Rapid assessment methods for stored maize cobs: weight losses due to insect pests

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Accepted 31 March 1998

Abstract

This paper describes a new method for the assessment of weight loss due to insect pests in stored maize cobs. The method involves scoring each cob in the sample on a visual damage scale and then using a simple equation to estimate overall sample weight loss. The coefficients in the equation are determined in advance of field work by calibrating the visual scale against a laboratory loss assessment technique. The visual scale method was found to be rapid, simple and had many advantages for on-farm work. Precision of the results was shown to be similar to that of existing weight loss assessment methods. © 1998 Elsevier Science Ltd. All rights reserved.

Keywords: Loss assessment; Maize; Visual scale; On-farm storage; Post-harvest; Ghana

1. Introduction

Data on stored food losses are needed for several reasons, including evaluating the impact of new varieties and pests, and estimating the potential benefits from new storage technologies. Although a number of methods already exist for the assessment of weight losses in stored grain (see Harris and Lindblad, 1978; FAO, 1983; Boxall, 1986; Reed, 1986; Pantenius, 1988; Irshad and Iqbal, 1991; Ratnadass and Fleurat-Lessard, 1991), most of these are relatively slow and demand specialised staff and equipment. A number of authors, for example FAO-PFL (1990), have called for the development of simpler methods which are suitable for use in rapid surveys and participatory rural appraisal.
This paper describes a rapid weight loss assessment method for cob maize based on a visual scale of damage, presents results on the precision and bias of the method, and finally discusses its practical advantages, based on extensive field experience in Ghana.

2. Methods

2.1. Development of the visual scale

A four-class damage scale was developed in Togo (Compton, 1991) which was later modified, in Ghana, to a five-class scale and then finally to a six-class scale. In all cases, the scale was defined by a group of field workers, who sorted and re-sorted a pile of insect-damaged maize into visual classes which roughly reflected farmer use categories (Table 1), until a consensus was reached about the limits of each class. Reference photographs were taken of each class.

2.2. Calibration of the scale to determine weight loss

The model used to estimate loss using the six-class scale is shown in Eq. (1).

\[
\text{Visloss} = \frac{aN_1 + bN_2 + cN_3 + dN_4 + eN_5 + fN_6}{NT}
\]

where:

- \( \text{Visloss} \) is the weight loss estimated using the visual scale,
- \( N_1 \)–\( N_6 \) = Number of cobs in classes 1 to 6 in sample,
- \( NT \) = Total number of cobs in sample
- \( a \)–\( f \) are damage coefficients for each class

Table 1
Description of visual scale categories and farmer use in Eastern Ghana

<table>
<thead>
<tr>
<th>Class</th>
<th>Damage level</th>
<th>Description and use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Undamaged.</td>
<td>For food or seed.</td>
</tr>
<tr>
<td>2</td>
<td>Slight damage.</td>
<td>A few infested grains. Always acceptable for food and usually mixed with Class 1.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sells at top price. May be used for seed after hand-cleaning.</td>
</tr>
<tr>
<td>3</td>
<td>Slight–moderate damage.</td>
<td>Less than about half the cob infested. Acceptable to farmers and traders for mixing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with Class 1 and 2, if in small proportion. Otherwise may be shelled selectively by</td>
</tr>
<tr>
<td></td>
<td></td>
<td>hand, separating good from bad grains, or occasionally mixed with Class 4.</td>
</tr>
<tr>
<td>4</td>
<td>Moderate damage.</td>
<td>More than about half the cob infested, but still with some areas of good grains on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cob. Acceptable for human food by poorer groups and in lean seasons. Rarely mixed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with good maize and only for immediate consumption. May be shelled selectively or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mixed with Class 5.</td>
</tr>
<tr>
<td>5</td>
<td>Severe damage.</td>
<td>Over about 90% of the cob infested. Normally animal feed; used for human food only</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in time of scarcity, when it is mixed with higher grades. Still saleable in certain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>conditions, at low price.</td>
</tr>
<tr>
<td>6</td>
<td>Very severe damage.</td>
<td>Cobs thrown away by farmer and unsaleable. Very little food value, even for animal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>feed.</td>
</tr>
</tbody>
</table>
Table 2  
Results of replicability test

