Developing and Disseminating Technology to Reduce Post-harvest Losses in Maize

Proceedings of a Working Group Meeting of the Hill Maize Research Project

Khumaltar, Lalitpur, Nepal
25-27 September, 2000

D. N. Manandhar, J. K. Ransom and N. P. Rajbhandari (Editors)
Developing and Disseminating Technology to Reduce Post-harvest Losses in Maize

Proceedings of a Working Group Meeting of the Hill Maize Research Project

Khumaltar, Lalitpur, Nepal
25-27 September, 2000

D. N. Manandhar, J. K. Ransom and N. P. Rajbhandari
(Editors)
NARC
The Nepal Agricultural Research Council (NARC) was established in 1991 as an autonomous research organization under the Nepal Agricultural Research Council Act of HMRG Nepal. NARC has as its objective to uplift the socio-economic level of the Nepalese by developing and disseminating technologies that increase the productivity and sustainability of resources devoted to agriculture. NARC's research programs are carried out in Agricultural Research Stations located throughout the country and with farmers in their fields.

CIMMYT
The International Maize and Wheat Improvement Center (CIMMYT) is an internationally funded, non-profit scientific research and training organization. Headquartered in Mexico, the Center works with agricultural research institutions worldwide to improve the productivity and sustainability of maize and wheat systems for poor farmers in developing countries. It is one of the 16 similar centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR comprises over 50 partner countries, international and regional organizations, and private foundations. It is co-sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), the United Nations Development Program (UNDP), and the United Nations Environment Program (UNEP).

HMRP
The Hill Maize Research Project (HMRP) is a collaborative project between NARC and CIMMYT with funds provided by the Swiss Agency for Development and Cooperation (SDC). HMRP was initiated in January 1999 with the objective of increasing the production and productivity of maize in the hills of Nepal through the development and dissemination of new maize varieties and crop management practices. The bulk of the research carried out by the HMRP is conducted in five Agricultural Research Stations of NARC. CIMMYT provides technical support and germplasm.

Copyright © 2000 NARC, Nepal


ISSN 1608-4322
## CONTENTS

1. Global Post-harvest Losses in Maize: An Overview  
   *D. Bergvinson, CIMMYT/Mexico*  
   3

2. An Overview of Post-harvest Losses in Maize in Nepal  
   *G.P. Shivakoti and D.N. Manandhar, Entomology Division, Khumaltar*  
   6

   *N.P. Rajbhandari, CIMMYT/Nepal*  
   10

4. Factors Affecting Post-harvest Losses in Maize  
   *J. Ransom, CIMMYT/Nepal*  
   14

5. Review of Research on Post-harvest Insect Control in Nepal  
   *D.N. Manandhar and B.P. Mainali, Entomology Division, Khumaltar*  
   19

6. Botanical and other Indigenous Knowledge Systems for the Control of Post-harvest Insects of Maize  
   *R.B. Paneru, Entomology Division, Khumaltar and Y.P. Sah, ARS-Pakhribas*  
   23

7. Review of Research in Nepal on Disease-related Post-harvest Losses in Maize  
   *G. Manandhar, Plant Pathology Division, Khumaltar and B.K. Batsa, NMRP-Rampur*  
   30

8. Drying and Storage Structures to Minimize Maize Post-harvest Losses in Nepal  
   *G.B. Manandhar and K.B. Shrestha, AED-NARC, Khumaltar*  
   35

9. Post-harvest Losses in Maize: Review of the Findings of the Rural Save Grain Project  
   *Ganesh K.C., IED, DOA*  
   47

10. Post-harvest: Current Extension Programme, Recommendations and Constraints to Effective Dissemination  
    *S. Adhikari, Post-harvest Loss Division, DOA*  
    50

11. Advances in Post-harvest Research at CIMMYT  
    *D. Bergvinson, CIMMYT/Mexico*  
    53

12. Report of the Working Group Meeting on Developing and Disseminating Technology to Reduce Post-harvest Losses in Maize  
    59
Global Post-harvest Losses in Maize: An Overview

David Bergvinson
Maize Entomologist, CIMMYT Maize Program, Mexico

Maize (Zea mais L.) originated from central America and has now become the highest production cereal grown worldwide. Maize has become particularly important in developing countries and will play an important role in meeting food security needs in the future. As with all agricultural crops, storage is a central issue in food security. Losses during the complete cropping cycle through to consumption are depicted in Figure 1. The shaded box in Figure 1 depicts losses associated with post-harvest. One of the major challenges in cereal storage is conditioning the grain to remove excess moisture and storing the grain in a dry environment protected from pests. Insect pests jeopardize food security throughout the developing world. Small-scale maize farmers, who generally store their grain as whole ears in slatted bins, in adobe rooms, among the rafters of their huts, or even in the field, are especially affected. Farmers are often forced to sell extra grain right after harvest, when the market is glutted and prices are lowest.

The two most damaging insect species of maize are the maize weevil, Sitophilus zeamais, and the larger grain borer (LGB), Prostephanus truncatus. The maize weevil is ubiquitous and first colonizes maize ears in the field. Fortunately for Nepal, the LGB is not present. Other important storage insect pests of maize and wheat in developing countries include:

1. Grainary weevil, Sitophilus granarius
2. Maize weevil, S. zeamais
3. Rice weevil, S. oryzae
4. Red flour beetle, Tribolium castaneum

---

Figure 1: Losses associated with the maize cropping and harvesting cycle. Post-harvest losses are normally associated with the region shaded in grey.
Control of insect pests in grain stores has largely focused on hygiene which is a safe and healthy means of control. These measures include the thorough cleaning of the storage structure/area, burning or burying trash around the storage area, removing all objects from the store (especially bags containing old grain), repairing storage structures and filling all cracks where insects can hide, and dusting the walls and ceiling of structure with a recommended insecticide (especially if infested). The use and promotion of biological controls has been successful in regulating pest populations but often at levels that are above the economic threshold. Chemical controls work, but are most effective for shelled grain which can impose a health hazard to those applying the insecticide but also to consumers. Most small holders have no access to shelling devices, and the chemicals themselves tend to be toxic, posing a serious hazard for farm households. Fumigation with phosphine gas generated from aluminum or magnesium phosphide pellets is very effective in controlling insect pests but farmers often do not have airtight storage containers to enable a thorough fumigation. Farmers often do not follow proper safety precautions, which put them and their families at risk during the treatment process.

One of the most successful means of controlling post harvest pests has been through selections made by farmers over time for good husk cover and kernels that resist insect attack (Dobie 1977). Genetic variation exists for both of these traits which, have long been recognized by farmers as important traits for selection (Dobie 1974). Moreover, only that seed that has escaped damage by insect pests will germinate the following cycle, which has also served as a means of selection for resistance to storage pests.

Despite the above control measures, losses experienced by farmers in developing countries are considerable. Several storage loss studies have been conducted throughout the developing world, with weight losses ranging from 2-6% and associated losses in grain quality being even higher (Table 1). Clearly, there is a need for improved small-scale storage systems throughout the developing world, including Nepal. In the humid tropics or in areas where harvest occurs during the rainy season, drying and storage structures which allow ventilation are important (FAO 1980). Drying and storage modifications for high-yielding varieties are needed to reduce pest losses and associated grain degradation from mycotoxin producing molds.

### Table 1: On-farm storage losses in developing countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Period of storage (months)</th>
<th>Cause of loss</th>
<th>Percent weight loss</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zambia</td>
<td>7</td>
<td>insects</td>
<td>1.7 - 5.6</td>
<td>Adams, Harman 1977</td>
</tr>
<tr>
<td>Kenya</td>
<td>up to 9</td>
<td>insect/rodent</td>
<td>3.3 - 3.8</td>
<td>de Lima 1979</td>
</tr>
<tr>
<td>Malawi</td>
<td>up to 9</td>
<td>insects</td>
<td>1.8 - 3.2</td>
<td>Golob 1981</td>
</tr>
<tr>
<td>Swaziland</td>
<td>6</td>
<td>insects</td>
<td>3.7</td>
<td>de Lima 1982</td>
</tr>
<tr>
<td>Nepal</td>
<td>6</td>
<td>insect/rodent/mold</td>
<td>2.5 - 8.9</td>
<td>Boxall, Gillett 1984</td>
</tr>
</tbody>
</table>

5. Confused flour beetle, *T. confusum*
6. Lesser grain borer, *Rhyzopertha dominica*
7. Larger grain borer, *Prostephanus truncatus*
8. Khapra beetle, *Trogoderma granarium*
9. Merchant grain beetle, *Oryzaephilus mercator*
10. Sawtoothed grain beetle, *O. surinamensis*
11. Cigarette beetle, *Lasioderma serricorne*
12. Indian-meal moth, *Plodia interpunctella*
13. Angoumois grain moth, *Sitotroga cerealella*
References


An Overview of Post-harvest Losses in Maize in Nepal

G. P. Shivakoti and D. N. Manandhar
Senior Scientists, Entomology Division, NARC, Khumaltar

Introduction

Maize is the second most important cereal crop and the major staple food of the people in the hills of Nepal. The total cultivated area of maize is 0.89 million hectares, 80% of which lies in the mid-hill and high-hill ecologies. The total production of maize in FY 1999-2000 was 1,445,450 tons which is almost 21% of the total cereal production of the country. Despite efforts made during the last 30 years to increase the production and productivity of maize, there has been little improvement.

Several production factors are responsible for the lack of success. Apart from other factors, insect pests and diseases have been playing a significant role in reducing production and productivity. A number of insect pests and diseases cause considerable losses, from the seedling stage through until harvest. Even after harvest the maize grains are not safe. A number of stored grain insects, fungal pathogens, rodents, birds and squirrels cause significant losses. Among the stored grain pests, the following insect species and diseases directly or indirectly cause post-harvest losses in maize. They are as follows:

(A) Insects

- Primary
  - Maize weevil
  - Rice weevil
  - Angoumois grain moth
  - Lesser grain borer
  - Khapra beetle

- Secondary
  - Red flour beetle
  - Confused flour beetle
  - Saw toothed grain beetle
  - Rusty grain beetle
  - Corn sap beetle
  - Indian meal moth

(B) Diseases

Among ear rotting fungal pathogens, Fusarium species are the predominant ones and can produce mycotoxins in stored maize grain. The predominant species prevailing in Nepal are:

- Gibberella fujikuroi (Mating population A) (anamorph Fusarium moniliforme), (synonym F. verticilliicida)
- Fusarium graminearum (Teleomorph) (Gibberella zea)
- Penicillium spp.
- Aspergillus spp.

(C) Rodents

Among rodents the following species are commons.

- Rattus rattus (House rat)
- Bandicota bengalensis (Field rat)

The stored grain insect pests and diseases not only cause direct losses but also affect the food value, food quality and acceptability. Golebiowska (1969) reported that Sitophilus oryzae and Rizopertha dominica can eat 0.49 mg and 1.5 mg of grain daily and produce 11-12 mg and 54 mg of waste products throughout their lives, respectively.

Mechanism of Infestation of Stored Grain Pests

In general the mechanism of infestation of stored grain pests starts from field and proceeds to the store or vice versa as shown in the Figure 1.

