AN ASSESSMENT OF LOSSES DURING HANDLING AND STORAGE OF MILLET IN MALI

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Abstract

This paper outlines the design and implementation of a study of the quality of bulrush millet purchased stored and distributed by a government cereal marketing board and of an assessment of the losses of grain that occured in the marketing system. The selection of appropriate techniques and methods for sampling bagged millet in central storage and for the analysis of samples is described. Problems encountered in the assessment of weight losses in millet are discussed and the choice of particular methods explained. Spillage from damaged sacks was found to be an important problem and high levels of fine impurities were found to be the most serious form of low quality. It is concluded that losses of grain to biological causes during the study were very low and it is argued that the measurement of weight losses in itself is of limited value. It is suggested that a thorough understanding of the attitudes to loss of those responsible for the grain is essential to the successful introduction of loss reduction measures.

Résumé

Ce rapport expose les grandes lignes du dessein et de la mise en oeuvre d'une étude sur la qualité du petit mil (*Penisetum* spp) acheté, stocké et distribué par un organisme gouvernemental de commercialisation des céréales et aussi sur les pertes de grain qui se sont produites au cours de la commercialisation. On décrit la selection des techniques et mèthodes appropriées à l'échantillonage du mil en sac stocké au niveau centrale et aussi à l'analyse des échantillons. On examine les problémes rencontrés dans l'estimation des pertes du poids dans le petit mil et on explique le choix des mèthodes adoptées. On a découvert que le versement des grains des sacs endommagés presentait un probleme grave et que la presence des impurités fines était la cause la plus importante d'une mauvaise qualité. On a constate que le niveau des pertes provoquées par les agents biologiques au cours de l'étude était faible et on estime que l'estimation des pertes de poids en lui-même est d'une importance moindre. Il est suggeré qu'une connaissance profonde de l'attitude envers les pertes des agents responsables pour les stocks est indisponsable à l'introduction des mesures destinés à reduire les pertes.

Resumen

En este artículo se reseña el diseño y la ejecución de un estudio sobre la calidad de mijo de enea comprado, almacenado y distribuido por un organismo gubernamental de commercialización de cereales, así como sobre una evaluación de las pérdidas de cereales que se produjeron en el sistema de comercialización. Se describe la selección de las técnicas y métodos apropiados para el muestreo del mijo ensacado con almacenamiento centralizado, así como para el análisis de las muestras. Se examinan los problemas planteados en la evaluación de las pérdidas de peso en el mijo y se explica la selección de los métodos concretos adoptados. Se comprobó que el derramamiento de los sacos averiados era un importante problema y se comprobó que el aspecto más grave de la deficiente calidad fueron los elevados niveles de impurezas diminutas. Se concluye que las pérdidas de cereales por causas biológicas, después del estudio, fueron muy escasas y se alega que la medición de las pérdidas de peso en sí tiene reducido valor. Se sugiere que es indispensable comprender la posición y actitudes de los responsables de los cereales respecto a las pérdidas para adoptar medidas destinadas a reducirlas que puedan tener éxito.

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Introduction

This paper summarises a more detailed report on a study carried out in Mali, West Africa, between February 1979 and April 1981. A major objective was to develop loss assessment methods which could be applied in a large central marketing board and to attempt to estimate the losses due to the major causes (e.g. insects, spillage etc). Experience in assessing losses at this level is limited and it was believed that the investigation of suitable methods would be of value in itself. Very little loss assessment work had been carried out on bulrush millet, which was to be the subject of this study, and consequently it was also thought that useful information could be gathered on the efficiency of current loss assessment methods with this cereal. A further objective of the project was to assess the quality of locally produced millet. This examination of the quality of millet would need to be carried out at the moment that it became the property of the marketing board and would also be the starting point for the assessment of losses. The attempts to study both initial quality and to assess losses were largely compatible although there was some conflict in choice of work sites and sampling procedures.

Grain crops, of which millet is the most important, are the staple food of both rural and urban populations in Mali. Millet is grown in the central dry savannah area of the country (see Figure 1) following the uncertain rains between June and September. Yields are naturally low (usually less than 500 kg/ha) and may be further reduced if the rains are poor or unevenly distributed. Rainfall is the main factor limiting yield. In 1976 the production of hard grains (millet and sorghum) in Mali was estimated to be about one million tonnes and this may be the average for a good year. Estimates of Mali's annual requirements of grain vary considerably but it is generally agreed that there is usually an overall deficit between production and needs.

Fig. 1 The regions of Mali and its areas of millet production, cereals surplus and cereals deficit

During the buying campaign, millet purchased in villages and small towns is moved to central stores in regional capitals. Figure 2 shows the movements of millet in the region of Segou during the study which includes two buying campaigns. The region of Segou is an important area of millet production and most of the millet moved out of this area goes to Bamako. Figure 2 shows that such inter-regional movements are sporadic and occur at most times of the year.