<table>
<thead>
<tr>
<th>Maize batch (1)</th>
<th>Pair of scorers (2)</th>
<th>Total cobs scored</th>
<th>Disagreement (% cobs scored differently)</th>
<th>Total 30-cob samples scored</th>
<th>Mean calculated weight loss of batch using Eq. (2)</th>
<th>Mean bias (1st–2nd scorer) (3)</th>
<th>S.D. of estimated weight loss (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>A-B</td>
<td>480</td>
<td>8%</td>
<td>16</td>
<td>14.1%</td>
<td>−0.38% n.s.</td>
<td>0.78%</td>
</tr>
<tr>
<td>1b</td>
<td>A-C</td>
<td>60</td>
<td>0%</td>
<td>2</td>
<td>16.4%</td>
<td>0.000 n.s.</td>
<td>0.0000</td>
</tr>
<tr>
<td>2</td>
<td>B-D</td>
<td>180</td>
<td>1%</td>
<td>6</td>
<td>1.1%</td>
<td>−0.04% n.s.</td>
<td>0.08%</td>
</tr>
<tr>
<td>Overall</td>
<td>Overall</td>
<td>720</td>
<td>5%</td>
<td>24</td>
<td>11.1%</td>
<td>−0.26% n.s.</td>
<td>0.64%</td>
</tr>
</tbody>
</table>

Notes: (1) Batches 1a and 1b—Local white variety ‘Fodome’ showing damage mainly from *Sitophilus* spp. and *P. truncatus*. Batch 2—High yield- ing flinty variety ‘Obatampa’ with slight damage, mainly from earworms. (2) Each letter (A–D) stands for a particular laboratory worker. (3) Mean bias = mean for samples in batch of Σ(wgt loss1—wgt loss2). n.s. = not significant at 5% level (4) SD = standard deviation, which is the variation between scorers averaged over each batch.
The scale was calibrated against a laboratory-based loss assessment methods to determine damage coefficients $a$ to $f$. Three steps were involved in calibration.

### 2.2.1. Preliminary estimate of coefficients

Fifty cobs were selected randomly from each damage class and weight loss was measured individually for each cob using a modification of the count and weigh technique (Boxall, 1986), in which the missing and destroyed grains on each cob were counted and the calculation adjusted to take account of these. The mean weight loss for each damage class was used as a preliminary estimate of the coefficient for that class. Two batches of white maize were used: a local Ghanaian floury variety (‘Kwadzeto’) and a high-yielding dent variety (‘Abeleehi’).

### 2.2.2. First-round model checking

The model for estimating $Vis\text{loss}$ obtained in step 1, was checked using a single batch of maize (variety ‘Kwadzeto’), consisting of 32 samples containing 20 cobs each, infested by a pest complex dominated by *Prostephanus truncatus* (Horn). For each sample, two estimates of weight loss were made: $Vis\text{loss}$ and $Wgt\text{loss}$. $Vis\text{loss}$ was estimated using the visual scale and Eq. (1) with the preliminary coefficients, while $Wgt\text{loss}$ was estimated using the modified count and weigh method (Compton et al., in press). $Vis\text{loss}$ was then plotted against $Wgt\text{loss}$, with each point representing a single sample. The fit between $Vis\text{loss}$ and $Wgt\text{loss}$ was quite good, but it was obvious from inspection that it could be improved by adjusting the coefficients slightly. An iterative graphical method was adopted in which the coefficients were repeatedly adjusted within reasonable ranges (i.e., close to the measured weight losses for cobs in each class) to give the best visual fit between $Vis\text{loss}$ and $Wgt\text{loss}$.

### 2.2.3. Second-round model checking

The revised coefficients obtained from step 2 were further tested against data from other cob samples obtained from a variety of sources, including trials and farmers’ stores, to see how
robust the equation would be with different varieties and types of pest damage (described in Table 3). For each batch, Visloss was plotted against Wgtloss. The coefficients were further adjusted, as above, and finally simplified to round numbers.

2.3. Determining replicability, precision and accuracy of results

After finalising the coefficients, a test was carried out to verify the replicability between scorers of results obtained using the scale. Visual scoring was carried out for three batches of maize in the course of storage trials; details of each batch are given in Table 2. Two workers scored each sample independently.

