# THE ASSESSMENT OF LOSSES DUE TO INSECTS AND RODENTS IN MAIZE STORED FOR SUBSISTENCE IN KENYA

by

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**Abstract**

In Kenya maize in subsistence storage is liable to insect and rodent attack. The losses have been studied over several years and appropriate field survey techniques employing area, cluster and line sampling methods have been developed.

The techniques described in the literature, eg volumetric (bulk density) and gravimetric methods were found to be subject to variation from several sources and therefore not suitable in surveys covering widely varying conditions. Alternative methods were therefore developed and are described in this paper. By the use of these techniques the annual loss in subsistence maize due to insects was found to be 4.54 per cent and that due to rodents 1.45 per cent. This loss of approximately 6.0 per cent is equivalent to US $12 million.

**Résumé**

Au Kenya, le maïs mis dans les entrepôts de subsistence est susceptible d'être attaqué par les insects et les rongeurs. Depuis plusieurs années, les pertes subies ont été étudiées et des techniques appropriées d'études sur le terrain, faisant intervenir des méthodes d'échantillonnage linéaire, groupée et sectorielle, ont été mises au point. Il s'est avéré que les techniques décrites dans les ouvrages publiés, par exemple les méthodes de volumétrie (densité apparente) et les méthodes de gravimétrie présentaient des différences suivant les sources et n'étaient, par voie de conséquence, pas appropriées pour des études réalisées dans des conditions extrêmement variables. D'autres méthodes furent donc mises au point et font l'objet d'une description dans le présent document. Du fait de l'adoption de ces techniques, les pertes annuelles en maïs de subsistance imputables aux insectes furent chiffrées à 4,45 pour cent et celles imputables aux rongeurs à 1,45 pour cent. Ces pertes -quelque 6 pour cent- représentent un équivalent de 12 000 000 de $ américains.

**Resumen**

En Kenya, el maíz almacenado para la subsistencia está expuesto a los ataques de insectos y roedores. Las pérdidas producidas se han venido estudiando durante varios años y, como consecuencia de las mismas, se han perfeccionado técnicas apropiadas para la evaluación de terrenos, utilizando métodos de muestreo por zonas, grupos y líneas. Las técnicas descritas en el material impreso, por ejemplo: los métodos volumétricos (densidad en masa) y gravimétricos, se comprobó que se hallaban sujetos a variaciones producidas por diferentes motivos, por lo cual no resultaban apropiadas en los estudios que abarcaban condiciones sumamente variables. Así pues, se perfeccionaron métodos alternativos, los cuales se describen en este artículo. Mediante el uso de dichas técnicas, se pudo comprobar que las pérdidas anuales de maíz de subsistencia debidas a insectos fueron de un 4,45 por ciento, mientras que las debidas a roedores fue de un 1,45 por ciento. Esta pérdida de aproximadamente un 6,0 por ciento equivale a 12 millones de dólares USA.

## Introduction

Maize is the staple food in Kenya of the majority of the population and plays a key role in the country's nutrition, agriculture and economy. Losses are caused mainly by insects and rodents. In most years moulds are not a problem, although the erratic rainfall pattern in 1977 and 1978 (almost continuous rain) caused drying problems and enhanced mould growth.

The assessment of losses in maize in Kenya has never been fully quantified although some 'guesstimates' have been given (Hall, 1970; Wheatley, 1973). In 1970, a survey of losses was carried out in which several techniques were investigated. This work (De Lima, 1973) also indicated the lines along

which future investigations on loss assessment in general should follow. These ideas were subsequently considered by other workers (Adams and Harman, 1977) and also developed further by the author (De Lima, 1975, 1977, 1978 and 1979c). The abridged results discussed here are part of the data accumulated during several years of work. The approach adopted is described, how the data was obtained is explained and examples of figures are given in order to show how the final tables on loss were derived. Of necessity the many practical difficulties and the manner in which these were overcome are left unmentioned. The author would be prepared to provide further details on request.

### Planning the Study

The philosophy behind the loss study exercise, the sampling programme, the establishment of priority areas for work and the handling of data are described in more detail elsewhere (De Lima, 1975, 1977, 1978, 1979a, 1979b, 1979c.)