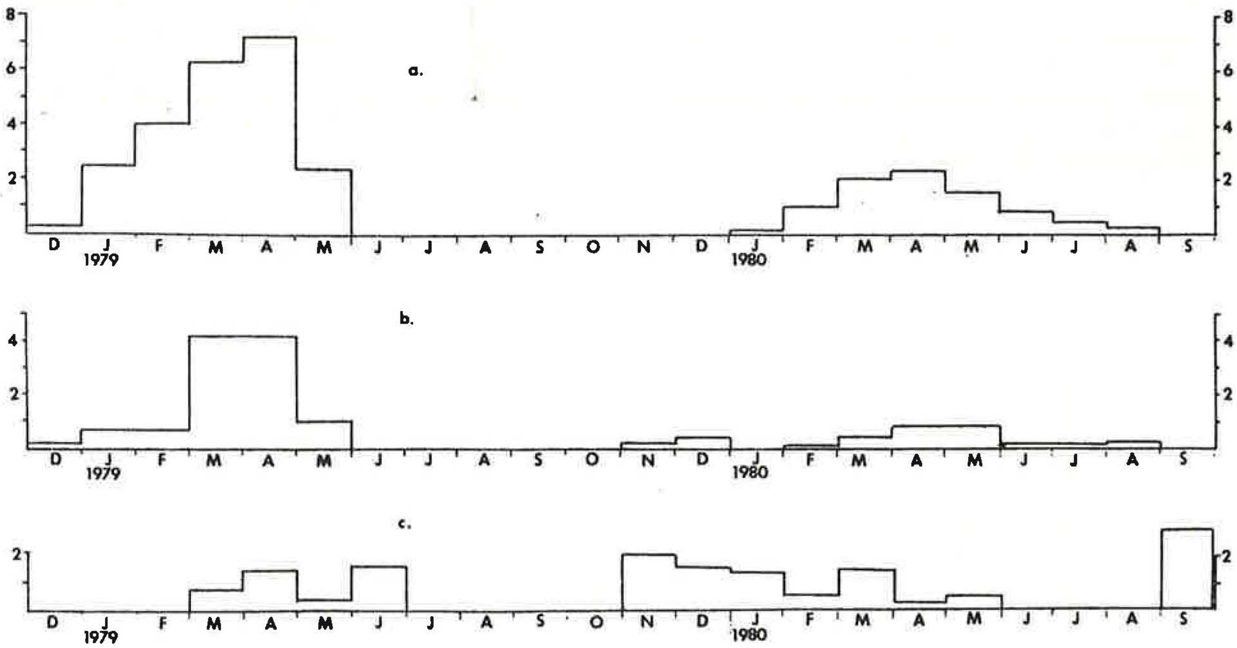

Fig. 2 Millet movements (tonnes x 1000) in Segou Region during the study period
a. Purchased millet
b. Movements to Segou from elsewhere
c. Movements from Segou to other regions

Development of a methodology

The development of a methodology that would permit the study to be carried out fell into three main parts:

a. the development of sampling and analysis procedures to obtain estimates of millet quality in individual 100 kg sacks;

b. the identification of a number of study sites and a programme of work so that the sacks studied might yield information on losses of millet in the system;

c. the determination of a system of selecting sample sacks at each site to obtain information representative of the grain moving in the system.

Analysis of quality in sacks. All millet is handled by the marketing board in sacks. The nominal weight of grain per sack is 100 kg but actual weights vary considerably. Preliminary work showed that samples taken by a Produce Flow Sampler (described by Golob, 1976) were accurately representative of the contents of whole sacks at least in terms of the fine impurities they contained (Figs 3, 4 & 5). This work also demonstrated that sieving by the TDRI (TPI) Produce Inspection Sieve (see also Golob, 1976) was acceptably accurate. The results of the two processes are inseparable and while the overall accuracy indicates that both are efficient, the observed error cannot be attributed to either process individually. The Produce Flow Sampler provided a sample of about 9 kg which was satisfactory for the estimation of impurities by sieving but too large for further work. Sample weight was reduced by collecting portions of the cleaned grain as it flowed off the sieving screen. This reduction was haphazard. Three separate portions were collected at different times during the sieving and the moisture content of each was estimated. The three subsamples were then combined to obtain sufficient grain (about 1 kg) to estimate the bulk density of the millet in a chondrometer. This apparatus weighs a constant and predetermined volume of grain in order to estimate its density.

