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assessment and collection of data on post-harvest foodgrain losses

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FOREWORD

The manual is intended to serve as a guide to the statistical methodology for assessing and collecting data on post-harvest foodgrain losses. It should be useful to those countries which plan to launch foodgrain losses reduction programmes but find themselves seriously handicapped because of lack of basic data. I am confident that the manual will go a long way in assisting those who will be charged with the responsibility of planning and implementing surveys for estimating post-harvest foodgrain losses.

The manual, at the request of the FAO, was prepared by the Indian Agricultural Statistics Research Institute. This Institute has a long tradition of developing and testing statistical methodologies as applied to agricultural research and development. A number of its senior officers have served FAO in several projects for the improvement of agricultural statistics in the developing countries. It should, however, be borne in mind that the methodologies suggested in this manual are offered only by way of guidelines which need further study and adaptation to suit the conditions prevailing in specific countries. The issuance of the manual in its present form should be considered as an invitation to the countries to communicate to the FAO their own experiences in this field, particularly taking into account the methodologies suggested therein. The initiation of such dialogue will indeed be very helpful for effecting further improvements in the techniques and methods which could be incorporated in subsequent editions of this manual.

Director
Statistics Division

1. INTRODUCTION

Foodgrain crops need protection in the field from a variety of pests and diseases and natural calamities. The problems do not end with the production of foodgrains which have to undergo a series of operations such as threshing, processing, transportation and storage before they reach the consumer, and there are appreciable losses of foodgrains at all of these stages of their handling and storage. Thus the losses occur at two different stages - the pre-harvest and the post-harvest stages. Information on the extent of losses at these stages is important not only for the scientists and technologists, but it would also be useful to the policy makers, administrators and industrialists. The scientists and technologists would be guided by these findings in carrying out improvements in the crop production and post-harvest technologies aimed at minimizing these losses.

The problem is of greater relevance to the developing countries where the production of foodgrains per head is much less as will be seen in Table 1 given below:

Table 1. Population and production of cereals in different regions*

	Total Annual Production of Cereals (Million tons)	Population (Millions)	Annual Production of Cereals per head (Kilograms)
Developed countries	470	757	621
N. America	274	236	1 161
W. Europe	149	364	409
Oceania	18	17	1 059
Developing countries	414	1 958	211
Africa	45	319	140
L. America	82	324	253
Near East	52	195	266
Far East	235	1 116	210

* FAO Yearbooks on Production

The wastage of foodgrains in the developing countries would, therefore, mean not only monetary loss of billions of dollars but also a decline in their already low nutritional standard and the destabilizing of economy. It is a very distressing situation when all the efforts in the production of more grains in these countries are frustrated by substantial post-harvest losses resulting in failure to meet the food requirements of their hungry millions.

The problem of control or minimizing these losses in the developing countries, where about 70 percent of the population live in villages and depend mainly on agriculture, is much more difficult to solve in the absence of reliable and objective estimates of such losses at different stages. Data on losses in different pre and post-harvest operations would be of considerable value to evolve correct policy to save foodgrains which are becoming scarce and expensive, particularly in the developing countries. At present, such estimates are not available and even if they are available they are simply the intelligent guesses of some experts. This is due to lack of suitable methodology for estimating the losses owing to various causes. The problem of identifying the cause of loss becomes much more difficult when several factors operate simultaneously. For example, at pre-harvest, various pests and diseases occur and cause loss to the crop simultaneously. The methodology for estimation of such losses should, therefore, be based on multivariate approach rather

than taking one or two factors alone into account. Similarly, the methodology for estimation of losses at the post-harvest stage should consider all the possible factors involved simultaneously.

The losses at the pre-harvest stage may occur mainly due to pests and diseases and natural calamities like drought, flood, hailstorms, etc. The losses at the post-harvest stage may occur due to faulty methods of harvesting, threshing, cleaning, drying, storage, transportation, processing, packaging, distribution of foodgrains etc. The present manual will, however, be concerned with the losses occurring at the post-harvest stage.

The seriousness of the problem of post-harvest foodgrain losses has been discussed at numerous meetings, conferences, symposia, etc., at national as well as international levels. Many studies for assessing the post-harvest losses have been conducted by several countries, particularly in the developed part of the world. Several international agencies have shown considerable interest in such studies. The FAO Council at its Seventy-first Session held from 6 to 17 June 1977, discussed the problem of post-harvest losses and it was recognized by the member countries that there was a lack of definitive loss data in many countries together with the need to conduct loss surveys before launching loss reduction programmes. They also felt that for conducting such surveys on an objective and scientific basis, there was a need to develop a statistical methodology for the collection and systematic assessment of data on post-harvest food losses. Consequently, the Indian Agricultural Statistics Research Institute, New Delhi, whose main function is to conduct research in agricultural statistics, was asked by FAO to review the available literature on post-harvest foodgrain losses and suggest suitable statistical methodology for the collection of data on foodgrain losses, taking into consideration the special conditions prevailing in the developing countries with particular reference to wheat, rice, corn, sorghum and millet.

To achieve the above objective, the first task was to study the work done by various experts and agencies in this line so that the problems posed by the FAO could be identified and suitable studies formulated to develop appropriate statistical methodologies, keeping in view the conditions obtaining in different countries, particularly the developing ones. In this connection, various specialists and organizations were contacted in person or through correspondence. The names of these specialists and organizations which helped either by supplying materials or giving references are given in Appendix V.

Only reports and proceedings, etc., which have been referred to are given in the list of references. Articles by individual authors are numerous and since most of them had been referred to in those reports/proceedings, they have not all been included. An attempt has been made to review all available literature on the subject published during the last decade. It is, however, not claimed that the review is exhaustive; only such literature as was available to the authors has been referred to in this manual.

After going through the material mentioned above it was observed that no uniform concepts, definitions and measurement techniques have been used in different studies. It was, therefore, felt necessary to develop some kind of concepts and definitions which could be appropriately used while collecting data on foodgrain losses.

The statistical methodology has been presented in Chapter 3. In Chapter 4 recommendations made have been given in brief. The references made in the text are given thereafter. The specimens of questionnaires, other forms, etc., to be used in the assessment and collection of data on post-harvest foodgrain losses are given in the Appendices I and II.

2. CONCEPTS, DEFINITIONS AND MEASUREMENT TECHNIQUES

In developing a suitable methodology for the assessment of post-harvest losses of foodgrains, it is necessary to consider initially the concepts of loss. There is a good deal of variation in the concepts and definitions of loss adopted by various research workers. This is not surprising since the operations of harvesting, threshing and processing of various foodgrains and the numerous operations and channels involved in the flow of grain from the producer to the consumer present a complex and varied picture. In developing a methodology for the assessment of losses it will be necessary to simplify the problem as far as possible to achieve feasibility keeping in view the fact that the demand for such a methodology has arisen out of the keenly felt need to reduce post-harvest foodgrain losses in developing countries.

A simple and practical definition of loss is 'reduction in weight of edible grain available for human consumption'. This is favoured by a number of research workers, e.g. Kenton Harris (1971). Though adequate for practical purposes and convenient because of its simplicity, it does not cover one situation satisfactorily, and that is reduction in weight due to driage. Drying of foodgrains is essential to permit their storage over long periods. Though this process involves considerable reduction in weight, there is no loss of food value and such reduction should not, therefore, be counted as loss. The other losses owing to pilferage, faulty weighing, wrong management practices, etc., are also not covered under the above definition of foodgrain loss, but it would be interesting to record such losses so as to separate such losses from the real losses. There are several kinds of losses such as weight loss, quality loss, food loss, economic loss, loss of goodwill or reputation, and seed loss. The present manual mainly considers the quantitative loss but records the observations on factors which cause qualitative as well as quantitative losses simultaneously.

The quantitative loss is caused by reduction in weight due to factors such as incidence of insects, mites, fungi and bacteria, rodents and birds, and also due to physical changes in temperature, moisture content and chemical changes. The qualitative loss is caused by reduction in the nutritive value due to factors such as attack of insect pests, mites, rodents and birds, or from handling or physical changes or chemical changes in fat, carbohydrates and protein and by contamination of micotoxins, pesticides residues, insect fragments, excreta of rodents and birds and their dead bodies. However, when qualitative deterioration makes the grain unfit for human consumption and is rejected, this will amount to a quantitative loss. In loss assessment, therefore, great care will be necessary to ensure uniformity of concepts as well as practices.

Another aspect of loss measurement requiring consideration is that in existing methods of processing a part of the grain is transformed to a by-product; for example in rice or wheat milling a part of the grain is lost with the separation of the bran. This is usually fed to livestock and thus utilized. Hence this results in loss of food value to human beings as per definition given above but this reduction may also be recorded as a loss up to a standard limit since it is a normal result of an established food processing technology. However, if an improved processing technology is developed later on, the saving that can be effected by the new process might be counted as a loss resulting from the adoption of the earlier method provided adoption of the new process is economically feasible. Similar reasoning will apply to broken grains; these are usually sold at cheaper rates but so long as they are utilized for human consumption, the yield of brokens should not be treated as loss but it may be taken into account while computing economic loss.

One difficulty that could arise in ensuring uniformity in measurement of losses in different countries is that practices adopted by them might differ. For example, a particular type of damage to grain might result in its rejection in one country while such grain might be used for human consumption in another. In such a situation the quantity of grain damaged in a particular way may be recorded separately in both countries to provide comparable results, regardless of whether it is used for human consumption or not. However, there may be no general solution to this problem of comparability and the problems may be considered

after gaining experience of such surveys in a number of countries.

With these introductory remarks the manual considers the various stages in the flow of grain and examines for each stage what losses may be considered for measurement and how they may be measured.

Harvesting

The operations include cutting the crop, gathering, bundling and stacking when done manually. The same operations may be done mechanically by a harvester. At this stage loss is mainly due to shedding of grains, the amount of loss depending on the time of harvesting. If the operation is done late, shedding is more. In either case the loss can be estimated by selecting a random sample of fields, locating a plot 10m x 5m in each selected field randomly and collecting and weighing shedded grain. The average yield of shedded grain compared with the yield obtained by harvesting will give the percentage loss. Since the shedding of grains depends on the time of harvesting, i.e., early, in time or late, due to difference of moisture content, the collection of such information (time and moisture content at harvest) is necessary at the time of harvesting.

Threshing/Shelling

In this process the grains are beaten to separate them from the husk as in the case of rice or from the plant to which they are attached as in the case of maize. The operation may be done manually or by mechanical threshers. In this case the loss is of two kinds, one due to damage to grain in processing. The first can be estimated by selecting a measured quantity of produce and hand-stripping it carefully and noting the yield and comparing it with that obtained by following the usual practice. Alternatively, a sample of straw, stripped cobs, etc., obtained in the process of threshing may be taken, escaped grain picked from it and the collected grain weighed. This will provide a measure of loss directly. For estimating damage to grain a small quantity, say half a kilogram of grain obtained after threshing can be examined carefully and separated into whole and damaged grain. Their respective weights will provide percentage loss from damage. However, the exact nature of loss would depend on how the damaged grain is used. Only if it is normally discarded will it constitute real loss. The process adopted whether manual or mechanical may be specified in detail.

Cleaning/Winnowing

In this process the grain is cleaned by blowing away the chaff from it. The loss occurs because of a part of the edible grain passing into chaff. For estimating this loss the total quantity of chaff and grain obtained in an operation may be recorded. A sample of chaff may be taken and examined for grains contained. The grains may be collected and weighed. This will provide an estimate of the grain lost. By comparing this quantity with the total grain obtained, percentage loss can be estimated. In case of paddy, the operation may be done in the rice mill and the procedure of estimation will be different. The cleaning operation may be done manually or mechanically (the winnower may be hand-operated or with an engine). The details of each of these operations may be observed and recorded.

Drying

Losses in drying can arise in two ways. On the one hand when a crop like paddy is spread out on the road or in the yard, a part of it will be eaten by birds, rodents, insect pests, etc. To estimate this quantity, it will be necessary to measure the moisture content of the crop before and after drying. The weight of the crop spread for drying and collected after drying should also be recorded. A comparison of the latter with the former after discounting for reduction in moisture will provide estimate of loss during drying. The process adopted, whether manual or mechanical, may be specified in detail.

The other type of loss will be the result of inadequate drying which may lead to fungal damage to grain or lower proportion of recovery in milling or greater brokens. To estimate the loss occurring in this way, it will be necessary to take a sample of the grain initially brought for drying, process it scientifically and compare percentage recovery of final product with that obtained by following the process in common use.

Storage

Losses in storage need greater attention than loss at other stages because greater losses have been reported by various investigations at this stage than at any other and also because they are relatively easier to estimate as well as prevent or reduce. The storage may be at the farm level or at trade or market level or even at the level of governmental agencies. The modes of storage may be (i) 'traditional', (ii) 'intermediate' or improved types of similar to traditional or (iii) 'modern' (steel or concrete storages). The governmental agencies might be expected to store grain in scientifically constructed warehouses. However, where such capacity is inadequate to meet the demands of public distribution system, some grain may be stored in hired buildings or in bags on raised platforms in the open. The agencies might be expected to keep detailed records regarding grains received and despatched and record the observations on the type of storage structure, moisture content and relative humidity, insects, mites, rodents and micro-organism attack, respiration, etc.

