41 09	64 98 64 00 04
72 53 85 61 90	20 90 49 02 34	62 44 65 84 78	79 50 31 92 09	24 69 27 12 90
98 46 89 72 14	97 23 66 64 20	15 03 76 37 82	46 60 11 19 37	33 21 70 66 22
06 24 34 88 30	15 45 54 17 35	00 36 54 73 00	35 51 22 67 90	23 24 44 41 35
58 04 12 76 64	86 67 89 49 16	42 68 37 98 71	24 43 90 05 76	73 23 95 33 18
41 84 53 49 74	89 35 92 48 41	43 22 75 96 75	47 51 00 81 92	34 86 03 32 65

Note: 100 is represented by 00

Next, by referring to the table of random numbers the first 'n' numbers within the range of l to 'n' are selected. If the consignment is divisible into 'n'—l or 'n'—2 groups of 'n' bags plus a final group consisting of fewer than 'n' bags the last number obtained from the random table must not be greater than the number of bags in the final group. The random numbers should be used in the same order as they are obtained to extract sample bags from the consignment.

Example The consignment to be sampled consists of 235 bags. From Table B it will be seen that 235 lies within the range 226 ... 256 for which the value of 'n' is 16. Thus the consignment should be arranged in groups of 16 bags. There will be only 14 ('n'—2) such groups plus a final group of 11 bags, so that a total of 15 random numbers within the range 1 to 16 is required of which the final number must not be greater than 11.

By reading the table of random numbers from left to right and starting at the top left number (73), the following numbers are obtained: 13, 12, 11, 09, 15, 12, 05, 14, 09, 06, 09, 15, 05, 02, 06.

Using these numbers, the sampler would take the 13th bag from the first group of 16 bags, the 12th bag from the second group of bags and so on.

Table B

Number of units to be sampled when total number of units is within the range 101-10,000

N	n	N	n	N	n
101 ... 121	11	1601 ... 1681	41	4901... 5041	71
122 ... 144	12	1682 ... 1764	42	5042 ... 5184	72
145 ... 169	13	1765 ... 1849	43	5185 ... 5329	73
170 ... 196	14	1850 ... 1936	44	5330 ... 5476	74
197 ... 225	15	1937 ... 2025	45	5477 ... 5625	75
226 ... 256	16	1026 ... 2116	46	5626 ... 5776	76
257 ... 289	17	2117 ... 2209	47	5777 ... 5929	77
290 ... 324	18	2210 ... 2304	48	5930 ... 6084	78
325 ... 361	19	2305 ... 2401	49	6085 ... 6241	79
362 ... 400	20	2402 ... 2500	50	5242 ... 6400	80
401 ... 441	21	2501 ... 2601	51	6401 ... 6561	81
442 ... 484	22	2602 ... 2704	52	6562 ... 6724	82
485 ... 529	23	2705 ... 2809	53	6725 ... 6889	83
530 ... 576	24	2810 ... 2916	54	6890 ... 7056	84
577 ... 625	25	2917 ... 3025	55	7057 ... 7225	85
626 ... 676	26	3026 ... 3136	56	7226 ... 7396	86
677 ... 729	27	3127 ... 3249	57	7397 ... 7569	87
730 ... 784	28	3250 ... 3364	58	7570 ... 7744	88
785 ... 841	29	3365 ... 3481	59	7745 ... 7921	89
842 ... 900	30	3482 ... 3600	60	7922 ... 8100	90
901 ... 961	31	3601 ... 3721	61	8101 ... 8281	91
962 ... 1024	32	3722 ... 3844	62	8282 ... 8464	92
1025 ... 1089	33	3845 ... 3969	63	8465 ... 8649	93
1090 ... 1156	34	3970 ... 4096	64	8650 ... 8836	94.
1157 ... 1225	35	4097 ... 4225	65	8837 ... 9025	95
1226 ... 1296	36	4226 ... 4356	66	9026 ... 9216	96
1297 ... 1369	37	4257 ... 4489	67	9217 ... 9409	97
1370 ... 1444	38	4490 ... 4624	68	9410 ... 9604	98
1445 ... 1521	39	4625 ... 4761	69	9605 ... 9801	99
1522 ... 1600	40	4762 ... 4900	70	9802 ... 10000	100

Notes: N = total number of units
n = number of units to be sampled

APPENDIX V EXAMPLES OF POST-HARVEST LOSS ASSESSMENT SAMPLING PLANS

The following pages are devoted to examples of how survey areas and sampling plans were decided in a selection of loss assessment projects.

Malawi

GOLOB, P. (1981). A practical assessment of food losses sustained during storage by small-holder farms in the Shire Valley Agricultural Development Project area of Malawi 1978/79. *Report of the Tropical Products Institute (Tropical Development and Research Institute)*, G154 vi + 47 pp.

In order to obtain accurate data it is necessary to obtain food consumption patterns throughout the storage season to take into consideration the declining quantities of produce in the store as the season progresses. Thus, any survey should continually monitor the food stored throughout the year, farmers being visited each month. To accomplish such an intensive undertaking the area to be surveyed must be limited and so rather than attempt a national survey, one of the Rural Development Programme areas, the Shire Valley Agricultural Development Project (SVADP), was chosen for investigation.

Selection of farmers

Farmers were selected using stratified random sampling.

The SVADP has six administrative areas, each subdivided into a number of units, 46 in total, and each unit is made up of a number of villages. The six areas differ in climate, topography and type of crops produced and so provided a convenient first stratification.

The number of farmers to be included in the survey determined by probability sampling methods was 20 per area—120 in total.

The distribution of farmers between units was made after consultation with the SVADP staff. A total of 28 units was recommended for the survey, this recommendation being based upon a consideraiton of accessibility during the rainy season, population density and maize production areas. The final distribution of units per area was somewhat uneven:

Area	*No. of units selected*
1	6
2	4
3	6
4	4
5	3
6	5

This created a problem regarding the numbers of farmers to be interviewed in each area. In order to spread the work load evenly throughout the units it was decided to disregard the 20-farmer limit per area. Twenty farmers from each of the six areas could easily have been chosen if the number of units in each area had been the same. As this was not the case the calculated total of 120 sample farmers was used as the minimum requirement. By increasing the total farmers to 140 an equal distribution of 5 farmers per unit could be achieved. The 20 extra farmers were included as reserves to replace farmers who might drop out of the exercise for reasons other than depletion of food.

Villages within the units and farmers within the villages were chosen at random using lists provided by the SVADP and local development offices. In order to achieve an even distribution of both villages and farmers per unit it was decided to select 3 villages in each unit. The third village was kept as a reserve in case one of the other two was found to be inaccessible. Two farmers were chosen from the first village and three from the second.

When the actual survey began it was found that not all the selected farmers could be located on the day; some had moved to other villages, whilst some had moved to other areas. Some farmers grew little or no food grains since they produced cash crops and bought maize from the marketing board. For all of these farmers, substitutes had to be found and this upset the random sampling strategy. The substitute was defined as the farmer present at the time of the visit who resided closest to the original choice. With hindsight it was considered that the problem might have been overcome if more reserves had been chosen initially. Whilst the stratified random sampling technique was efficient until the random choice was made, it was considered that a saving in time would have been possible if a single large cluster sample had been obtained from each unit.

India

BOXALL, R. A., GREELEY, M., TYAGI, D. S., LIPTON, M., and NEELAKANTA, J. (1978) *The prevention of farm-level storage losses in India. A social cost benefit analysis. IDS Research Report*. Institute of Development Studies, Brighton: 239 pp.

A research project to study farm storage losses was conducted in the state of Andhra Pradesh. This location was selected for the following reasons:

(a) it is one of the most important rice-producing states, (approximately ll% of all-India production) and has, at least in some districts, a surplus of rice;

(b) rice is important in several other developing countries with reasonably similar production/climatic, etc. conditions, and therefore any research results might have a wider relevance;

(c) the Indian Grain Storage Institute had a field station in the state which was concerned with farm-level storage practices and problems, in relation to rice.

(d) while it was recognized that losses for paddy/rice were expected to be lower than those suffered by other crops, particularly sorghum and wheat, the choice of paddy was justified by the predominance of rice in the food consumed by the majority of the population.

In the selection of sample households it was decided to use random sampling techniques modified only by budgetary/manpower/data availability constraints and allowing that sample analysis required reasonable communications with the project base. Care was taken not to allow this to prejudice the selections towards households along the roadside. The sampling design was multistage with probability of selection proportional to size.