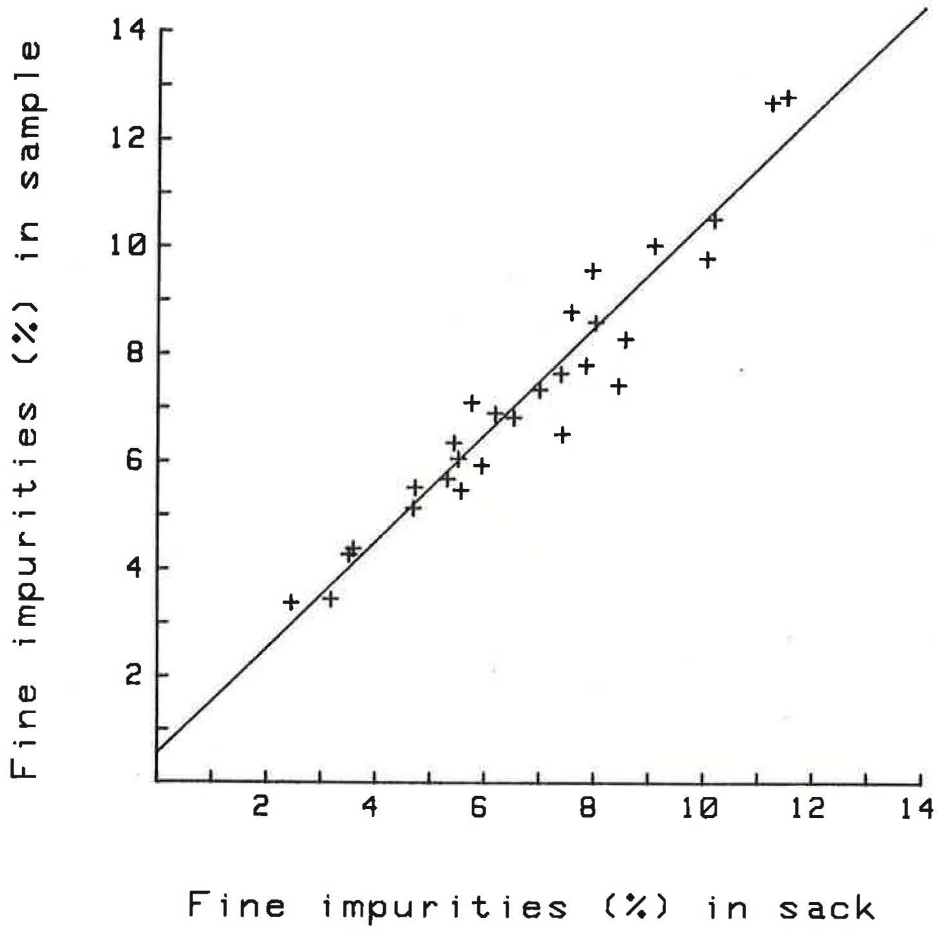

Fig. 3 The efficiency of the Produce Flow Sampler, using the fine impurities content, extracted by the Produce Inspection Sieve, as a parameter. (Correlation co-efficient r = 0.968, number of samples n = 28)

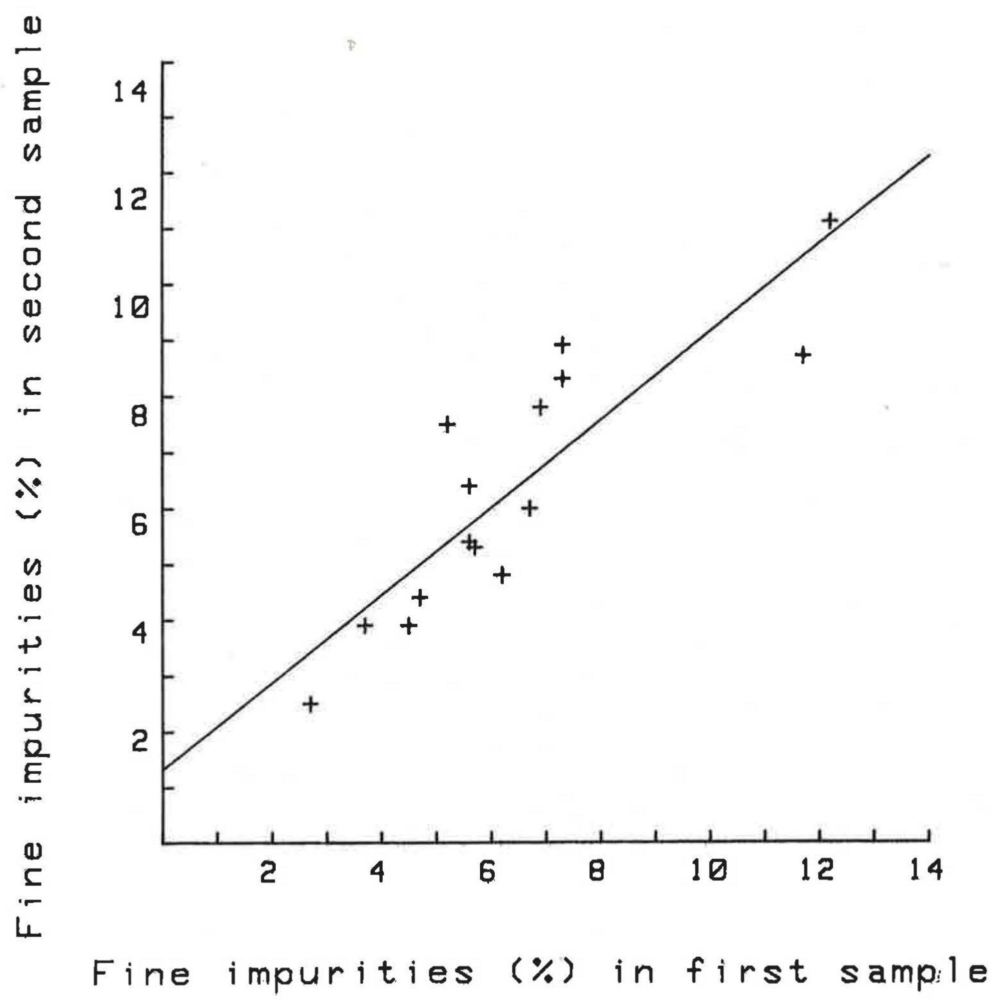

Fig. 4 The repeatability of results with the Produce Flow Sampler, comparing 2 samples for each of 15 sacks: (r = 0.867, n = 15)