### The Surveys

As a result of a great deal of survey work done in 1970 (De Lima, 1973) a fairly clear idea of the problem was obtained. Subsequently three surveys were done over the 1975-76 period employing different sampling frames. In the 1973-74 survey a 7 x 7 Latin Square was superimposed over a map of the area surveyed to obtain sample stores. This was followed in 1974-75 with a cluster sampling technique and in 1975-76 a line sampling technique was adopted using a vehicle and stopping at fixed distances along the road. All the three methods were found useful although the last method was found to give lower values for loss because it was biased towards the more progressive farms along the road, but its sampling costs were the lowest.

### Sampling within stores

At every examination, on every farm, 10 maize cobs were collected. A number was pre-selected from a table of random numbers. Then a rough visual estimate was made of the number of cobs in store; this guess was divided by 10 and added successively nine times to the pre-selected number to give a list of 10 numbers. The store was then emptied of cobs, counting one by one, and the cobs corresponding to the listed numbers put on one side as the sample for that store. Handling the cobs in this way causes considerable disturbance so the store was never examined more than once in a season.

On subsequent sampling occasions a new set of stores was therefore selected at random in each area (this procedure is analogous to sampling without replacement).

**Table 1** **Percentage loss in weight under various categories of causes in untreated grain (1973-74)**

| | *S. zeamais* Larva | *S. cerealella* Larva | *S. zeamais* 1 Adult | *S. zeamais* 2 Adults | *S. zeamais* 3 Adults | *S. zeamais* 4 Adults | *S. zeamais* 5 Adults | *S. cerealella* 1 Adult | *S. cerealella* 2 Adults | *S. cerealella* 3 Adults | *S. zeamais* 1 Adult + *S. cerealella* 1 Adult | Destroyed | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| At Harvest | | | | | | | | | | | | | |
| KAKAMEGA | 0.03 | | 0.18 | 0.12 | | | | | | | | | 0.33 |
| MERU | 0.54 | | 0.08 | | | | | | | | | | 0.62 |
| KIANYAGA | 0.68 | | | | | | | | | | | | 0.68 |
| KERICHO | 0.42 | | 0.27 | 0.13 | | | | | | | | | 0.82 |
| EMBU | 0.44 | | 0.07 | | | | | | | | | | 0.51 |
| KISII | 0.12 | 0.45 | 0.30 | | | | | 0.09 | | | | | 0.96 |
| KITALE | 0.01 | | 0.29 | | | | | | | | | | 0.30 |
| 9 Months after Harvest | | | | | | | | | | | | | |
| KAKAMEGA | 0.56 | 0.84 | 2.47 | 3.70 | | | | 1.21 | 0.42 | | 0.11 | 2.68 | 11.99 |
| MERU | 1.75 | 1.01 | 6.26 | 4.70 | | 0.38 | | 1.41 | 0.25 | | | 2.98 | 18.74 |
| KIANYAGA | 1.55 | 0.00 | 3.11 | 1.89 | | | | 0.09 | 0.01 | | 0.01 | | 6.66 |
| KERICHO | 0.86 | 3.00 | 2.71 | 1.42 | 0.13 | 0.05 | 0.07 | 3.88 | 1.51 | 0.50 | 0.19 | 1.59 | 15.91 |
| EMBU | 2.64 | 1.43 | 2.99 | 1.94 | | 0.04 | | 0.98 | 0.15 | | | 2.01 | 12.20 |
| KISII | 0.59 | 1.10 | 1.76 | 1.53 | 0.35 | 0.14 | 0.04 | 2.13 | 1.94 | 0.36 | 0.10 | 2.90 | 12.94 |
| KITALE | 0.24 | 1.61 | 1.84 | 1.29 | | | | 4.24 | 1.13 | | 0.10 | | 10.45 |