In a country like Nepal where traditional storage systems of maize are quite common, the possible cause of infestation by insects, pests and diseases in the storage and in the field could be as follows:

- Natural infestation in the crop in the field.
- Migration of insect pests and diseases from the store to the field.
- The barter system (exchange system) of maize (seed/food grain) among farmers.
- Transportation of maize (seed/food grain).
- Alternate non-food host plants.
- Germplasm exchange.
There are some publications that document the migration of *S. zeamais* and *S. oryzae* and *Sitotroga cerealella* from the store to field and vice versa. Russell (1962) reported field infestations of *Sitotroga cerealella* 3 to 4 weeks before the normal harvest of maize. Gills *et al.* (1971) found that adults of *S. zeamais* when introduced artificially into maize cobs with a moisture content of 60%, develop progeny in 46 days. The authors further reported that adults of *S. zeamais*, when introduced 18 days after pollination were found alive for 121 days and bred successfully in the ears indicating that adults try to survive in the ear until they could produce progeny. These evidences clearly indicate that pre-harvest infestations are quite common in maize.

**Post-harvest Losses in Maize**

In this overview, post-harvest losses in maize caused by weevils will mainly be considered. However, other insect species cause considerable post-harvest losses. Golebiowska (1969) reported that *S. oryzae* and *R. dominica* can eat up to 0.49 mg and 1.5 mg of grain daily and produce 11-12 mg and 54 mg of waste product throughout their lives, respectively. Maize cobs stored in the local storage structures (*Thangro, Suli, Kunew,* etc.) were found to be heavily infested by *Sitotroga cerealella* in the mid- and high-hills of Nepal (personal observation).

Boxal and Gillet (1980) recorded 5.5 % average weight loss due to weevil attack in the eastern hills of Nepal. Khanal *et al.* (1990) estimated maize storage loss of 10.6% due to weevils under Pakhrribas conditions. However, Paneru *et al.* (1993) found storage losses of up to 32% due to the maize weevil. Similarly, based on the examination of several maize cobs stored in a *thangro* for a period of 8 months, Golob (1994) found infestation levels of between 50 to 100% by *Sitophilus* weevils. The actual quantitative loss from the 100% infested grain was estimated to be 10-20%. However, from the consumption point of view the loss was considered as 100%. Ghimire *et al.* (1996) indicated that the loss in terms of weight of up to 20% in a typical post-harvest storage situation.

K.C. (1992) reported post-harvest losses in cereals of about 15-20%. In a review work, Upadhyay (2000) mentioned that about 20-25% loss of agricultural production occurs annually due to stored grain pests. He reported that storage loss of maize in the mountains,
hills and terai was 8, 7.4 and 13 percent, respectively. Pradhan and Manandhar (1992) reported the total loss of cereal grain from rodents is 44.3% on a national basis and in maize alone is about 21.5% in the mountains, hills and terai regions. The post-harvest molds such as Penicillin and Aspergillus also cause about 1 to 5% losses in maize depending upon the time of maize harvest, duration of storage and storage conditions. These molds besides deteriorating the grain also produce aflotoxin which is carcinogenic to man and animals.

According to Sah (1998) the level of weevil infestation varied from 51.1 to 97.0% in the mid altitude (1500 masl) to low altitude (750 masl) irrespective of yellow or white maize when stored in a kunew (local storage structure) for a period of 5 months. Similar levels of infestation (100% at low altitude and 60.3% in the mid altitudes) were reported when white maize was stored in a bucket storage system. However, the maximum weight loss of 15% and 10.0% at 100% and 60.3% infestation levels, respectively, were reported when equal numbers of adults were given an opportunity to infest the grain. Shivakoti (1981) reported an infestation level of up to 49% by Sitotroga cerealella and weevils stored in sul and thangro for a period of 6 months. The percent weight loss varied from less than 1% to 6% in different years. The summary of post-harvest loss in maize in given in Table 1.

<table>
<thead>
<tr>
<th>Percent loss</th>
<th>By</th>
<th>Area</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td>Sitophilus spp.</td>
<td>Eastern hill</td>
<td>Boxal &amp; Gillet (1980)</td>
</tr>
<tr>
<td>10.6</td>
<td>Sitophilus spp.</td>
<td>PAC</td>
<td>Boxal &amp; Gillet (1980)</td>
</tr>
<tr>
<td>32</td>
<td>S. zeamais</td>
<td>Pakhrbas</td>
<td>Paneru et al. (1993)</td>
</tr>
<tr>
<td>*49</td>
<td>&quot; &amp; S. cerealella</td>
<td>Rampur</td>
<td>Shivakoti (1983)</td>
</tr>
<tr>
<td>20-25</td>
<td>Storage pests</td>
<td>hills &amp; terai</td>
<td>Upadhyay (2000 reviewed)</td>
</tr>
<tr>
<td>8, 7.4 &amp; 13</td>
<td>Storage pests</td>
<td>On a national basis</td>
<td>Upadhyay (2000 reviewed)</td>
</tr>
<tr>
<td>44.3</td>
<td>Rodents</td>
<td>Mountain, hills &amp; terai</td>
<td>Pradhan &amp; Manandhar (1992)</td>
</tr>
<tr>
<td>21.5</td>
<td>Rodents</td>
<td>Monsoon maize</td>
<td>Pradhan &amp; Manandhar (1992)</td>
</tr>
<tr>
<td>1-5</td>
<td>Molds</td>
<td>PAC</td>
<td>Batsa, B. K. (Per. Comm.)</td>
</tr>
<tr>
<td>15</td>
<td>Weevils</td>
<td>Rampur</td>
<td>Sah (1998)</td>
</tr>
<tr>
<td>0.79-6.12</td>
<td>Weevils and moth</td>
<td>-</td>
<td>Shivakoti (1984)</td>
</tr>
</tbody>
</table>

* percent infestation, other values are in percent weight loss.

References


Post-harvest Losses of Maize in the Mid Hills of Nepal: Insights from Rapid Rural Appraisals

Neeranjan P. Rajbhandari
Hill Maize Research Project, CIMMYT/NEPAL

Background

Post-harvest losses of agricultural commodities in general and maize in particular have been considered as a major problem area where research could have meaningful impact. In the Hill Maize Research Project (HMRP) it has received prominent focus similar to the problem of soil fertility decline in the hills of Nepal. In the past numerous agricultural projects have been implemented in the country. Among those the Rural Save Grain Project focused specifically to reduce post-harvest losses. There is no dearth of research efforts in the past and there are plenty of recommendations already available to farmers. However, farmers have not accepted most of the recommendations and some are irrelevant under farmers’ circumstances. The technology is either unaffordable or simply not available to farmers (e.g. metal bins and aluminum phosphide fumigation). This raises the question, which needs to be verified objectively as to whether the maize farmers in the mid hills give similar priority and same seriousness to the post-harvest problem as perceived by entomologists.

The purpose of this paper is to highlight the following:

- Results of RRA and baseline surveys by HMRP and Hill Agricultural Research Project (HARP)
- Post-harvest loss estimates and problems with those estimates
- Farmers indigenous storage system and available technology
- Arguments that post-harvest losses in the mid hill are not that serious

In addition, this paper tries to put the issues of post-harvest, loss assessment, actual loss as problem perceived by farmers and entomologist, and the need for increased research focus in perspective. It is suggested that we take a hard look at the problems and issues of post-harvest losses in the hills of Nepal through multiple accounts of multiple perspectives. “Every grain that is saved from post-harvest loss is an extra grain produced”. No body can argue against it, yet additional investment in post-harvest research must be justified by hard evidence that returns from investments from real farm problems. To get an insight to problems and issues of post-harvest losses of maize in the hills - the answer to the following question will be helpful:

- How serious are the post-harvest losses in hills?
- Are the RRA survey results on post-harvest losses convincing enough to justify an increased focus on post-harvest research?
- Do we really need to increase the investment on post-harvest research, if so, what will be the additional benefits to hill farmers?
- What is the status of available technology? Is it enough?

Post-harvest Processes and Practices in the Hills

Methods of post-harvest handling and storage practices of maize are unique to the hills of Nepal. The indigenous systems have evolved over centuries and seem to have served the farmers well over time. The noteworthy aspect of the whole system is that no external input is required and there are local innovations developed to reduce post-harvest losses. The process and practices of post-harvest could be summarized as follows:

Process of harvesting and storage

- Most of the maize in the Nepalese hills is harvested in the month of September.
- The first activity after harvest is the selection of cobs good enough to make bunches.
- All of the selected cobs are tied in a Jhutta (bunches) of 4-6 cobs.
- Those bunches are sun dried for 4-5 days before putting them on a Suli or Thankro.
- The remaining cobs are shelled and the grain is stored separately in Bhakari/Dalo (bamboo baskets) for immediate consumption.
- Normally maize stored on Suli/Thankro is taken out in December or later, shelled manually and stored in local storage structures. The maize is utilized over time as food, feed and also sold to fulfill cash needs.
Practices of *Jhutta* making for storage

- Cobs are separated by size and quality after harvest.
- Undersized and deformed cobs are completely de-husked, sun-dried, and shelled for immediate or near future consumption.
- Two to three husk layers of selected cobs are removed.
- Large and good-looking cobs are tied using the husk (4-6 cobs) and sun-dried for 4-5 days.
- After drying, the cobs in bunches are piled/hanged on the storage structure, locally called *Thankros* or *Sulis*.
- The maize stored on such an open store remains untouched until December unless some maize is required for consumption.
- No chemicals are used to protect grain from storage pests.

**RRA Survey Results Relative to Stored Grain Pests in Maize**

The recent surveys conducted under HMRP and HARP focused on maize production problems in general and not specifically on post-harvest losses of maize. Available information on issues related to post-harvest losses on maize during the period of the surveys were scanty at best. Furthermore the information was based on interviews with farmers and not on actual measurements.

**HMRP RRA Survey Results**

Weevils, moths, termites and rodents were the major storage pests in all of the study districts. The extent of damage to maize grain differed according to the duration of storage.

In the food deficit areas, where maize is stored only for a short period, the damage was up to 5 percent

**Table 1: Post harvest losses, frequency and trends due to insects, pests and rodents in maize in the hills of Nepal.**

<table>
<thead>
<tr>
<th>District</th>
<th>Problem</th>
<th>Frequency</th>
<th>Loss %</th>
<th>Trend in infestations in past few years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panchthar</td>
<td>Termite</td>
<td>1</td>
<td>-10</td>
<td>Increasing</td>
</tr>
<tr>
<td></td>
<td>Weevil</td>
<td>1</td>
<td>5-25</td>
<td>Constant</td>
</tr>
<tr>
<td></td>
<td>Moth</td>
<td>1</td>
<td>5-25</td>
<td>Constant</td>
</tr>
<tr>
<td>Sankhuwasabha</td>
<td>Termite</td>
<td>0.5</td>
<td>5</td>
<td>Increasing</td>
</tr>
<tr>
<td></td>
<td>Weevil</td>
<td>1</td>
<td>15</td>
<td>Increasing</td>
</tr>
<tr>
<td></td>
<td>Moth</td>
<td>1</td>
<td>15</td>
<td>Increasing</td>
</tr>
<tr>
<td>Sindupalchok</td>
<td>Termite</td>
<td>1</td>
<td>1</td>
<td>Increasing</td>
</tr>
<tr>
<td>Nuwakot</td>
<td>Termite</td>
<td>0.3</td>
<td></td>
<td>Increasing</td>
</tr>
<tr>
<td>Lamjung</td>
<td>Weevil</td>
<td>1</td>
<td>20</td>
<td>NR</td>
</tr>
<tr>
<td>Baglung</td>
<td>Weevil</td>
<td>1</td>
<td>5-10</td>
<td>Increasing</td>
</tr>
<tr>
<td></td>
<td>Moth</td>
<td>1</td>
<td>2-3</td>
<td>Increasing</td>
</tr>
<tr>
<td>Pyuthan</td>
<td>Weevil/moth/rodents</td>
<td>1</td>
<td>5-10</td>
<td></td>
</tr>
<tr>
<td>Salyan</td>
<td>Weevil/moth/rodents</td>
<td>1</td>
<td>5-10</td>
<td></td>
</tr>
<tr>
<td>Dailekh</td>
<td>Termites</td>
<td>3-5</td>
<td></td>
<td>Constant</td>
</tr>
<tr>
<td></td>
<td>Weevil</td>
<td>10</td>
<td></td>
<td>Up-down</td>
</tr>
<tr>
<td></td>
<td>Moth</td>
<td>5-30</td>
<td></td>
<td>Up-down</td>
</tr>
<tr>
<td>Achham</td>
<td>Weevil</td>
<td>1</td>
<td>10</td>
<td>Constant</td>
</tr>
<tr>
<td></td>
<td>Moth</td>
<td>1</td>
<td>4-5</td>
<td>Constant</td>
</tr>
<tr>
<td>Bajhang</td>
<td>Termite</td>
<td>0.5</td>
<td>5-10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weevil/moth/rodents</td>
<td>1</td>
<td>4-5</td>
<td></td>
</tr>
<tr>
<td>Baitadi</td>
<td>Weevil</td>
<td>1</td>
<td>5-10</td>
<td>Constant</td>
</tr>
</tbody>
</table>

Source: RRA survey report, HMRP 2000
and in other areas where maize was stored for the whole year damage by those insects was reported as high as 50 percent of the quantity remaining in the store.