If we are interested to know the losses for each of the structures of storage system at the farm level, trade and market level, we will have to select samples from these systems separately in the selected areas. Further, to assess the loss due to various factors as mentioned above, we will have to record the observations on the samples taken by sampling probes specifying each of the sampling probes in detail as well as conduct laboratory tests periodically to record the damages due to insects, mites, micro-organisms, etc.

Since some of the factors causing quantitative and qualitative losses are interrelated, the statistical analysis by multivariate approach may give some interesting results regarding causes of losses by various factors occurring simultaneously.

They are also expected to keep record of losses due to spillage and pilferage whether in storage or transit as also of grain destroyed, say, by flood or fire or discarded because of deterioration as unfit for human consumption. Such agencies if properly administered might be expected to provide a wealth of data on storage losses. The estimation of losses at the other two levels, namely at farm level and trade level, need special consideration. At the farm level, information regarding storage losses can be secured by means of sample survey technique by selecting a random sample of farmers and collecting from them data regarding quantities of grains stored, modes of storage and losses sustained. In developing countries where the holdings are generally small, no records are likely to be kept of quantities stored, quantities taken out from time to time or of losses. It will be necessary for the survey agency to contact the farmers periodically - monthly or fortnightly - to collect such information. Experience of such a survey conducted in India is reported later in this manual. It is also desirable to associate food analysis with such a survey so that samples of grain could be taken from the sample storages periodically and inspected for deterioration, pest infestation, rodent or other damage, etc.

The problem of estimating losses at trade level is no different basically except that sampling will have to be done for markets and traders. Some experience of such investigation has been obtained in a marketing survey conducted in India. This is also reported later.

Transport

In the post-harvest operations transport, such as bullock-cart with wooden wheels, improved carts with pneumatic wheels, tractor trollies, trucks, trains, ships, etc., is involved at several points. In manual harvesting the produce may be transported in the first instance from the field to the threshing floor. From threshing floor it may be

transported to the farmer's storage and eventually, and usually in instalments, from there to the assembling markets. From the assembling markets the wholesalers may transport it over long distances by truck, train or ship to distant and possibly foreign markets, and from the terminal markets, near and far, grain may be transported by retailers to their shops/storages. In all these operations, including loading and unloading, the concept of loss would usually be the weight of grain lost whether due to spillage or pilferage. However, damage to grain in train, truck or ship where it remains for considerable time, resulting in rejection, might also be counted as transit loss. Estimation of losses at various points could be a most painstaking job. However, if the grain is weighed at each point before and after unloading the loss could be easily estimated by the difference. The observations on moisture content before loading and after the transportation of foodgrains from one place to another is necessary so as to separate the loss due to this factor from transit losses at different points. A more detailed discussion regarding measurement of these losses will be presented in the next chapter.

Processing

Foodgrains pass through different types of processing before being consumed. Rice, which is the cereal consumed by a major part of the population in developing countries, is obtained by dehusking paddy, either by farmers themselves by handpounding or, what is more common now, in rice mills. Some of the operations involved in the process are pre-cleaning, hulling, husk separation, parboiling (pre-milling treatment), polishing and glazing. There are different types of rice mills (such as sheller and huller types) and the efficiency of milling is measured by recovery in terms of whole grain, brokens and brown grains. Losses in this case might be defined on the basis of comparison with a standard type of rice mill. In other grains, particularly wheat which is ground in flour mills for the production of refined flour and other products, a similar approach could be adopted. It may be repeated that bran or residues which are obtained as a by-product need not be treated as loss provided they are fit to be used as animal feed; however according to our definition given earlier it is a loss for the human beings. Moisture content of the final product is likely to be less than that of the original grain. It is necessary, therefore, to measure the moisture content of grain before processing and of products obtained afterwards on the basis of properly drawn samples and make allowance for driage while measuring losses.

Packaging

Losses owing to methods of packaging and handling can arise at different stages, for example, in transport from farm to storage and storage to market, at different stages of marketing and at the retail trade level. The common methods of handling are handling in bulk or in gunny bags or cloth or plastic-lined bags. The study of packaging will have to be made at each stage before the nature of loss can be ascertained and measurement techniques developed. Of course, losses of both types, namely, directly due to reduction in weight or due to rejection because of spoilage can arise as a result of defects in packaging and handling.

Distribution

Losses at the farm level and wholesale trade level have already been mentioned as likely to arise in storage, transport, packaging and handling. At the retail level, the grain is usually handled in gunny bags or cloth bags or sold to customers loose in their own containers. Losses at this level including those in handling or weighing could be studied on sample of retail shops.

3. STATISTICAL METHODOLOGY

In the light of the foregoing chapters the problem of assessment of post-harvest foodgrain losses has to be viewed in its proper perspective. It must be borne in mind that the purpose of loss assessment is to achieve expeditious loss reduction. It may also be observed that it will be prohibitively expensive to take up loss reduction efforts in the whole post-harvest system. It is necessary to identify the most serious grain loss points in a country's post-harvest food supply system and concentrate loss reduction efforts initially on high-loss points only. The objective of developing a statistical methodology for the assessment of post-harvest foodgrain losses is, therefore, to provide methods yielding standardized results so that effective grain loss reduction efforts can be made and priorities for loss reduction determined in developing countries.

For assessing loss at any stage, it is necessary to define the population for which it is desired to estimate the loss. Data required are to be specified and suitable proforma drawn up for recording them. Next a sampling procedure and a measurement technique appropriate to the situation are to be evolved. The details of field organization are to be worked out, data collected, scrutinized and analysed to obtain estimates of losses in keeping with the sampling design. As far as possible standard errors of estimates should also be worked out to judge the reliability of the information thus obtained. The estimation of losses at various stages enumerated earlier, namely harvesting, threshing or shelling, cleaning or winnowing, drying, storage, transport, processing, packaging and distribution, may be considered at three levels: (i) losses at the farm level; (ii) losses at the level of intermediaries; and (iii) losses at the level of public agencies. At each of these levels the procedures of sampling, collection of data, estimation of losses, etc., are discussed in the following sections.

Losses at the Farm Level

Sampling frame. The first step in designing a loss assessment survey is the construction of an appropriate sampling frame. The ultimate sampling unit will differ according to the stage of the post-harvest process at which losses are being measured. These are likely to be as follows:

a. Harvesting

Villages will be the primary sampling unit, cultivators the secondary sampling unit and fields the tertiary unit. Lists of fields under cultivation have to be prepared for each selected cultivator and plots of approximately 10m x 5m have to be designated within fields. In fact, this may have already been done for a crop-cutting survey and indeed it may be advantageous to link this part of a loss assessment survey with a crop-cutting survey if one is being run. In any case the frame of villages, cultivators and fields constructed for the crop-cutting survey might be utilized. Although it is not strictly necessary to introduce the cultivator as an intermediate sampling unit between the village and the field this is appropriate if cultivation methods differ fairly widely between cultivators within villages, and may also be more convenient administratively.

b. Threshing, cleaning, drying, transportation, processing

Villages will be the primary sampling unit and cultivators the secondary units.

c. Storage

Villages will be the primary sampling units, cultivators the secondary units and store structures the ultimate sampling units if a cultivator possesses more than one type of structure. It is possible that communal stores might exist at the village level, in which case a separate listing should be made of these and they should then be sampled separately.

Cluster sampling

If distances between villages are large it may be desirable, in order to cut travelling time and costs, to concentrate a loss assessment survey in several groups of adjacent villages. In this case a cluster sample design is appropriate. Villages within an area are divided into groups of three or four in the same area and a simple random sample of these clusters is selected. All villages within each selected cluster are then included in the sample. It is important that, as far as possible, the clusters should each contain approximately the same number of cultivators and that clusters should be as alike as possible in terms of climate, cultivation practices, etc. If the latter is not true, then villages should be stratified into reasonably homogeneous zones before the clusters are constructed. A random sample of clusters within each zone may then be selected. A major advantage of cluster sampling is that it is not necessary to have a list of cultivators for every village before the sample is selected, the listing may be restricted to those villages selected, and the sampling fraction for the secondary units, probably the cultivators, may be adjusted according to the number of units found in each cluster.

Selection of second or third-stage units is usually more straightforward. Methods of doing so are discussed below with reference to the stage of the post-harvest system at which they are appropriate.

a. Harvesting

A simple random sample of cultivators may be selected, or alternatively if cultivators within a village differ widely in respect of harvesting technique (e.g., mechanical or by hand) or size of holdings, it may be desirable to stratify by one or both of these factors. In fact it is likely that the degree of sophistication of technique is highly correlated to size of farm so that stratification by one or other of these factors will be adequate. A simple random sample of plots within fields of each selected cultivator may then be selected.

b. Threshing, cleaning, drying, transportation, processing

For all these processes the cultivator is the second stage unit and may be selected within villages in either of the two ways described above, i.e., by simple random sampling or by stratified random sampling. It will also be necessary to sample the processes in some way, making the design a three stage one. Simple random sampling will usually be adequate, e.g., selection of a random sample of produce to be threshed by the cultivator and then examined for "lost" grain; observation of a random sample of loads transported from field to threshing floor. It may be more convenient to use systematic sampling with a random starting point in situations such as these, and this may be acceptable as long as one can be sure that the periodicity of sampling does not conform with some periodicity of the characteristic being measured (e.g., there are five people carrying grain and the sampling fraction chosen is 20 per cent). However it should always be remembered that this is not a random sample, because once the first unit has been selected, remaining units do not have an equal probability of selection, and that random sampling is to be preferred whenever possible. It is desirable to sample these processes more than once in order to obtain a measure of "within cultivator" variation. If, however, resources do not permit this the design simplifies to a two-stage one.

The primary sampling unit is thus in all cases the village. Lists of villages are usually available within regions compiled by government authorities for the purpose of household surveys, crop-cutting surveys of the types mentioned above or similar surveys. These may then form a sampling frame for the selection of villages. It is also desirable to have available a measure of the size of villages within a region either in terms of number of cultivators or the number of fields/area of land under each crop under investigation or, ideally, both. There are sample designs for which it is not necessary to obtain this information until after the sample villages have been selected, but it is likely that more precise estimates of losses may ultimately be obtained if it is known beforehand. If a suitable listing of villages is not available then one has to be compiled before any loss assessment study can be carried out. However, it is unlikely that no listing is available,

although some updating may be necessary. Listings of secondary sampling units should be prepared anew within the selected villages even if some measure of size was available prior to selection unless this data had been collected very recently. This is because cultivators and particularly land under crops may alter from year to year. However, this listing will probably not be necessary if the frame was prepared for the current crop-cutting survey.

Sample design. There are several options which may be considered for the selection of sample villages.

a. Simple random sample

This is the simplest method of drawing the sample. All villages within the region are numbered and a sample of the size required is selected using random number tables. The disadvantage is that each village has an equal chance of selection regardless of its size, with the result that unless the villages are of roughly equal size, a sample of say 10 per cent of villages is unlikely to include 10 per cent of cultivators within the region. Other characteristics of importance, such as types of climate, may also not be adequately represented in the sample if they vary widely over the region.

b. Stratified random sample

If villages within a region differ widely in size (as measured by the number of cultivators or the area of land under the crop being investigated) and if prior information is available on this, then more precise estimates of loss will be obtained if the villages are divided into groups, or strata, according to their size. A simple random sample may then be selected from each stratum either using a uniform sampling fraction (i.e., a proportionate stratified sample) or a different sampling fraction within each stratum (i.e., a disproportionate stratified sample). The latter is often a more appropriate design when stratification is based on the size of units. It may also be desirable to stratify a region into zones homogeneous in respect of climate, cultivation practices, soil conditions, etc. This will often depend on the size of the region and it is possible that if the region contains widely diverse zones it may in fact not be meaningful to construct regional estimates of post-harvest losses but to present comparable data for the different zones.

c. Sampling with probability proportional to size

This is an alternative to stratification when villages differ widely in size, although ideally a pre-requisite for its use is that exact and up-to date data should be available on the number of cultivators in each. It may, however, still be useful if an approximate measure is available. Each village is given a probability of selection proportional to its size and, if the same number of cultivators are then selected from each irrespective of size then in effect each cultivator will have an equal probability of selection.

Collection of Data

a. Loss during harvesting

As already pointed out, it may be convenient to link this phase of the loss assessment survey to a crop-cutting survey if one is being run. In India, the crop-cutting work is generally done by the local revenue agency. In such a situation it is convenient to select a large number of primary sampling units and a few second-stage units, namely fields under the crop and locate a plot approximately 10 metres x 5 metres in selected fields for conducting crop-cutting experiments on cereal crops.

The crop-cutting plot is randomly located just before the harvesting by the cultivator, the crop inside the plot is harvested and the yield of the plot is weighed and recorded. After the harvested produce is removed from the plot, all grains shed or missed should be carefully picked up for estimating harvest loss.

These plots would, however, not serve the purpose of estimating the crop losses if the harvesting of the plot is not done according to the normal practice of the cultivator. In such a situation, the correct procedure for estimating the crop loss would be to locate independently plots of suitable size in the fields sampled for crop-cutting survey. After the crop has been harvested in the field by the farmer, the plots chosen for estimating the harvest loss should be carefully marked by pegs and strings and the investigator should then examine carefully and pick up all grains shed or missed. These should be collected, threshed by hand and the weight of grain noted. A sample of the grain may also be sent to a laboratory for the determination of moisture content from each plot. Similarly, a sample may be taken from the entire produce of the field, after it is threshed by the cultivator, for moisture determination. This information may be useful for determining its relationship with the harvest loss.