Size in this context meant relevance to the factor which was to be measured—storage loss. This had to be modified at the early stages of the selection because data were not available and a proxy had to be used. The proxy used to measure relevance to farm-level storage losses was paddy area sown per head, a statistic for which data was readily available for the various administrative units—districts, taluks, villages. Other factors taken into consideration in the selection procedure were: agroclimatic zone, types of storage structure used and different income groups for farmers. This sample design was considered sufficiently flexible to take into account a wide range of different characteristics of the sample population, yet remained sufficiently rigorous to enable the establishment of scientific results that would be applicable in the wider context of Andhra Pradesh as a state and which might be of relevance elsewhere, particularly in India.

The stages in the random selection were:

(I) *Division by agroclimatic zone*

Basic data were obtained from the Indian Council of Agricultural Research publications describing the division of Andhra Pradesh into agroclimatic zones based upon the suitability of zones for different varieties of rice. Five zones were identified. The project design allowed for eighteen units of study, three per area, and it was decided that each unit would be a village and the area would be the lowest administrative unit—the taluk. Because of the relative importance of one zone with regard to paddy production, it was decided that two areas should be selected from this zone, and one from each of the remaining four zones.

(2) *Selection of taluks*

Using the latest available data, taluk-level figures for all districts within each zone were compiled for (i) area under paddy (ii) population and (iii) area under paddy per head. Using the cumulative total of area under paddy per head, districts were listed in order and random numbers used to select taluks.

(3) *Selection of villages*

Similar procedures were used to select villages. Village-level data on population, irrigated area and un-irrigated area and taluk-level data on the proportion of irrigated and non-irrigated land under paddy cultivation gave the cumulative total by village of area sown to paddy per head within the taluk. Three villages per taluk were selected using random numbers as above. However, since each group of three villages per taluk were to be under the control of one field investigator, consideration had to be given to the distribution of villages within the taluk in order to avoid long travelling distances between villages.

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(4) *Selection of households*

A census of storage and economic characteristics was conducted in each village to provide data on which a selection of households could be made. Three income groups were identified. Whilst conducting the census, field investigators assessed the degree to which farmers would be willing to co-operate on a scale of 0—4. The selection of households took only those farmers in the upper two categories of very co-operative or co-operative. (In the almost complete absence of local loss-prevention measures it was believed that this would not introduce bias towards household stores with lower than average losses).

A chart was compiled giving a list of all the co-operative farmers, their income group and the distribution of store types. In each village a sample of 20 stores was made and first households were selected in relation to their distribution by income groups. The store types were then selected based upon their relative importance in the village and availability within the farmer/income groups.

Turkey

PROCTOR, D.L. (1982). Prevention of post-harvest crop losses in Central Anatolia, Turkey. *Consultancy report. AG.GCPP/TUR/027/NET, Field Document 1,* Rome: FAO.

A pilot study of losses of wheat stored on farms was undertaken in the two adjacent provinces of Corum and Cankiri in Central Anatolia. The area was chosen because it was the site of a Rural Development Project which was able to contribute manpower to assist in the collection of data and samples for the loss assessment study.

Farmers in these two provinces store a variety of crops in various ways and often for various purposes, but wheat was chosen as the crop to be studied because it is widely produced and grown in greater quantities than any other crop.

It is estimated that there are approximately 90,000 farm families living in fairly distinct village communities in the two provinces. All villages can be identified on maps of the area.

Selection of sample villages

The two provinces are divided into a number of counties. Each village in each county was given a number. From the total number (N) of villages in a county the approximate square root (n) was derived (*see* also Appendix IV) to determine the number of villages to be included.

The draft list of village names was critically examined by senior technical staff of the Rural Development Project and some changes were considered necessary. One selected village was in fact a salt mine. Another selected village was in remote mountainous country, and inaccessible for much of the year. On the basis that the random process of selection had indicated the area in which a sample village should be, the nearest suitable villages to those disqualified were adopted as alternatives. Thus a final list of 67 villages representing Cankiri Province and 78 villages representing Corum Province, 145 in total, was prepared.

Selection of farmers

One farmer was required to represent each sample village and he was selected by the local Rural Development Project agent who would sample the store. The following procedure for selecting the farmer was adopted:

(i) A list of names of all farmers in the village who stored wheat for consumption was prepared.

(ii) The names of these farmers were written on separate small pieces of paper which were folded and placed in a box or similar container.

(iii) An independent person was then asked to withdraw one piece of paper from the box and to read out the name. This farmer was included in the survey unless he had good reasons for not participating. If it was felt that the farmer should not participate, another name was drawn in the same manner.

Full survey

BOXALL, R.A. (1983) Prevention of post-harvest crop losses in Central Anatolia, Turkey. Storage loss assessment. *Consultancy Report AG.GCPP/TUR/027/NET, Field Document 2,* Rome: FAO, 50 pp.

The objective of the pilot study was to allow field staff to gain experience in loss assessment techniques and to prepare the way for a study which would extend over a full storage season. Many farm grain stores in the project area were constructed from wood and farmers alleged that most problems and therefore storage losses were minimal. However, supplies of timber for construction of these types of store are now scarce and therefore expensive and farmers are now building stores using other materials such as stone and sun-dried mud bricks. Often farmers report that such stores are less satisfactory than the old style wooden ones and that storage losses are higher. The stores sampled in the pilot survey were selected entirely at random and so wooden stores were predominant. Stores constructed of stone, mud brick, etc. were poorly represented in the sample and the loss figures did not confirm that these were indeed less satisfactory structures.

The objective of the full season's study was to assess the performance of different types of grain store including some prototype improved stores, rather than to obtain an estimate of the average level of storage loss. Stores were therefore to be selected so that the major types were well represented.

The villages selected for the pilot study were widely scattered and field staff often had to travel long distances between villages to collect only a single sample each month. Consequently it was decided to reduce the number of villages and to increase the number of sample stores per village in the full season's survey. Field staff were asked to prepare lists of villages from which a random selection could be made. Remote villages were to be excluded because the excessive cost of travelling was an important constraint. Other villages would be excluded if they were inaccessible for long periods during the winter months or if they were located in areas of low wheat production.

In each village, two wooden ('good') and two stone/mudbrick ('poor') stores were to be selected using a procedure similar to that used in the pilot study.

The names of all farmers would be listed and then each name written on separate pieces of paper which could be drawn from a suitable container to identify those farmers to be included in the survey. The farmers' stores would be examined in the order in which the names were drawn and the procedure repeated until two 'good' and two 'poor' stores were chosen. For example, if the first two stores examined were 'good' ones they would be included in the study. If the third farmer also had a 'good' store this would be omitted and another name drawn, and so on until two 'poor' stores were chosen.

APPENDIX VI PROCEDURES FOR ESTIMATING LOSSES DURING DRYING

Estimation of losses during field drying of maize

The procedure described below is based upon work by de Breve *et al.* (1982) in Honduras.

From a selected plot in a field of maize, approximately 50 maize cobs were chosen at random.

(iii) An independent person was then asked to withdraw one piece of paper from the box and to read out the name. This farmer was included in the survey unless he had good reasons for not participating. If it was felt that the farmer should not participate, another name was drawn in the same manner.

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APPENDIX VI PROCEDURES FOR ESTIMATING LOSSES DURING DRYING

Estimation of losses during field drying of maize

The procedure described below is based upon work by de Breve *et al.* (1982) in Honduras.

From a selected plot in a field of maize, approximately 50 maize cobs were chosen at random.

After removing the sheaths the cobs were inspected and segregated into damaged and undamaged lots. The number of cobs in each lot was counted and the cobs shelled. After weighing the grain in each lot the potential yield (Yp) was calculated by substituting figures into the formula:

$$\frac{Un}{Nu} \times (Nu + Nd) = Yp$$

where Un = weight of undamaged grain
Nu = no. of undamaged cobs
Nd = no. of damaged cobs

The actual yield (Ya) was the total weight of shelled maize. The total loss in the field, due to birds, insects and mould damage, was the difference between the potential and actual yields (Yp—Ya).

The damaged fraction was then sorted and grain which was obviously unfit for human consumption separated and weighed. This could be further categorized, if required, as being damaged by insects or mould.

The quantity which could be consumed was weighed and the amount of food grain available calculated by adding the weight of acceptable damaged grain and the weight of undamaged grain. The loss of food was then determined by substracting the weight of available food grain from the potential yield.