Mean biases and standard errors for the estimate of weight loss obtained using the visual scale equation were calculated for several different batches of maize described in Table 3, using inverse regression prediction (Draper and Smith, 1981) with Genstat 5.3 software (The Numerical Algorithms Group Ltd., Oxford, UK). The bias was calculated for each sample within a batch as the difference between the predicted value using the visual scales (Visloss) and the measured loss using the modified count and weigh method (Wgtloss). A t-test was performed to determine whether the mean bias for each batch differed significantly from zero. Standard errors for prediction of weight loss estimates (SEs) were calculated as the square root of the mean square error (MSE) of each batch. MSE = \frac{0.5 \cdot (Wgtloss - Visloss)^2}{N_T}$, where $N_T$ is the number of samples in the batch.

3. Results

The final scale had six classes. Damage classes 2–5 are illustrated in Fig. 1; typical ‘best’ and ‘worst’ cobs are shown for each class. Class 1 was defined as undamaged and Class 6 as damage worse than the worst of Class 5.

The final set of simplified coefficients developed for the batches of maize examined is shown in Eq. (2), where the symbols have the same meaning as in Eq. (1).

\[
\text{Visloss} = \frac{0\%N_1 + 2\%N_2 + 15\%N_3 + 30\%N_4 + 50\%N_5 + 80\%N_6}{N_T}
\] (2)

In the field, the scale is used by taking a sample of maize cobs from the store to be assessed (see Boxall 1986 for a discussion of sampling); each cob is dehusked (if necessary) and tapped on a tray to dislodge any dust; and the damage class of each cob is then scored using reference photographs such as those shown in Fig. 1. The weight loss in the sample can be calculated on the spot by tallying the cobs in each damage class and using Eq. (2) (or a similar equation obtained by local recalibration). The cobs can then be returned to the farmer. Sampling and scoring take less than 10 min for a 30-cob sample.

Fig. 2 shows a typical example of the relationship between the weight loss estimated using Eq. (2) (Visloss) and measured weight loss (Wgtloss), based on data from maize batch 1, described in Table 3. It can be seen that Visloss is highly correlated ($r^2 = 0.82$) with Wgtloss, with no significant bias: i.e. the slope and intercept of the regression line are not significantly different from 1 and 0 respectively.
Fig. 1(a and b). Caption on facing page.
Fig. 1. (c and d) Typical ‘best’ and ‘worst’ cobs for classes 2–5 of visual scale: (a), Class 2; (b), Class 3; (c), Class 4; (d) Class 5.
Table 2 shows the results of the test of replicability between scorers. On average, only 5% of scores for individual cobs differed between scorers. Where disagreements in scoring were noted, these were only by one scale class, with only three exceptions (0.4% of all cobs scored) where scores differed by two classes. The overall correlation coefficient between scores was 0.99 (or slightly lower, 0.93, if the batch of maize scored by pair B–D, which had very low weight loss, was omitted). The overall standard deviation due to variation between scorers was 0.64%, which is very low. No significant systematic bias by individual scorers could be discerned.

Table 3 shows, for each maize batch tested, the mean biases and standard errors associated with the use of the simplified predictive equations. There was significant bias ($p = 0.002$) in only one batch, and this bias was very small (0.7%). Average SEs using the scales were between 0.9 and 4.5% weight loss for a single sample. This is comparable with the precision in estimates produced by other methods of weight loss assessment (Reed, 1986). For some batches, there was evidence that SEs increased with the magnitude of losses when these were over 20% (Fig. 2), but such high losses are rarely found in farm stores (Compton et al., 1993). Hence, a standard error of around 3% is probably realistic for most uses of the scale.

4. Discussion

Several features distinguish the visual damage scale described in this paper from other damage scales developed for stored maize (Helbig, 1995; P. Giles, personal communication). First, it was based on farmer use categories (Table 1) rather than the arbitrary numerical categories (e.g. 1–10 and 11–20% damaged grains) used by the other scales cited. This made...
the scale intuitively easier for rural users to grasp, and also made possible a subsequent study which related the scale to the market value of the maize (J.A.F. Compton, P.A. Magrath and A. Ofosu, unpublished data). Secondly, a single scale was used to represent the combined damage from different pests. This was partly to reflect farmer practice (farmers look at damage as a whole) and partly because using separate scales for different pests and adding the results tends to give overestimates of total loss (Jago, 1993). Thirdly, scoring was based on overall damage as shown on a reference photograph, rather than on counting the percentage of damaged grains on the cob as done by Helbig (1995) and others. Visual scoring is not only a great deal more rapid than counting, but is likely to give a more realistic appraisal of losses where cobs are attacked by a variety of pests. For example, a percentage damage-based scale is likely to overestimate weight losses due to *Sitotroga cerealella* (Olivier), which normally only bores small holes, relative to losses due to *P. truncatus*, which can turn whole grains to powder, since in this type of scale all pests are presumed to produce the same average weight loss per grain.