Some background information regarding the village selected for crop-cutting is generally collected by the agency conducting these surveys. Similarly, some information about the farmers cultivating the sampled fields is also collected. However, it cannot be presumed that the information required by the statistician conducting the crop losses survey will be available in the crop-cutting surveys. It is, therefore, recommended that background information regarding the sampled villages, cultivators and fields may be collected as per schedules 1.1, 1.2 and 1.3 given in Appendix I.

In any region selected for survey on post-harvest losses of foodgrains, it is not necessary that the entire sample of fields under the crop selected for the purpose of crop-cutting surveys is retained. If the sample is too large in the context of resources available for the crop losses survey, a sub-sample of villages, cultivators or fields may be selected. Especially in a pilot study where there is no advance information regarding variabilities at different stages of sampling, it may be necessary to select a smaller sample size (not less than 2) at different stages and modify the sample size at different stages depending on the variability in subsequent rounds for the degree of precision desired and the availability of resources. Since harvest practices in a given region would not change very fast, estimates of harvest loss obtained scientifically once may be used for several years.

While estimating losses in harvesting it may be found that the normal harvesting practices differ from region to region. In some regions harvesting may be done manually whereas in others it may be done mechanically. In some regions both practices may exist side by side. Where only one method of harvesting is in use, only one estimate of loss can be obtained. In those regions where both methods are in use, estimates may be worked out separately for each method of harvesting. The estimation procedures are described in Appendix II (1). Although in crop-cutting surveys, substratification of the cultivators is not done according to the size, it may be useful to present the results of harvest losses according to farm sizes. For this purpose, post-stratification may be done and separate estimates worked out for different size classes. Provision for recording data regarding size classes has been made in the schedule mentioned earlier.

b. Loss due to threshing or shelling

The operation of threshing or shelling is commonly done by hand in the developing countries. However, in some progressive areas mechanical threshers are used. The losses occur during threshing due to spillage, by incomplete removal of grain from stalks or by damage to grain during threshing. Incomplete stripping usually occurs in regions of high labour cost at harvest time when labour is too expensive to justify final hand-stripping. For estimating losses during threshing the following procedure may be followed.

Random samples of bundles of harvested crop from sampled fields/cultivators are chosen and threshed by the method adopted by the cultivators which could be manual or mechanical. In both cases, the quantity taken should be adequate so that the cultivator can adopt his normal threshing procedure. The threshed grain obtained by following this procedure is carefully weighed and recorded. The straw is then examined for grain which has escaped the threshing process. This could be done by hand-stripping. Both the grain samples, one

obtained by the normal threshing of the sampled bundles and the second obtained through hand-stripping of the straw, are hand-winnowed carefully to bring the two samples to the same quality standard. The moisture content is measured in both samples and weights converted to a standard moisture content. These data should be recorded in schedule 1.4. Another type of threshing loss resulting from damage to grain will be of a qualitative nature. This can be determined by taking a sample of grain from the bulk of grain and separating the whole and damaged grains. The two are weighed and the respective weights recorded. These provide estimate of qualitative loss. For obtaining the average loss for the region as a whole, the estimation procedure is described in Appendix II(2).

c. Loss during cleaning/winnowing

At this stage losses occur due to the part of the edible grain passing into the chaff. For estimating this loss, a sample of grain in a single batch is taken and the quantity of chaff and grain obtained in the operation are recorded. A sample of chaff, say 2 kg., is then taken and examined for grain content. The grain may be collected and weighed. The other data recorded are the total quantity of grain obtained by the normal procedure. Both these data are recorded in schedule 1.5. Two or more such samples may be taken depending on the volume of production of the grain on the farm. Data recorded for the entire sample of cultivators may be utilized to obtain estimate of average loss for the region as a whole by the estimation procedure described in Appendix II(3).

d. Losses in drying

As at other stages, losses in drying would be observed on a sample of farms. The procedure of drying differs according to crops. In paddy, however, it is usual practice to spread out grain for drying in yards or sometimes even on roads. The losses at this stage can arise partly due to the grain eaten by birds, rodents or carried away by wind, etc. To estimate this quantity, it is necessary to know the quantity spread out initially and its moisture content, as also the quantity of dried grain collected by the farmer after drying as well as its moisture content. It will be recalled that the reduction in weight resulting from loss of moisture will not be counted as loss. A number of procedures for sampling for moisture determination are available. However, the method for determining moisture content should be uniform in a region. The collection of data mentioned above on a sample of farms will provide the basic material for the determination of loss at this stage. The data will be recorded in schedule 1.6. For an individual cultivator the loss will be the difference between the grain spread out and the grain later collected both reduced to standard moisture content. The average loss for the region as a whole may be estimated by procedures described in the Appendix II(4).

In developing countries, the drying practices are not always scientific, losses due to attack of micro-organisms, insects, mites, etc., might occur. To estimate such losses, it will be necessary to sample such grains, sort out good and damaged grains and record the respective portions. If food standards are strictly enforced, the damaged grain will generally be rejected. In cases of mild damage and minor qualitative loss, the grain may be retained for human consumption. In either case the two parts should be weighed and the data recorded. For working out the average loss for the region as a whole, the procedure indicated in Appendix II(4) should be followed. Note that the method of estimation of these losses is parallel to that for estimating such losses in storage.

e. Losses in storage

Losses in storage are the most important from the point of view of loss reduction because on the one hand they are believed to be of a sizeable magnitude and also relatively easier to prevent by better methods of storage. The storage is at three different levels, namely at the farm level, at the trade level and at the level of public distribution agencies such as the national food authority. The methods of estimating losses naturally differ according to the level at which they are to be estimated. In this section losses at the farm level will be discussed.

For estimating the losses in the storage at the farm level, a representative sample of cultivators should be selected. As mentioned earlier, it should be possible to obtain such a sample of cultivators in countries where crop-cutting surveys for estimation of crop yields are being conducted annually. In cases where no crop-cutting surveys are being conducted, for sampling cultivators stratified multi-stage design as described in earlier sections can be adopted. It may also be useful to classify the cultivators according to the size of their farms and then sample adequate number of farmers from each size class. It is presumed that storage practices followed by different farmers depend on the size of their farm produce and the method of disposal. Depending upon the period and mode of storage, the data on losses are collected at frequent intervals. Quite an amount of data are required to estimate losses at this stage as well as to study factors which cause these losses.

First of all, we may be interested in estimating losses according to the mode of storage, namely 'traditional', 'improved' or 'modern' meaning thereby storage in steel or concrete structures or silos. At the farm level, because of the small size of holdings in the developing countries, the modes of storage are likely to be 'traditional' or 'improved' types. The degree of adoption of the alternatives will be dependent on the size of holding which may be related to the level of production which in turn would depend on the area cultivated.

Cultivators, particularly in developing countries do not maintain any records of production, disposal and storage losses. The data on storage losses may, therefore, have to be collected by making frequent visits. The periodicity of the visit will depend upon the method of storage and mode of disposal. In cases where the farmer stores particular kinds of produce for marketing at a particular time, the visit in that particular month will yield more reliable information. However, in cases where the disposal is very frequent, then it will be desirable to increase the frequency of visits. In the absence of reliable records, the only way of getting accurate data is to make frequent inquiries to win over the memory bias of the cultivators. It might also be useful to collect similar data for the previous year. However, although this would be useful in order to judge the order of magnitude of losses for comparability, studies have shown that responses to such questions are difficult to obtain and of doubtful reliability (Adams and Harmans, 1977). Of course the interpretation of loss in this case would be generally quantitative, i.e., the grain just rejected. However, an effort may be made to collect information regarding the qualitative damage also, i.e., the quantity of grain damaged in quality resulting in disposal at a lower price. Such data collected periodically would provide information regarding the storage capacity required by the cultivators, their usual modes of storage and the possibilities of improvement and the losses in different modes of storage, the quantities stored and the period of storage. A case study on these lines is reported in Appendix III. The procedure cannot be described as rigorous but some compromise on scientific requirements needs to be made to make its adoption easy. The schedules required for collection of such data are given in schedule 1.7. The total loss of any particular grain stored by the farmer will be the aggregate of losses reported in the successive visits.

It is desirable, if possible, to supplement the questionnaire approach with quantitative and qualitative tests. The cultivator may be asked to draw the amount of grain he needs for consumption during the following week and sort it himself into that which he would use, discard, or discard as fit only for animal feed. This would give a direct measure of the state of the grain at that point and a series of such observations over the season would give a profile of its deterioration. The study would become more scientific if the samples of grain were then analysed in the laboratory for moisture content as well as insect infestation and other damage because of physical and chemical changes. Such analysis would enable the investigator to obtain an objective estimate of damage during storage. If cooperation from cultivators is satisfactory, such studies may be undertaken but considering the effort involved, it may be necessary to confine them to a sub-sample of cultivators. It would also then be necessary to recompense the cultivator with an amount of clean grain equivalent to the total amount of grain sampled and taken away for analysis.

f. Losses in transportation

Losses in transport at the farm level may occur in (i) transport from field to the threshing floor; (ii) from threshing floor to the storage; and (iii) from storage to the market. Different modes of transport are used at different stages, for example, the produce may be carried manually or by bullock-carts from field to the threshing floor. From threshing floor to the storage it may be transported by bullock-cart, tractor-trailer, etc. To the market, grain may be sent either by bullock-cart or tractor-trailer or truck. Normally the loss is estimated as difference of weights between the quantity loaded and the quantity unloaded. However, where the transport operation is likely to take considerable time, say a few days, it will be necessary to take samples at the loading stage and again at the unloading stage and examine them in the laboratory to study change in the moisture content as well as qualitative damage due to different causes during transit.

The information may be recorded in schedule 1.8 and the estimates of damage for the region may be worked out by estimation procedure described in Appendix II(6).

g. Losses in processing

Processing at the farm level is not common for most of the crops. However, in the case of paddy hand-pounding, dehusking/debranning at the farm level is not uncommon in developing countries. Here, the data such as the initial quantity of paddy used in a batch and the different products and by-products, viz., headgrain, brokens, brown-grains and bran obtained will have to be recorded. The samples of grain may also be examined for moisture content and any qualitative damage that may have occurred during the process. The data may be recorded in schedule 1.9. Considering that much of the grain processing is done in mills of various sizes even in developing countries, it would be more important to study losses in processing at the mill stage. This will be discussed in the section on estimating losses at intermediary level. The estimate of average loss for the region may be worked out by the procedure given in Appendix II(7).

h. Losses in packaging and handling

It may be of some interest to study the losses occuring due to defects in the methods of packaging and handling of grains. The methods of packaging are not likely to be very diverse in developing countries. The most common modes may be packing in gunny bags and handling in bulk. The data for the different types of packaging could be collected for a sample of cultivators to study the efficiency of the alternative methods of packaging. In the context of the entire post-harvest system the losses at this stage may not be important enough to deserve priority. However, an investigation could be undertaken and data, as indicated in schedule 1.10 collected for the sample of produce. Estimation procedure for assessment of such losses for the region is described in Appendix II(7).

Losses at Intermediary Level

The wholesale and retail traders, marketing cooperatives, mills and Governmental distribution agencies fall in this category. Since the Government agencies have special facilities and differ in the scale and mode of operation from private intermediaries, they will be considered separately. At the intermediary level also the losses are to be estimated at a number of stages, namely, transport, storage, processing, packaging and distribution. For studying losses in the operations of transport, storage and handling by market functionaries, a sample of such functionaries will have to be selected. This may be done by stratified two-stage random sampling. Initially the markets in the region dealing in the commodity may be listed and divided into size classes - small, medium and large, the size being determined by annual turnover. From each stratum a number of markets may be selected by simple random sampling. If some markets are very important they may be included in the sample purposely. In each of the markets the market functionaries of each kind such as wholesalers, retailers and cooperatives may be listed separately and at least two of these may be selected in each class by simple random sampling. Information regarding selected markets may be recorded in schedule 2.1.

Similarly a random sample of mills/processing factories may be chosen by listing such units in the region, classifying them according to size and selecting at least two in each size class by simple random sampling.

For the sample of wholesalers, retailers and marketing cooperative societies information may be collected initially regarding points of purchase (whether farm, market or government depots), procedure of weighing, mode of storage and storage capacity, sale outlet, mode of transport, etc. Subsequently information regarding transactions, i.e., volume of purchase and disposals and consequent changes in stock, losses in transport, storage and handling and due to other causes may be collected weekly or fortnightly and recorded in schedule 2.2. Samples may also be taken periodically from stored grain by means of sampling probes from different parts of storage and examined in the laboratory for damage due to insects, mites, micro-organisms, moisture, etc. These data will also be recorded in the proforma.

For the sample of mills/processing units, information will be similarly collected periodically and recorded in schedule 2.3.

It may be noted that in the plan of field work described above, provision has been made for recording data on losses during transportation, storage, processing, packaging and distribution.

Estimates of losses at various stages due to different causes for the region as a whole may be worked out by estimation procedure given in Appendix II(8).

Losses at Government Warehouses

Government warehouses and public distribution agencies are expected to maintain detailed records regarding quantities of grains received from different sources, dispatched to different destinations, stored in various warehouses in their charge and so on. The operations being generally large-scale, food technologists - chemists, analysts, etc., - may also be employed by these agencies for recording data on condition of the grain stored. These specialists are expected to take samples of grain periodically and record information regarding moisture content, insect and pest infestation and other causes of grain damage. Very comprehensive data on magnitude of losses and their causes should therefore be readily available from such agencies. However, if the number of units belonging to the organization (warehouse) is large, sampling may become necessary to make collection of data manageable. This can be done as follows:

All the units/warehouses owned by the public distribution agencies may be grouped according to the size, into three categories - small, medium and large. At least two units may be selected randomly in each category. Then the following data may be recorded for these sampling units.