The loss in weight due to insects in the acceptable grain would be determined by using any of the standard techniques described in Section 5, *Losses during storage*.

A further refinement of the method took account of the way in which farmers selected cobs when they were eventually harvested. Some cobs would be so heavily damaged at harvest-time that they would be unacceptable as food grain and so this additional loss had to be measured by calculating the potential yield of the discarded cobs.

Losses during drying of paddy

The procedure described here is taken from Dendy and Harris (1978). Samples of undried paddy are collected as the grain is received at the drying site. The samples are blended and a composite or bulked sample of about 1-1.5 kg submitted for laboratory analysis. At the end of the drying process a similar size sample is collected and also submitted for laboratory analysis.

The first (wet) sample should be carefully dried, preferably using a laboratory dryer with forced air convection at 1.5-2.0°C above ambient air temperature, to bring the sample to an equilibrium moisture content (i.e. about 14%) in about 36 hours. After drying, the sample should be stored in a moisture-proof container and allowed to stabilize for 3—4 days. If a laboratory dryer is not available it is suggested that the sample could be dried in the sun with care. The paddy should be spread on a clean concrete drying floor, at a depth not exceeding 2.5 cm and turned and blended thoroughly at intervals of approximately ten minutes. The grain moisture content and the air temperature must be checked regularly. At moisture contents of 20% or less the turning and blending should be at five minute intervals. If the temperature reaches 27°C then the grain should not be allowed to remain in the sun if the moisture content is below 16%.

After determining the exact moisture content of the sample the paddy should be milled on a standard laboratory mill in a standard manner according to the manufacturer's instructions. The rice will be separated from the husk and the bran in the laboratory mill and the whole and broken proportions can be weighed after separating on standard rice grading equipment such as a hand trier (indented tray) or small rotary trier (indented cylinder).

At the end of the drying process the sample should normally be submitted to the same careful drying and milling. However, if the grain is being dried immediately prior to milling it is more appropriate to process a sample in the laboratory at the moisture content at which it is actually milled. This may be possible if the laboratory processing can be undertaken very soon after sample collection or if the moisture content is between 14% and 15%. If the moisture content is higher than 15% and there is likely to be delay in processing, then the sample must be dried to 14-15% to avoid deterioration of the grain.

A small commercial mill can be used in the absence of a laboratory mill or if information is required for one particular mill. Large samples of paddy (1-2 kg) must be collected from the grain delivered for drying so that the total bulked sample for processing weighs at least 25 kg. This sample should be carefully dried in a small batch drier. A similar size sample of the dried paddy should be collected and the two samples should then be milled on a small commercial mill of the local type and the total product collected. The product can then be separated into whole and broken grains, preferably using the separator installed at the mill, but alternatively by winnowing and hand separating. After weighing the fractions the out-turn of whole grain can be calculated. It may be inconvenient to deal with large samples, but use of a commercial rather than a laboratory mill ensures that the results are directly applicable to the local situation.

APPENDIX VII THE VOLUMETRIC METHOD OF ASSESSING LOSSES CAUSED BY INSECTS

Apparatus

The volumetric method is based upon the use of equipment for the determination of the bulk density of grain (bushel weight or hectolitre weight). All equipment used for the determination of bulk density employs the basic principles of (a) causing a sample of material to fall from a standard container through a standard height into a standard weighing bucket, (b) levelling the surface of the material in the weighing bucket in such a way as not to influence its packing, and (c) weighing the loaded bucket.

In the USA the official 'test weight per bushel' apparatus is that designed and described by Boerner (1916) and little modified since (*see* Figure C). Bulk density is measured in pounds per bushel using a quart weighing bucket or in kilograms per hectolitre using a 1 litre weighing bucket. Levelling of the grain in the bucket prior to weighing is done with a strike-off stick using three zig-zag strokes.

A British-made bulk density tester (*see* Figure D) operates on a slightly different principle. The weighing bucket is fitted with a filling tube and a cut-off knife. With the cut-off knife in the closed position and a plunger resting upon it, the filling tube is loaded with grain. The cut-off knife is then removed, which causes the plunger and the column of grain to fall into the bucket. Holes in the bottom of the bucket allow air to escape as the plunger descends. The cut-off knife is inserted (to level the contents of the weighing bucket) and permits surplus grain to be discharged. The full bucket is then weighed, and results read off in bushel or hectolitre weight.

Other bulk density testers may be similar to the French-made apparatus (*see* Figure E).

When using bulk density testers for determining loss due to insect infestation in a sample of grain the same principles of operation must be adopted except that the actual weight of grain contained in the weighing bucket is usually recorded rather than the bulk density.

Figure C

Boerner bulk density tester (USA)

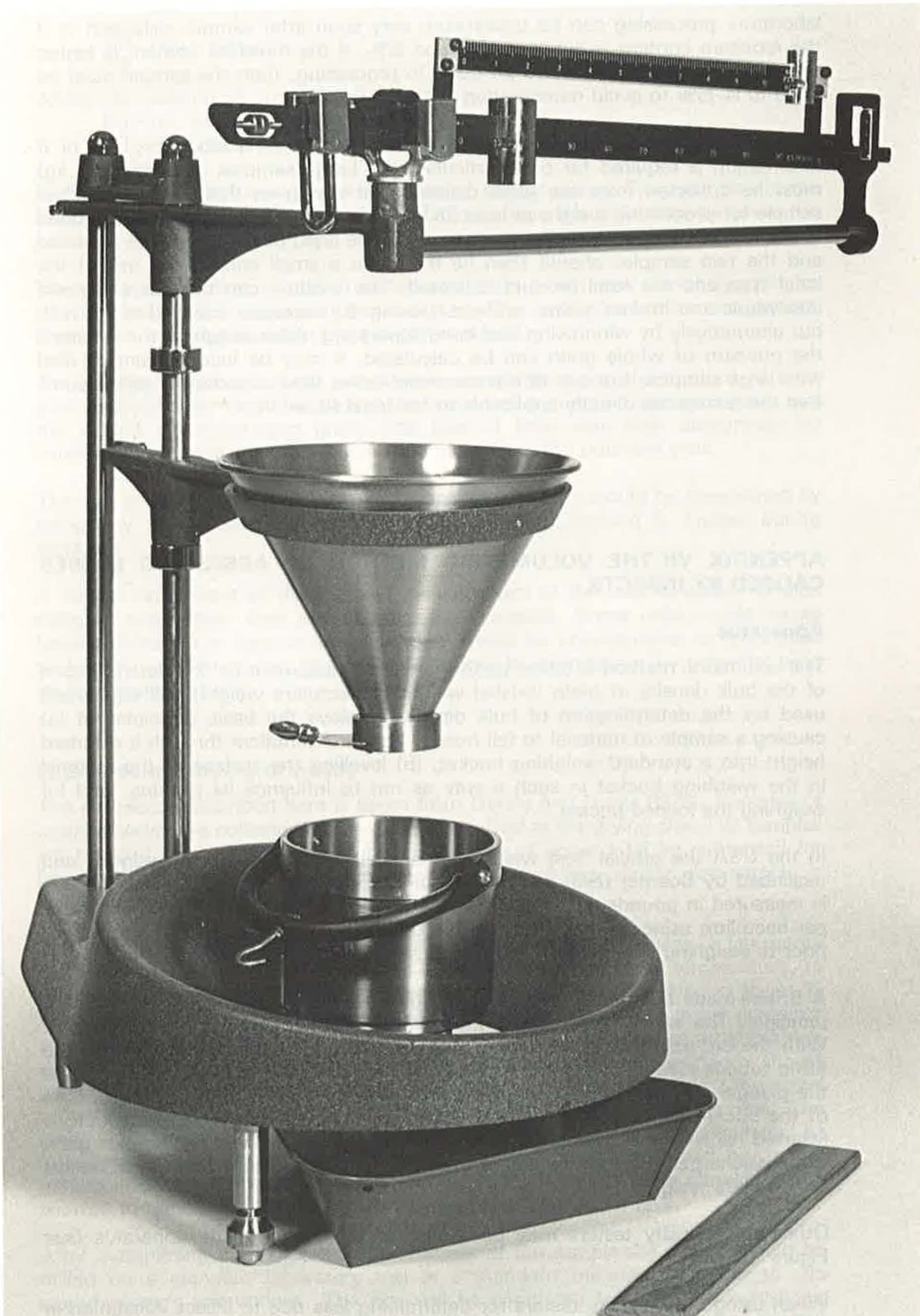


Figure D

Bulk density tester (United Kingdom)