**Results of the HMRP Baseline Survey in Dailekh and Dolakha Districts**

**Storage methods**
- 46% of the households (HH) stored their maize after shelling in bamboo storage structures while 35 percent kept their maize unshelled in outdoor storage structures i.e. Suli, or Thankro.
- 7% of the households kept unshelled maize indoor and 12% kept shelled maize in small a container.

**Treatment with insecticide**
- Only 4% of the households (8 out of 214 HH) treated their maize - of which nearly half treated it by using an insecticide and the rest by ash and cooking oil.
- 20% of the households reported that it is unnecessary to treat maize to save it from insect damage and 67% felt they lacked knowledge on how to treat maize.
- 87% of the households depended on shelling, drying and cleaning to avoid insect damage.

**Post-harvest loss by insects**
- Farmers reported an 18% loss from the combined effects of weevils, moths, termites, rodents and other pests on stored maize leftover after consumption over a period of one year.
- Weevils and moths are major post-harvest insects causing damage to stored maize.

**Dailekh RRA Survey, (HARP report, 1999)**
- 90% of the farmers in the mid and far-western regions stored maize on Thankros, Sulis or by just hanging it inside the house.
- Only 12% of the households have knowledge about seed treatment.
- 72% of the households have food sufficiency for less than 6 months and 37% of the households purchase maize for consumption.

**Loss estimates**
- HMRP RRA survey – loss of 5% in food deficit areas and up to 50% in food sufficient areas of maize stored for a year.
- HMRP baseline survey 2000 — 18% on maize left over after consumption.
- Rural Save Grain Project — 15-20%.
- Paneru, 1993, PAC — 31%.
- Shah, 1999, PAC, 6-12% in a *Kunio* system and 10-16% in plastic buckets; losses were estimated to be 80,981 MT in the hills.

The loss extrapolation was very simplistic. It seemed to be over estimating the actual losses but the following conclusions from the experiment were noteworthy:
- The rate of infestation of weevil decreased with altitude.
- Powder of the local botanical, *Bojo* rhizome, was very effective for weevil containment.
- Weight loss of grain due to weevils in the untreated control was 6% and 12% in low and medium altitude areas in the *Kunio* storage systems respectively.

**Characteristics of farmers’ indigenous storage system and available technology**
- Farmers utilized locally available resources for maize storage.
- They do a very good job with cleaning, drying and manually separating poor quality maize grain for animal or chicken feed.
- Local storage, *Dalo*, Bamboo basket, *Bhakari*, *Thankro*, *Suli* and *Kunio* have served them well for generations.
- Maize farmers often mix the seed/grain with treatment materials such as, kerosene oil, mustard oil, Ash, *Timbur* or other local herbs and with millet to protect it from storage pests.

**Available Technology**
- Indigenous storage structures.
- Improved local structures made with local materials.
- Metal bins.
- Storage additives, such as ash, oil and other (how effective?).
- Botanicals.
- Aluminum phosphide fumigation.
Post-harvest losses of maize are not serious in the hills

The actual tonnage loss is minimal as a proportion of the total production
The storage loss figures are misleading and do not give a clear picture of the extent and quantum of losses. Even if loss is estimated to be 5-10%, it is not 10% of the total maize produced in the hills. It is probably 10% of the left over maize during the hot and humid period after the month of June. A simplistic extrapolation of the quantum of insect damage under controlled condition leads to inflated loss estimates. Insect damage is greater during hot and humid periods only after the onset of monsoon in May/June in the mid hills when the environment is conducive to population build up. A better estimate of losses by insects would be to estimate the losses based on the quantity of maize remaining in storage during the monsoon and beyond in the mid hills.

Nothing goes to waste
Maize, being a staple in the hills, is regularly inspected for damage while in storage. Frequent vigil is very common of stored maize. If insects are found to be damaging the shelled maize grain or in the Thankro, it is immediately taken out in the front yard for drying and cleaning. The insect damaged grain is fed to chicken/livestock as feed. Nothing goes to waste.

Cool temperature in the hills keep the loss in check or to a bare minimum
The bulk of the maize in the hills is harvested in September. After the late monsoon rains in October, there is enough sunshine, a decline in humidity, and particularly low temperatures in winter months to keep the insect population under check. Most of the maize in the hills is planted in the month of May. Storage conditions are favorable to insects only after temperature and humidity begin to rise in March.

How many farmers (%) have maize left in their home beyond the planting season of maize?
Because of food deficits in the hills the actual quantity of maize that is subject to weevil assault is limited to those farmers who have food sufficiency beyond six months. How much maize is left with farmers when conditions are conducive for insect damage? How much maize is kept in store after the winter season and after maize planting in May in the mid hills? Most hill farmers consume maize before the weevils get active.

Conclusion
In conclusion it will be fair to say that farmers in the mid hills of Nepal do not perceive the post-harvest losses as a serious problems. In the lower altitude river valleys the losses could be substantial for farmers with a large farm size who store their excess maize through the hot and humid monsoon season. Even these farmers dispose of their excess maize to traders in most cases before the monsoon.

In spite of numerous loss assessment studies it is unclear on the total quantum of post-harvest losses of maize in the mid hills. In general the studies are conducted in controlled condition and the losses are extrapolated to maize stored in Thankros, Sulis or Kunios. It is proposed that most studies over estimate the losses and extrapolation of total losses in the country are at best very much inflated. In the future it will be useful to make a comprehensive study of maize crop use profile from harvest to harvest and develop a flow chart of what happens to the harvested maize and the subsequent losses incurred at every stage in various agro-ecologies.

References


Factors Affecting Post-harvest Losses in Maize

Joel Ransom
CIMMYT/Hill Maize Research Project, Nepal

Introduction

Post-harvest losses of maize occur throughout the world to one degree or another. Post-harvest losses are particularly problematic, however, to farmers in subsistence systems, like the maize-based systems in the hills of Nepal, where losses usually mean there will be less food available for the family. The severity of post-harvest losses can vary considerably and are dependent on not only the management practices of the farmer, but the environment in which he or she lives and the prevalence of post-harvest pests. The purpose of this paper is to review the factors involved in post-harvest losses of maize and principles associated with the control of these losses.

Definition of Terms

1. **Loss** – denotes a measurable decrease in the grain or value of the grain, which may be quantitative, qualitative, nutritive or economic.

2. **Damage** – refers to the superficial evidence of deterioration from which loss may result (e.g. holed grain by insects or broken grain as a result of threshing). There is often a great deal of confusion in the use of the terms damage and loss. For example, it is common to see references to 100% losses. Although insects may have damaged 100% of the kernels, the actual loss in terms of weight may have only been 20%. In this example the correct use of the terms would be 100% of the kernels were damaged and there was a 20% loss in grain weight.

3. **Quantitative loss** – usually denotes a loss in grain weight but could be applied to other losses that can be measured (i.e. protein losses, etc.).

4. **Qualitative loss** – losses that can be observed and usually represents damage or contamination of the grain. Generally qualitative losses are based on subjective judgements.

5. **Germination loss** – represents a reduction in germination ability of a seed due to deterioration or stresses on the seed. This loss is determined through a lab test. This loss is most problematic for kernels that were intended for use as seed. Loss of germination ability does not affect the seed’s nutritional value in and of itself.

6. **Economic loss** – denotes a reduction in monetary value of the product as a result of loss either in quantity or quality of the product. For example, weevils may cause a 20% reduction in the weight of the grain. However, if because of this damage, which is visible to a potential buyer, the grain could not be sold, then the economic loss would be 100%.

Factors that Cause Post-harvest Losses in Maize

Physical factors

The two most important physical factors that are involved in post-harvest losses are temperature and moisture. Generally speaking the higher the temperature, the faster the biological processes. At higher temperatures, seeds respire more, insects reproduce faster and are more active and certain damaging fungi can be more prevalent. Similarly, the moisture in the air surrounding the grain and the moisture content in the grain itself can determine which detrimental biological process are active and their relative activity. Moulds become problematic in grain stored with a high moisture content. Furthermore, temperature and moisture interact. High humidity coupled with high temperature can quickly reduce seed viability and allow insects and diseases to establish quickly (Table 1). Maize must be dried to at least 13% in order for it to be stored safely for any period of time. Insect activity is greatly reduced when the temperature of the stored grain is 19 degrees or less. Fungi are problematic only when the moisture content of the grain exceeds 15%, regardless of temperature.

There is a direct relationship between the relative humidity in the air and the moisture content of stored grain. There can be large variations in the moisture content of grain within the course of a day of a standing maize crop due to variation in the relative humidity during the day. Grain at 13% moisture is in equilibrium with air with a R.H. of 70%. Drying grain to 13% is problematic in Nepal, as maize generally matures in
the middle of the monsoon. As an example, this year (2000) up until the time of writing (14 September) there was substantial rainfall during at least two-thirds of the days after the harvest of maize (Table 2). This makes it difficult to dry the harvested maize to the desired moisture content quickly or without a focused effort.

Moisture content of the grain can be determined gravimetrically, with portable moisture testers or estimated with techniques like biting the kernel and the salt test. Moisture content of seed is generally expressed on a wet weight basis. This is calculated as the weight of the water in the grain, divided by the wet weight of the grain.

Reducing the oxygen content in a storage structure can reduce insect survival if it is reduced below 3% of the volume of the air. This can be done using airtight containers. Low oxygen content can reduce the germination of seed, however, after prolonged storage.

**Biological factors**

Insects, mites, bird, rodents, other wildlife, microorganisms and man can be major sources of post-harvest losses of maize. The relative importance of these various biological agents vary from site to site. The physical factors previously discussed can have a significant impact on the prevalence and damage caused by insects and microorganisms. Warmer temperature and higher moisture content in the grain predispose grain to losses by insects and microorganisms. Conditions for drying and storage are very poor for a two-month period immediately after harvest, but during the dry winter months, conditions are quite favorable for limiting the build up of insects and diseases (Table 3). If one uses the rule of thumb that under 19 degrees the risk of insect heating is minimal, only September and October (in the case of Dailekh only) are months that are prone to this problem. Fungal heating can be problematic if the grain that is improperly stored and moisture level exceed 15%.