Information regarding storage system, capacity, mode of storing, that is whether in bags or bulk, weight of grain stored, and control measures adopted for protection of the grain may be recorded in schedule 3. Subsequently, observations on receipt and disposal, mode of transport, source of purchase, and destination of grain dispatched, may be recorded periodically - fortnightly or monthly, on the basis of records maintained by the unit. Data on moisture content, infestation by insects and micro-organism and other causes of damage, may also be recorded. The losses occurring at the stages of transportation, storage, packaging and distribution may also be recorded in schedule 3.

Estimates of losses of grain at various stages and due to different causes may be worked out for warehouses in various categories by procedure given in Appendix II(9).

Estimation

As has been discussed above, there are many different designs which could be adopted for a loss assessment survey, too many for which to present details of the calculation of loss estimates and their variances in this manual. One of the most common designs will be

the two-stage stratified sample, that is one in which villages are stratified (by size or similar factor) and a random sample is drawn (without replacement) from each, and within each village the second stage units (the cultivators) are also stratified (by size of holding/ sophistication of technique) and a random sample chosen from each. The detailed calculations for this design are presented in Appendix II.

Details of calculations for other designs may be found in standard text books such as Cochran (1977), Murthy (1967), Yates (1960). The use of replicated samples should also be mentioned here. By taking a number of independent sub-samples an estimate of the variance of a measurement may be obtained very simply no matter how complex the design may be (see Mahalanobis, 1946). This technique may also be used to obtain estimates of some non-sampling errors.

Non-Sampling Error

Possible sources: close observation of cultivator whilst harvesting, threshing, etc., may lead him to take more than usual care; cultivator may over-estimate storage losses if he expects help in improving them; enumerators may use slightly different measurement techniques.

Measurement of non-sampling errors: use of replicated samples.

Ways of eliminating such errors: careful training of enumerators; physical measurement of grain storage losses to back up questionnaire approach.

4. SUMMARY AND RECOMMENDATIONS

With the rapidly growing population, it has become extremely important to save and preserve every ounce of food-grain produced. Reports have been received that a considerable amount of foodgrain is lost at different stages of its handling and storage. Such losses are reported to be more in developing countries which are still following by and large traditional technologies of crop production and thus in developing countries it is not only the problem of producing more foodgrain but it is equally important to save whatever is produced. Knowledge with regard to the magnitude of losses at various stages of handling and storage is considered to be very important to introduce necessary improvements for saving and preserving grain for human consumption. Lack of adequate data and appropriate sampling and measurement techniques are recognized as prime deterrents in obtaining satisfactory estimation of losses. Not much systematic work has been done on developing appropriate statistical methodology for estimation of post-harvest crop losses on a large scale. Some literature is, no doubt, available on the subject but it mostly relates to the work done in the developed countries. In developing countries modern statistical methodology has hardly been used for the estimation of post-harvest foodgrain losses. India is one of the few among developing countries where efforts have been made to estimate post-harvest losses by adopting sample survey techniques.

The Indian Agricultural Statistics Research Institute, New Delhi, has been engaged in evolving statistical methodologies as applied to agricultural research and development. It has evolved modern sampling techniques for collection of agricultural data. The present manual prepared by the Institute is mainly dependent upon the experience that it has gained during the course of conduct of various agricultural sample surveys. The methods recommended in this manual for the collection and assessment of data on post-harvest foodgrain losses are not foolproof. They will need further study and modification depending upon the conditions prevailing in the different countries. In this context, the following recommendations are made:

a. Before making an inquiry into post-harvest foodgrain losses, appropriate terminologies, concepts and definitions should be evolved for uniform adoption within a region or country.

b. The scope of the inquiry may be mainly confined to the quantitative and qualitative losses.

c. To economize the collection of data on foodgrain losses, it will be desirable to link such surveys with some other agricultural surveys such as crop-cutting surveys for the estimation of total food production, food consumption surveys, etc.

d. Sampling design and the size of the samples and its distribution at various stages should be determined on the basis of a well-designed pilot sample survey.

e. The mode of inquiry (mail, interview, objective measurement, etc.) will depend upon the conditions obtaining in the countries and the technologies being used there. This should also be determined on the basis of pilot investigations.

f. Although the foodgrain losses occur at a number of points of post-harvest operations, all may not be equally important. The position may vary from country to country. The points and stages of serious losses should be determined in advance in consultation with the local experts. Priority should be given to determining the losses at these points.

g. Since post-harvest technology may not change very fast, particularly in developing countries, results of an inquiry conducted once may be applicable for several years.

h. The estimation of post-harvest losses of foodgrains will involve multi-disciplinary approach and therefore in planning such inquiry, specialists such as statisticians, plant pathologists, entomologists, agricultural engineers and other technologists should be associated.

i. The other types of losses such as economic, goodwill and seed may also be linked with these sample surveys, if desired.

j. Further research using the data collected on effects of insects, mites, micro-organisms, moisture content, temperature, relative humidity, etc., especially in storage, should be done to evolve statistical techniques with multi-variate approach which could be used for predicting the losses during storage, etc., where loss depends on various factors including time.

Appendix I

Sample survey to estimate post-harvest foodgrain losses

Schedule 1: Losses at farm level
1.1: Village schedule

a) Identification

		Code			Code
(i)	Country		(ii)	State/Province	
(iii)	District		(iv)	Year	
(v)	Name of village				

b) Area (in hectares) under crops in the previous year (19)

	village-1	village-2	village-3
Geographical area			
Cultivated area			
Irrigated area			
Area under			
i. Rice			
ii. Wheat			
iii. Maize			
iv. Sorghum			
v. Millets			
vi. All cereals			
vii. All crops			

c) Distribution of holdings according to size (in hectares)

	Village-1	Village-2	Village-3
i. less than 2.5			
ii. 2.5 - 5.0			
iii. 5.0 - 10.0			
iv. 10.00 - 20.0			
v. 20.0 and above			

d) Communication

	Village-1	Village-2	Village-3
Distance (km) from nearest:			
i. Motorable road			
ii. Railway station			
iii. Grain market			

e) Storage facilities

	Village-1	Village-2	Village-3
Number available/in use:			
i. Public warehouses			
ii. Modern (metal/concrete) storage structures			
iii. Intermediate (improved storages)			
iv. Traditional storages			

f. Number of mechanical equipment in use

	Village-1	Village-2	Village-3
i. Tractors			
ii. Trailers			
iii. Pumps (energised)			
iv. Trucks			
v. Harvesters			
vi. Threshers			
vii. Others (specify)			

Date .....

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Signature of the Investigator

Sample survey to estimate post-harvest foodgrain losses

Schedule 1.2: Operational details of holdings

a) Identification

		Code				Code
i.	Country			ii.	State/Province	
iii.	District			iv.	Year	
v.	Name of village			vi	Name of cultivator	
vii.	Size class					

b) Assets of holding

		Code
i.	Area of holding	
ii.	No. of fields	
iii.	Area cultivated	
iv.	Source/s of irrigation	
v.	Farm structures (sheds, barns, etc.)	
vi.	Storage facilities	
vii.	Farm machinery (number)	
	Tractors	
	Trailers	
	Pumps (energised)	
	Trucks	
	Harvesters	
	Threshers	
	Others (specify)	

c) Methods of farm operations cropwise

	Operation	Method of operation	Equipment used	Code
i.	Ploughing/tillage			
ii.	Harvesting			
iii.	Threshing			
iv.	Transport			
v.	Others (specify)			

d) Crop sown (specify)

Crop	S.No. of field	Crop area (hect)	Harvesting		Threshing	
			Expected date	Method Manual/mech.	Expected date	Method Manual/mech.

e) Disposal of produce for the last year (grainwise)

	Grain	Code	Grain	Code	Grain	Code	Grain	Code
i. Quantity produced (quintals)								
ii. Quantity sold (quintals)								
iii.a. Market where sold								
b. Distance of market (km)								
iv. Mode of transport to market								
v. Mode of packing for market								
vi. Grain losses during transport to market								
vii. Grain payments in kind (wage, gift, etc.)								
viii. Quantity stored (quintals)								
ix. Period of storage (months)								
x.a. Losses in storage (kg)								
b. Causes of losses								

Date ---------

Signature of the Investigator

Sample survey to estimate post-harvest foodgrain losses

Schedule 1.3: Loss at harvest in selected field

a) Identification

		Code				Code
i.	Country			ii.	State/Province	
iii.	District			iv.	Year	
v.	Crop and season			vi.	Name of village	
vii.	Name of cultivator			viii.	Size class	
ix.	S.No. of field			x.	Area under the crop (Hect.)	

b) Particulars of the field

		Code
i.	Topography	
ii.	Soil type	
iii.	Variety	
iv.	Seed rate	
v.	Whether irrigated	
vi.	Source of irrigation (if irrigated)	
vii.	Date of sowing	
viii.	Date of harvesting	
ix.	Whether harvested manually or mechanically	

c) Location of plot/s

		Length (metres)	Breadth (metres)
i.	Dimension of field		
ii.	Distance of the nearest corner from the reference point. (Plot 1) (Plot 2)		

d) Results of mechanical harvesting

		Actual	Per hectare	Moisture percent
i.	Yield of grain of whole field			
ii.	Picked grain yield			
	Plot 1			
	Plot 2			

e) Results of manual harvesting

	Yield of grain (Kg. & grm.)		Moisture percent
	Crop cutting	Picked	
Plot 1			
Plot 2			

Date .....

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Signature of Investigator

Sample survey to estimate post-harvest foodgrain losses

Schedule 1.4: Loss due to threshing/shelling

a) Identification

		Code			Code
i.	Country		ii.	State/Province	
iii.	District		iv.	Year	
v.	Crop and season		vi.	Name of village	
vii.	Name of cultivator		viii.	Size class	

b) Particulars of threshing/shelling

		Code
i.	No. of bundles sampled	
ii.	Type of threshing floor	
iii.	Method of threshing (beating on the board in the tubs, trampling by driven animals, tractor wheels, etc.)	
iv.	Weight of grain after threshing	
v.	Weight of grain hand-stripped from the straw	
vi.	Moisture content	
	Moisture content of grains (after threshing)	
	1. obtained from grain through normal threshing	
	2. obtained from the grain through hand-stripping	
	a. weight (1) converted to a standard moisture content	
	b. weight (2) converted to a standard moisture content	
vii.	Weight of damaged grain from a sample* of threshed grain	

* sample of two kg may be drawn from grains after threshing.

Sample survey to estimate post-harvest foodgrain losses

Schedule 1.5: Losses due to cleaning/winnowing

a) Identification

		Code			Code
i.	Country		ii.	State/Province	
iii.	District		iv.	Year	
v.	Crop and season		vi.	Name of village	
vii.	Name of cultivator		viii.	Size class	

b) Losses due to cleaning

		Code
i.	Weight of sampled grain before cleaning (in kg)	
ii.	Method of cleaning/ winnowing:	
iii.	Weight of grain after cleaning (in kg)	
iv.	Weight of grain from left-over material	

Date .....

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Signature of the Investigator

Sample survey to estimate post-harvest foodgrain losses

Schedule 1.6: Loss due to driage

a) Identification

	Code		Code
i. Country		ii. State/Province	
iii. District		iv. Year	
v. Crop and season		vi. Name of village	
vii. Name of cultivator		viii. Size class	

b) Loss due to driage

	Code
i. Weight of the sampled grain before driage (in kg)	
ii. Moisture content before driage	
iii. Method of driage (mechanical/manual) Specify the method in detail	
iv. Place where the driage was done (courtyard, brick floor, road, tarpaulin, etc.)	
v. Is there any loss due to birds, rodents, animals? (Yes/No)	
v. If yes, cause of loss birds rodents animals other (specify)	
vii. No. of days of driage	
viii. Moisture content after driage	
ix. Weight of grain after driage	
x. Weight converted to a standard moisture content before driage after driage difference	

Date . . . . . .

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Signature of the Investigator

Sample survey to estimate post-harvest foodgrain losses

Schedule 1.7: Losses due to storage

a) Identification

		Code				Code
i.	Country			ii.	State/Province	
iii.	District			iv.	Year	
v.	Crop and season			vi.	Name of village	
vii.	Name of cultivator			viii.	Size class	

b) Losses due to storage

		Code
i.	System and capacity of the storage	
	a. system (traditional/intermediate/modern)	
	b. capacity	
ii.	Mode of storage (bags/bulk or loose)	
iii.	Duration of storage	
iv.	Weight of the grain stored	
	a. at the beginning	
	b. at the end	
	c. difference	
v.	Interval of the periodical observations (fortnightly, monthly, etc.)	
vi.	Periodical observations	
	a. weight of grain in storage	
	b. weight of grain taken out	
	c. weight of the remaining grain	
	d. moisture content of the grain	
	e. relative humidity	
	f. temperature	
	g. loss due to rodents, if any	
	h. observation on 1000 grains taken by sampling probes	
	i. weight of 1000 grains	
	ii. no. & weight of damaged grain	
	iii. no. & weight of damaged grain by mites	
	iv. no. & weight of damaged grain by micro-organisms	
	i. no. and weight of excreta	
	j. no. & weight of dead bodies of insects, etc.	
	k. content of acidity	
	l. content of toxicity	
	m. control measures adopted (if any) details	

N.B.: (1) Repeat information vide item (vi) periodically.