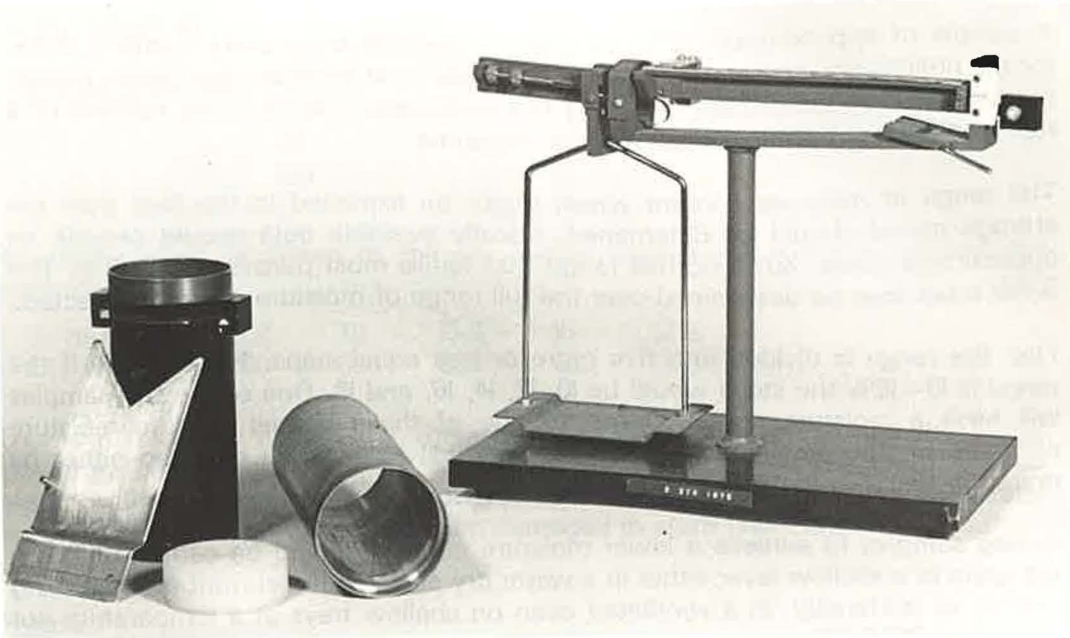
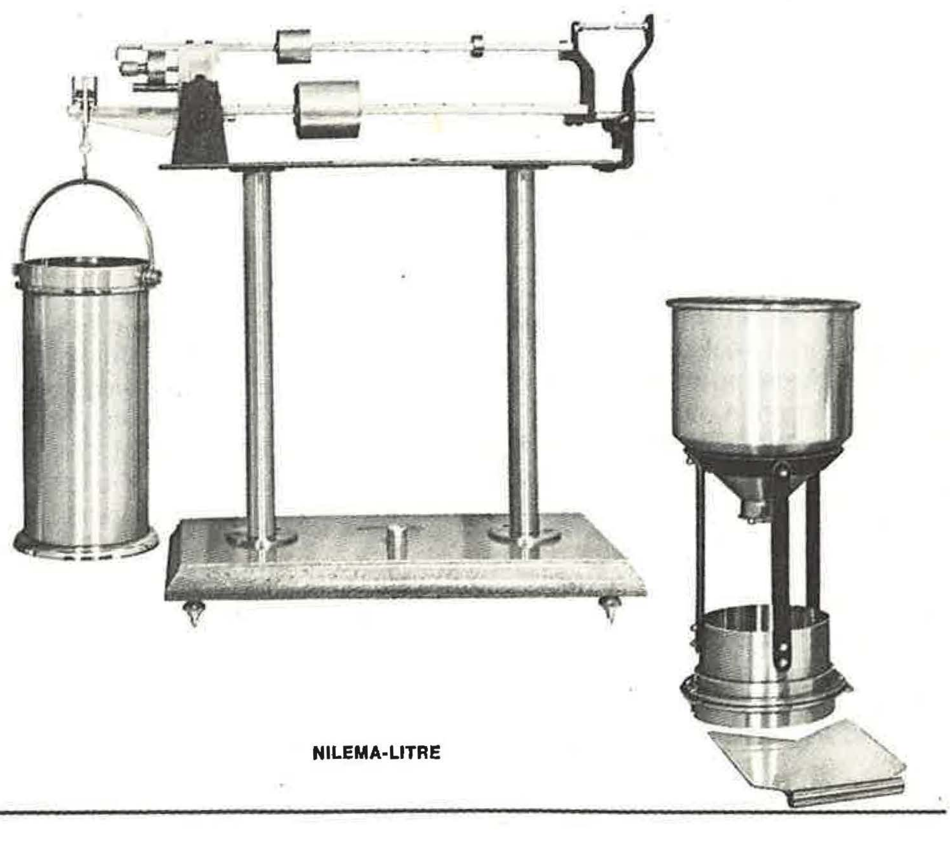


Figure E

Bulk density tester (France)



The procedure described below is based on work by Adams and Schulten (1978).

Preliminary laboratory work to determine a baseline (reference) standard volume weight (SVW) of grain

A sample of approximately 5 kg of grain is required from every farmer's store, for the preliminary laboratory work. Each sample must be sieved to remove foreign matter and then subdivided to obtain five replicates. The moisture content of a representative sub-sample must also be measured.

The range of moisture content which might be expected in the field over the storage period should be determined. Locally available data should provide an approximate guide, but a normal range that fulfills most purposes is 8-18%. The SVW must then be determined over the full range of moisture contents selected.

First the range is divided into five more or less equal steps. For example if the range is 10—18% the steps would be 10, 12, 14, 16, and 18. One of the sub-samples will have a moisture content close to one of these figures but the moisture contents of the remaining four sub-samples will have to be changed either by drying or wetting, in order to cover the range.

Drying samples to achieve a lower moisture content should be carried out with the grain in a shallow layer either in a warm dry place with a current of air passing over it, or preferably, in a ventilated oven on shallow trays at a temperature not exceeding 35°C. The approximate moisture content should be checked at regular intervals after allowing a sample to cool. When the sample has reached the required moisture content, it should be placed in a sealed container to cool and the moisture content should be measured accurately.

Samples that need wetting should have a calculated amount of water added to achieve the required moisture content. The weight of water to be added is given by the formula:

$$\text{Weight of water to be added (g)} = \text{weight of grain} \times \frac{\text{required \% m.c.} - \text{initial \% m.c.}}{100 - \text{required \% m.c.}}$$

For example, for a sub-sample of 1,000 g of grain at 12% moisture content and a required moisture content of 16% the calculation is:

$$\begin{aligned}\text{Weight of water} &= 1{,}000 \times \frac{16-12}{100-16} \\ &= 1{,}000 \times \frac{4}{84} \\ &= 47.6 \text{ g}\end{aligned}$$

The water can be weighed or, since 1 g of water occupies 1 ml it can be measured out as a volume. In this example 48 ml would suffice. The water must be added to the grain in a sealed container, allowing sufficient headspace for mixing, and mixed well. A period of two weeks for conditioning must be allowed, but during this period the grain must be vigorously shaken every day. When wetting samples to moisture contents of 16% or higher the container should be kept at a temperature of 5-10°C in a refrigerator to discourage mould growth. At the end of the conditioning period, an accurate moisture content must be determined for each sub-sample.

The SVW for each of the five sub-samples should be determined. The container must be filled according to the instructions provided with the apparatus and the same method used throughout the loss assessment study. The contents of the SVW container should be weighed to the nearest 0.1 g. The SVW should be determined five times and a mean result obtained for each sub-sample.