**Examination of samples in the laboratory**

Every cob was inspected in the field as collected and weevil emergence holes and moth windows counted. Approximately 500 cobs were examined in each district on each sampling occasion in this way. A proportion of these cobs (approximately 10 per cent) was taken to the laboratory for further examination. In the laboratory the grain obtained from each cob was weighed and divided with a seed sampler to give a quarter or an eigth of the kernels. These were dissected after soaking overnight and staining (to detect egg plugs) and all immature stages were removed and classified. The remaining kernels were weighed and kept in a CT room at 27°C and 70 per cent R H. Five of the latter samples were sieved every 2 days for at least 6 weeks to give a net estimate of loss. Sieving then ceased when no weevil or moth emerged in 3 successive counts. Then the sample was weighed: the kernels were examined individually and grouped into categories by the numbers and kind of hole found. Each group was weighed and the numbers of kernels in them counted and the average weight of each category calculated on a dry weight basis after removal of frass, exuviae etc. The other 40-45 samples not treated in this way were sieved at weekly intervals for 5 weeks then weighed and the number of kernels counted. Between 80-120 grains were then obtained by a coning and quartering technique and were individually examined to give a damage profile.

Statistical analysis indicated significant difference ($P < 0.001$) between places and between damage categories and reflected the effects of environment on the rate of pest development. Significant differences ($P < 0.05$) recorded for samples taken through the storage period indicated that seasonal climatic effects also had a direct bearing on the amount lost. More was lost (per grain) in the same place per insect in the cool than in the hot season.

**Estimation of Loss (1973-74)**

To calculate the losses caused, the estimates obtained from samples for holed grains were applied to all the kernels from that region. For immature stages the damage was taken as half that caused by a single adult of the same species. This will slightly bias the estimation figure because less damage is done when two or more larvae develop in the same kernel.

The values for loss in weight were calculated by multiplying the respective proportions (numbers per 100) of kernels in each category and adding. For example, loss at harvest due to one *Sitophilus zeamais* larva in Meru 1973-74 (Table 1) was obtained by taking:

i. the figure for percentage weight loss due to one *S. zeamais* larva (in Meru), ie 6.82, and

ii. the figure for percentage of grains showing one *S. zeamais* larva ie 7.96 and calculating the loss in weight as:

$$\frac{6.82}{100} \times 7.96 = 0.54 \text{ (Table 1)}$$

The loss estimates made in this way for all categories of damage in the sample, were summed up into a total loss column for each district at each sampling period. Data for loss at harvest and 9 months after are given in Table 1.

**Stratification for loss in treated and untreated grain**

During the surveys it was noticed that relatively many farmers were using some form of insecticidal treatment. The amount of damage in these treated grains was generally less than in untreated grains but was not negligible no doubt because of poor and insufficient application of the pesticides. A record was kept of the damage in treated grains as a percentage of the untreated and this figure was used to evaluate the loss in treated grains over the season.

**The amount of food remaining in store on each sampling occasion**

As each sample store was emptied, a good estimate of the quantity of grain remaining in store was made from the samples collected. It was not possible to weigh the entire contents of the store but sample estimates were reliable because an accurate measure of cob weights was obtained from the samples and the exact number of cobs in the store was known once it was emptied. The quantity of food remaining in store was thus estimated for each sample store on every occasion.

Since there was variation between the quantities stored by individual farmers, rates of consumption were calculated from the data using regression analysis of variance techniques and the quantity remaining at each point in time for each area calculated from the regression line.

**Table 2** **Estimated loss in the western province of Kenya in 1973-74**

| | Amount tonnes | Amount treated tonnes | Amount untreated tonnes | Loss treated tonnes | Loss untreated tonnes | Total Loss tonnes |
|---|---|---|---|---|---|---|
| At Harvest | 246,167 | 7,385 | 238,782 | 24 | 788 | 812 |
| After 3 months | 161,486 | 45,216 | 116,270 | 520 | 3,802 | 4,322 |
| After 6 months | 76,804 | 33,025 | 43,779 | 1,139 | 2,916 | 4,055 |
| After 9 months | 2,462 | 1,452 | 1,010 | 82 | 121 | 203 |
| Total Loss | | | | | | 9,392 |
| % Loss in weight | | | | | | 3.82% |