It is shown in this paper that visual scale scores can be calibrated against a laboratory-based loss assessment method to produce an equation which can be used to transform the raw scale scores into a quantitative estimate of percentage weight loss. The precision of this estimate is shown to be comparable to the precision obtained using other common loss assessment methods, probably because most error is due to sampling cobs from store rather than to the assessment method itself, as also noted by Golob (1981) and Boxall (1986). Bias in estimation of weight loss was not observed with the maize and pest complexes examined, although it is possible that the method might underestimate loss in some situations, e.g. when most pest damage is concealed inside or beneath grains. The scale shown in Fig. 1 together with the coefficients in Eq. (2), have proved to be robust for use in Ghana. For use in new geographical areas, either the scale shown in Fig. 1 could be recalibrated to determine appropriate damage coefficients, or alternatively a modified visual damage scale, using new photographs and based on local levels and perceptions of insect damage, could be developed and calibrated as has recently been done in Kenya (J.A.F. Compton, J. Mbugua, C. Ngatia and B. Nyambo, unpublished data).

While this paper is directed towards use of visual scales in obtaining quantitative data on weight loss, it should be pointed out that visual scale data can also be analysed as scores, using cross tabulation and associated log-linear models, ordinal logistic regression (McCullagh, 1980) or proportional odds models. Variables such as the percentage of 'good' cobs (classes 1–3), which can be analysed by logistic models, are often more meaningful to farmers than weight loss (Magrath et al., 1996). The visual scale method has also been used in station trials as a supplement to more conventional loss assessment methods, in order to get a picture of cob to cob variation in damage. Individual cob by cob assessments of insects and damage can be of value in ecological studies and in studies investigating the effect of cob-specific factors such as husk cover (Compton et al., 1997).

In our experience, the visual scale method has numerous advantages over conventional loss assessment methods for on-farm use. It requires no special equipment, in contrast to other methods which require balances, sieves, and moisture testers. It is easily used by non-specialist staff, for example extension workers evaluating on-farm trials. It is suitable for rapid single-visit surveys (Compton et al., 1998, in press), in contrast to several other methods, for example
the thousand-grain mass and standard volume–weight methods (Boxall, 1986; Reed, 1986) and the sample weight method (Pantenius, 1988), all of which require undamaged baseline samples to be taken at the beginning of the storage season. The speed of use of rapid assessment methods such as visual scales means that increased sampling (e.g. of villages, farms, stores or cobs within stores) is possible, thus enabling wider coverage and/or reduced sampling error. Results are obtained on the spot, unlike other assessment methods which generally involve removing samples for assessment in a laboratory. This reduces the risk of samples being lost or spoilt during transport; eliminates laboratory and copying errors; and means that anomalous results can be double-checked before leaving the store. Instant feedback also maintains user interest and minimises the incentive for data fabrication by bored technical staff (Poate and Daplyn, 1993). The fact that the cobs are handed back to the owner after scoring avoids the problem of how to compensate farmers for any samples removed; this is a significant advantage for investigators on low budgets, and in areas where farmers have very little maize in store and are reluctant to sell samples. Finally, the use of the scales is ‘participatory’; stimulating the interest of farmers and generating their information and opinions. Participatory methods are likely to increase data quality as well as increasing farmers’ interest and involvement in the outcome of the research (Farrington and Martin, 1988).

Acknowledgements

The UK Department for International Development (formerly ODA), the UK Natural Resources Institute, the Post-Harvest Unit of the Ghana Ministry of Food and Agriculture and the Service de Protection des Végétaux, Togo financed and supported this work. The photographs in Fig. 1 were taken by Priscilla Magrath. Many thanks to them and to the numerous other people who helped, especially Blaise Agbo and other LGB project staff for lab work; Cliff Gay for statistical analyses of the earlier Togo data; James Compton, Chris Haines and an anonymous reviewer for comments on earlier versions; and Dr D. Agounké, Robin Boxall, Pete Golob, Priscilla Magrath, Tony Ofosu and Anna Stabrawa for their encouragement.

References