The five mean weights must now be converted to a dry weight according to the formula:

$$\text{Dry weight} = \text{weight of grain} \times \frac{100 - \%\ \text{m.c.}}{100}$$

For example, if the grain weighed 750 g and had a moisture content of 15%, then its dry weight is:

$$\text{Dry weight} = 750\text{x}\ \frac{100-15}{100}$$

$$= 750 \times \frac{85}{100}$$

$$= 637.5\ \text{g}$$

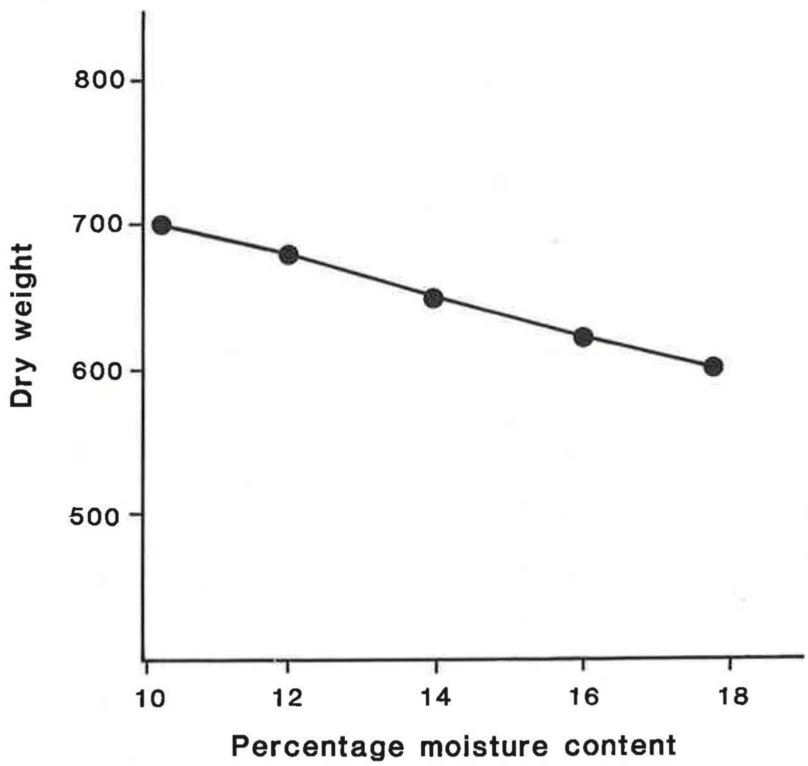
A graph should be drawn of the dry weight against the moisture content; for example:

% m.c.	10.2	12	13.9	16	17.8
Dry weight	700	680	650	620	600

This is a reference line of dry weights as determined by measuring the actual moisture content and the SVW at the time a test is made. The graph is then used throughout the study to represent the dry weight of the sample at any moisture content as if it had not been damaged in store (*see* Figure F).

Figure F

Example of baseline graph for dry weight of standard volume of grain at a range of moisture contents



Source: Adams and Schulten (1978)

Treatment of sample of grain collected from store during survey of losses

The sample of grain from store should be weighed and sieved (whether or not the weight of sievings is recorded will depend upon the requirements of the study, but it is not essential to the calculation of the SVW). The moisture content must be measured.

The SVW should be determined by the same method used to determine the baseline SVW. Five replicates should be used and the mean calculated. The mean SVW should be converted to a dry weight, using the formula given in *Preliminary laboratory work to determine a baseline (reference) standard volume weight (SVW) of grain* above.

The graph should then be used to find the dry SVW at the same moisture content as the sample. The loss is equal to the difference between the SVW from the graph and the sample SVW.

Example:

(i) Mean SVW of sample = 700 g
Moisture content = 12%
Dry SVW = 616 g

(ii) From the graph, SVW at 12% = 690 g

(iii) Weight loss % $= \frac{680-616}{680} \times 100$
$=9.4\%$

This is the dry weight loss

Discussion

The method requires a great deal of care and time in an adequately equipped laboratory.

In order to reduce the amount of laboratory work it was suggested that instead of preparing a baseline graph for every store, a graph for each distinct variety of grain under study could be used. Adams and Harman (I977) adopted this approach in Zambia.

In their own particular case, two distinct varieties of maize were found and two baseline graphs appeared to suffice, the assumption being that the grain was fairly homogenous. When these field experiences were interpreted as guidelines (Adams and Schulten I978) it was recommended that if grain varieties are not uniform (i.e. do not have standard weight-to-volume variation with moisture content due to intravarietal variations of the grains) or if each grain store is to be treated as an individual case study, then baseline graphs will have to be prepared for each individual lot of grain under study. Clearly this involves a substantial amount of preparatory laboratory work and exceptionally large amounts of grain; for example, if only I00 stores are to be included in a survey, then according to the guidelines a total of 500 kg of grain will be needed to complete the baseline graphs for all stores. The tendency has been to attempt to use baseline graphs for distinct varieties of grain or, whilst noting that there is an effect of moisture content in the dry weight of a given volume of grain, to ignore it as negligible if the range of moisture contents is narrow. This may be justifiable if the effect is indeed very small, but it must be realised that the loss may be considerably over- or underestimated depending upon whether the grain is drying or becoming wetter during storage. As a general rule the dry weight of the standard volume of grain decreases as the moisture content increases, as shown in the graph above. If the same figures from the earlier example are used, the possibilities of over- or underestimating the loss can be demonstrated as follows:

(i) With a baseline sample with moisture content of I0.2% the dry weight of grain occupying the standard volume container would be 700 g.

If the moisture content of the grain in store increases fo 12% and the weight of the damaged sample occupying the standard volume container is 700 g the dry weight as before is 616 g.

If the two dry weight figures are then used to calculate the loss the result will be:

$$\frac{700-616}{700} \times 100 = 12\%$$

whereas the loss allowing for changes in bulk density with moisture content (from the graph) is 9.4%

i.e. an *overestimate of 2.6%*

(ii) With a baseline sample with moisture content of 16% the dry weight of grain occupying the standard volume container would be 620 g.

If the mositure content of the grain in store decreases to 12% and the dry weight of the damaged sample occupying the standard volume container is the same as before, 616 g, then the loss using the two dry weight figures will be:

$$\frac{620-616}{620} \times 100 = 0.65\%$$

i.e. an *underestimate of 8.75%*

In a study of farm storage losses of maize in Malawi, Golob (1981) found that the sizes of maize grains varied greatly. The cultivation of a number of different maize varieties produced hybrids with grain of widely differing shapes, sizes and densities. Consequently, when an attempt was made to determine baseline graphs on a selection of samples, the relationships between moisture content and the dry weight of a standard volume were vary variable. It was found that samples at the same moisture content had very different standard volume weight values. These inconsistencies were a major constraint in using the volumetric method for determining losses. It was concluded that it would have been necessary to have prepared baseline graphs for each individual store but this was impracticable in the survey.

Boxall and Gillett (1982) working with wheat and maize in Nepal found that ideally a baseline graph should be prepared for each individual store under study, but as in Malawi this approach was impracticable because of limited laboratory facilities, manpower and time constraints. Eventually two graphs were prepared for wheat—one for each of two distinct groups of varieties identified, i.e. 'traditional' and 'improved', and these provided satisfactory results for this particular study. A single graph was prepared for maize using aggregate data since no significant difference was found between the standard volume weight/moisture content relationships of maize samples collected from five different areas.

Tyler (1981) encountered difficulties with the volumetric method in measuring loss due to insects in barley in Cyprus, due to the type of grain and the insect pest complex present. Experience in using the method with long-eared barley led to the conclusion that extreme care was necessary when filling the weighing bucket in order to obtain good replication. More difficult, however, was the need to resolve the problem encountered with the mixture of varieties and grains with varying characteristics delivered into store, starting with relatively immature, light grains. The heterogeneous nature of some grain bulks in all these regards prevented the monitoring of loss from these stores. A further problem was the variation in the type of damage that different insect species caused to the grain; the action of internal feeders such as *Sitophilus* sp. would be revealed by a decrease in the bulk density, but action of surface feeders sometimes led to a measured increase in bulk density, because of closer compaction of the grains.

APPENDIX VIII EXAMPLE OF HOW TO DETERMINE A CONVERSION FACTOR

A sample of grain is separated into damaged and undamaged fractions and grain in each fraction counted and weighed:

Total number of grains	=	1044	=	N
Weight of undamaged grains	=	215.8	=	U
Weight of damaged grains	=	47.1	=	D
No. of undamaged grains	=	793	=	Nu
No. of damaged grains	=	251	=	Nd

Count and weigh formula:

$$\% \text{ Weight loss} = 100 \times \frac{(UNd)-(DNu)}{UN}$$

$$100 \times \frac{(215.8 \times 251)\ (47.1 \times 793)}{(215.8 \times 1044)}$$

$$= 100 \times \frac{16815.5}{225295.2}$$

$$= 7.5\%$$

Calculation of conversion factor:

$$\% \text{ damaged (hollowed) grains} = \frac{\text{No. of damaged grains}}{\text{Total no. grains}} \times 100 = \frac{Nd}{N} \times 100$$

$$= \frac{251}{1044} \times 100 = 24\%$$

$$\text{Conversion factor} = \frac{\% \text{ damaged grains}}{\% \text{ weight loss}}$$

$$= \frac{24}{7.5}$$

$$= 3.2$$

APPENDIX IX ASSESSMENT OF LOSSES DUE TO RODENTS

The problems associated with the exact measurement of losses due to rodents are discussed in some detail by Jackson and Temme (1978) and Greaves (1978). Rodent losses may be measured directly by weighing grain before and after damage, but consideration is often given to estimating losses from population counts and feeding trial data. When assessing rodent losses it is usual to consider not only the measurement of loss due to the removal of grain, but also the loss due to contamination.