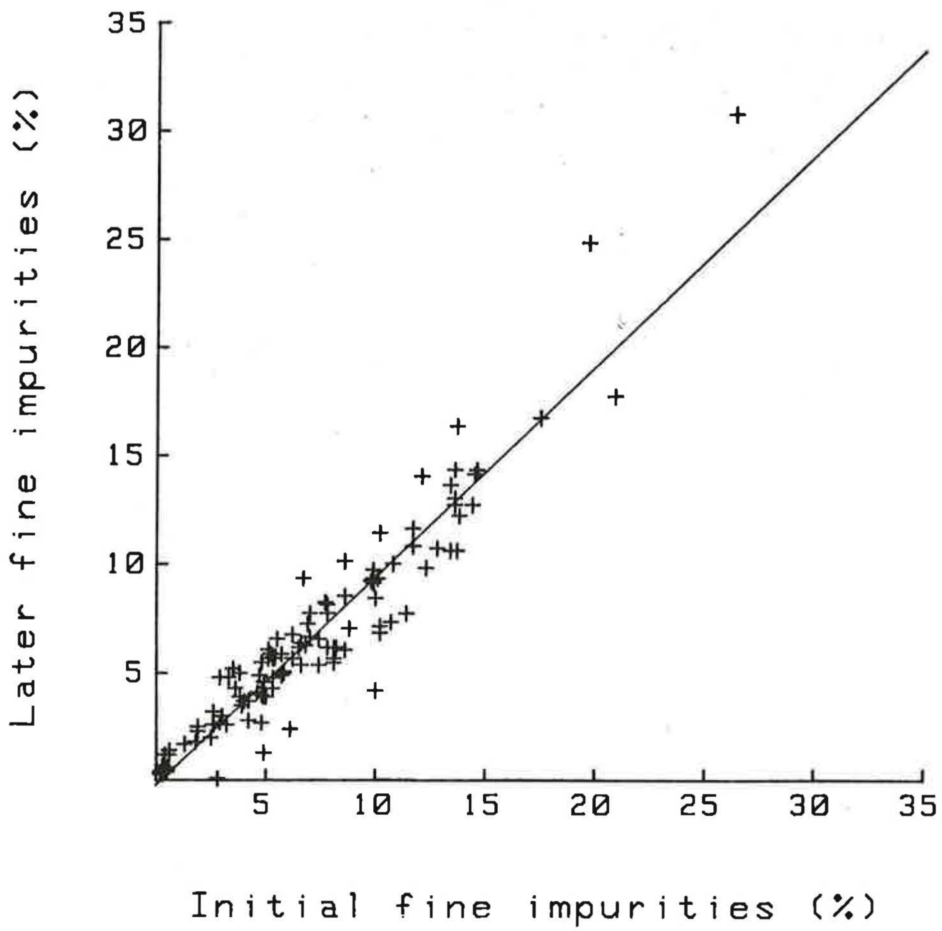

Fig. 5 The correlation between initial samples and later samples taken when the sack was recovered during the course of the survey: ($r = 0.948$, $n = 117$)

The counting and weighing of undamaged and damaged grains in a sample can be used to obtain estimates of weight loss due to insect attack by way of several different procedures. The Count and Weigh method and the Converted Damage Percentage method both require the visual examination and counting of grains and the Thousand Grain Mass (TGM) method also requires that grains in a sample be counted (Proctor & Rowley, 1983). In order to carry out these procedures it was necessary to obtain a sample of millet that could be inspected visually and to have the means of separating the grains into different categories and of counting and accurately weighing the grains in each category. Impurities that were not removed by sieving, ie those of approximately the same size as millet grains, would also be removed and weighed during this process.

The programme of work. In order to estimate initial millet quality it was essential to study the grain at the time of procurement by the marketing board. The work strategy was that the grain studied at this time would be restudied at later stages and the observed changes in quality would be used to assess losses. Various plans were proposed to put into the system grain which could be withdrawn separately from the grain belonging to the marketing board. Suggestions included using small sacks in amongst the 100 kg sacks and also using small sacks inside the 100 kg sacks but technical difficulties prevented these methods being pursued. Instead plans were made to mark the sacks in such a way that they could be identified at later stages in the marketing chain.

Consideration of the available resources of personnel, equipment and time reduced the scope of the study to a single chain through the marketing network. The work was to be carried out by two people, with only enough equipment to carry out the complete analysis procedure at one site at a time. The distances involved and the means of transport available meant that, in each week working in the field, two days would have to be set aside for travelling and setting up the equipment. It was estimated that in the remaining time in each week 30 sacks could be examined.