(2) Information may be recorded after observing the laboratory where it is not possible to record at the storage place.

(3) This schedule could usefully be split into 3 parts. The first could deal with data on storage practices of the cultivator (questions (i) - (v) of section (b)), the second with the fortnightly observations "on the farm" (question (vi) (a) - (g) and (m)) and the third with the analysis carried out in the laboratory (question (vi) (h) - (l)). Accurate analysis of the latter set of questions will require a trained technician and should invariably be carried out in the laboratory rather than on the farm. The amount of grain to be analysed in this way could more usefully be specified in terms of weight or volume rather than number of grains.

The set of questions asked every fortnight could be simplified: there seems no reason to ask the weight of grain in store and the weight of the remaining grain on every visit. It should be adequate to record the amount of grain removed from store since the last visit and to record the proportion of useable grain in a sample drawn and sorted by the cultivator at the time of the visit. This schedule should also cover the possibility that a cultivator may possess more than one type of store and that he may be storing more than one type of grain. Observations of different store types and grain types should be separated.

Date.....

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Signature of the investigator

Sample survey to estimate post-harvest foodgrain losses

Schedule 1.8: Loss due to transport

a) Identification

		Code				Code
i.	Country			ii.	State/Province	
iii.	District			iv.	Year	
v.	Crop and season			vi.	Name of village	
vii.	Name of cultivator			viii.	Size class	

b) Losses due to transport

		Code
i.	Weight of grain sold	Wheat/Rice/Sorghum/Maize/Millet
ii.	Mode of transport used for carrying the produce (bullock-cart with wooden wheels, tractor trailers, bullock-cart with pneumatic wheels, trucks, back of animal (horse, camel, etc.) head of person, etc.)	
	a. from field to threshing floor	
	b. from threshing floor to drying place	
	c. from threshing floor to cleaning place	
	d. from farm to storage (in case of manual operations of harvesting, threshing, drying, etc.)	
	e. from farm to storage (in case of mechanical operations)	
	f. Others, if any (specify)	

b) Losses due to transport (cont.d)

		Code
	Before/After/Difference	
iii. Weight of sampled produce transported		
a. from field to threshing floor (bundles)		
b. from threshing floor to drying place (grain)		
c. from threshing floor to cleaning place (grain)		
d. from cleaning place to storage (grain)		
e. from farm to storage (grain) (in case of mechanical operations)		
f. Others, if any (specify)		
iv. Moisture content of transported grains (in the laboratory)	Before/After/Difference	
a. from threshing floor to drying floor		
b. from threshing floor to cleaning place		
c. from cleaning place to storage		
d. from farm to storage (in case of echanical operations)		
e. Others, if any (specify)		
v. Total loss due to tranport at farm level		

N.B.: Information for different crops collected vide item Nos. (ii) to (v) separately

Date.....

.....

Signature of the Investigator

Sample Survey to estimate post-harvest foodgrain losses

Schedule 1.9: Losses due to processing

a) Identification

		Code				Code
i.	Country			ii.	State/Province	
iii.	District			iv.	Year	
v.	Crop and season			vi.	Name of village	
vii.	Name of cultivator			viii.	Size class	

b) Losses due to processing (cropwise)

		Code
i.	Weight of the sampled grain (in case of wheat, sorghum, maize, millet, etc.)	
	before	
	after	
	difference	
ii.	Weight of the sampled paddy	
iii.	Moisture content	
iv.	Mode of processing (manual/mechanical)	
v.	Weight of products	
	head grain	
	broken grain	
	chalky grain	
	brown grain	
	other specify	
vi.	Loss due to processing	

Date .....

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Signature of Investigator

Sample survey to estimate post-harvest foodgrain losses

Schedule 1.10: Losses due to packaging/handling

a) Identification

		Code			Code
i.	Country		ii.	State/Province	
iii.	District		iv.	Year	
v.	Crop and season		vi.	Name of village	
vii.	Name of cultivator		viii.	Size class	

b. Losses due to packaging and handling

		Code
i. Mode of packaging (gunny bags/ plastic bags, loose, etc.)	Rice/Wheat/Sorghum/Maize/Millet	
ii. Weight of grain handled		
iii. Loss of grains due to packaging and handling		

Date .....

.....

Signature of Investigator

Sample survey to estimate post-harvest foodgrain losses

Schedule 2: Losses at intermediaries level

Schedule 2.1: Particulars of the markets

a. Identification

		Code			Code
i.	Country		ii.	State/Province	
iii.	District		iv.	Year	
v.	Name of market and its address		vi.	Size of market	

b. General Information

		Code
i.	Whether connected by rail/ motorable road/water way & others	
ii.	Quantity of grain handled	Rice/Wheat/Sorghum/Maize/Millet
iii.	Total intake/ handling of grains separately of each grain	

Date .....

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Signature of Investigator

Sample survey to estimate post-harvest foodgrain losses

Schedule 2.2: Particulars of the traders

a. Identification

	Code		Code
i. Country		ii. State/Province	
iii. District		iv. Year	
v. Name of market		vi. Size of market	
vii. Name and address of the trader		viii. Whether wholesaler/ retailer	

b. Business details

		Code
i. Annual turnover in weight (for all the crops)	Rice/Wheat/Sorghum/Maize/Millet	
ii. Quantity procured from different sources		
(i) Producer		
(ii) Govt. warehouse		
(iii) Market		
iii. Annual turnover		
c. Transport		
iv. Mode of transport		
v. Loss during transport		

d. Storage

		Code
vi. Mode of storage	Rice/Wheat/Sorghum/Maize/Millet	
vii. Quantity stored		
viii. Loss due to rodents		
ix. Loss due to dampness		

d. Storage (cont.d)

		Code
x. Other observations at storage with respect to sample taken by sampling probe (1000 grain) a. weight b. moisture content c. relative humidity d. no. and weight of damaged grain by insects e. no. & weight of damaged grain by mites f. no. & weight of damaged grain by micro-organims g. no. & weight of excreta h. no. & weight of dead bodies of insects etc. i. content of fat j. content of acidity k. content of toxicity	Rice/Wheat/Sorghum/Maize/Millet	
xi. Control measure taken, if any (in detail)		
xii. Total loss in storage		
e. Processing Loss due to processing if done by the trader (enquiry method)		
f. Packaging and handling i. Mode of packaging gunny bags plastic bags loose other ii. Loss due to packaging and handling		

N.B.: Such information vide item (x) should be collected periodically.

		Code
g. Distribution	Rice/Wheat/Sorghum/Maize/Millet	
i. Mode of distribution in bags loose others		
ii. Loss due to damage to container		
iii. Loss due to moisture content		
iv. Loss due to pilferage		
v. Loss due to handling		
vi. Loss due to weighment		
vii. Loss due to rain		
viii. Loss due to others (specify details, etc.)		
h. Total loss due to distribution		
i. Information regarding transaction (periodical position at each fortnight)		
i. Interval (week, fortnight, month)		
ii. Stock at the beginning (of the fortnight) in kg		
iii. Purchase(in kg)		
iv. Sale (in kg)		
v. Stock at the end (of the fortnight) in kg		
vi. Loss (in kg)		
j. Total loss (transportation, storage, packaging and handling, distribution, etc.)		

Date .....

.....

Signature of the Investigator

Sample survey to estimate the post-harvest foodgrain losses

Schedule 2.3: Losses at mills

a. Identification

		Code			Code
i.	Country		ii.	State/Province	
iii.	District		iv.	Year	
v.	Name and address of mill		vi.	Size class	

b. Particulars of selected mill

		Code
i.	Name of grain handled	
ii.	Annual turnover	
iii.	Points of purchase Farm Market Govt. depot	
iv.	Procedure of weighment (specify details)	
v.	Sale outlet	

c. Transportation

		Code
i.	Loss during transport	
	a. due to spillage	
	b. due to pilferage	
	c. due to handling	
	d. due to moisture content	
	e. due to relative humidity	
	f. due to rain	
	g. other (specify)	
ii.	Total loss due to transportation	

d. Storage

		Code
i. System of storage (weight of grain stored) traditional intermediate modern total		
ii. Capacity of storage traditional intermediate modern total		
iii. Weight of grain kept in bags bulk loose total		
iv. Duration of storage system (in days/ months) weight of grain stored (in kg)		
v. Loss due to rodents		
vi. Loss due to dampness		
vii. Other observations at storage with respect to sample taken by sampling probe (1000 grains) a. interval of periodical observations (weekly, fortnightly, monthly, etc.) b. weight c. moisture content d. relative humidity e. number and weight of damaged grain by insects f. number and weight of damaged grain by mites g. number and weight of damaged grain by micro-organisms h. number and weight of excreta i. number and weight of dead bodies j. content of fat k. content of acidity l. content of toxicity		
viii. Control measures taken, if any (in detail)		
ix. Total loss due to storage		

N.B. Such information should be collected periodically

e. Processing

	Code
i. Method of processing	
ii. Total weight of product before processing	
iii. Total weight of grain after processing	
iv. Loss due to processing	
v. Other observations regarding rice processing	
a. moisture content	
b. weight of head grain	
c. weight of broken grain	
d. weight of brown grain	
e. weight of chalky grain	
f. other (specify)	

f. Packaging and handling

	Code
i. Mode of packaging	
gunny bags	
plastic bags	
loose	
other	
ii. Loss due to packaging & handling	

g. Distribution

	Code
i. Mode of distribution	
in bags	
loose form	
others	
ii. Loss due to	
a. damage to container	
b. moisture content	
c. pilferage	
d. handling	
e. weighment	
f. rain	
g. others (specify details etc.)	
iii. Total loss due to distribution	

h. Information regarding transaction
(periodical position at each fortnight)

		Code
i. Interval (week, fortnight, month)		
ii. Stock at the beginning of the fortnight (during the fortnight) (in kg)		
iii. Purchase (in kg)		
iv. (During the fortnight) Sale (in kg)		
v. Stock at the end (of the fortnight in kg)		
vi. Loss (in kg), if any.		
Total loss (transportation, storage, packaging, handling and distribution, etc.)		

Date .....

.....

Signature of the Investigator

Sample survey to estimate post-harvest foodgrain losses

Schedule 3: Losses at warehouses

a. Identification

		Code			Code
i.	Country		ii.	State/Province	
iii.	District		iv.	Year	
v.	Name and address of warehouse		vi.	Size class	

b. Particulars of selected warehouse

		Code
i.	Annual turnover	Rice/Wheat/Sorghum/Maize/Millet
ii.	Points from where the grain is taken Farm Market Govt. agencies	
iii.	Sale outlet	

Note: Turnover = Total weight of grain handled by the warehouse

c. Transportation

		Code
		Rice/Wheat/Sorghum/Maize/Millet
i.	Mode of transport	
ii.	Weight of grain transported to warehouse	
iii.	Weight of grain received at warehouse	
iv.	Loss during transport	
	a. due to spillage	
	b. due to pilferage	
	c. due to handling	
	d. due to moisture content	
	e. due to relative humidity	
	f. due to rain	
	g. due to other cause (specify)	
v.	Total loss due to transportation	

d. Storage

		Code
i. Types of storages (specify each of those)	Rice/Wheat/Sorghum/Maize/Millet	
ii. Capacity of storage		
iii. Weight of grain stored		
iv. Weight of grain stored in: bags bulk loose Total		
v. Duration of storage (in days/ months, etc.)		
vi. Loss due to rodents		
vii. Loss due to dampness		
viii. Other observations at storage with respect to sample taken by sampling probe (1000 grains)		
a. interval		
b. weight		
c. moisture content		
d. relative humidity		
e. no. and wt of damaged grain by insects		
f. no. and wt of damaged grain by mites		
g. no. and wt of damaged micro-organisms		
h. no. and weight of excreta		
i. no. & weight of dead bodies of insects, etc.		
j. content of fat		
k. content of acidity		
l. content of toxicity		
ix. Control measures taken, if any, (in detail)		
x. Total loss due to storage		

N.B.: Such information should be collected periodically.

e. Processing

		Code
	Rice/Wheat/Sorghum/Maize/Millet	
Loss due to processing, if the processing has been done at warehouse		
f. Packaging and handling		
i. Mode of packaging: gunny bags plastic bags loose others		
ii. Loss due to packaging & handling		
g. Distribution		
i. Mode of distribution in bags loose form others		
ii. Loss due to damage to container		
iii. Loss due to moisture content		
iv. Loss due to pilferage		
v. Loss due to handling		
vi. Loss due to weighment		
vii. Loss due to rain		
viii. Loss due to others (specify details, etc.)		
ix. Total loss due to distribution		
h. Information regarding transaction (periodical position at each fortnight)		
i. Interval(week, fortnight,month)		
ii. Stock at beginning of the fortnight (in kg)		
iii. Grain received (in kg) during fortnight		
iv. Grain despatched (in kg) during fortnight		
v. Stock at the end of the fortnight(kg)		
vi. Loss (in kg), if any		
vii. Total loss: (transportation, storage, packaging, handling and distribution etc.)		

Date .....