Outline of procedures for assessing losses due to rodents from population counts:

An essential element of a study of rodent losses is a preliminary survey of the infestation. During this survey, full details of the store and the stored commodity should be recorded. The site should be inspected thoroughly for signs of rodent infestation, such as burrows, excreta, smears, footprints, damage to commodities and structure and points at which rodents may enter the store. These signs should be recorded on a sketch map.

Tracking patches (talcum or finely powdered chalk) will be found useful in detecting the presence of rodents, particularly in warehouses, but they may also be used occasionally in farm-level studies, e.g. where grain is stored in bags inside the dwelling house or in a small 'warehouse'. However, when grain is traditionally stored in a basket, mud bin or similar structure, either placed inside the home or as a free-standing structure outside, the use of tracking patches is more difficult. Even when they can be used, the presence of tracks will not necessarily indicate that rodents are actually entering and feeding on grain stored in a particular container.

Where it is impracticable to use tracking patches, an indication of the activities of rodents in the vicinity of the store might be obtained from the presence of tracks in the soil or dust surrounding the store. However, in most cases additional evidence of the presence of rodents, e.g. fresh rodent droppings, damage to the container or produce, etc. must be sought to establish the presence of an active rodent infestation. A preliminary survey of a warehouse can usually be completed in two days, but a survey at farm level may have to extend over at least 3-4 days.

Once it has been established that there is a rodent problem and the feeding sites, etc. have been identified, the next stage is to assess the rodent population. This can be done by trapping all the rodents in the population that have access to the stored grain or by estimating the size of a population using a standard census technique for small mammals known as the Lincoln-Petersen (or trap-mark-recapture) method. (Full details of both methods are given in Harris and Lindblad, 1978).

In the first method—trapping to extinction—if all rodents are trapped, the daily grain loss to rodents can be estimated by multiplying the number of rodents by their daily food requirement. This trapping must necessarily be extended over a period of two to three weeks. The assumption is made that rodents with access to stored grain will use it as their primary food source, and while the method may be useful in warehouses it has limitations when applied to the farm level. The method might work satisfactorily in a farm household where the grain store is inside the house and the rodent population is primarily associated with the house. If the rodent population is at any time living outside the method will not be particularly satisfactory, since rodents may be using a food source other than the stored grain.

The principle of the trap-mark-recapture method for population estimating is as follows:

> A sample of rodents is caught alive, the individuals counted, marked and released.
>
> A second sample of rodents is then trapped and the number of marked and unmarked individuals counted. From a knowledge of the proportion of marked individuals in the second population and the number of marked individuals originally recorded, the size of the total population can be calculated. The ratio of marked: unmarked individuals in the second sample is the same as that of the number marked originally and released, to the total population. The complete exercise should be finished within three weeks.

The method is suitable for use in large warehouses, but could also be adapted for use in the field. It is however more appropriate for whole village studies rather than individual households. When used in rural communities some care is needed. Trapping sites will have to be carefully selected and well marked to ensure that the traps can be relocated after they have been laid. Consideration must also be given to screening the traps to reduce the risk of their discovery and removal. Careful planning is essential and an important preliminary activity should be a meeting of villagers at which the objectives of the exercise and method should be explained. Where rodents are considered a serious problem it can be a little disconcerting for villagers to find that a team of people have come to trap rodents only to release them again a few days later.

Losses due to rejection of contaminated grain

Contamination of grain by rodents is often serious to the extent that far more grain is contaminated or damaged than is actually consumed by the rodents. The amount of grain lost through contamination will depend upon the degree to which the consumer rejects contaminated grain. Individual grains may be picked out and discarded or the whole batch may be rejected. It must therefore be determined what is and what is not used as food. The level of loss will depend upon subjective measurements and will vary with time, place and the degree of hunger, etc.

Estimates of losses due to rodents are therefore likely to be difficult to obtain and although several methods of assessment have been described it may be best to combine a number of techniques. More information is required about the suitability of the methods described and the constraints that are likely to arise under field conditions. However, it should be emphasized that before embarking upon a lengthy study of rodent losses the investigators should have a clear idea of the objectives of the study. If the objective is to determine the need for a rodent control programme then, as mentioned elsewhere, it may only be necessary to establish that the infestation is regarded as a problem by the community if the benefits of the control programme are to be measured by a reduction in health risks and damage to property as well as a reduction of food loss.

APPENDIX X SAMPLE REDUCTION

Coning and quartering

Coning and quartering is the simplest method of reducing the size of a sample whilst at the same time ensuring that the final sample is still representative of the original batch from which it was obtained. It can be used for relatively large batches of grain, for example, I or 2 bags, or for samples submitted to the laboratory.

The sample to be reduced should be poured onto the floor or other flat surface, where it will naturally assume the shape of a cone. The grain should be thoroughly mixed whilst maintaining its cone shape. After mixing, the top of the cone should be levelled and the bulk divided into halves and then quarters using a flat piece of wood or specially prepared quartering irons. In most instances the quarter of the bulk will still be too large as a sample and further reduction will be necessary. To achieve this, two opposite quarters should be combined, mixed, and again coned and quartered. The procedure should be repeated until a sample of the required size is obtained (*see* Figure G).

Whilst coning and quartering is perfectly acceptable for the reduction of samples in the laboratory, it is more usual to use a grain divider under these conditions.

The riffle (multiple slot or box) divider

The riffle divider is the simplest of the sample dividers recommended by the International Organization for Standardization.

It consists of several rectangular-mouthed funnels arranged side by side so that alternate funnels lead to opposite sides of the apparatus. The funnel assembly is fitted inside a box which is open at the bottom. Three sample boxes each identical in size, form part of the apparatus. They are so designed that the funnel assembly box can sit on any two of them while the third is used to pour a sample through the hopper (*see* Figure H).

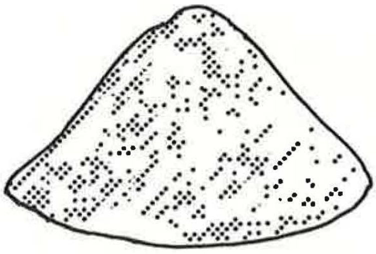
The sample should be thoroughly mixed before division. It is then placed in one of the sample boxes and shaken gently so that the surface of the grain is more or less level. One long side of the box containing the sample is placed against the side of the hopper, and the grain is slowly tipped into the divider. The sample is then more or less equally divided between the two sample boxes underneath the funnel assembly. If further division is required the above procedure may be repeated with the contents of either or both sample boxes as often as necessary.