Three sites in the region of Segou (Sy, San and Segou itself) were to be visited regularly to examine millet purchases during the buying campaign. Although these places handle a large proportion of the millet commercialised in the region of Segou, a more complete survey of the quality of millet would have required visiting more areas in the region. This was not compatible with the losses study. The three study sites were to be revisited later whenever marked sacks re-appeared or became accessible due to movements of grain.

A five-week rota was established to visit the three sites and provide time in Bamako for laboratory analysis of samples. The unpredictable nature of grain movement in the marketing system and the large distances involved meant that it was necessary to rely on warehouse staff to intercept marked sacks in order to separate losses in different parts of the study chain. Storekeepers were asked to isolate and weigh individual marked sacks entering their stores and to set aside outgoing marked sacks so that they could be re-examined by the research team on a return visit. Final interceptions of the sacks in Bamako, should any marked sacks progress that far, could be carried out directly by the researchers. It was intended that 270 sacks (90 at each site) would be put into the marketing system during the buying campaign. The proportion that this would make of the total amount of millet would be determined by the eventual success of the campaign.

Sampling and analysis. The selection of sacks of millet being purchased at the smallest sub-regional centre presented few problems since the inflow of grain was slow and all arriving sacks could be studied. At higher levels in the chain, most of the millet arrived in lorry-loads of 8-10 tonnes (ie 60-100 sacks). Random sampling of each lorry might have been possible but would have required the continuous attention of the research team which would have reduced the number of sacks that could have been examined. It was felt that there would be greater variation between millet from different areas in the region than within shipments from the same area. Therefore the researchers examined as many sacks as possible by working continuously on the analysis of samples and saved time by selecting sacks haphazardly from incoming lorries. Examining sacks from as many areas of the region as possible was also intended partly to fulfil the objective of examining millet quality in the region.

Each sample sack was opened and the contents passed through a Produce Flow Sampler to obtain a sample of about 9 kg, the remainder returning directly to the original sack. The 9 kg sample was sieved using a locally-made Produce Inspection Sieve. During sieving, most of the 9 kg sample was returned to the original sack but a small proportion (approximately 1 kg) was collected for further analysis. Moisture content and bulk density were measured first and the sieved sample was then reduced, by repeated division with a riffle divider, to produce a very small final sample (approximately 5 g) which could be examined for insect damage. The sacks were marked with paint and then all the impurities and grain, except for the final sample, were returned to the original sack which was stitch-closed and weighed.

It was expected that estimates of loss would be obtained from the measurements of the weight of whole sacks and of the bulk density of samples; also from calculations based on the observations of grains in the final sample through the Count and Weigh method, the Converted Damage Percentage method and, later, by the TGM method. Further qualitative indications would come from incidental observations of such things as handling practices, sack condition and insect abundance.

Results

In the initial phase of the study fewer sacks than originally intended (207 not 270) were analysed as they went into store. This was due to an unpredicted relatively low intake. In the later stages of the study no interceptions were made of marked sacks as they arrived at stores. Although a large number of sacks were recovered leaving store (106 re-examinations were made) the pattern of recoveries did not allow loss assessment to be carried out on all sections of the study chain.

Of 30 sacks examined and marked in San in February, 20 were recovered and re-examined in October, which allowed estimates of losses in store during that period to be assessed. However, such useful patterns of recovery were rare. None of 20 sacks examined on arrival at Sy in March was ever seen again. Seven sacks originally examined entering store in Segou in April were re-examined again in Bamako in November. The observed losses might have occurred in storage at Segou, in transport from Segou to Bamako or in storage at Bamako.

Whole sack weights. Weighing whole sacks produced more problems than anticipated with an unacceptably large proportion of study sacks showing an apparent increase in weight. Some increases could be the result of inaccurate weighing machines but others are so extreme that another explanation is required. It is possible, for example, that where study sacks were the last sacks remaining in store spillage from the final evacuation was swept up and added to the sacks. Table 1 summarises the results of weighings of whole sacks. It may be that a whole sack is not a useful unit of grain for study and that attention should be focused on whole stores or lorry-loads or shipments of grain.

Table 1 Observed weight changes in marked sacks recovered during the survey

Wt. change (kg)	2	4	6	8	10	12	14	16	18	20	20+	Total
Sacks showing increased weight	21	9	6	3	6	–	–	2	–	–	1	48
Sacks showing decreased weight	21	11	9	7	4	3	3	2	–	–	6	66
Sacks showing no change within the limits ± 1 kg												21
Overall total of observations*												135

* Not equal to total number of sacks recovered (106 see text) because some bags were intercepted at more than one point in the sequence of movements, allowing multiple observations.

Bulk density. The chondrometer produced estimates of bulk density that could not be related to the moisture content of the millet. This made it impossible to establish a baseline relationship between dry weight and moisture content. Estimates of bulk density also showed no relationship to levels of insect damage and impurities or to average grain weight. It is possible that the chondrometer is capable of registering changes in bulk density that would be of value in quality assessment and that its failure to do so in this study was the result of several characteristics of the millet acting simultaneously to interfere with the estimates of density. Since this is likely to be the case with any field work on millet it is unlikely that the chondrometer can be usefully applied to this cereal in the field.