.....
Signature of Investigator

APPENDIX II

Sample survey to estimate post-harvest foodgrain losses

1. Estimation of losses in harvesting

The design assumed is a stratified two-stage random sampling design with the village as the primary sampling unit and the cultivator as the second-stage unit. Fields selected for crop cutting may constitute the sample, or a subsample of fields may be selected in case of cultivators having more than two fields under the crop. As mentioned in Chapter 3, page 9 plots of 10 metres x 5 metres will be selected for collecting data on losses in harvesting. For each sample cultivator, an estimate of production per hectare and loss per hectare will be worked out on the basis of data on sample fields and plots belonging to the cultivator.

If p_{ij} is the production per hectare of the j^{th} cultivator of the ith village, a_{ij} the area under the crop in the holdings, the estimate of production per hectare for the stratum will be given by

$$\hat{\bar{P}} = \frac{\sum_{i=1}^{n} A_i \cdot \frac{\sum_{j=1}^{m} a_{ij} \; p_{ij}}{\sum_{j=1}^{m} a_{ij}}}{\sum_{i=1}^{n} A_i}$$

where m is the number of cultivators selected in a village, n is the number of villages selected in a stratum and A_i is the area under the crop in the i^{th} village.

If l_{ij} is the loss per hectare of the j^{th} holding of the i^{th} village the estimate of loss per hectare $\hat{\bar{L}}$ can be obtained by replacing p_{ij} by l_{ij} in the above formula.

The percentage loss in harvesting for the stratum will be given by

$$\hat{\bar{L}}_{\%} = \frac{\hat{\bar{L}}}{\hat{\bar{P}}} \times 100$$

Estimate of variance of $\hat{\bar{L}}_{\%}$ will be given by

$$\hat{V}(\hat{\bar{L}}_{\%}) = \left\{\frac{\hat{\bar{L}}}{\hat{\bar{P}}}\right\}^2 \cdot \left\{\frac{\hat{V}(\hat{\bar{L}})}{(\hat{\bar{L}})^2} + \frac{\hat{V}(\hat{\bar{P}})}{(\hat{\bar{P}})^2}\right\}$$

ignoring the covariance term.

The estimates of variances of $\hat{\bar{L}}$ and $\hat{\bar{P}}$ are easily obtained from the equation

$$\hat{V}(\hat{\bar{Y}}) = \frac{1}{n\bar{A}^2} \times \frac{\sum_{i=1}^{n} A_i^2 (\bar{Y}_i - \hat{\bar{Y}})^2}{n-1}$$

where Y is the variable (loss or production) and $\bar{Y}_i$ stands for the estimate of average Y for the i^{th} village. The finite sampling corrections are ignored for simplification and also because the sampling fractions are expected to be small.

The estimate of average over strata for the region will be obtained as a weighted average of stratum-wise estimates, the estimates of production in the respective strata serving as weights. The variance of the weighted average will be calculated from stratum-wise estimates of variance.

If holdings in a village are sub-stratified according to size or method of harvesting (manual/mechanical) the estimates of each such class may be worked out for the region as a whole initially to provide comparison between classes. The average over the classes can be worked out later as a weighted average, estimates of production in respective classes serving as weights.

References:

1. "Sampling theory of surveys with applications" by P.V. Sukhatme and B.V. Sukhatme, 1977

2. "Sampling techniques" by W.G. Cochran, 1963

2. Estimation of losses in threshing/shelling

As mentioned in Chapter 3, page 10 data on grain loss in threshing/shelling will be collected for the sample cultivator from a sample of his produce. Data on loss due to spillage and incomplete removal of grain represent quantitative losses, whereas loss due to damaged grain will be a qualitative loss. The percentage loss due to spillage and incomplete removal of grain might be calculated separately, the latter on the basis of weights converted to standard moisture content. Similarly, percentage loss of qualitative nature, viz., due to damaged grain may also be estimated for the cultivator. If x_{ij} is the percentage loss of any kind for the j^{th} cultivator of the i^{th} village, the estimate of average for the stratum will be given by

$$\hat{\bar{x}} = \frac{\sum_{i=1}^{n} P_i \left(\sum_{i=1}^{m} p_{ij} x_{ij} / \left(\sum_{i=1}^{m} p_{ij} \right) \right)}{\sum_{i=1}^{n} P_i}$$

where p_{ij} is the production of grain in the j^{th} holding of the i^{th} village, P_i is the estimated production of the grain in the ith village, the sample consisting of m cultivators selected in each of n sample villages. Estimated variance of $\hat{\bar{x}}$ will be given by

$$\hat{V}(\hat{\bar{x}}) = \frac{1}{n \bar{P}^2} \times \frac{\sum_{i=1}^{n} P_i^2 (\bar{x}_i - \hat{\bar{x}})^2}{n-1}$$

where $\hat{\bar{x}}_i$ is the estimate of average percentage in the i^{th} village.

The regional estimates and their standard errors can be worked out from the stratum-wise estimates as indicated in the previous section.

3. Estimation of losses in cleaning/winnowing

As described in Chapter 3, page 11 the lost grain is isolated from a sample of chaff. This has to be raised to represent the total quantity of chaff obtained in the batch and then percentage taken on the basis of grain obtained by normal cleaning in the same batch of produce winnowed. If two or more samples are taken they may be averaged to obtain percentage loss in winnowing for the cultivator. The cultivator-wise observations on percentages may be used to calculate the stratum-wise and regional averages and their standard errors on the same lines as explained in the previous section.

4. Estimation of losses in drying

In this case as in estimation of other losses at the farm level the design is a stratified two-stage random sampling design with cultivator or farm as the ultimate unit. Data will be available on quantity of grain spread for drying and dried grain collected. Both have to be brought to standard moisture content and the difference between the corrected values will represent the loss. The percentage loss can be calculated by dividing this difference by the original quantity subjected to drying, converted to standard moisture content. The qualitative type of loss will be determined by examination of grain on samples and the quantities of damaged grain and total grain which are recorded will give the percentage damage of this kind directly. From the cultivator-wise percentage figures the stratum-wise and regional averages and their standard errors may be worked out as indicated in section 2 of this Appendix.

5. Estimation of losses in storage at farm level

There are some features peculiar to the estimation of storage losses at the farm level. The data are collected by inquiry at frequent intervals. Information regarding quantities put in storage and taken out can be fairly reliable if inquiry is made at the right time so as to reduce memory errors. Losses and causes of losses will be reported by the cultivator only when he becomes aware of them. If periodical sampling of stored grain on a sub-sample of holdings forms part of the study the cultivator will get timely warning of any deterioration and damage and preventive steps could be taken which will reduce the losses for the sub-sample of holdings which is likely to differ from the rest of the sample as a result. The periodical sampling coupled with laboratory examination would also provide data on slow imperceptible deterioration which information may be of interest to nutritionists.

However, the principal objective of estimation will be to estimate the average loss in storage and its break-up according to reported causes of damage. For each cultivator household therefore, a figure of average quantity of grain stored, aggregate loss over the period and its break-up according to cause of damage will be calculated. Since the design for the farm level enquiry is uniform, the stratum-wise and regional estimates of average quantity stored per holding, average quantity lost due to different causes, and the aggregate loss can be worked out by the procedure described in section 1. Similarly, estimates for percentage loss and their standard errors could be worked out by the procedure described in the same section. It is interesting to study variation in percentage loss according to size classes. Procedures for arriving at such estimates are also described in section 1. The mode of storage,viz., traditional, improved and modern, is likely to be dependent on holding size. To work out the estimates for different types of storages will also be possible but the sample size available for different types of storage will differ in the different size classes and this will complicate estimation. It may be more useful to work out for each class the proportion of grain stored in each type of storage and relate it to percentage loss in each size class.

Laboratory observations recorded on samples taken periodically from stored grain will not only provide estimates of percentage damage but also permit the study of relation of different causes of damage to the total damage by means of a multivariate approach. However, such analysis is beyond the scope of this bulletin which is confined to the estimation of losses only.

6. Estimation of losses in transportation

On the basis of data contained in schedule 1.8 percentage losses at various stages can be worked out, allowance for moisture content being made where necessary. On the basis of these data percentage loss for the region as a whole and its standard error can be worked out by procedure indicated in section 2 of this Appendix.

7. Estimation of losses in processing, packaging and handling

For estimating percentage losses at these stages at the farm level also the approach indicated in the previous section can be followed.

8. Estimation of losses at intermediaries level

In this case the design is two-stage stratified random sampling with the market as the first stage unit and the market functionary the second-stage unit. For each functionary percentage losses of various kinds can be worked out and the estimates for the region as a whole worked out by the procedure analogous to that of section 2 of this Appendix, the quantities of grain handled serving as weights at the two stages. In case of mills the selection is made only in a single stage and the procedure of estimation will be simplified in consequence.

9. Estimation of losses at Government warehouses

Selection of warehouses is also done by single stage simple random sampling and the estimation of average and percentage loss might be done as indicated for mills in the previous section.

APPENDIX III

1. Sample survey for estimation of crop losses in storage - Aligarh district (India)

The survey was undertaken in 1973-74 (crop year) in the Aligarh district of Uttar Pradesh (India) by the Indian Agricultural Statistics Research Institute, New Delhi. The principal objective of the survey was methodological, namely, to develop a sampling survey technique for estimation of such losses. The survey was confined to storage losses in principal foodgrains at the farm level, as storage at farm level is a very important stage in the flow of grain from producer to consumer and a substantial part of the grain produced being retained by the cultivator for varying periods. This is so mainly because agriculture is the source of livelihood directly for a major part of the country's population.

Aligarh is a fertile district in the gangetic plain and wheat is the most important cereal grain produced in the district. Estimation of losses in storage of this grain was given greater importance in the study though storage of maize, gram, barley and paddy was also studied.

Sampling Design: The survey was linked with another agro-economic survey in the district and field investigators of the other survey were asked to collect information on modes of storage as well as storage losses. This information also served the objective of the principal survey.

The district has over 1 700 villages divided into 17 Community Development Blocks. These were treated as primary sampling units and ten of them were randomly selected for the main survey. However, together they covered over half the district and were treated as strata for the crop losses survey. In each block 4 clusters of 2 villages each were selected by simple random sampling. In each selected cluster households were enumerated and classified into three categories, small, medium and large, the class limits being less than 2 hectares, 2-4 hectares and above 4 hectares respectively. From each class 4 cultivators were selected for the main survey, 480 in all in 40 clusters (p.s.u's) in 10 blocks. However, the crop losses study was confined to a subsample of the main sample and data were collected in 6 blocks, 2 cultivators were subsampled from each size class.

Collection of Data: Data were collected from sample cultivators by fortnightly inquiry. Initially the fieldmen collected data in schedules CL-I and CL-II regarding details of storage and crop losses during the previous year by enquiry. Subsequently data were similarly collected by them in schedule CL-III at fortnightly intervals. The schedules are appended at the end. Thus data on crop losses in storage were available for two years, for 1972-73 by enquiry after the year was over and for 1973-74 by fortnightly enquiry.

Analysis of Data and Results: The data were analysed by procedures on the lines indicated in Appendix II and results of considerable methodological interest have emerged. Some of the results are given below for the purpose of illustration.

Percentage loss in storage

Crop: Wheat	Year: 1972-73	Year: 1973-74
Size class		
small	3.3	5.9
medium	2.7	5.1
large	1.5	5.0
overall	2.0	5.2

The results for the two years differ, the estimates of percentage damage being greater for 1973-74. It appears that more reliable data can be collected by fortnightly visits. However, the conclusion is tentative and needs to be confirmed by further study.

The analysis of variance was carried out for estimating standard errors. These come out to be rather high. This might be explained to some extent by the relatively small magnitude of the percentage damage.

Estimation of Losses of Grain in Storage - Aligarh District (India)

Form - CL-I

Details of Storage

Name of the Tehsil _____ Block _____ Village _____

Name of the cultivator _____ S.No. as in proforma for listing of H.H. _____

Season/Month _____

Serial No. of the Crop	Names of Crop Sown Last Year	Area (in Acres/ Hectares) Under the Crop	Total Quantity of Grain Produced	Quantity Disposed Of	Mode of Disposal	Total Quantity of Grain Stored	Mode(s) of Storage (Specify)	Quantity Stored in that Manner	Measures Taken for Protection of Stored Grain, if any	Remarks
1	2	3	4	5	6	7	8	9	10	11

Note: Quantities to be recorded in columns (4) onward should be in quintals and Kg.

Signature of Enumerator _____ Signature of Supervisor/Inspector _____

Estimation of Losses of Grain in Storage Aligarh District (India)

Form - CL-II

Damage to Grain Last Year

Name of the Tehsil _____ Block _____ Village _____

Name of the cultivator _____ S.No. as in proforma for listing of H.H. _____

Serial No.	Name of the Crop	Grain Stored Last Year		Measures Taken for Protection of Stored Grain, if any	Causes of Damage	Quantity Damaged	Remarks
		Mode of Storage	Quantity Stored				
1	2	3	4	5	6	7	8

Estimation of Losses of Grain in Storage - Aligarh District (India)

Form - CL-III

Changes in Stock and Damage to Grain - Fortnightly

Name of the Tehsil _____ Block _____ Village _____

Name of the cultivator _____ S.No. as in proforma for listing of H.H. _____

Season/Month _____

Serial No. of the Crop	Crop	Initial Stock		Addition		Total in Storage	Reduction		Final Stock	In Case of Damage		Remarks
		Mode of Storage	Quantity Stored (a)	Source of Addition	Quantity Added		How Reduced	Quantity Reduced		Causes of Damage (b)	Quantity Damaged	
1	2	3	4	5	6	7	8	9	10	11	12	13

(a) Record separately for each mode of storage.

