# Dividing the harvest: an approach to integrated pest management in family stores in Africa

C. Henckes*

*Abstract*

Field trials were carried out in northern Tanzania to develop a concept for integrated pest management (IPM) to reduce the input of synthetic insecticides in family maize stores and to increase the potential impact of alternative control measures. Dry-weight loss, damage and insect pests were assessed in traditional maize stores. It was found that losses were much lower in stored shelled maize than in maize cobs. In shelled maize the economic loss was 4% of the value of the total stored maize and in cobs it was 28%. In shelled maize the 'key-pests' were *Sitophilus* spp., *Tribolium castaneum* and *Sitotroga cerealella*. *Prostephanus truncatus* was a pest in maize cobs only.

By comparing economic losses with the costs of insecticide treatment it is shown that recommended applications of synthetic insecticides in stored maize grains are economically not justifiable. Insecticide use can be optimised (reduced) by dividing the harvest into two parts before storage. One part, to be stored for longer is treated with insecticide: the other part is stored untreated. The sizes of the two parts of stored product can be determined by using the economic damage threshold. Furthermore, the insecticide-free part of the stored product provides a potential place for alternative control measures such as biological control with which chemical control is often incompatible.

## Introduction

In many African countries, on-farm food storage is essential for food availability throughout the year. In Tanzania about 80%, or 1.6 million t, of the total maize production is stored in on-farm systems (FAO 1986). They supply the households with food, animal feed and, in some cases, with extra maize for sale in times of financial need (Tyler 1985). The stored maize reserves frequently suffer losses as a result of insect pests and other damage. For pest control the actual official recommendations in Tanzania and other African countries say that all maize after harvest should be treated with synthetic insecticides before storage.

The use of these synthetic pesticides can be problematic. The wrong application of chemicals which often happens, especially at a smallholder level, can be very harmful to humans and the environment (Schwab 1989). For example, it has been reported several times that farmers use chemicals for seed dressing, antibiotics and dieldrin for pest control in their stored product (O. Mück and R. Harnisch, pers. comm. 1993). Chemicals or their ingredients have to be imported and paid for in foreign exchange. This is an additional expenditure for a country with an extremely limited budget. For some farmers the chemicals are too expensive. Furthermore, the distribution of the insecticides in Tanzania does not work sufficiently; they are not at the right place at the right time (FAO 1991). Resistant insect populations reduce the effectiveness of pesticides. Therefore, major research in the field of integrated pest management with reduced reliance on chemical control in farm stores is demanded (Dick 1990; McFarlane 1988). New control methods must be integrated into the existing systems. The integration of chemical, biological and other control methods can help to control pests in an economically efficient and environmentally sound manner.

The Tropical Pesticides Research Institute (TPRI), Tanzania, and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) have carried out field experiments from 1988 to 1991 in Tanzania in order to develop integrated pest management to reduce the input of insecticides in family stores and to increase the potential impact of alternative control measures.

## Dry-weight losses, Damage and Insect Pests

The dry-weight losses and damage of maize stored on farms were assessed in northern Tanzania using the count and weigh method (L'Agronomie Tropicale 1969).The maize was collected during two storage seasons, 1989/90 and 1990/91. In total, samples of maize from 40 stores were assessed. The maize was not treated with insecticides and was stored as cobs (ears with husks) (28 stores) and as shelled maize (12 stores).

Table 1 shows the mean cumulative dry-weight losses and damage of the stored maize grains and the stored maize cobs. The mean dry-weight loss of the shelled grains was 8% after nine months of storage. The low losses in the first storage months were especially remarkable. The losses of maize cobs were much higher: after nine months of storage the mean dry-weight loss amounted to 32%. Cobs and grains showed a similar damage percentage. In grains the mean damage was 64% and in cobs 63%.