The Boerner divider

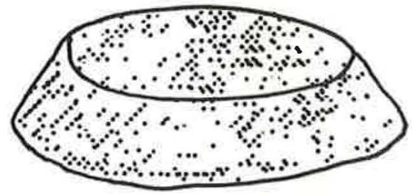
The Boerner divider is a gravity, mechanical divider, also recommended by the International Organization for Standardization. The sample to be divided is fed from a hopper on to a cone around which it flows evenly. Around the periphery of the cone there is a series of channels—the mouths of funnels which alternately

Figure G

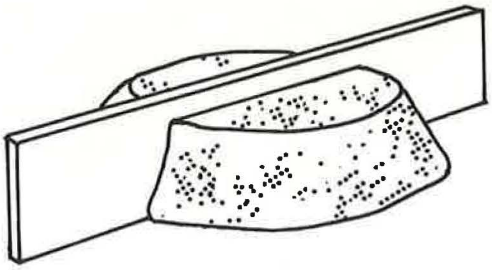
Coning and quartering



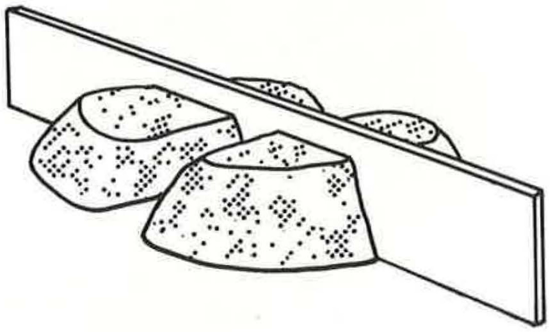
A Grain mixed and coned



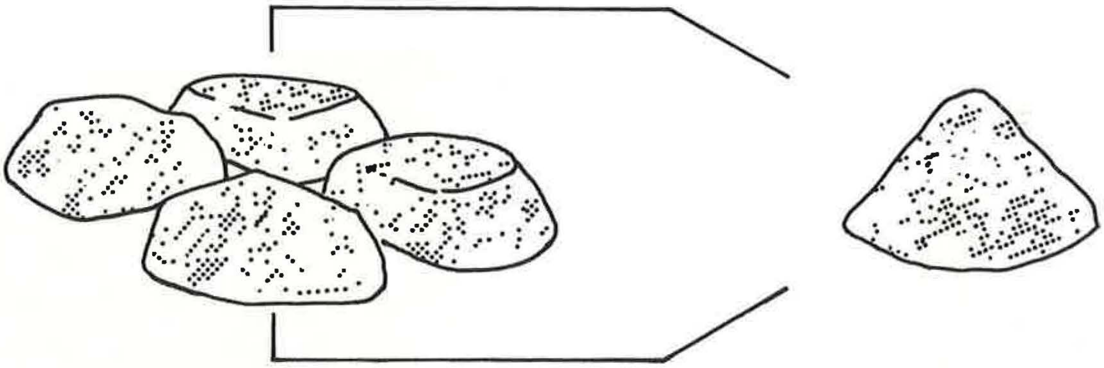
B Cone flattened for quartering



C First division



D Second division



E Opposite quarters taken for mixing and forming: **F** the reduced sample

direct the grain into an inner and outer collecting funnel. From these funnels the grain flows into equal-sized receiving pans (*see* Figure I).

By virtue of its design, the Boerner divider is superior to the riffle divider in producing reduced samples of equal quality and quantity. However, it is very much more expensive and is better suited to research-type laboratory work rather than routine loss assessment requirements.

Motorized divider

Motorized dividers of different designs are available, but are perhaps rather expensive for loss assessment studies. Nevertheless, an example is included here for the sake of completeness.

The Gamet divider (*see* Figure J) has a large (2 kg) hopper from which the sample falls onto a revolving disc from which it is flung into a chamber divided into two (sometimes more) outlets at the bottom. The divider is said to be extremely accurate at splitting a sample into halves.