Hand sorting of millet. After some trials it was found possible to sort millet grains into insect damaged, broken and undamaged fractions using forceps to pass the final sample over an illuminated mirror. The process is slow and tiring and the weights of minor fractions very small. The use of figures obtained by this procedure in the Count and Weigh method gave very variable estimates of loss and many (10% of all analyses) gave negative estimates which were obviously meaningless. The variability meant that individual estimates of loss could not be treated as reliable. The variation and unreliability is caused by the small size of the final samples, the natural variability of millet grains and the inaccuracies involved in the weighing of small quantities of grain. These same considerations were responsible for the very variable results also produced by the TGM method.

In both cases larger samples might have produced more reliable estimates of loss but would have required a prohibitive amount of time. However, visual scoring of the grains did allow observations to be made of the levels of insect damage, albeit with wide margins of error. Hidden infestations are unlikely to be a problem since almost all the observed species of insect were surface feeders. A rough estimate of losses to insects could be made by way of the Converted Damage Percentage method which involves the calculation of a conversion factor to express the difference between average undamaged grain weight and average damaged grain weight. The approach recommended in Post Harvest Grain Loss Assessment methods (Harris & Lindblad 1978) is shown in Figure 6. The relationship between observed percent damaged grains and the weight loss calculated by the Count and Weigh method gives a Conversion Factor of 0.18. Selected data (ie those where a large number of damaged grains made the estimate of average damaged grain weight more reliable) were used in another approach which (see Figure 7) suggested Conversion Factors of 0.25 or 0.17. The conversion factor eventually used was 0.2, ie damaged grains were taken to be 20% lighter than undamaged grains on average. The observed proportion of damaged grains varied widely (0-22%) although the average for recovered sacks was 2.9%. This average figure and the conversion factor suggest an average weight loss to insects of 0.6% and it is probably reasonable to state that losses to insects in the millet in the study were less than 1%.

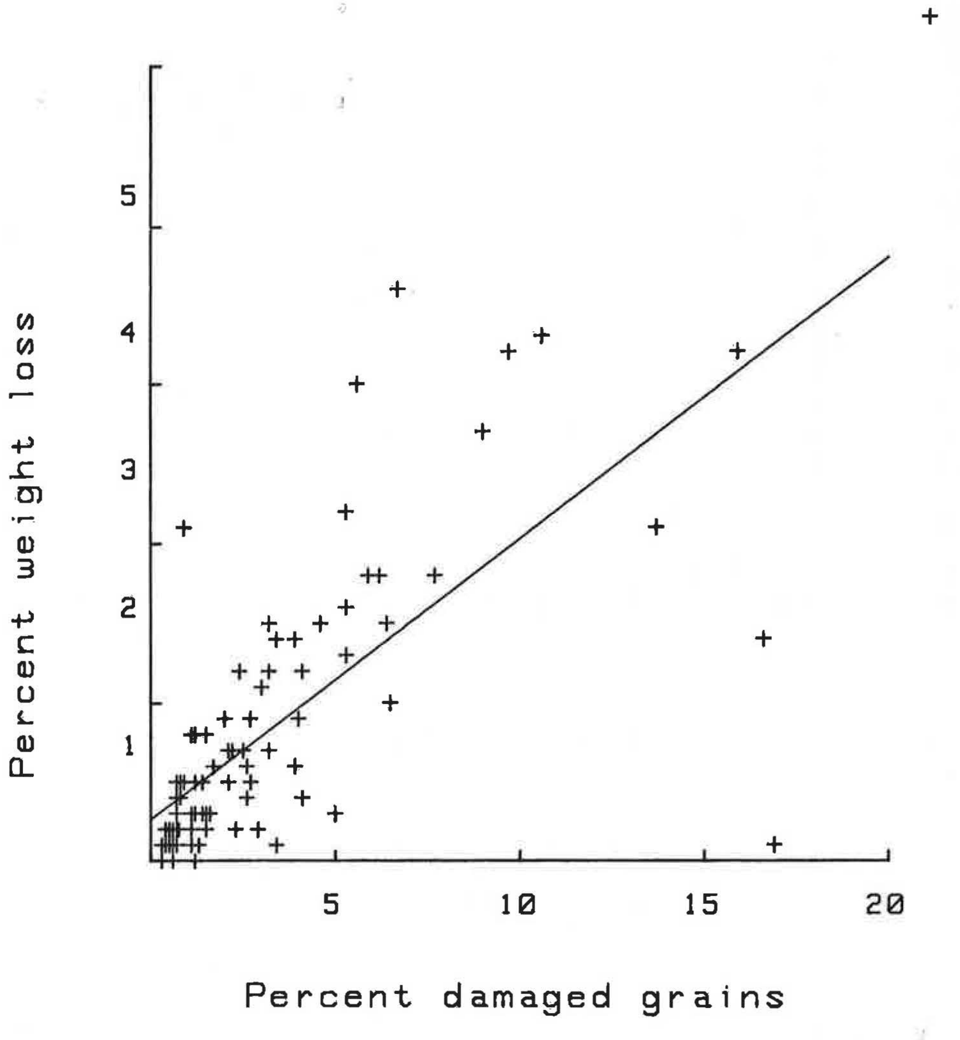

Fig. 6 The correlation between weight loss % and insect damaged grains %, for millet, in this survey: (r = 0.74, n = 92)