The relative importance of pests as a cause of damage and dry-weight losses was estimated. Therefore, the relative number of pests (living adults) occurring in stores was multiplied with the coefficient of correlation between pests, damage and losses. It was found that *Sitophilus* spp. was significantly the most important cause of damage and losses in maize cobs as well as in grains (see Tables 2 and 3). Also *Prostephanus truncatus* was of relatively high importance (value: 7.7) as a cause of losses but only of maize cobs (see Table 2) whereas *P. truncatus* was not of any importance for shelled grains (see Table 3).

## Economic Losses and Costs of Insecticides

In addition to the loss of dry-weight, the economic loss due to pest infestation in stored maize was estimated. The economic

* Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), GmbH, OE 423, Post-Harvest Project, Postfach 5180, 65726 Eschborn, Germany.

**Table 1.** Mean cumulative damage percentage per month (% damage) and dry-weight loss percentage (% loss) in stored shelled maize grains and cobs (values in brackets).

| | Months after harvest | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| % loss [a] | 1 (1) | 1 (1) | 1 (3) | 1 (6) | 2 (8) | 3 (12) | 4 (17) | 7 (21) | 8 (28) | 8 (32) |
| % damage [a] | 2 (5) | 6 (6) | 13 (12) | 24 (24) | 41 (35) | 42 (44) | 50 (52) | 64 (56) | 66 (64) | 64 (63) [b] |

Source: Henckes 1992, revised.
[a]Assessed with the count-and-weigh-method.
[b]Values lower than values of previous month are due to experimental error.

**Table 2.** The relative importance of pests for damage and loss of stored maize cobs.

| Damage | | | Loss | | |
|---|---|---|---|---|---|
| Position | Species | Value[a] | Position | Species | Value[a] |
| 1 | *Sitophilus* spp. | 20.3 a | 1 | *Sitophilus* spp. | 26.9 a |
| 2 | *P. truncatus* | 1.9 b | 2 | *P. truncatus* | 7.7 b |
| 3 | *T. castaneum* | 1.3 bc | 3 | *T. castaneum* | 2.0 c |
| 4 | *S. cerealella* | 1.2 bc | 4 | *Carpophilus* spp. | 0.7 c |
| 5 | *Carpophilus* spp. | 0.1 c | 5 | *S. cerealella* | 0.4 c |

Source: Henckes 1992.
[a]Values are the product of the relative frequency of pests in stores and the coefficient of correlation between pests, damage and loss. Values followed by the same letter within one column are not significantly different in p=0.05 by Tukey-test.

**Table 3.** The relative importance of pests for damage and loss of stored shelled maize grains.

| Damage | | | Loss | | |
|---|---|---|---|---|---|
| Position | Species | Value[a] | Position | Species | Value[a] |
| 1 | *Sitophilus* spp. | 13.0 a | 1 | *Sitophilus* spp. | 16.4 a |
| 2 | *S. cerealella* | 2.8 b | 2 | *T. castaneum* | 2.6 b |
| 3 | *T. castaneum* | 0.8 c | 3 | *S. cerealella* | 0.9 c |
| 4 | | | 4 | *Carpophilus* spp. | 0.1 c |

Source: Henckes 1992.
[a]Values are the product of the relative frequency of pests in stores and the coefficient of correlation between pests, damage and loss. Values followed by the same letter within one column are not significantly different in p=0.05 by Tukey-test.

loss was expressed in terms of money and focused on the conditions on small farms. Five parameters were needed:

1. The data of dry-weight loss of maize in nine months of storage.
2. The maize prices—prices of the storage season 1989/90 were used (MALDC 1990).
3. The whole amount of maize to be stored (nine bags).
4. The amount of maize taken out of a store every month—it was assumed that a farm family removed an average of one bag per month from the store for consumption.
5. The costs of control—the treatment of one bag of maize (90 kg) with an insecticide cost Tanzanian shillings (Tsh) 100 (Tanganyika Farmers' Association Limited, pers. comm. 1991). The costs of control were constant at Tsh900 for the whole season (Fig. 1), since all stored maize (nine bags) was treated once at the beginning of the storage season following the official recommendation in Tanzania.