<table>
<thead>
<tr>
<th>Grain Moisture Content</th>
<th>Insect Heating</th>
<th>Germination Loss</th>
<th>Fungal Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21</td>
<td>35</td>
<td>&gt;40</td>
</tr>
<tr>
<td>10</td>
<td>19</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>15</td>
<td>19</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>20</td>
<td>19</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>25</td>
<td>19</td>
<td>All</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 2:** Number of rainy days in August, September and October in four sites in the hills of Nepal (1987 data from HMG/N, 1992).

<table>
<thead>
<tr>
<th>Site</th>
<th>August</th>
<th>September</th>
<th>October</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pakhribas</td>
<td>24</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>Lumle</td>
<td>29</td>
<td>23</td>
<td>11</td>
</tr>
<tr>
<td>Jiri</td>
<td>26</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Dailekh</td>
<td>25</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 3:** Average daily temperatures for 8 months following harvest at four sites in the hills of Nepal (1987 data from HMG/N, 1995).

<table>
<thead>
<tr>
<th>Site</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pakhribas</td>
<td>20.0</td>
<td>19.8</td>
<td>17.3</td>
<td>14.5</td>
<td>11.9</td>
<td>10.7</td>
<td>12.3</td>
<td>14.2</td>
</tr>
<tr>
<td>Lumle</td>
<td>19.9</td>
<td>19.8</td>
<td>16.7</td>
<td>14.0</td>
<td>11.5</td>
<td>9.6</td>
<td>11.2</td>
<td>13.5</td>
</tr>
<tr>
<td>Jiri</td>
<td>19.6</td>
<td>19.5</td>
<td>15.0</td>
<td>10.5</td>
<td>8.6</td>
<td>7.5</td>
<td>9.4</td>
<td>11.7</td>
</tr>
<tr>
<td>Dailekh</td>
<td>23.3</td>
<td>22.8</td>
<td>19.1</td>
<td>15.6</td>
<td>12.9</td>
<td>11.3</td>
<td>13.3</td>
<td>17.3</td>
</tr>
</tbody>
</table>
Another important biological factor that affects the rate of post-harvest losses is the seed. Seed hardness has been found to reduce the rate of damage. Furthermore, there can be anti-feeding chemicals within the kernel that can reduce the rate at which insects develop and damage the grain. Selecting hard grain types and those that are known to slow the build up of insects can be one way to reduce the losses due to insects.

**Mechanical factors**
Mechanical factors can also affect post-harvest losses. In the case of Nepal, there is little mechanization involved in the harvesting and storing process. However, within the context of the theme of mechanical factors in the hills of Nepal, losses can occur during transport when there is spillage. Furthermore, some methods currently used by farmers during shelling can cause significant breakage. Broken kernels make the grain highly susceptible to attacks by insect pests, mites and moulds. Drying structures can help reduce the amount of time needed to bring the grain moisture content down to a safe level. Similarly, storage structures can affect the physical environment in which the grain is stored and the ease at which insects and mammals can access the grain.

**Socio-economic factors**
Socio-economic factors that affect losses include: the level of protection that can be afforded during storage, the rate at which the grain will be used or deposed of, and whether the grain is to be marketed or consumed by the farm family. If the grain is to be marketed, socio-economic factors (e.g. when the cash is needed), enter into the decision of how long the maize will be stored. The longer that maize is stored, in most cases the greater the price at the time of selling, but also the greater the risk of losses. In many of the hill areas of Nepal, the maize produced on-farm is sufficient only to last 3 to 6 months. In such cases, the loss by the time the grain is used is small. Many commercial farmers dispose of their crop almost immediately after harvest because of the urgent need they may have for cash. In this system, post-harvest losses are usually not significant for the producer.

For maize kept for seed, the storage time will be greater than 6 months and it is critical that storage conditions are optimum so that seed viability can remain high and the seed’s value be maintained. Farmers in a recent survey in Dailekh district indicated that they have about 9.5 months of food sufficiency, indicating that storage is critical over a relatively long period of time. Furthermore, on average only 34 kg of maize is actually sold per household in Dailekh District (HMRP, 2000).

---

**Where Do Losses Occur**
- A case study from Africa

In a recent review of research carried out in Africa the principle points in the post-harvest handling process where grain losses occurred were identified as: field drying and harvesting, transporting, on-farm drying, threshing shelling and cleaning, storage and marketing (Figure 1).

**Field drying and harvesting:** This segment is generally where the greatest losses are recorded. Losses result from lodging in the field, sprouting, molding and damage by mammals. Damage during this phase is much higher in wet climates, like Nepal, than dryer climates.

**Transport:** Losses during transport are caused by leakage of bags and other containers as maize is moved after being shelled to storage containers or from one storage structure to another. Transport losses are usually small, averaging 1-2% (Odogola and Henriksson, 1991 and Boxall, 1998).

**On-farm drying:** Losses in this step are dependent on the length of time needed to achieve the desired moisture content of the grain which in turn is dependent on the moisture content of the grain and the environmental conditions that prevail. Maize can be dried on the cob (with or without husks) or as shelled grain. Drying is difficult in the Nepalese context as maize generally matures many weeks before the end of the monsoon rains. In the dryer climates of Africa, losses during this step average 3-6%. Drying can take a great deal of labor if it requires moving the grain into the sun and then later into protected areas during the night or during rainy periods.

**Threshing/shelling and cleaning:** Damage during threshing is related to the physical damage that may occur when flails or other equipment are used to extract the kernels from the cob. Shelling by hand usually causes minimal losses. Losses during threshing in Africa were estimated at 2-5% if a machine was used and 1% if shelling was by hand.

**Storage:** The factors described in the first part of this paper interact and affect the magnitude of loss during storage. Damage to the crop during harvesting makes the crop susceptible to attack by insect pests, mites and moulds. Furthermore, losses are least in cool dry areas and highest in hot damp areas. Storage structure used, the moisture content of the grain during storage and the management practices used, also affect the...
rate of losses. Losses during storage in Africa during an entire storage season averaged 5-6%.

These data suggest that of the various factors affecting losses, the greatest losses occur while the crop is still in the field. The management of this factor, however, may not be as easy to control as other factors as there are few options available to farmers to deal with the problems associated with drying the crop in the field.

Principles for Managing Post-maturity Losses and Recommendation for Research and Development Activities

1. **Timely harvesting can help reduce field losses.**
   In order to avoid field losses, maize should be harvested as near to physiological maturity as is possible. Earlier harvesting means that more on-farm drying will be required and provision for this is needed if early harvesting is to have a positive impact. In many areas of Nepal, it is a fairly common practice for farmers to harvest maize soon after physiological maturity. Furthermore, the traditional way of hanging cobs to facilitate drying may be a reasonable approach to on-farm drying, although one that is labor intensive. Drying proceeds slowly with this technique, however, and given the high moisture content of the grain and the high relative humidity that prevails during the post-harvest period, there is substantial risk of diseases damaging the grain, particularly if there has been some type of physical damage to the cobs during or after harvest.

2. **Drying maize to 13% moisture as soon as possible after harvest protects the grain from insect and disease buildup.**
   Research is probably justified to determine if the current systems of drying maize in Nepal can be improved upon. De-husking can speed up the process of drying, but may expose the grain to additional threats. Shelling generally increases the rate of drying, but is very labor intensive and shelling right after harvest would occur at the same time as other labor requiring on-farm operations. Protective structures that would keep the rain off of cobs but would still allow for good air movement, might offer some improvement over existing systems. Storage of grain in airtight containers has been widely promoted as a means of reducing post-harvest losses. However, when the moisture content of the grain in such structures exceeds 13%, insect or fungal heating can occur which can severely damage the quality of the grain.

3. **Insect activity is correlated to temperature.**
   In the context of Nepal, insects are most active soon after harvest (before the cooler weather of winter) and then again in the spring. It is generally during the springtime when most insect damage occurs. Accordingly, control of insects should be most focused on this period of the year.

4. **Storage losses increase over time.**
   When insects are the major cause of storage losses, it is important to consider that losses increase as storage time increases. In the context of maize in the hills of
Nepal, many families report that most of their grain is consumed by the spring. For these families, stored grain losses may be of only incidental concern. However, for those with substantial quantities of stored grain, particularly those that sell grain during the hungry period just prior to the harvest of the next season’s crop, controlling insect pests becomes critical, as it is February through July when the potential for damage is greatest. Recommendations that target those that store grain for more than 6 months, particularly during the warmer months of the years, should be developed. Some better quantification of the actual situation in the field with regards to the amount of grain that is stored during the various months of the year is justified.

5. Damaged grain is more susceptible to storage losses than whole grain.

Care is needed when threshing grain so that broken kernels can be minimized. Shelled grain should be carefully sorted and broken and damaged kernels removed before placing it in containers for longer-term storage. Hand-held devices that help to shell the cobs may be useful in reducing damaged grain, particularly in areas where flails are currently used for shelling.

6. Sanitation can slow the build up of insect pests.

Storage vessels should be washed and disinfected prior to use for storage. Sisal and nylon sacks previously used to store grain must be washed and boiled in hot water to kill off insect pest or their eggs and larvae and dried prior to use. Baskets and silos used for storage should be cleaned and re-plastered if appropriate.

7. Post-harvest strategies for handling grain may differ depending on uses.

Grain that is used within a very short period of time after harvesting will obviously require less vigorous protection than that which is intended for longer-term storage. It is therefore recommended, that a range of recommendations that target the various intended uses be developed. Different recommendations potentially are needed for grain with the following types of uses: short term storage, season-long storage, long-term storage and stored for seed.

Literature Cited


Review of Research on Post-harvest Insect Control in Nepal

D. N. Manandhar and B. P. Mainali
Senior Scientist and Technical Officer, respectively, Entomology Division, NARC, Khumaltar, Nepal

Background
Maize in Nepal is cultivated throughout the year under different climatic regimes. The crop is grown in both the hills and the Terai. The majority of the crop area is distributed in the hills where maize is grown as a summer crop. Since maize is a staple food grain of the people in the hills of Nepal, the loss of even a marginal quantity before harvest or after harvest can have a great impact on their livelihood. The total amount of production coupled with the actual post harvest grain losses determines the total availability of food grain for consumption. The grain losses in maize can be considerable, depending on the season, the type of storage structures and the method of management used. Loss in maize during post harvest operations probably accounts for a greater amount than has been estimated in the past. However, emphasis is now being given to increasing the availability of food grains by reducing post harvest losses. Losses in storage have been recognized as the highest among the losses during various post harvest operations (Fig. 1). Post harvest losses in weight, in quality, in food value and acceptability, and in the actual loss of seed materials can occur. These losses are caused by a number of factors and insect damage is considered as one of the major factors.

insect Infestation and Grain Loss
Maize during storage can be infested by several primary and secondary insects (Table 1). However, grain stored in go-downs or warehouses is mainly infested by *Sitophilus* spp, *Tribolium* spp. and *Rhizopertha dominica*. The grain weevil is considered as the most important pest. The highest level of infestation by these insects occurs in April to August. Heavy infestations of Angoumous Grain Moth, *Sitotroga cerealella*, have been reported in maize stored in outside structures such as the thangro, kunew or suli in the hills.