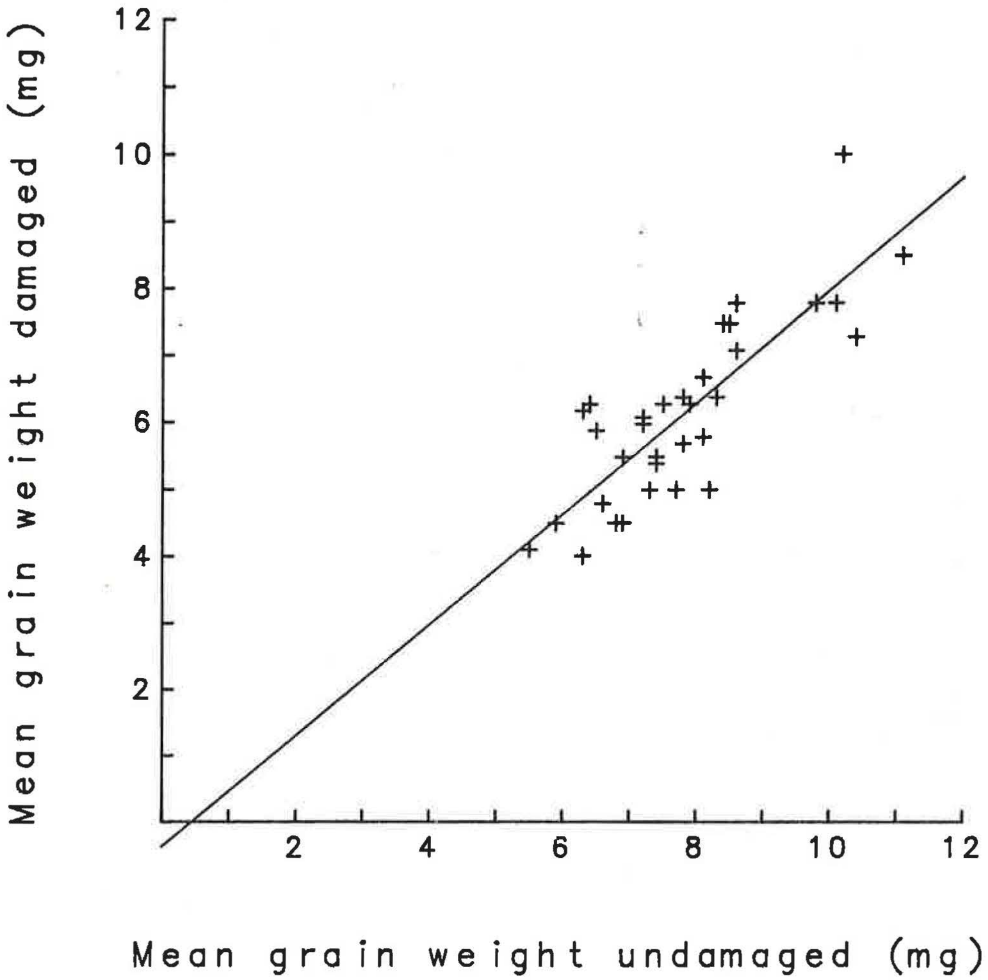

Fig. 7 The correlation between the mean weights of damaged and undamaged grains for selected samples: ($r = 0.825$, $n = 33$)

Insect infestation. Insects were observed at low levels at all study sites. Forty-seven of the 207 sacks examined at the moment of purchase were found to contain live insects. *Rhyzopertha dominica* and *Tribolium castaneum* were the most common (Table 2). Infestations were observed to become more widespread and more severe during storage and infestation by *Trogoderma* sp apparently began in store after purchase. The short duration of the storage season, the harsh climate and the work of the marketing board's pest control team meant that infestations did not become very severe and losses to insects were thus contained at the low levels indicated above.

Table 2 Sacks of millet % found to be infested by particular species and by any species

Insect species	% at intake (Feb-April)	% ultimately (Oct-Nov, after storage)
Tribolium castaneum	12.7	24.5
Rhyzopertha dominica	9.7	25.5
Trogoderma sp	1.0*	22.6
Corcyra cephalonica	1.9	17.0
Cryptolestes spp	3.4	6.6
Oryzaephilus surinamensis	0.5	Nil
Latheticus oryzae	Nil	1.9
Psocoptera (*indet.*)	Nil	5.7
Heteroptera (*indet.*)	1.4	7.5
Any species (1 or more)	22.7	57.5
Actual number examined:	207 (= 100%)	106 (= 100%)

* Found in sacks that had been used before and may have been carrying this infestation

Spillage. Spillage of millet is a serious problem and sweeping up spilled grain a continuous pre-occupation for store-keepers. Rough handling and overfilling cause damage to sacks, which may also be cut by petty thieves. Twenty percent of recovered sacks had noticeable holes or broken seams. Spillage is a source of loss in itself and may encourage theft and insect or rodent infestations.