In the above described scenario, maize cobs valued at Tsh4514.were lost after nine months of storage (Fig. 1), which is equivalent to about 28% of the value of the total stored maize (Tsh16105—9 bags of maize × Tsh1789.4/bag). Starting from the fourth month after harvest, the economic losses of maize cobs were higher than the costs of insecticide control would have been. In this case, the use of insecticides would have resulted in a higher profit for the farmer. Shelled grains worth Tsh 664 at a maximum were lost, this is about 4% of the value of the stored maize. The costs of insecticide control would have been higher than the economic loss of grains. Therefore the use of insecticides for grains would have reduced the farmers' profit.

The use of insecticides for shelled grains could be optimised by reducing the amount of maize treated (alternative model, Fig. 2). Considering the monthly maize removal from the store for consumption by the farm family (1 bag per month) and taking into account insecticide treatment only for the maize left in the store, the costs of control decrease (Tsh100 per month). Calculating with the same values as in the above described scenario but with decreasing costs of control, then, after six months of storage, the costs of control are lower than the economic loss of shelled grains (Fig. 2). Here, the treatment of the four bags of maize for consumption from the sixth month to the ninth month is economically justifiable. The five bags stored for consumption during the first months of storage should not be treated since the farmers profit would be reduced. Under these conditions insecticide treatment of shelled maize grains is profitable only when the harvest is divided in a treated and an untreated portion.

## The Economic Damage Threshold

The storage month in which the costs of insecticide treatment become lower than the economic loss (Fig. 2) varies depending on the prices for maize and insecticides. This

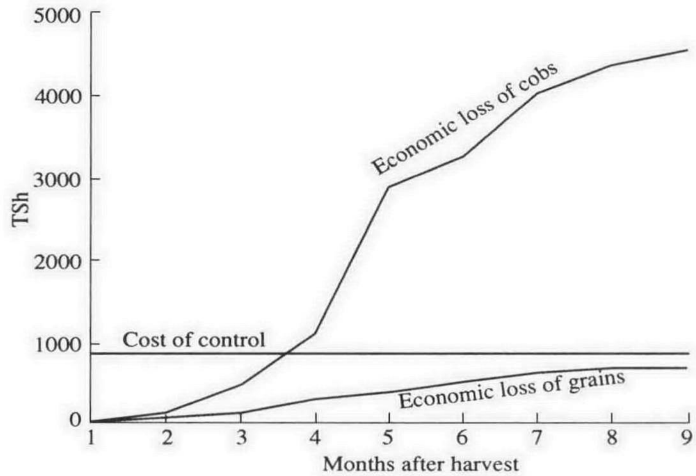


**Fig. 1.** Economic loss (ec. loss) of stored maize cobs and shelled grains and the costs of insecticide control [in Tanzanian shillings (Tsh), storage of nine bags (= 810 kg) of maize]. The costs of control are constant over the storage period since all maize is treated once at the beginning of the storage season (current recomm-endation). (Source: Henckes 1992)