(b) Record separately for each type of damage.

Signature of Enumerator _____ Signature of Checking Officer _____

2. Survey on Marketable Surplus and Post-harvest Losses of Paddy in India (1972-73)

This survey was undertaken by the Directorate of Marketing and Inspection, Ministry of Agriculture and Irrigation, Government of India in all paddy producing states with statistical guidance of IASRI. To collect reliable data by size categories of cultivators on (i) retention of agricultural produce, (ii) marketed and marketable surpluses and (iii) physical losses occurring post-harvest, was the main objective of the survey. The results of the survey have not been published but the methodology adopted in the survey is described as it is likely to be of interest to many research workers. The survey reported here formed the first round of the survey being conducted by the Directorate on a number of important cereal crops.

Sampling Design: The survey covered 81 paddy growing districts. In each district 8 villages were selected with equal probability. In each selected village paddy growers were listed and divided into 3 size classes, small, medium and large, the class limits being less than one hectare, 1-3 hectares and above 3 hectares respectively. Ten cultivators were selected for study in each selected village, 4 from the small (more numerous) class and 3 each from the other two classes. A great variety of farm level data including data on post-harvest losses were collected from the cultivators by periodic (monthly, quarterly, etc.) visits by field investigators. Further, two markets were selected in each district purposively and in each market 9 intermediaries in the various categories - wholesalers, retailers, cooperatives, etc. - were selected by simple random sampling to collect data on crop losses at intermediaries' level.

Data Collection: As mentioned above data were collected by enquiry by periodic visits by the field investigators. Schedule I (appended) was used to collect data on losses at producers' level and Schedule II (appended) at intermediaries' level.

Analysis of Data and Results: The large body of data thrown up by the enquiry presented considerable difficulty in their scrutiny and analysis. The process was made somewhat easier by computerization of analysis. While the methodological conclusions would become available when the report is published, some tentative results obtained are given for purposes of illustration. They are purely tentative and are likely to be revised.

Losses at Producers' level

Size class	Loss in percent of production (Average of all states)
small	5.0
medium	4.5
large	3.6
overall	4.3

At the intermediaries' level the aggregate loss was estimated to be 0.44 percent, 70 percent of it being accounted by storage losses, 23 percent by transport losses and 7 percent by handling losses. The methodology employed needs further examination by deeper analysis.

SURVEY OF MARKETABLE SURPLUSES AND POST-HARVEST LOSSES

Schedule I - Losses at Producers' Level

			CODE
1.	Year of study (1-7-19__ to 30-6-19__)	_____	_____
2.	Crop season	Kharif(1)/Rabi(2)/Other(3)	_____
3.	Name of village	_____	_____
4.	Block	_____	_____
5.	Tehsil/Taluka	_____	_____
6.	District	_____	_____
7.	State	_____	_____
8.	Household code number	_____	_____
9.	Category of household	small/medium/large	_____
10.	(a) Name of crop under study	_____	_____
	(b) Other major crops covered	1. _____	
		2. _____	
		3. _____	
11.	Name of the cultivator	_____	
12.	Father's/Husband's name	_____	

Cultivator _____ Village _____ District _____

Losses at producer's level

1. Losses at operational level

Name of the Crop	Variety	Source of Power Used*		Total Quantity of Produce Obtained After Threshing and Winnowing (in quintals)	Total Quantity of Produce Lost (in Kg)		
		For Threshing	For Winnowing		In Threshing	In Winnowing	Total
1	2	3	4	5	6	7	8
1	HYV						
	TV						
	Total						
2	HYV						
	TV						
	Total						
3	HYV						
	TV						
	Total						
4	HYV						
	TV						
	Total						

*(a) Mechanical (b) Bullocks (c) Manual

Cultivator _____ Village _____ District _____

2. Losses at transport level (field to storage place)

Name of the Crop	Variety	Type of Transport		Method of Transport		Quantity Transported (in Qtls)	Quantity lost/ Wasted (in Kg)		TOTAL	CAUSES
		Field to Threshing Floor	Threshing Floor to Storage	Field to Threshing Floor	Threshing Floor to Storage	Threshing Floor to Storage	Field to Threshing Floor	Threshing Floor to Storage		
1	2	3	4	5	6	7	8	9	10	11
1	HYV									
	TV									
	Total									
2	HYV									
	TV									
	Total									
3	HYV									
	TV									
	Total									
4	HYV									
	TV									
	Total									

N.B.: Type of transport: (1) Head loads, (2) Pack animals, (3) Bullock cart, (4) Tractor trolly, (5) Others

Method of transport: (1) In bags, (2) In bulk.

Cultivator _____ Village _____ District _____

3. Losses at storage level (for stocks from the crop of the year under study)

Name of the Crop	Variety	Capacity of Storage		Method of Storage			Quantity Stored (In Qtls)	Quantity Wasted/ Spoiled (In Kg)	Causes of Loss***	Incidence of Wastage		Time When		Cost of Storage for the Period Stored	
		Kaccha* (Qtl)	Pakka** (Qtl)	In Bags	In Bulk	Both				In Rainy Season (In Kg)	In Rest of the Year (In Kg)	Stored	Taken Out	Kaccha Rs	Pakka Rs
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	HYV														
	TV														
	Total														
2.	HYV														
	TV														
	Total														
3.	HYV														
	TV														
	Total														
4.	HYV														
	TV														
	Total														

N.B.: The percentage figures in cols. 10 and 11 should equal 100.

*Kaccha storage means traditional storage with earthen floor, walls and roof.
**Pakka storage means modern storage with cemented floor, walls and roof.
***Quality deterioration, infestation, rodents, driage, handling, others.

SURVEY OF MARKETABLE SURPLUSES AND POST HARVEST LOSSES

Schedule II - Losses at the Level of Intermediary Agencies

(Schedule II is to be filled in for the following intermediaries for every selected market):

(1) Wholesalers - 2 (2) Retailers - 2 (3) Fair Price Shop - 1

(4) Cooperative Marketing Society - 1 (5) Warehouse - 1

(6) Regulated Market Committee } SELECT ONE PROCESSING UNIT FOR EACH OF
(7) Processing units } THE CROPS COVERED IN THE DISTRICT

II-1

1. Year July 19__ to June 19__ 2. Crop season Kharif(1)/Rabi(2)/Other(3)

3. State_____ 4. District_____ 5. Market_____

6. Name of the firm/agency/shop_____

7. Address_____

8. Nature of function performed*_____

9. Main crop under study_____

Other major crops covered_____

_____

10. Type of storage

	Capacity (in Qtls)			Cost (Rs/Qtl/Month)		
	Kaccha**	Pakka***	Total	Kaccha	Pakka	Total
Owned						
Hired						
Total						

11. (i) Method of storage (bags/loose)_____
(ii) Proportionate share of each (in Qtls) In bags_____
Loose _____

12. (i) Method of transport used Rail Truck Carts Others
(ii) Proportionate share of each (in Qtls)

---

*Wholesaling, Retailing, Fair Price Shop, Cooperative Marketing Society, Warehousing, Processing or Regulated Market Committee.

**Kaccha storage means traditional storage with earthen floor, walls and roof.

***Pakka storage means modern storage having cemented floor, walls and roof.

II-2

PHYSICAL LOSSES: Name of Firm_____ Function_____

Name of the Crop	Item of Information	July - September 19			Causes of Loss	October - December 19		
		HYV	TV	Total		HYV	TV	Total
1	2	3	4	5	6	7	8	9
	Quantity purchased							
	From whom purchased							
	Quantity stored							
	Quantity processed*							
	Loss in storage							
	Loss in transport							
	Inward (1)							
	Outward (2)							
	Total (3)							
	Loss in handling							
	Loss in handling for processing*							
	Quantity purchased							
	From whom purchased							
	Quantity stored							
	Quantity processed*							
	Loss in storage							
	Loss in transport							
	Inward (1)							
	Outward (2)							
	Total (3)							
	Loss in handling							
	Loss in handling for processing*							

*To be filled out in the case of processing agency only.

II-3

Market ____________ District ______________

Causes of Loss	January - March 19 HYV	TV	Total	Causes of Loss	April - June 19 HYV	TV	Total	Causes of Loss	Total July 19 to June 19 HYV	TV	Total
10	11	12	13	14	15	16	17	18	19	20	21

3. Project on the Improvement of Grain Storage

The Institute rendered guidance in the statistical methodology in the "Research project on the improvement of grain storage", carried out in Andhra Pradesh during 1974-77, jointly by the Indian Grain Storage Institute (India) and Institute of Development Studies (London). Estimation of storage losses for different types of storages formed part of the studies.

Stratified multi-stage random sampling technique was adopted with taluka as stratum, cluster of villages as the first stage unit and the cultivator as the second stage unit. The data, collected during the survey, are being analysed at I.D.S. (London). The statistical methodology in detail and the results obtained would be available in the report.

APPENDIX IV

REVIEW OF WORK DONE IN BRIEF

Prevention or reduction of post-harvest food losses is the principal objective of food technology. A large number of papers on the subject has been appearing in recent years in various journals. Many of these deal with laboratory-scale experiments. Commodity and regional-scale studies are not at all common. Even so the number of publications is too large to permit anything akin to an exhaustive review, nor is it warranted by the objective of this manual. In presenting this review it has been necessary to be selective and to confine attention to more recent publications, and those of greater relevance to the problem studied and, of course, those that were available. To make the text manageable, the review roughly covers the publications brought out during the last decade.

In the late sixties, the Government of India appointed a committee under the chairmanship of Dr. V.G. Panse, then Director of the Indian Agricultural Statistics Research Institute, to go into the problem of post-harvest foodgrain losses and make recommendations regarding prevention or reduction of such losses and other relevant matters. The Committee collected considerable information on the magnitude of crop losses from various governmental agencies, research institutions, etc. The estimates of losses in percentages, averaged over the three years 1962-63, 1963-64 and 1964-65, according to that Committee are given in Table IV-1.

Table IV-1. Estimates of foodgrain losses at different stages in important crops (in percentage)

Stage at which the loss occurred	Wheat	Rice	Jowar	Bajra	Maize	Gram	Millet	Pulses (excl. gram)
Threshing yard	1.0	2.5	2.0	0.5	0.5	0.5	1.0	0.5
Transport	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Processing	-	2.0	-	-	-	-	-	-
Storage								
i) Rodents	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
ii) Birds	0.5	1.0	1.0	1.0	0.5	0.5	2.0	0.5
iii) Insects	3.0	2.0	2.0	1.0	3.0	5.0	0.5	5.0
iv) Moisture	0.5	0.5	2.0	0.5	0.5	0.5	0.5	0.5

N.B. Losses have been worked out on the basis of loss in food value only. Driage which causes loss in weight but not loss in food value, spillage, loss in weight on account of theft, loss on account of conversion where some quantity may be lost for human consumption but is available for animal consumption, have not been considered as loss.

However, although these estimates have subsequently been frequently quoted by various workers, the estimates are only notional figures, mostly guesses by various experts working in the field.

Majumdar and Parpia (1967) gave some estimates of losses in different countries, as follows:

Table IV-2. Estimates of foodgrain losses in different countries

Country		Loss % or value	Reference
World	All crops	10%	FAO Grain Storage News. 1(2):2, 1959
Nigeria	Sorghum Cowpea	46% 41%	Colonial Res. Publ. 12:40
U.S.A.	Stored grain Packed food All crops	$500 million $150 million $3 500 million	Metcalf, R.L., 1962 Destructive and Useful Insects, McGraw-Hill, pp. 41-43
India	All grains	25% field loss 15% storage loss 7% handling and processing 3% other losses	CFTRI, Mysore 1965, Res.Ind. Conf.
Indonesia	Rice	15% field losses	Int. Rice Yearbook, 1957, p.36
Germany	Harvested	DM71.4 million	Frey, W., 1951, Flugblat Biol. Bundesanstat. No. 5, 8
Sierra Leone	Rice Maize	41% 14%	Colon. Res. Stud. 1959, No. 28, 52. Rech. Rep. 12 W. Afr. Stored Prod. Res. Unit, 1962
Tropical Africa	All crops (storage and handling)	30%	FAO Informal Working Bull. 24, 1964

Pradhan (1968) in his presidential address at the 29th Annual General Meeting of the Entomological Society held in 1968 at Varanasi (India) enumerated various problems in relation to grain storage in India in detail and made recommendations for the improvement of storage systems. He suggested control measures to avoid foodgrain losses in storage. The question of estimation of losses was, however, not emphasized.

Mookherjee et al (1968) indicated the percentage range of damage in cereal seeds for different zones of the country (India) for paddy, wheat, maize, barley, sorghum and pearl millet on the basis of limited data.

Krishnamurthy (1968) reported that the loss of foodgrains suffered annually by the Government during storage, 7 to 10 million tons, was less than 0.2 per cent. The co-operative organizations (2 to 6 months of storage) and warehousing corporations (up to 8 months of storage) suffered losses of 1 to 3 per cent and 1 per cent respectively. In the rural storages the losses owing to insects in wheat stored up to 8 months varied from 2.03 to 9.52 per cent, the data being based on reports of such organizations.

Khalon (1970) studied the impact of changing conditions on grain markets in the former Punjab (India). He studied the marketing system, including inputs, credit, storage, etc., with respect to wheat, paddy and maize grains. He used a regression model for working out the prices of these foodgrains. However, the estimation of losses was not one of the main objectives of the study.