The average weight loss of maize during storage was estimated at 7.8% for the nation as a whole and for the mountains, hills and terai at 8.0%, 7.4% and 13.1%, respectively (RSGP, 1986). The losses due to insects in the mountains, hills and terai were 2.2%, 3.9% and 0.7%, respectively (RSGP, 1986). Boxal and Gillet (1980) recorded a 5.5% average loss due to weevil attack in the eastern hills of Nepal. Khanal et al. (1990) estimated 10.6% loss due to weevil under Pakhribas (eastern hills) conditions. The highest storage loss of up to 32% was reported in the eastern hills due to grain weevils (Paneru et al., 1993). As a result of these significant losses due to weevils, farmers were reluctant to use high yielding varieties of maize. Golob (1994) found 50 to

Table 1: Primary and secondary storage insect pest of maize

<table>
<thead>
<tr>
<th>Primary Pests</th>
<th>Secondary Pests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize weevil</td>
<td>Red flour beetle</td>
</tr>
<tr>
<td>Rice weevil</td>
<td>Confused flour beetle</td>
</tr>
<tr>
<td>Angoumous grain moth</td>
<td>Saw toothed grain beetle</td>
</tr>
<tr>
<td>Lesser grain borer</td>
<td>Rusty grain beetle</td>
</tr>
<tr>
<td>Khapra beetle</td>
<td>Indian meal moth</td>
</tr>
</tbody>
</table>

**Primary Pests**
- *Sitophilus zearais*
- *S. oryzae*
- *Sitotroga cerealella*
- *Rhizopertha dominica*
- *Trogoderma granarium*

**Secondary Pests**
- *Tribolium castaneum*
- *Tribolium confusum*
- *Oryzaephilus surinamensis*
- *Cryptolestes f. farugies*
- *Carpophilus sp.*
- *Plodia interpunctella*
100% of the maize ears stored in thangro for a period of 8 months infested with Sitophilus weevils.

Research Areas
A review of the literature has revealed that limited research has been carried out on the control of post harvest insects of maize. The major research areas where research has been conducted include: storage structures, use of plant materials as bio-insecticides, lime, insecticides, and varietal screening with a primary focus on indigenous plant materials. For storage structures the major emphasis was given to local structures such as the thangro, mud bin (ghyampo), mud plastered bamboo mat bin (bhakari) and the improved metal bin. The indigenous plant materials tested for its pesticidal effectiveness were bojho (Acorus calamus), neem (Azadirachta indica), masala (Eucalyptus spp), titepati (Artemesia vulgaris), mustard (Brassica compestris), siltimur (Litsea cubenae), babai (Melia azadirach), baberi (Mentha spicata), pudina (Mentha arvensis), timbur (Zanthoxylum armatum) and lantena (Lantena camera). Among the insecticides used malathion and celphos or phosfume were the most common.

Research Results
Storage Structures
Based on a 3 years study, insect incidence was highest in thangro and suli as compared to other structures. Insect infestation, particularly S. cerealella was highest in the month of May. The average grain loss was 10.0%. In outside storage structures where the cobs still in their husks were stored, the thangro covered with a 250-gauge plastic sheet was found to be better than the suli. Polylined bags with or without celphos, mud bins and mud plastered bamboo mat bins with celphos were found to be superior containers for the storage of shelled maize grains (Shivakoti, 1984).

Grain loss in an improved type of thangro was least (6.5%) when compared to the traditional types of thangros (Table 2). Metal bins made with 24 gauge GI plain sheet have been effective for the control of stored grain pests especially, wheat and maize (PHL RD 1999).

Use of plant materials, lime and insecticides
Effectiveness of locally available plant materials (neem, titepati, bojho, asuro, chiraito, lemon grass, citronell, bori) were tested for the control of weevil and was compared with malathion dust under Pakhrivas conditions (800m). There was no significant effect of the applied treatments (Dawadi, 1993).

Different plant materials were tested against the maize weevil (Sitophilus zeamais) at Khumaltar. Among the botanicals, Acorus stem powder was the most effective (96% dead weevils after 4 days) followed by Eucalyptus leaf dust (78% dead weevils after 4 days). Other botanicals that provided significantly better control than ‘no treatment’ were in order of their effectiveness: Artemesia leaf powder, Brassica seed powder, Acorus leaf powder, Azadirachta leaf, Litsea seed, Melia seed, Mentha spicata leaf and M. arvensis leaf (Entomology Division, 1995).

In 1996, only selective plant materials were tested at different doses. Among the plant material tested, bojo (Acorus calamus), neem oil and neem seed extract were found highly effective as compared to other plant materials and the untreated control. Bojo and neem oil showed a quick knock down effect. Different

<table>
<thead>
<tr>
<th>Thangro type</th>
<th>Wt. of maize cob with husk (kg)</th>
<th>Moisture (%)</th>
<th>Average storage loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Initial</td>
</tr>
<tr>
<td>Single bamboo w/out roof</td>
<td>40.5</td>
<td>33.6</td>
<td>14</td>
</tr>
<tr>
<td>Rectangular floor w/ bamboo poles &amp; thatch roof</td>
<td>50.0</td>
<td>43.0</td>
<td>14</td>
</tr>
<tr>
<td>As above w/ rat guards &amp; roof covered with plastic sheet</td>
<td>60.0</td>
<td>54.9</td>
<td>14</td>
</tr>
</tbody>
</table>


20 Post-harvest Maize Losses - Working Group Meeting
concentrations of neem oil were quite effective in causing higher weevil mortality. Neem oil at 2 gm per 100 gm of seeds, gave 100% weevil mortality within 3 days. It took almost 1 month to reach 88% mortality when the same treatment was applied at only 0.5 gm. Different concentrations (2 gm, 1 gm and 0.5 gm per 100 gm of grains) of bojo root powder showed satisfactory response at all concentrations and gave 100% mortality within one week and 50% mortality within 3 days (Entomology Division, 1996).

Bojo powder was found to be superior to the bojo rhizome pieces for the control of weevils in stored maize cobs in mid- and low-altitude conditions. Bojo powder was effective in minimizing weevil infestations on grain stored in buckets and on the cob stored in a kunew. Bojo powder applied as three layers in the kunew system at 30 gm kg⁻¹ grain reduced weevil infestation from 51% to 5% in the mid-altitude and from 99% to 10% in the low-altitude. Bojo powder at the same rate reduced weevil infestation from 60% (control) to 7% in the mid-altitude and from 100% to 15% in the low-altitude in the bucket storage system. The grain weight loss was reduced from 6% to <1% in the mid-altitude and from 12% to 1% in the low-altitude in cobs stored in the kunew. In the bucket system, the weight loss was reduced from 10% to 1% and from 16% to 2% in the mid- and low-altitudes, respectively, (Sah, 1999).

Household lime was applied to stored maize either by dusting or by dipping. Maize ears were dusted with a thin layer of household lime at 225 g per 100 ears in the dusting methods and in the dipping method maize ears were dipped once in a 30% mixture of lime in water and then were sun dried for three hours. The lime was effective in reducing weevil numbers in stored maize ears for a period of 9 months (November - July). The weevil infestation level was observed at the range of 21 to 54% with the dipping method, 51% with the dusting method and 65 to 92% in the untreated control (Paneru et al., 1977). Malathion dust, at different concentrations, was found to be effective in controlling weevils in maize for more than 180 days under Kathmandu conditions (Neupane, 1977). Malathion and celphos were effective in killing weevil populations completely after 4 days (Entomology Division, 1995).

**Varietal Screening**

A study on the effect of loose and tight husk cover of maize against maize weevil was carried out in 1999 by Maize Research Program, Rampur. Maize cultivars with both loose and tight husks were selected and then exposed to a high population of weevils in a seed drum for a week. The adult weevils were removed from the cobs when dehusking the cob. The number of adult weevils was observed and damaged grains were recorded after 35 days to evaluate differences in the level of weevil infestation. High level of infestation was observed in a maize cultivar with loose husks. (Personal communication with S. Arayl).

**Summary**

Results obtained from the research reviewed were variable and inconsistent. Some results were even inconclusive. Efforts have been made to test and select plant materials for effective management of stored grain pests, particularly the grain weevil (Sitophilus spp.). However, the development of an effective strategy to deploy plant material that has been proven to be effective for the control of weevil is still on going. It is recommended that the bojo powder treatment technology be refined and verified and then be taken to the farming communities through extension agents. The review clearly discovered that there are large differences in the range of losses of grain due to stored grain insects, particularly weevils. It is recommended that post harvest field losses be verified through properly planned studies.
References


Rural Save Grain Project. 1986. Study on farm level grain storage structures in Nepal. RSGP, Kathmandu, Nepal.


Botanical and Other Indigenous Knowledge Systems for the Control of Post-harvest Insects of Maize

Ram B. Paneru and Y. P. Sah
Entomology Division, Nepal Agricultural Research Council

Abstract
The potential for using botanicals and other indigenous knowledge systems for the control of post harvest insect pests of maize are discussed. Post harvest losses of maize can be very high. The use of some botanicals and indigenous knowledge are in practice to manage insect pests in farmers’ storage systems. Sweet flag rhizome powder at the rate of 20-30 g kg⁻¹ of grain was found to be superior to other botanicals tested. Similarly, other indigenous knowledge such as choice of variety, harvesting time, drying, appropriate sites or places for storage, use of locally available materials (household lime, wood ash, oil cake) are commonly used by farmers to reduce infestations of storage insects. Acorus calamus powder was effective in minimizing infestations of Sitophilus weevils on maize kunios (a heap of maize cobs placed in the store) but the application of Acorus pieces was not as effective as powder when both were applied at the rate of 30 g kg⁻¹ of grain at three different layers (i.e. bottom-, middle- and top-layer of the maize kunio). Adaptive research is required to ensure that botanicals and other indigenous knowledge system are effective, that the method of preparation and application are well described and their performance properly evaluated.

Introduction
Any resources derived from higher plants are referred to as botanicals. Similarly, plant extracts and plant-derived compounds with potent anti-insect activity are often referred to as botanical insecticides. Traditional farming methods and practices which have been developed by farmers over many generations comprises the body of knowledge that we now call indigenous knowledge. Here, we assumed the traditional methods and practices for insect pest management are indigenous knowledge systems (IKS). Agriculture was traditional up to the early fifties in Nepal and insect pest control was limited to the use of herbs only. In the case of insect pest attack, farmers were in the practice of applying different kinds of locally available herbs, like Timur (Zanthoxylum spp), Sweet Flag (Acorus calamus), and Turmeric. Over time, these practices were found to be insufficient to meet the increasing demand of the people and they had to shift from the traditional approach to a modern concept of insect pest management. Managing improved cultivation practices in crop husbandry undoubtedly enhanced the crop production capability of farmers but, at the same time, the vulnerability of crops to insect pests has increased in the same parlance. Insect pest control measures were mainly based on the use of chemical insecticides. Though farmers’ acceptability of insecticides against the crop insect pests was high, the actual use of synthetic insecticides seemed to be doomed because of socio-economic and environment repercussions. Above all, the government enforced pesticide act and regulations forbid farmers from using hazardous insecticides and encourages them to use those that are effective but which have low mammalian toxicity. In this context, agrochemical companies are also alert to exploiting alternatives, and have returned to the plant kingdom for novel chemical compounds as a basis for synthetic insecticides, which should be as mild as a plant extract but as good as the conventional insecticides. The potential for using botanicals and other indigenous knowledge for the control of post harvest insect pests of maize is discussed below.