Millet quality. The most important aspect of the quality of the millet observed was the level of fine impurities; sand and dust. The overall average level of impurities, of which fine impurities were by far the most abundant, was 10.1%. The range of levels was wide; from less than 1% to more than 30%, with some areas apparently producing significantly cleaner grain than others. Those areas supplying the largest quantities of millet were also those from which the highest levels of impurities were received. The occasional appearance of extremely high levels, sometimes including large quantities of rock or lumps of soil, suggests that deliberate contamination sometimes occurs. Quality could be improved and savings might be made on transport if millet were cleaned. Cleaning operations would be most effective, in reducing the total quantities of impurities in the system, if they were carried out in those areas that supply large quantities of millet containing high levels of impurities. Cleaning would also have some effect in reducing initial insect infestations. The introduction of a more formal quality control programme is not necessarily advisable because of the lack of necessary resources and the difficulties that a marketing board may face in attracting grain sales.

Moisture content. The millet was found without exception to be very dry. Grain coming into store in February and March had a moisture content of about 8% while that leaving store between October and December (after the rains) had about 10% moisture content. There were no significant differences in moisture content of millet coming into store from different sources. Grain held in store for long periods would probably follow a cycle of drying from October to April, then increasing in moisture content again from May to September. At all times, moisture contents of local millet were well below the maximum recommended for safe storage.

Conclusions

Sampling bagged grain. When dealing with bagged produce, a bag is an obvious sampling unit but it may be more reliable to treat large groups of bags as separate units. This will be the case particularly where there is considerable variation of quality between sacks or when grain may be lost from sacks but not subsequently from the food handling system; eg by spillage which is later recovered. If biological causes of loss (eg insects, mould, rats etc) are thought to be of major importance it may be more reliable to examine losses using a whole store as a unit. Representative sampling of a store containing bagged produce is not usually possible since each sack in the store does not have an equal chance of being in the sample. It would be necessary to sample bags, as they became accessible, when stacks were broken down. Initial examination and final re-examination of a sufficient number of bags, selected with reasonable randomness and marked for identification, provides a system of great potential value especially if such a system can be coupled with the monitoring of spillage in the store being studied.

Analysis of millet quality. Millet can be sampled successfully using a Produce Flow Sampler and sieved adequately using a TPI Produce Inspection Sieve. Dividing samples down to quantities of grain that can be examined by visual inspection is laborious. Each reduction is a simple division by two and there is a need for techniques that produce a greater reduction with each operation. Great variation in individual grain size and the small weight of millet grains make it essential to use large samples (more than 1000 grains) for loss assessment methods that involve counting and weighing grains. This means that considerable effort and time are needed for any such analysis and the final accuracy of the weight loss estimates may not repay the expenditure of resources. Careful examination of the use to which the estimates of loss are to be put should be made before resources are committed to hand-sorting analyses. The TGM method offers a simplification of the sample analysis procedure by generally eliminating the need to score and separate different categories of grain. It may be useful where very large numbers of grains can be counted easily. The measurement of bulk density has no application in quality determination or loss assessment for millet.

Loss assessment in a marketing board. The responsibility of a storekeeper to grain in his store is utterly different from that of farmers to their own stored grain. Attempts must be made to understand the storekeeper's attitude to the grain in his charge so that losses can be better assessed in terms of potential improvements to the system and so that the degree and nature of likely interest or co-operation in a loss assessment exercise can be estimated. Attitudes towards losses and suggested loss reduction measures will vary and it can never be reliably assumed that it is in a storekeeper's interest to reduce any particular loss or adopt any particular loss reduction measure.

Loss assessment exercises in general. This project shows clearly all the problems of loss assessment exercises. The resources available were barely sufficient to allow more than a pilot study. This presented a continuous problem, during planning, as to whether work should be concentrated into an exercise of narrower scope, producing more detailed results, or spread into a wider survey producing more general observations. The research team believed at the outset that the application of standard techniques would produce accurate estimates of loss and opted to concentrate their efforts into a smaller study so that sufficient work could be put into using these techniques. However, the difficulties of working in the marketing system and the difficulties of working with millet meant that the data collected were of little absolute value or were of limited application. The important observations on the levels of impurities, the numbers and species of insect present, handling techniques, storage practices, sack quality, scale of theft and the attitudes of those responsible for preventing losses, might have been made in a more general exercise spread over a much wider area.

It is important that future loss assessment studies should produce, alongside quantitative observations of the physical characteristics of the system under study, qualitative observations on all relevant aspects of the biological, economic and social environment in which the system operates. It is a mistake to place too much emphasis on the collection of numerical data: it must be recognised that food loss is not simply a quantity waiting to be measured.

Acknowledgements

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