Hall (1970) prepared a manual on handling and storage of foodgrains in tropical and sub-tropical areas, giving in detail the principles of handling and storing foodgrains, with particular reference to the storage of cereals, legumes and oilseeds. His work is based on information collected from research workers in Africa and in 11 countries in

other parts of the world and from organizations concerned with store products problems. Some of this information appeared in FAO Informal Working Bulletin No. 24. He described in detail the different types of losses such as loss of weight, food loss, loss of quality, loss of goodwill and seed loss. He also described various factors affecting food value and deterioration, design of stores, storage methods and insect control methods. He has also indicated the methodology for taking samples from the stored grain.

The report of the Committee on Post-harvest Losses of Foodgrains in India (1971) indicated the loss of foodgrains of wheat, paddy, jowar, bajra, maize, etc., at various post-harvest stages. The estimates of losses given in the report pertain to the period prior to 1970. The storage losses during the period from 1963-64 to 1968-69 were as given below (Table IV-3):

Table IV-3. Losses of foodgrains in storage

Year	Quantity stored (in tons)	Loss % in relation to quantity stored
1963-64	59,34,351	0.20
1964-65	60,92,374	0.26
1965-66	47,12,823	0.13
1966-67	43,30,063	0.14
1967-68	27,73,576	0.10
1968-69	20,22,386	0.074

The percentage of losses during transportation for the period 1962-67 in respect of wheat was reported as follows (Table IV-4):

Table IV-4. Losses of wheat grains in transportation

Year	Loss as percentage of the quantity transported
1962-63	0.75
1963-64	0.59
1964-65	0.31
1965-66	0.29
1966-67	0.17

The proceedings of the Seminar on Post-harvest Technology of Foodgrains, sponsored by the Indian National Science Academy (INSA), Indian Council of Agricultural Research (ICAR), Council of Scientific and Industrial Research (CSIR) and Food Corporation of India (FCI), held at New Delhi (India) in December 1972, covered the problems of losses in harvesting, drying, processing, storage, transport, etc., with respect to cereals and pulses. Fifty-four papers were presented and discussed at this Seminar dealing with the problems of (i) harvesting and losses that occur in different techniques of harvesting; (ii) mechanization of markets; (iii) drying of foodgrains after harvest and drying during

processing; (iv) storage and transport; and (v) by-product utilization. Prof. B.R. Seshachar, President, Indian National Science Academy, said in his address that about 10 million tons of foodgrains were lost annually during the process of drying, transportation, storage and distribution. This amount could feed at least 50 million people. Other speakers gave different degrees of losses owing to different causes or occurring at different stages. Girish and Krishnamurthy, in their paper entitled "Losses in Foodgrains in Storage", reviewed the extent of losses owing to different causes such as insect pests, diseases, storage systems, birds and rats for different periods of storage. They also mentioned in their paper that the methods of assessment of losses were not uniform and, hence, these losses were not comparable. They suggested that the assessment of losses from farm storage, markets, large-scale storages, should be made by random sampling techniques.

A manual on post-harvest rice technology based on the compilation of lectures at the Regional Training Course, University of the Philippines (1973) sponsored by the International Development Research Centre, indicated an appropriate system of post-harvest handling, distribution and utilization of rice in the developing regions of the world. A study made during the Training Course indicated losses of grain as 0.39% and 4.9% by the hand-cut and combined methods respectively. One of the studies made during the Training Course gave estimates of losses of important nutrients such as protein, fat, calcium, thiamine, riboflavin, niacin, panthothenic acid, and pyridoxine during milling, on the basis of laboratory tests. The results regarding estimated grain losses in marketing as a result of the survey conducted by the Asian Productivity Organization in 14 Asian countries disclosed that the working average physical losses in grain marketing were about 16.5 per cent. The break-down of this loss was as follows: 2.0 during field transportation, 2.0 in drying, 1.5 in drying-to-storage transportation, 4.0 in storage, 1.0 in storage-to-processing transportation, 5.0 in processing, 0.5 in packaging for distribution and 0.5 in transportation for distribution. The experiences of pilot projects in India and other South-East Asian countries such as Lao, Malaysia, Philippines, Sri Lanka, Indonesia and Thailand, were also presented. In one of his lectures on "Rice inspection and grading covering sampling, inspection grading and certification" Thet Zin discussed the size of sample from bulk as well as from sacks and from small and big lots. These samples were tested in the laboratory for preliminary observations, moisture in paddy, odour, insect infestation, impurities and foreign matter, milling yield (total rice, head rice, etc.), classification according to length and breadth, seeds and foreign matter in test milled rice, red grains, chalky and immature grains, damaged grains and foreign grains. The types of sample drawn by the use of sampling probe were called primary sample, the combined primary samples when thoroughly mixed called composite sample, and when a composite sample was reduced it was called a submitted sample and a portion removed from the submitted sample for testing was called the working sample. The method of testing working sample from the submitted sample by a mechanical divider or by quartering when the mechanical divider was not available was also explained. The study thus provides useful guidance on sampling and testing for quality.

Samson and Duff (1973) in their IRRI Seminar showed the pattern and magnitude of losses of paddy in the harvest and post-harvest stages on the basis of experimental trials (completely randomized design) conducted during wet and dry rice seasons at the IRRI farm.

Srivastava et al (1973) reported weight loss due to damage by insects in villages to the extent of 9.7% and kernel damage to the tune of 30.1%. Girish et al (1974) assessed losses of wheat in farm storage in different regions of Uttar Pradesh ranging from 0.6 to 9.7 per cent.

In the report of the Committee on Cost of Handling of Foodgrains by the Food Corporation of India (1974), the transit and storage losses in the Food Corporation of India from 1969-70 onwards were given as follows (Table IV-5):

Table IV-5. Foodgrain losses in transit and storage

Year	Rs. (in crores)	Quantity (in lakh tons)	Percentage of transit and storage losses on purchase and sale value
1969-70	15.29	2.06	1.03
1970-71	15.00	1.76	1.06
1971-72	18.36	2.12	1.09
1972-73	21.47	2.33	1.08

These figures are based on official records and are good indicators of the efficiency of handling of grain by public agencies.

Krishnamurty (1975) reviewed the work done regarding post-harvest losses in foodgrains in India and abroad. These estimates of losses were mainly based on small-scale studies. He reported that the losses of foodgrains in rail transit were estimated by the Food Corporation of India at about one per cent during 1970-71. He also assessed the loss in commercial storage of foodgrains as 3 to 5 per cent when storage was for 8 months and around one per cent when the storage was up to 4 months. In underground structures the loss was 6 to 10 per cent. He also observed that a loss of 3 per cent was due to use of hooks; 0.1 to 0.2 per cent due to spillage, and 0.5 per cent due to loss of moisture in general during storage.

Duff and Toquero (1975) presented a paper at the workshop on "Rice post-production technology", University of the Philippines at Los Baños based on experiments, field trials and laboratory work concerning the assessment of qualitative and quantitative losses in the post-production sequence of operations such as harvesting, handling, threshing, drying, etc.

Girish et al (1975) assessed the average loss of wheat due to insect damage as 2.90, 0.85 and 0.95 per cent after 7 months of storage in grain markets of Western U.P., Punjab and Haryana respectively.

A manual on "Rice Post-harvest Technology" (1976) was prepared on the basis of the material compiled for the "Training Course in Post-harvest Technology" conducted at the University of the Philippines in 1973. The manual gives very useful information to those who are concerned with rice production, processing, marketing, distribution, etc. Under the heading "Experimental Design" of the chapter entitled "Standards", the techniques such as completely randomized designs (CRD), randomized block designs (RBD), latin square and factorial designs have been explained.

In the Annual Report (1976) of the All India Co-ordinated Scheme on Post-harvest Technology (ICAR), the results of the studies made on post-harvest technology of rice have been presented. In some cases experimental designs such as randomized block design, split-plot and strip-plot design were adopted.

A study was being made by the IRRI/UPLB/BRBC on rice production technology in Bicol River Basin, Philippines (1976) determining the magnitude and source of losses in the post-production sequence of operations, harvesting, threshing, drying, storage and milling by conducting field and laboratory trials.

Toquero and Duff (1976) in a profile of rice post-harvest industry in Camarines Sur (Philippines) regarding expansion in on-farm production of rice, discussed improvements in the technology, marketing mechanisms and operations in harvesting, handling, threshing,

drying, storage, transportation, milling, wholesaling and retailing. The preliminary results, obtained on the basis of information collected from farmers selected at random in the vicinity of mills, which were stratified according to size and type, were also presented.

Supporting Study 12 on Post-harvest Grain Losses (1976) of the main study "All India Grains Storage and Distribution", prepared by the Administrative Staff College of India and sponsored by the Ministry of Agriculture and Irrigation, presented a very good review of work on post-harvest grain losses and gave 170 references in this field work. They also presented the results obtained from surveys in two regions, Punjab (Ludhiana) and Andhra Pradesh (West Godavari and Medak), on wheat and maize crop respectively. The stratified random sampling technique was adopted in these two regions. Topics such as stages of losses, grain losses with their causes and measurement, farm storage, trade and market level storage, public storage, transportation loss and loss in processing, have been dealt with in this supporting study. In Supporting Study 11 on "Farm Level Storage", they have dealt with production, retention and sale, storage structures, losses and preservation practices, evaluation of structures, farm storage, and public distribution and trade storage.

Harris (1977), in his paper, introduced the study being made regarding post-harvest grain loss assessment methodology. He is of the opinion that specific and in-depth studies should be followed by the design and setting up of tests to identify and measure losses at the designated point(s) using scientific procedures derived from established statistical, entomological, anthropological, sociological, marketing and grain science disciplines.

FAO (1977) summarized the reports regarding the post-harvest crop losses in the developing countries received from them. In this manual losses in cereals, fruits, vegetables, animal products and fish products have been covered. It has also been proposed to organize loss assessment programmes in the countries which would be implemented as an integral part of loss reduction programmes.

Caliboso (1977) in his paper "Studies on the Losses of Stored Grains due to Insect Pest Infestation" reviewed the work and gave the results of the study made in Manila during 1975-76 adopting a randomized block design.

The FAO report (1977) of the action-oriented "Field-workshop for Prevention of Post-harvest Rice Losses" held at Alor Setar, Kedah (Malaysia) in 1977 gives the recommendations made at the workshop for assessing quantitative and qualitative losses in post-harvest operations in rice. Twenty-nine papers were presented and discussed at the workshop in different sessions. Methodology for assessing post-harvest rice losses was also suggested.

Adams and Harman (1977) drew conclusions and made recommendations on the basis of the project for the evaluation of losses in maize stored in two small areas (Zambia). The information was collected by conducting surveys through questionnaires. They indicated that this approach might have some value when assessments were made for a large number of farmers. However, they also suggested that such a survey should preferably be coupled with a more detailed survey on a smaller sample.

Padua (1977) in his paper on "Rice Post-harvest Problems in South-East Asia" presented at the Annual Meeting of the Institute of Food Technology held at Philadelphia (U.S.A.) in 1977, gave the losses of rice at different stages of post-harvest as follows (Table IV-6):

Table IV-6. Losses of rice at different stages of post-harvest

Stage	Range of loss in percentages
Harvesting	1 to 3
Handling	2 to 7
Threshing	2 to 6
Drying	1 to 5
Storage	2 to 6
Milling	2 to 10
Total range of loss	10 to 37

The Final Review Draft of Post-harvest Grain Losses Assessment Methods published by the American Association of Cereal Chemists (1978) has dealt with assessment problems in detail, touching almost all the aspects of post-harvest foodgrain losses. The statistical approach has been mentioned in brief. In this review the concepts, definitions and measurement techniques have been dealt with very systematically and these could be adopted in the studies to be made in different countries in future with necessary modifications according to local conditions.

The Directorate of Marketing and Inspections, Department of Agriculture, Government of India, initiated in 1972-73 a large-scale sample survey for the estimation of marketable surplus and post-harvest losses of foodgrains, covering paddy in the first year. In this round of the survey, 81 important paddy producing districts were covered. In each such district 8 villages were selected with equal probability. In each selected village, the paddy growers were classified according to their holding sizes into 3 categories, small, medium and large. Ten cultivators were selected from each sampled village for collection of data, 4 from the small holdings' class and 3 each from the other two categories. In addition to the sample of cultivators, 1 458 market functionaries were selected from 162 markets for studying post-harvest losses in the intermediaries stage. The report of the survey has not been published but the methodology employed in the survey is available and will be useful for planning large-scale studies for the estimation of post-harvest losses of foodgrains.

The Institute of Agricultural Research Statistics conducted in 1973-74 a pilot methodological survey in one district, namely Aligarh (India), to study foodgrain losses in storage under the farmer's conditions. In this survey 24 clusters of villages were selected from 6 community development blocks and in each cluster the data on foodgrains stored, losses and causes of losses were collected from 6 randomly selected cultivators in each cluster during fortnighly visits. The results of the survey have not yet been published but the survey has provided considerable information of methodological interest for estimating losses in storage by the method of random sampling surveys.

It may be observed in conclusion that many workers have dealt with the problems of assessment according to their own needs and situations. Their experience will be useful in developing a uniform standard approach to assessment of post-harvest losses of foodgrains. In fact, the Final Review Draft of Post-harvest Grain Loss Assessment Methods (1978) mentioned earlier examines the problems comprehensively. The two surveys conducted in India mentioned at the end also provide useful material for suggesting a suitable methodology, which has been dealt with in a later chapter.

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