Botanicals, their Use and Prospects in Insect Pest Management
According to Grainge and Ahmed (1988) plants are the richest source of renewable active chemicals that can be used to check insect populations. These are secondary metabolites, which disrupt the fundamental or physiological or biochemical process of the insect. Plants are natural ‘chemical factories’ providing the richest source of organic chemicals on earth. Many plant taxa have evolved highly sophisticated defense chemicals that are effective against insects, mites, pathogens and even other plant species. Globally, about 2,400 plant species have been reported to contain chemicals that have pesticidal properties (Grainge and Ahmed, 1988), among them Nepal possesses 311 species (Neupane, 1999). On the same line, Gyawali (1993) found farmers traditionally using more than 50 plant species available in Nepal against insect pests in crops and stored grains. Some examples are Evodia fraxinifolia (babis), Zanthoxylum alatum (prickly ash/Boketimur), Artemisia vulgaris (mug-wort/titepati), Eupatorium adenophorum (crofton weed/banmara),...
Azadirachta indica (neem), Justicia adhatoda (malabar nut tree/asuro), Allium sativum (garlic), Capsicum annum (hot pepper), Mentha arvensis (field mint/pudina), Tagetes patula (marigold/saypatri), Vitex negundo (Indian privet/simali). Nepalese farmers have a long tradition of using indigenous plant materials to protect standing crops and post-harvest agricultural products. Nevertheless, the formulation, dose and method of application for locally available materials needs to be validated in farmers storage conditions of Nepal.

Post Harvest Losses of Maize
Maize (Zea mays L.) is one of the important staple food crops of Nepal. In addition to grain, maize stalks are used for temporary fencing and staking for creeping crops, like peas and beans together with maize husks as livestock fodder. Maize must be stored on farm for domestic consumption and planting for the coming seasons. The majority of the households store maize cobs on vertical wooden or bamboo frames outside the house (Thangro/crib). Some households store the maize cobs inside the upper room or loft of their houses with the ears being heaped into a regular shape with no material supports (Kunio) or by hanging them on the eves of the house or across balconies.

Grain losses in storage can be caused by a number of factors including insects, diseases and rodents (Table 1). Grain damage caused by these factors in storage has been estimated by a number of scientists within the country. Depending upon the storage structure, losses were found to be in the range of 2–30% on a weight basis. Among the causal factors, Sitophilus weevils was considered as the major factor responsible for reducing the quality and quantity of maize grains particularly in mid- and low altitude regions of Nepal.

A survey jointly conducted by Pakhrribas Agricultural Center (PAC), Dhankuta (currently Agriculture Research Station, Pakhrribas) and the Natural Resource Institute (NRI-UK) on priority pest problems as perceived by farmers found that weevils in stored maize were the farmers’ priority problem (Duwadi et al., 1997). Lama et al. (1997), reported that the major reasons for the rejection of high yielding maize varieties like, Manakamana-1 in eastern Nepal was due to the problem of storage losses caused by weevils. Paneru et al., (1996), reported storage losses due to weevils of up to 31% on a weight basis in maize. Golob (1994), reported that maize stored in cribs becomes heavily damaged by insects. Ears examined on several farms (after eight months in a crib) were heavily infested by Sitophilus weevils. All the ears examined were heavily damaged and 50% or more losses in crib were recorded. Heavily infested grains are fed to animals; although the quantitative weight loss from 100% damaged grain may only be 10–20%, real loss for human consumption may approach 100%. A study on the post harvest storage situation in the eastern hills (Ghimire et al., 1996) indicated that loss up to 20 % in terms of weight and market price were reported by farmers in maize. Besides Sitophilus weevils, grain moth, Sitotroga cerealella Oliv. (Lepidoptera) is another equally important pest of maize storage. The nature of the damage from this pest has been observed to be more or less similar to that caused by weevils. Losses caused by the grain moth, however, have not yet been rigorously assessed.

Use of Botanicals as Natural Insecticides to Combat Post Harvest Insects
Among the tested local materials, the use of sweet flag rhizome powder was observed to be very effective against weevils on maize for a period of up to six months.

<table>
<thead>
<tr>
<th>Table 1: Post harvest insect pests of maize</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
</tr>
<tr>
<td>Maize weevil</td>
</tr>
<tr>
<td>Rice weevil</td>
</tr>
<tr>
<td>Angoumois grain moth</td>
</tr>
<tr>
<td>Indian meal moth</td>
</tr>
<tr>
<td>Lesser grain borer</td>
</tr>
<tr>
<td>Khapra beetle</td>
</tr>
<tr>
<td><strong>Secondary</strong></td>
</tr>
<tr>
<td>Red flower beetle</td>
</tr>
<tr>
<td>Confused flour beetle</td>
</tr>
<tr>
<td>Saw toothed grain beetle</td>
</tr>
<tr>
<td>Rusty grain beetle</td>
</tr>
<tr>
<td>Corn sap beetle</td>
</tr>
<tr>
<td><strong>Insects</strong></td>
</tr>
<tr>
<td>Sitophilus zeamais</td>
</tr>
<tr>
<td>Sitophilus oryzae (L)</td>
</tr>
<tr>
<td>Sitotroga cerealella (Olive)</td>
</tr>
<tr>
<td>Plodia interpunctella (Hbn.)</td>
</tr>
<tr>
<td>Rhizopertha dominica (F.)</td>
</tr>
<tr>
<td>Trogoderma granarium (Events.)</td>
</tr>
<tr>
<td>Tribolium castaneum (Hbst.)</td>
</tr>
<tr>
<td>Tribolium consfusum (Davel)</td>
</tr>
<tr>
<td>Oryzaphilus surinamensis (L)</td>
</tr>
<tr>
<td>Cryptolestes furigieus (Steph.)</td>
</tr>
<tr>
<td>Carpophilus sp</td>
</tr>
</tbody>
</table>
Similarly, powder prepared from sweet flag rhizomes collected at both high (1700 m) and low (900m) altitudes in eastern Nepal when admixed with wheat grains infested with *Sitophilus oryzae* or *S. granarius* adults at concentrations in the range 0.05–2% (w/w) the mortality of both species was significantly lower at 20°C than at 30°C. β-asarone, a compound with insecticidal activity, was found to present in the sweet flag rhizomes and was thought to be responsible for the mortality of the weevils (Paneru et al., 1997).

Recently the Nepal Agricultural Research Council (1999) recommended the following botanicals in order to manage weevils in post harvest storage:

- Use of *A. calamus* rhizome powder at the rate of 1 g in 100 g of stored maize grains.
- A formulated product of neem containing 0.15% azadirachtin (Trade name: MargoSom 0.15%) and neem seed powder, respectively, at the rate 1 ml and 1 g per 100 g of grain against stored grain insects.
- Use of turmeric (*C. longa*) powder at the rate of 2 g in 100 g of stored grains.
- Use of commercial mustard oil (*B. kompestris* var. *toria*) at the rate of 1 ml per 100 g of stored cereals.
- Use of *Timur* (*Zanthoxyllum armatum*) fruits mixed with stored grains.

During the period 1980 to 1983, Shivakoti (1984) studied different kinds of internal and external storage structures (grain containers) to estimate the post harvest losses due to storage grain pests of maize. Over the 3 years, poly lined bags with or without celphos had the least losses. Next to the poly lined bags, the *Ghyampo* (earthen pot) with celphos tablets during storage was the most effective. The third ranked container was the plastered *Bhkari* with celphos tablets in the grain. Among the external storage structures, *thangros* covered with 250 gauge plastic was better than *sulis*.

*Bojo* powder was superior to treatments using *bojo* rhizome pieces to reduce weevil infestations in the stored cobs under both mid- and low altitude conditions. This experiment found that the *bojo* powder treatment can minimize grain infestations not only on grains but also on cobs stored under both the *Kunio* and bucket storage systems. The response of *bojo* powder to minimize weevil infestations was similar for both white and yellow varieties of maize. This experiment indicated that *bojo* powder simply applied in three layers of *Kunio* at the rate of 30 g kg⁻¹ grain can reduce weevil infestation from 51 to 5.4% in the mid-altitude and from 97 to 10% in low altitudes (Table 2). While on the cob, storing in plastic buckets can reduce the infestation of weevil from 60 (control) to 7% at mid-altitudes and from 100 to 15% at low altitudes (Table 3). Similarly, with this treatment grain weight losses were reduced

| Table 2: Weevil damage over time in a kuniyo storage system (% of grains bored by weevils) |
|---------------------------------|-------|-------|-------|-------|-------|-------|-------|
| Treatment                      | 0 day | 30 days | 60 days | 90 days | 120 days | 150 days |
| **mid altitude:**              |       |        |        |        |         |         |
| White maize + A. Piece         | 0.00  | 4      | 10     | 14     | 24       | 34       |
| White maize + A. Powder        | 0.00  | 1      | 2      | 3      | 4        | 5        |
| White maize + control          | 0.00  | 12     | 23     | 27     | 37       | 50       |
| Yellow maize + A. piece        | 0.00  | 2      | 5      | 9      | 17       | 29       |
| Yellow maize + A. powder       | 0.00  | 1      | 2      | 3      | 4        | 6        |
| Yellow maize + control         | 0.00  | 10     | 17     | 22     | 35       | 51       |
| **low altitude:**              |       |        |        |        |         |         |
| White maize + A. piece         | 0.00  | 6      | 14     | 36     | 59       | 79       |
| White maize + A. powder        | 0.00  | 1      | 3      | 4      | 7        | 11       |
| White maize + control          | 0.00  | 18     | 36     | 57     | 79       | 99       |
| Yellow maize + A. piece        | 0.00  | 5      | 15     | 37     | 56       | 75       |
| Yellow maize + A. powder       | 0.00  | 1      | 3      | 4      | 7        | 10       |
| Yellow maize + control         | 0.00  | 17     | 36     | 55     | 79       | 97       |
| Grain bored 150 days: altitude: ***<0.001 level, cv 1.23%, treatments: ***<0.001 level, cv 9.23%. |

from 6 to 1% at mid- and from 12 to 1% at low altitudes in the cobs stored in a Kunio (Table 4), and from 10 to 1% and 16 to 2% at mid- and low altitudes, respectively, in the cobs stored in plastic bucket (Table 5). These are all encouraging results indicating that locally available bojo material can be effective in minimizing weevil damage to maize still on the cobs.

Gyawali et al. (1996), reported that existing stored grain protection measures adopted by farmers, include:
- Mixing ground dry leaf/seed of Artemisia vulgaris (Titepati) and Xanthozylum alatum (Timur) with stored grain.
- Mixing ground dry leaf/seed of Melia azederach (Bakaino) and storing grains.