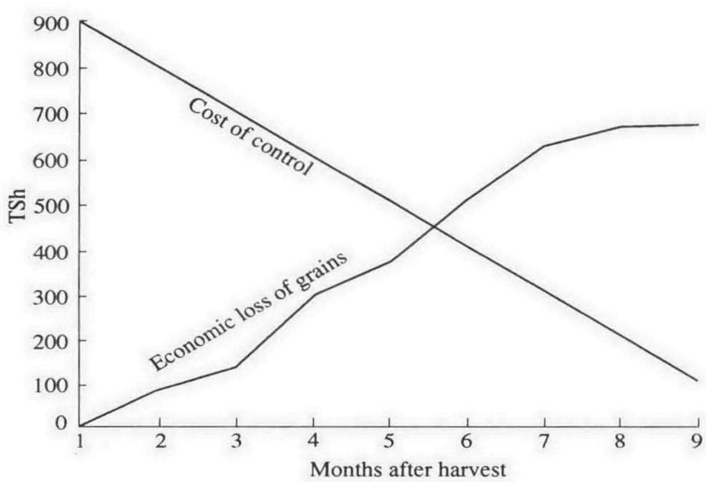


**Fig. 2.** Economic loss (ec. loss) of stored shelled maize grains and the costs of control [in Tanzanian shillings (Tsh), storage of nine bags (= 810 kg) of maize]. Costs of control are decreasing during the storage season since only the maize left in the store is considered for the treatment with insecticides; the monthly maize consumption is taken into account (alternative model). (Source: Henckes 1992).

month can be determined by using the economic damage threshold. The economic damage threshold expressed as dry-weight loss in per cent was calculated using the following equation (compare Table 4):

$$e = \frac{a \times 100}{b}$$

e = economic damage threshold (%)

a = costs of control (here: price of treatment)

b = benefits of control (here: maize price)

As soon as the expected loss becomes higher than the economic damage threshold the use of insecticides increases the farmers profit. The thresholds in northern Tanzania were between 2% and 6% weight loss (Table 4). In storage season 1990/91, after five months of storage, the economic damage threshold (2%) was lower than the expected loss (3%). Therefore, the application of insecticides to maize stored five months and longer increased the farmers profit. In this case, the maize for consumption in the first four months of storage could have been stored without insecticide treatment since after four months of storage the loss (2%) was still lower than the economic damage threshold (3%). (1)

## Conclusions and Recommendations

The results of the field trials in Tanzania have shown that maize stored as grains suffers less dry-weight loss and economic loss than maize stored as cobs. Also, in grains, *P. truncatus*, a severe maize pest in several African countries, plays a minor role compared to maize cobs. Therefore, it is recommended to store the maize as grains. All control measures should focus on the 'key' pests. In northern Tanzania, the 'key' pests in stored shelled maize were *Sitophilus* spp. > *T. castaneum* and *S. cerealella*.

Dividing the harvest before storage into a part to be treated with insecticides and a part not to be treated with insecticides corresponding to the duration of storage should be the basis for an integrated pest management strategy in family stores. The division of the harvest can increase the farmers profit (by reducing the costs of pest control) and reduce the use of synthetic insecticides. The untreated part is stored for consumption by the farm family during the first months after harvest (when the pest abundance, damage and losses are relatively low) and the treated part is for consumption for the following months when the damage and losses are higher.

Furthermore, the division of the harvest before storage into a treated and an untreated part improves the impact of alternative control measures. For example, the effect of *Anisopteromalus calandrae*, a parasitoid associated with stored-product pests, or the effect of *Teretriosoma nigrescens*, known as a predator of the larger grain borer, *Prostephanus truncatus*, on pest populations in stores will be very low or not existing when all the maize is contaminated with synthetic insecticides.

Smallholders are the potential target group for the integrated pest management strategy. On small farms where most of the maize is stored for consumption by the farm family, the maize remains on the farm and is not transported over long distances: the place of production is also the place of consumption. The use of insecticides can be reduced and insects and crop losses tolerated as long as the maize remains suitable for consumption and as there are no economic losses. Every year the farmer should be advised by the agriculture extension service how to divide the harvest into an untreated and a treated part before storing it. The size of the two parts of stored product should be determined by using the economic damage threshold.