Figure H

The riffle divider

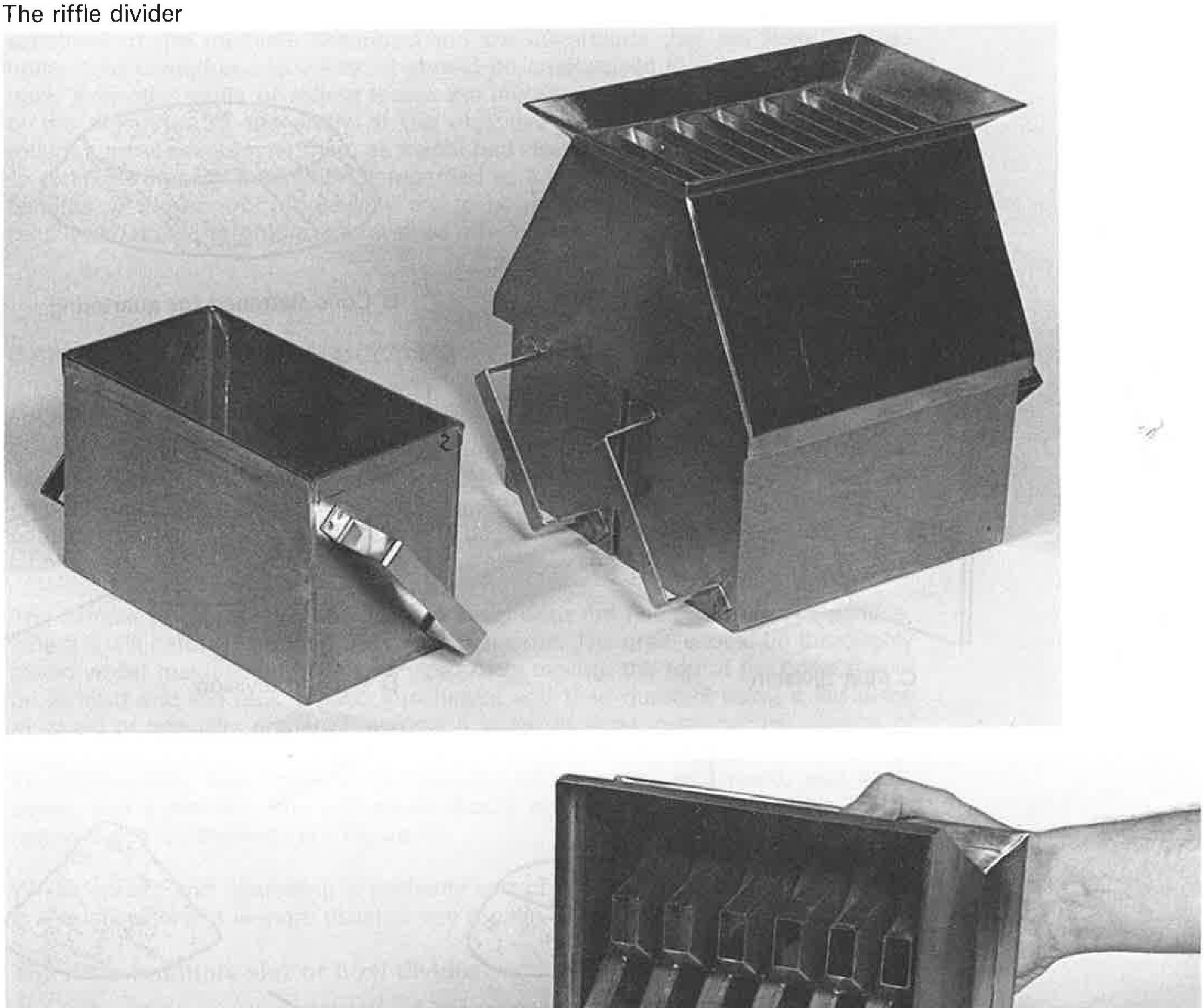


Figure I

The Boerner divider

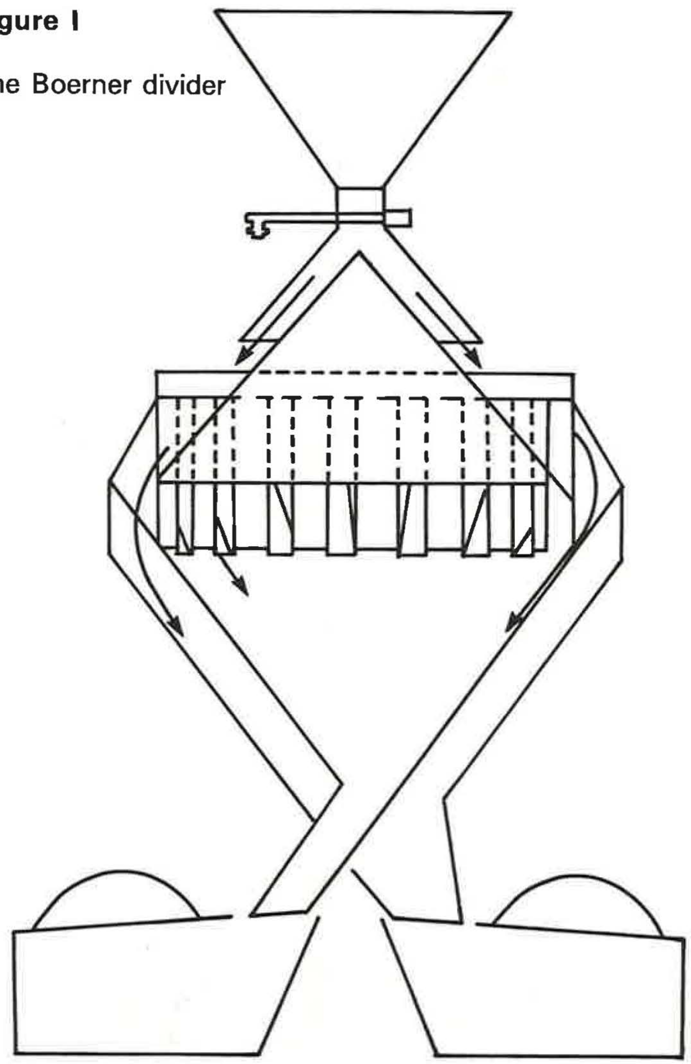
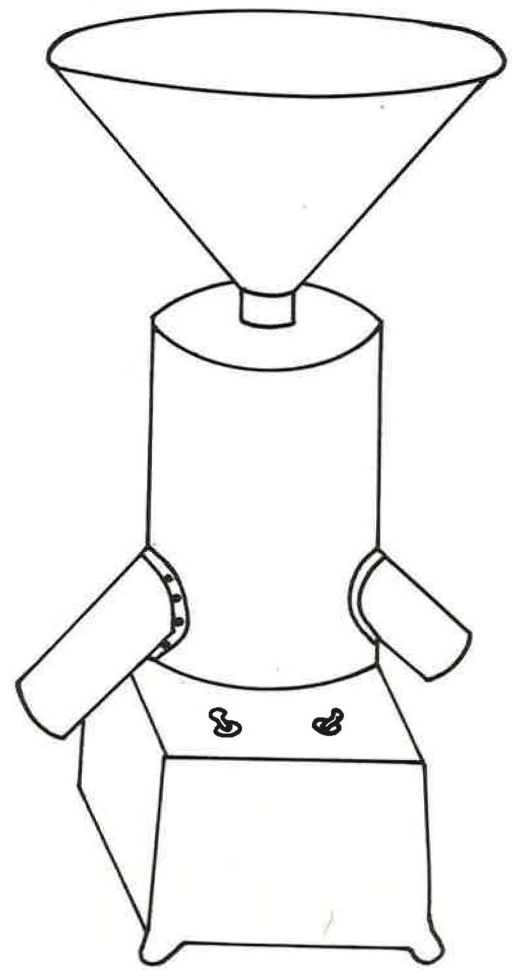


Figure J

Motorized divider



APPENDIX XI CALCULATION OF TOTAL STORAGE LOSS

The general principles for calculating the total storage loss were discussed in Section 7. This section is devoted to a series of worked examples to illustrate the procedure to be adopted.

1 *Grain removed on one occasion*

A store was filled with 672 kg of grain and when it was emptied an apparent weight loss of 41 kg was recorded. From analysis of samples collected at the beginning and end of the storage period, a loss of 4.4% due to insect infestation was calculated. Assuming that there is no change in the grain moisture content then the total loss would be:

$$\frac{41}{627} \times 100 = 6.1\%$$

The loss due to insects is 4.4%
and so the unaccounted loss, which may be attributable to rodents, birds, etc. is:

$$6.1 - 4.4 = 1.7\%$$

2 *Grain removed on several occasions*

A store was filled with 672 kg of grain and after one month 150 kg were removed. At this time a weight loss of 1.0% due to insect infestation was recorded. After a further two months 200 kg were removed and an analysis of a sample of grain revealed a 2.5% loss due to insects. At the end of the storage period only 280 kg were removed, and a final sample revealed a 3.1% loss due to insects.

Assembling the information recorded, the total loss (assuming no change in the moisture content of the grain) will be

$672 - (150 + 200 + 280) =$
$672 - 630 = 42$ (or 6.25%)

Total loss due to insects must be calculated in relation to the pattern of consumption and so:

150 kg suffered a 1.0% loss
200 kg suffered a 2.5% loss
and 280 kg suffered a 3.1% loss

This information could be substituted into a table similar to that on page 61 in order to calculate the cumulative weight loss due to insects (*see* Table C).

Table C

Relationship between weight loss and grain consumption

	Grain removals		
	1	2	3
Quantity removed	150	200	280
Weight loss in sample	1.0	2.5	3.1
Weight loss (as % of quantity originally stored)	0.2	0.7	1.3
Cumulative weight loss (as % of quantity originally stored)	0.2	0.9	2.2

The total loss due to insects is therefore 2.2% and the unaccounted loss, which may be attributable to rodents, birds, etc. is:

$$6.25 - 2.2 = 4.05\%$$

However, a closer examination of the method of calculating the insect loss will show that the figure might be a slight underestimate. When a quantity of grain is removed, the percentage weight loss calculated from a sample of that grain is usually applied directly to the actual quantity removed. For example 1% of 150 kg = 1.5 kg. However, strictly speaking, the 150 kg represents the weight of grain which has lost 1% by weight (i.e. 99%). The original weight of this quantity of grain (in the absence of damage) would have been:

$$\frac{150}{99} \times 100 = 151.52$$

and so the loss = 1.52 kg

On the second occasion, 200 kg represents the weight of grain which has lost 2.5% by weight. The original weight would have been:

$$\frac{200}{97.5} \times 100 = 205.13$$

and so the loss = 5.13 kg

On the third occasion the corrected figure would be

$$\frac{280}{96.9} \times 100 = 288.96$$

or 8.96 kg loss

Summing the weights of grain lost on each occasion gives a total weight loss of 15.61 kg or, expressed as percentage of the quantity originally stored:

$$\frac{15.61}{672} \times 100 = 2.3\%$$

This figure is not very different from that calculated by the first method. It is usual to apply the percentage loss figure directly to the quantity of grain removed as in the table above because this simplifies the calculation and it is considered that the refinement of the calculation does not add significantly to the accuracy of the results. Only in a research study could such a refinement be justified.

3 *Cases where it is impossible to weigh all grain removed*

In practice it is seldom possible either to weigh the grain into and out of store or to sample every quantity of grain removed.

Samples may be collected at regular intervals and whilst some of these may actually be from the grain removed, others will be taken from that part of the store from which grain will next be removed. If the samples are drawn, at say, monthly intervals and the dates and quantities of grain removals are known, an approximation of weight loss at the 'correct' time can be made by applying the estimated loss to quantities of grain removed two weeks either side of the sampling date.

Where quantities of grain are roughly estimated the loss may be obtained by calculating the percentage of the total quantity stored which was removed at each sampling date and applying the percentage loss to this.

Calculation of loss

Example:

A store was filled with 750 kg of grain on 2 February.

Grain was removed and sampled as follows:

2/MAR	100 kg weighed out, sample collected. Loss = 1.5%
3/APR	100 kg weighed out, sample collected. Loss = 2.7%
10/APR	50 kg (approximately) removed by householder—no sample

5/MAY	150 kg weighed out, sample collected. Loss = 3.2%
17/MAY	60 kg (approximately) removed by householder—no sample
1/JUNE	200 kg weighed out, sample collected. Loss = 3.4%
28/JUNE	20 kg (approximately) removed by householder—no sample
2/JULY	20 kg weighed out, sample collected. Loss = 7.0%
3/AUG	Store emptied, 15 kg weighed out, sample collected. Loss = 10.5%

As before, this information can be summarized in a table to calculate the total loss (*see* Table D).

Table D

Summary of field and laboratory data for calculation of loss

Total quantity stored = 750 kg

Date	MAR 2	APR 3	10	MAY 5	17	JUN 1	28	JUL 2	AUG 3
Quantity removed (kg)	100	100	50	150	60	200	20	20	15
(%)	13.3	13.3	6.7	20	8	26.7	2.7	2.7	2.0
Weight loss in sample (%)	1.5	2.7	N/S[1]	3.2	N/S[2]	3.4	N/S[3]	7.0	10.5
Weight loss as % of quantity stored	0.2	0.4	0.2	0.6	0.3	0.9	0.2	0.2	0.2
Cumulative weight loss as % of quantity stored	0.2	0.6	0.8	1.4	1.7	2.6	2.8	3.0	3.2

TOTAL QUANTITY REMOVED = 715 kg (95.4%) TOTAL LOSS = 4.6% of which 3.2% due to insects
1.4% due to other causes

Notes: N/S[1] = No sample—weight loss % from sample collected 3/Apr applied
N/S[2] = No sample—weight loss % from sample collected 5/May applied
N/S[3] = No sample—weight loss % from sample collected 2/July applied

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