### Table 3: Weevil damage as affected by botanical treatment and maize variety over time using the plastic bucket storage system

<table>
<thead>
<tr>
<th>Treatments</th>
<th>0 days</th>
<th>30 days</th>
<th>60 days</th>
<th>90 days</th>
<th>120 days</th>
<th>150 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid altitude</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White maize + A. Piece</td>
<td>0.00</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>10</td>
<td>27</td>
</tr>
<tr>
<td>White maize + A. Powder</td>
<td>0.00</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>White maize grain + A. powder</td>
<td>0.00</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>White maize + control</td>
<td>0.00</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>25</td>
<td>60</td>
</tr>
<tr>
<td>Low altitude</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White maize + A. Piece</td>
<td>0.00</td>
<td>2</td>
<td>9</td>
<td>1</td>
<td>50</td>
<td>91</td>
</tr>
<tr>
<td>White maize + A. Powder</td>
<td>0.00</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>White maize grain + A. powder</td>
<td>0.00</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>White maize + control</td>
<td>0.00</td>
<td>4</td>
<td>12</td>
<td>12</td>
<td>84</td>
<td>100</td>
</tr>
</tbody>
</table>

Grain bored 150 days: altitude: ***<0.001 level, treatments:***<0.001 level, cv 16.34%
Source: Sah YP (1999)

### Table 4: Effect of maize variety and treatment method using Acoris sp. on grain weight and germination loss in a Kuniyo storage system

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grains bored (%)</th>
<th>1000Grain weight at 12% MC (g)</th>
<th>Grain weight loss</th>
<th>Germination %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial Final</td>
<td>Infested</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid altitude</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White maize + A. Piece</td>
<td>34</td>
<td>325</td>
<td>312</td>
<td>4.15</td>
</tr>
<tr>
<td>White maize + A. Powder</td>
<td>5</td>
<td>325</td>
<td>323</td>
<td>0.68</td>
</tr>
<tr>
<td>White maize + control</td>
<td>50</td>
<td>325</td>
<td>306</td>
<td>5.94</td>
</tr>
<tr>
<td>Yellow maize + A. Piece</td>
<td>29</td>
<td>331</td>
<td>320</td>
<td>3.46</td>
</tr>
<tr>
<td>Yellow maize + A. powder</td>
<td>6</td>
<td>331</td>
<td>329</td>
<td>0.71</td>
</tr>
<tr>
<td>Yellow maize + control</td>
<td>51</td>
<td>331</td>
<td>311</td>
<td>6.11</td>
</tr>
<tr>
<td>Low altitude</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White maize + A. piece</td>
<td>79</td>
<td>325</td>
<td>295</td>
<td>9.36</td>
</tr>
<tr>
<td>White maize + A. powder</td>
<td>11</td>
<td>325</td>
<td>321</td>
<td>1.29</td>
</tr>
<tr>
<td>White maize + control</td>
<td>99</td>
<td>325</td>
<td>287</td>
<td>11.8</td>
</tr>
<tr>
<td>Yellow maize + A. piece</td>
<td>75</td>
<td>331</td>
<td>302</td>
<td>8.91</td>
</tr>
<tr>
<td>Yellow maize + A. powder</td>
<td>10</td>
<td>331</td>
<td>327</td>
<td>1.28</td>
</tr>
<tr>
<td>Yellow maize + control</td>
<td>97</td>
<td>331</td>
<td>292</td>
<td>11.8</td>
</tr>
</tbody>
</table>

Grain wt. loss: altitude: ***<0.001 level, cv 13.96%, treatments:***<0.001 level, cv 13.96%
Source: Sah YP (1999)
Table 5: Grains weight loss in the plastic bucket storage system

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mean final</th>
<th>1000 Grain</th>
<th>Grain Weight</th>
<th>Germination %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean initial</td>
<td>weight (g)</td>
<td>loss %</td>
<td>Initial</td>
</tr>
<tr>
<td><strong>Mid altitude</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White maize + A. piece</td>
<td>27</td>
<td>325</td>
<td>310</td>
<td>4.5</td>
</tr>
<tr>
<td>White maize + A. powder</td>
<td>7</td>
<td>325</td>
<td>321</td>
<td>1.4</td>
</tr>
<tr>
<td>White maize grain + A. powder</td>
<td>5</td>
<td>325</td>
<td>322</td>
<td>0.8</td>
</tr>
<tr>
<td>White maize + control</td>
<td>60</td>
<td>325</td>
<td>293</td>
<td>10.0</td>
</tr>
<tr>
<td><strong>Low altitude</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White maize + A. piece</td>
<td>91</td>
<td>325</td>
<td>281</td>
<td>13.5</td>
</tr>
<tr>
<td>White maize + A. powder</td>
<td>15</td>
<td>325</td>
<td>318</td>
<td>2.3</td>
</tr>
<tr>
<td>White maize grain + A. powder</td>
<td>9</td>
<td>325</td>
<td>320</td>
<td>1.5</td>
</tr>
<tr>
<td>White maize + control</td>
<td>100</td>
<td>325</td>
<td>273</td>
<td>15.9</td>
</tr>
</tbody>
</table>

Grain weight loss: mid altitude: ***<0.001 level, treatments: ***<0.001 level, cv 17.31%
Source: Sah YP (1999)

- Drying and grinding leaves of *Azadirachta indica* (*Neem*) and mix with seeds.
- Drying and grinding leaves of *Adhatoda vasica* with stored grains.
- Dusting lime in open store and applying around.
- Placing millet or soyabean seeds on top of other stored grains.
- Mixing edible oils with seeds.
- Mixing turmeric powder with seeds and the grains.
- Storing ginger and grains together.
- Mixing powder rhizomes of *Acorus calamus* (*Bojo*) with storage grains.

There is a need to validate insect killing properties of such materials, to explore their properties fully and to develop more effective methods for utilizing them to ensure safe and effective control.

Other Indigenous Knowledge to Combat Post Harvest Insect Pests

Choice of Variety
Nepalese farmers are very selective about which maize varieties they grow. They prefer to grow maize varieties that have hard intact teguments or tightly closed husks. The principle behind this preference is it acts as a physical barrier to larvae which die before they are able to bore their way through to the germ. Seeds or germs can themselves contain ingredients which prevent or hinder the growth of larvae. Modern hybrid maize varieties often posses open husks which do little to prevent the infestation by weevils. Traditional varieties are naturally better protected because their husks are generally more closed.

Choice of Harvesting Time
In general, farmers do not harvest maize unless it is fully matured because of the weevil problem. They have the perception that harvesting maize early encourages attack of insect pests. Timely harvesting followed by drying the cobs can ensure that weevils cannot easily bore into grains.

Drying
Usually farmers dry the maize cobs and grains on a sunny day to protect maize from insects. Drying is an important procedure to ensure protection. It worsens condition for the development of insect pests. A moisture content of not more than 12-13%, depending on the relative humidity is essential before seeds can be stored safely. Drying helps to reduce the grain moisture content in the cobs. The sun is commonly used for drying. Hanging maize over a kitchen fire (*hanging Jhutta*), spreading cobs in the sun, and storing maize in a *Thangrol* or *Kunio* are also methods commonly employed by farmers to dry the harvested maize crop.

Storage Hygiene
The first step towards good storage hygiene is choosing a suitable site for the *Thangro*, hanging *Jhuttas* or *Kunio*. They should be airy, shady, cool and dry locations. New and old lots of maize should not be stored together.
Use of household lime

Farmers believe that simple lime has the property of killing weevils. The fact is that lime particles, when attached to an insect’s body can rupture the cuticle of the insect. When the cuticle is ruptured, dehydration will take place in the insect body and the insect will eventually die.

Maize ears treated by dipping them in a 30% mixture of household lime and water, and ears treated by a thin layer of lime dusting, significantly reduced weevil attack as compared to untreated maize ears. These data strongly suggest that further study to find out the most effective and economical dose of lime to reduce weevil infestations is needed. Further testing of fine quality/grade household lime, differing doses and methods of application in differing storage structures (i.e. Thangro, Jhutta and Kunio) is recommended. The fine graded lime could have higher persistence than coarse graded lime. Therefore, it could be more effective in controlling weevil infestations. At the same time, the effect of lime treated husks on animals needs to be tested.

Use of Ash

Wood ash is effective against numerous pests including weevils. The authors observed during a recent field visit that a few farmers apply wood ash and oil cake to protect their maize from weevil attack.

Improved technologies recommended to farmers have often failed or have not been adopted by farmers. This may be in part due to the failure of the researchers to incorporate indigenous knowledge (IK) into the research process. Farmers are often not aware of chemical hazards. They focus on the quick knock down effect of the chemicals on the target pests and neglect to consider the potentially negative side effects of the chemicals on the consumers and on the environment. All of these situations have enhanced the disappearance of indigenous knowledge. There is a big gap between academic research and farmers regarding indigenous practices of insect pest management. Further research on botanicals and IK are highly recommended in order to verify and confirm the reliability of those practices under farmers’ conditions. The majority of Nepalese farmers cannot afford to purchase pesticides and expensive grain storing technology (storage in metal bins). The use of recommended fumigants (Celphos or malathion) is either expensive or erratic as they are not easily available and can cause serious damage to the environment if not used properly.

Recommendations

Plant extracts or dried plant parts are most appropriate for the individual farmers because it should be possible to readily obtain a cheap source of a locally available material. Adaptive research is required to ensure that such materials is used effectively, that the method of preparation and application are well described, and that their use is evaluated. Resistance of maize varieties to Sitophilus, one of the most important post harvest pests of maize, needs to be investigated. Most of the work in Nepal seems to be concentrated on the management of weevils but losses and damage caused by the grain moth can be equally important and needs to be documented. Sweet flag rhizome powder is not effective in controlling the grain moth. The different plant materials having a positive indication in reducing weevil damage could be mixed together in a specific ratio for their combined effect against weevils. The potentiality of indigenous knowledge and local methods for pest control need to be explored and included in the formal research program. Assessment of shelf life and persistence of effective plant products need to be studied.

References


Lama Sherpa, N.G., P.R. Ojha and A.R. Sharma. Why farmers adopt or reject agriculture technologies? A case of improved maize and wheat varieties in the local target area of Pakhribas Agriculture Centre at Dhankuta District of Eastern Nepal. PAC Technical Paper No 177. Pakhribas Agriculture Centre, Dhankuta c/o BAPSO, PO Box 106, Kathmandu, Nepal.


Review of Research in Nepal on Disease-related Post-harvest Losses in Maize

G. Manandhar and B. K. Batsa
Plant Pathologists, Plant Pathology Division, Khumaltar and the National Maize Research Program, ARS-Rampur

Introduction

Maize is an important crop in Nepal both as food as well as feed. It is grown on almost 0.8 million ha with an average yield of 1681 kg ha⁻¹. Disease is one of several factors affecting its productivity (CBS, 1997). A total of 130 pathogens can cause diseases of maize (Malcom & Charles, 1997). Research on maize diseases started in Nepal in 1964, beginning with disease surveys. Many diseases were identified over time and a total of 72 fungi belonging to 44 genera, 3 bacteria and 7 nematodes were found associated with the crop (Amatya and Shrestha, 1969; Khadka and Shah, 1967; Manandhar, 1983; Manandhar and Shah, 1975; Pawsey, 1989; Shrestha, 1977; Shrestha, 1978). Field symptoms suggest that viruses are also present but this has not yet been confirmed (Manandhar, 1983).

Of the many pathogens causing diseases of maize, several cause problems in the grain after harvest and include mainly the fungal pathogens causing ear rots and storage rots. Eleven ear rot fungal pathogens have been recorded in Nepal (Manandhar, 1983; Table 1). Species of Aspergillus, Penicillium, Rhizopus, Cladosporium, Fusarium are the most common organisms observed as significant for storage rot under high moisture conditions. All those fungi are seed-borne in nature and occur internally or externally on the seed. Earlier, 18 fungi belonging to 16 genera were reported on maize seed during routine testing of seed samples (Shrestha, 1977; Shrestha, 1978). At present a total of 31 fungi, belonging to 22 genera are known to be associated with the seed (Table 2). Their incidence

| Table 1: Prevailing ear rot diseases and their causal organisms in Nepal |
|---------------------------------|---------------------------------|
| 1. Gibberella ear rot (Fusarium graminearum) | |
| 2. Fusarium kernel rot (Gibberella fujikuroi complex) | |
| 3. Aspergillus ear rot (Aspergillus flavus) | |
| 4. Trichoderma ear rot (Trichoderma viride) | |
| 5. Cladosporium ear rot (Cladosporium sp.) | |
| 6. Rhizoctonia ear or Sclerotial rot (R. solani, R. zeae) | |
| 7. Penicillium ear rot (Penicillium spp.) | |
| 8. Diplodia ear rot (Diplodia zeae) | |
| 9. Nigrospora ear rot (Nigrospora oryzae) | |
| 10. Helminthosporium ear rot (Helminthosporium spp) | |
| 11. Grey ear rot (Physalospora zeae) | |

| Table 2: List of fungi known to be associated with maize seed in Nepal |
|---------------------------------|---------------------------------|
| 1. Fusarium moniliforme | 17. Curvularia geniculata |
| 2. F. proliferatum | 18. C. lunata |
| 4. F.graminearum | 20. Phoma sp. |
| 6. F. equiseti | 22. Diplodia zeae |
| 7. Aspergillus flavus | 23. Epicoccum purpureascens |
| 8. A. niger | 24. Rhizoctonia zeae |
| 9. Cephalosporium sp | 25. R. solani |
| 15. Helminthosporium maydis | 31. Ustilago maydis |
| 16. H. Carbonum | |
differs from genotype to genotype and from region to region. Post harvest losses in maize is estimated to be around 20% but losses due to diseases alone have not been studied experimentally.