**Table 3** **Summary of losses due to insects 1973-76**

| | 1973-74 | | 1974-75 | | 1975-76 | |
|---|---|---|---|---|---|---|
| | Total loss tonnes | Percentage loss | Total loss tonnes | Percentage loss | Total loss tonnes | Percentage loss |
| Western Province | 9,392 | 3.82 | 13,149 | 6.29 | 11,503 | 3.73 |
| Nyanza Province | 6,287 | 5.38 | 5,161 | 4.14 | 3,926 | 2.89 |
| Rift Valley Province | 26,375 | 7.00 | 39,829 | 6.89 | 33,906 | 4.24 |
| Central Province | 5,909 | 3.28 | 7,460 | 3.37 | 7,531 | 3.31 |
| Eastern Province | 15,192 | 5.40 | 14,058 | 4.88 | 8,395 | 3.46 |
| Average National loss % (± S.E.) | | 4.98±0.74 | | 5.11±0.73 | | 3.53±0.25 |
| Total harvest estimate (tonnes) | | 1,461,382 | | 1,859,673 | | 2,268,860 |
| Total loss (tonnes) | | 72,777 | | 95,029 | | 80,091 |
| Range of losses (tonnes) | | 61,963 - 83,591 | | 81,454 - 108,605 | | 74,419 - 85,763 |
| Value K.Shs. (millions) (at Sh.800/- per (tonne) | | 49.6 - 66.9 | | 65.2 - 86.9 | | 59.5 - 68.6 |

Annual average loss due to insects over 3 years = 66.1 million K.Shs.
(approximately 4.5 million £ sterling; 8.8 million U.S. $)

**Estimation of loss in the Provinces in treated and untreated grain**

A record was also kept of the percentage of farmers with treated grain and it was noticeable that the percentage of farmers holding treated grain increased in the 3rd and 6th month after harvest. By the 9th month the percentage of farmers with treated grain was still high because farmers who expect to store for that length of time are invariably the more wealthy and therefore protect their grain well in advance.

The amount of grain harvested in each province was estimated from the annual crop returns in each area, and by using the estimates obtained in the survey for the quantity in store on each sampling occasion, the quantity of the harvest remaining in each province was obtained.

The estimates for the proportion of the grain treated on each occasion were used to separate the losses caused in each and the final loss figures were calculated for each province. Data for the Western Province are given in Table 2.

**Table 4** **Losses due to rodents calculated from regression estimates**

| Province | Loss | 1973-74 | 1974-75 | 1975-76 |
|---|---|---|---|---|
| Western | Total (tonnes) | 1935 | 4403 | 1990 |
| | percent | 1.79 | 2.11 | 0.94 |
| Nyanza | Total (Tonnes) | 1705 | 825 | 1520 |
| | percent | 1.46 | 0.66 | 1.12 |
| Rift Valley | Total (tonnes) | 5683 | 11548 | 14564 |
| | percent | 1.51 | 2.00 | 1.82 |
| Central | Total (Tonnes) | 3173 | 3446 | 2976 |
| | percent | 1.76 | 1.56 | 1.31 |
| Eastern | Total (tonnes) | 4573 | 4870 | 3412 |
| | percent | 1.63 | 1.69 | 1.41 |
| Average % wt. loss ± Standard error | | 1.43 ± 0.18 | 1.60 ± 0.29 | 1.32 ± 0.17 |

**Estimation of Country Loss**

The three separate surveys covering the 1973-76 period gave estimates of annual loss due to insects (Table 3) as 4.98, 5.11 and 3.53 per cent. This represents the average annual weight loss due to insects as 4.54 per cent. Since the samples taken on each occasion were entire cobs, losses due to rodent feeding could be determined from partly eaten grain. Grain entirely missing from the cob was also largely attributed to rodents. The decline in the average number of grains per sample was significant and directly related to time ($P < 0.05$). Linear regressions calculated to give the amounts of grain lost to rodents (Table 4) provided an annual average estimate of 1.45 per cent. The combined annual losses in maize due to insects and rodents at the subsistence level is therefore nearly 6.0 per cent. In monetary terms this is equivalent to approximately 12 million US dollars. Kenya is a net exporter of maize and so these losses represent potential foreign exchange earnings. More important however, for rural health, is the nutritional loss both of quality and quantity, and yet more than four-fifths of these losses could be avoided by the use of simple preventative measures.

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