The benefit of the integrated pest management approach in stored maize depends on the spatial distribution of storage. In a country where most of the commodity is stored in big central warehouses and later redistributed to the consumers the application of integrated pest management is very much limited. In Tanzania, as in most other African countries, the storage is distributed to small units (farmers store). Eighty per cent of the annual maize production (about 1.6 million t) is stored on small farms for on-farm consumption (FAO 1986). To treat this maize 1778 t of insecticides would be needed every year. This is equivalent to an expenditure of Tsh1.78 billion or US$ 8.9 million per year. Assuming that integrated pest management will result in a 50% decrease of the use of insecticides, then the country could save Tsh890 million every year. Since the active ingredient of the insecticide is imported, a major part of these savings would be in foreign currency.

**Table 4.** Economic damage thresholds of stored maize for three seasons in northern Tanzania and losses of stored maize (in % dry-weight loss)

| | Months of storage | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 4 | | | 5 | | | 6 | |
| Storage season[a] | 88–89 | 89–90 | 90–91 | 88–89 | 89–90 | 90–91 | 88–89 | 89–90 | 90–91 |
| Maize price[b] | 1675 | 1438 | 3500 | 1675 | 1565 | 4280 | 1675 | 1850 | 4313 |
| Price of treatment[c] | 58 | 87 | 10058 | | 87 | 10058 | | 87 | 100 |
| Economic damage threshold (%) | 3 | 6 | 3 | 3 | 6 | 2 | 3 | 5 | 2 |
| Loss in store (%) | 2 | | | 3 | | | 4 | | |

Source: Henckes et al. 1991, revised.
[a]Storage season from September to September.
[b]Consumer prices on open markets (Tanzanian shillings (Tsh)/bag of maize).
[c]Prices of insecticide dust (Tsh/100g of insecticides/bag of maize).
[d]Average storage losses of shelled maize without insecticide treatment in northern Tanzania.

## References


Dick, K.M. 1990. Biological control of the LGB in Africa: A component of an integrated pest management strategy. In: Markham, R.H. and Herren, H.R. eds, Biological Control of the LGB, Proceedings of an IITA/FAO Coordination Meeting, Cotonou, Republic of Benin, 2–3 June 1989, International Institute of Tropical Agriculture, Ibadan, Nigeria, vii + 171 p.

FAO 1986. Report of the Food Security Review Mission to Tanzania. Food security assistance scheme, Rome, Italy, May 1986, Annex I, 47 p.

FAO 1991. Special Program for Pest Control in Africa. Rome, Italy. Plant Protection Services in Tanzania, A brief review and proposed structure for the 1990s, 5–15.

Henckes, C. 1992. Investigations into insect population dynamics, damage and losses of stored maize—An approach to integrated pest management on small farms in Tanzania with special reference to *Prostephanus truncatus* (Horn). Hamburg, GTZ Post-harvest Project, Pickhuben 4 D-20457 Hamburg, Germany, xiv + 124 p.

Henckes, C., Ringo, D.F.P. and Mushi, A. 1991. Integrated Pest Management in Stored Maize—Strategy for Tanzania. GTZ Post-harvest Project, Pickhuben 4, D-20457 Hamburg, Germany.

L'Agronomie Tropicale 1969. Rapport d`activité de la comission d`évaluation des pertes dans les denrées stockées crée á l`issue du congrés de Marseille sur la protection des cultures tropicales. L'Agronomie Tropicale 24 (8), 872–876.

McFarlane, J.A. 1988. Pest management strategies for *P. truncatus* (Horn) (Coleoptera: Bostrichidae) as a pest of stored maize grain: present status and prospects. Tropical Pest Management 34(2), 121–132.

MALDC (Ministry of Agriculture, Livestock Development and Cooperatives) 1990. Market Bulletin, Dar es Salaam, Tanzania Market Information Service. P.O. Box 9192.

Schwab, A. 1989. Pestizideinsatz in Entwicklungsländern; Gefahren und Alternativen, Weikersheim, Margraf, Pesticide Action-Network e.V, 274 p.

Tyler, P.S. 1985. Opportunities for improving the availability of data on post-harvest grain losses in Tanzania. Luxembourg. Report for the Statistical Office of the European Community, August 1985.