Regarding grain yield reduction in the field due to ear rot diseases, losses of up to 37% due to red ear rot ( *Gibberella zeae* (Schw.) Petch., the teleomorph of *Fusarium graminearum* (Schwabe), in the hills and up to 44% due to sclerotial rot (*Rhizoctonia zeae* Voorhees, the anamorph of *Waitea circinata* Warcup & Talbot) in the inner-terai were observed in Arun-4 and Rampur Yellow maize genotypes, respectively, under artificially inoculated conditions (Manandhar and Poudel, 1998; Anonymous, 1997).

Damage to ears caused by various agents such as birds and insects or delays in harvest predispose the ears/kernels to many fungi, which can cause rapid deterioration in the kernel just before or soon after the harvest. In such cases ears are usually invaded by species of *Aspergillus*, *Trichoderma*, *Rhizopus*, *Penicillium* and/or *Fusarium*.

In two different studies, the most dominant species observed to infect seed was *Fusarium* (Table 2, 4). Six species of *Fusarium* were confirmed to infest maize seed and the maximum occurrence of strains was reported in those belonging to *Gibberella fujikuroi* (Desjardins et al., 2000). A mean infection rate of 32% (±21%) by *Fusarium* strains was found using *Fusarium* specific medium. A higher infection percent of seed was observed due to species of *Fusarium*, *Aspergillus*, *Cladosporium* and *Penicillium* while a lower percent was obtained by *Alternaria*, *Phoma*, *Curvularia*, *Pestalotiopsis*, *Helminthosporium*, *Botryodiplodia* and *Colletotrichum*.

A range of infestation from 3% to 54% (Table 4) was observed in pretreated maize samples (9 in total) grown at different locations in the hills and inner terai regions on special medium (Manandhar et al., 2000). The

Table 3: Fungi associated with maize seed and their infection percent on a blotter test based on 200 seeds (Rampur Composite foundation seed), 1999

<table>
<thead>
<tr>
<th>Organisms</th>
<th>Percent Infected</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Fusarium</em> species</td>
<td>81.0</td>
</tr>
<tr>
<td><em>Aspergillus</em> species</td>
<td>31.0</td>
</tr>
<tr>
<td><em>Cladosporium</em> species</td>
<td>21.5</td>
</tr>
<tr>
<td><em>Penicillium</em> species</td>
<td>21.0</td>
</tr>
<tr>
<td><em>Nigrospora</em> species</td>
<td>12.5</td>
</tr>
<tr>
<td><em>Rhizopus</em> species</td>
<td>6.0</td>
</tr>
<tr>
<td><em>Epicoccum</em> species</td>
<td>1.5</td>
</tr>
<tr>
<td><em>Botryodiplodia theobromae</em></td>
<td>0.5</td>
</tr>
<tr>
<td><em>Helminthosporium maydis</em></td>
<td>0.5</td>
</tr>
<tr>
<td><em>Curvularia</em> species</td>
<td>0.5</td>
</tr>
<tr>
<td><em>Macrophomina</em> species</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 4: *In vitro* effect of seed dressing on seed borne infection of *Fusarium* in two maize genotypes, Khumaltar, 1999

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate</th>
<th>Ganesh-2</th>
<th>Rampur Comp</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Captain</td>
<td>2 gm</td>
<td>9</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>Thiride (thiram)</td>
<td>2 gm</td>
<td>4</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>Bavistinn (carbendazim)</td>
<td>2 gm</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Benilate (benomyl)</td>
<td>2 gm</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vitavax (carboxin)</td>
<td>2 gm</td>
<td>17</td>
<td>75</td>
<td>46</td>
</tr>
<tr>
<td>Garlic extract</td>
<td>2 ml</td>
<td>14</td>
<td>73</td>
<td>44</td>
</tr>
<tr>
<td>Surface sterilization</td>
<td>-</td>
<td>13</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>Control (not sterilized)</td>
<td>-</td>
<td>18</td>
<td>84</td>
<td>51</td>
</tr>
</tbody>
</table>
percent of seed infection was observed higher in non-
surface sterilized seeds, on blotter (Table 1) and on
other media and ranged from 13% to 96%. On white
maize (Population 22, grown at ARS-Pakhribas), the
highest percent of seed infection was observed due to
Aspergillus spp. (29%), followed by Cephalosporium
spp. (16%), Fusarium spp. (14%), Penicillium spp
(13.5%) and Rhizoctonia solani (12%). The
considerable percent of infection in seed by Rhizoctonia
solani f. sp. sasaki in Population 22 could have been
due to the early infection of the ears by the pathogen
while the crop was still in the field. The kernels from
such ears could have mixed in the seed lot. On yellow
maize (Rampur Composite, grown at National Maize
Research Program at Rampur in inner terai), the highest
percent infestation was observed by Fusarium (84%),
followed by Aspergillus species (5%) and the lowest
by Penicillium spp. (Manandhar et al., 2000).

In addition to infecting the seed and thereby reducing
the quantity and quality of the crop, some strains of
fungi are important for their ability to produce
mycotoxins on contaminated kernels. Mycotoxins can
be hazardous to animal and human health (Munkvold
and Desjardins, 1997). Aspergillus species are a
significant source of aflatoxin contamination.
Aflatoxins are considered as potent hepatotoxins and
carcinogens. Aflatoxin B1 caused by A. flavus and A.
parasiticus contaminated 17% and 22% of the seeds
sampled in the hills and terai, respectively. The
tolerance limit of 30 ppb as suggested by the Protein
Advisory Group, was exceeded more frequently in the
terai samples (9.8%) than in the hills (4.3%) (Karmacharya, 1988). Mycotoxin contamination is
reported to be more problematic during the rainy
season. Similarly, 10 percent of the 101 maize food
samples were found to have aflatoxin levels above those
found to be safe to livestock, 25 out of 58 in poultry
feed, were reported to be highly contaminated by
aflatoxins beyond the tolerance limit, 10 to 50 ppb
depending upon the age of the animals according to
EEC (Karmacharya, 1984).

Strains of G. fujikuroi complex in MP-A can produce fumonisins that can cause equine
leukoencephalomalacia (LEM), porcine pulmonary

### Table 5: Fusarium ear and kernel rot disease incidence, severity and grain yield in seed
treatment field experiment at Khumaltar, 1999

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ear Rot Incidence</th>
<th>Severity (1-7)</th>
<th>Grain Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R.C.</td>
<td>G-2</td>
<td>R.C.</td>
</tr>
<tr>
<td>Garlic</td>
<td>11</td>
<td>13 ab</td>
<td>1.3</td>
</tr>
<tr>
<td>Bavistin</td>
<td>15</td>
<td>3 c</td>
<td>1.6</td>
</tr>
<tr>
<td>Benlate</td>
<td>16</td>
<td>8 bc</td>
<td>1.2</td>
</tr>
<tr>
<td>Vitavax</td>
<td>6</td>
<td>6 ab</td>
<td>1.2</td>
</tr>
<tr>
<td>Thiride</td>
<td>11</td>
<td>17 ab</td>
<td>1.3</td>
</tr>
<tr>
<td>Untreated</td>
<td>13</td>
<td>18 a</td>
<td>1.3</td>
</tr>
<tr>
<td>CV %</td>
<td>39</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>F-test</td>
<td>NS</td>
<td>0.05</td>
<td>NS</td>
</tr>
</tbody>
</table>

### Table 6: Infection percent of Fusarium in maize seed samples grown in different locations,
1999.

<table>
<thead>
<tr>
<th>Maize genotypes</th>
<th>Source (seed)</th>
<th>Original infect. % on seed</th>
<th>Nigale</th>
<th>Khumal (summer season '98)</th>
<th>HCRP Dolakha</th>
<th>NMRP Rampur wint. '96</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramp. Comp</td>
<td>NMRP-Rampur</td>
<td>19%</td>
<td>37%</td>
<td>24%</td>
<td>54%</td>
<td>18%</td>
</tr>
<tr>
<td>Population 22</td>
<td>ARS-Pakhribas</td>
<td>10%</td>
<td>—</td>
<td>23%</td>
<td>27%</td>
<td>3%</td>
</tr>
</tbody>
</table>

wint. = maize grown in winter season
"—" = seed not tested
edema (PPE) and liver cancer in laboratory rats. Epidemiological studies have co-related the consumption of maize containing high level of *G. fujikuroi* MP-A and fumonisins on the occurrence of high rates of human oesophageal cancer (Marasas et al., 1984; Munkvold and Desjardins, 1997). By high-performance liquid chromatography (HPLC) or immunoassays, fumonisins in 22% of 74 maize samples were found above the safe level of 1000ng/g set by the Food and Drug Administration of the USA (Desjardins et al., 2000). The maize samples were collected from farms in Lumjung, Kathmandu, Kaski, Chitwan, Nuwakot, Lalitpur, Morang, Dhankuta and Dhanusha districts.

Strains of *F. graminearum* are responsible for the production of deoxynivalenol and nivalenol, which are known to be potent protein synthesis inhibitors. Such toxins can cause anemia and immunosuppression, haemorrhaging, nausea, diarrhea etc. In Nepal these chemicals were found to be above the safe limit (1000ng/g) by flurometry or immunoassay in 16% of 74 samples (Desjardins et al., 2000).

Symptomless kernels can also be infected by species of *Fusarium*. High moisture is the main factor to be considered when trying to manage the post harvest problem. Use of resistant genotypes to avoid fungal infection and aflatoxin contamination, selecting the proper season for sowing and harvesting to avoid mould infection and employing an efficient drying, storage and aeration system suitable to varying ecological regions of the country are suggested as ways of reducing the problem (Karmacharya, 1984). Hence, rapid drying of ears and/or kernels to a safe moisture content just after harvest and maintaining proper moisture content during storage are the best means of managing post harvest losses.

Some seed dressing chemicals such as Benlate, Bavistin, Thrilde and Captan have been shown to be effective against the infection of seeds by *Fusarium* species in vitro (Table 2). In field experiments, however, the effect of seed treatment did not significantly reduce the incidence of ear rot disease and or increase grain yield (Table 3). By selecting out visibly moldy kernels, toxin levels could be reduced to an acceptable and safe level (Desjardins et al., 2000).

**Acknowledgement**

The authors are thankful to Mr. K. Adhikari, Maize Co-ordinator, NMRP for his kind permission in allowing this paper to be presented. Thanks are due to Dr. S. K. Shrestha, Chief, Plant Pathology Division, Dr. C. B. Karki, Mrs. S. Joshi, Mrs. S. Sharma and Mrs. R. D. Timila, Senior Scientists, NARC for their valuable suggestions and inspiration and to Mrs. S. Karmacharya, Food Research Officer, Central Food Research Office, for her kind help in providing some vital information and literature.

**References**


Drying and Storage Structures to Minimize Maize Post-harvest Losses in Nepal

Gautam B. Manandhar and Khadga B. Shrestha
Senior Scientists, Agricultural Engineering Division, Nepal Agricultural Research Council, Khumaltar

Summary

Maize is a staple food in Nepal in mid-hill regions covering 70% of total maize area. It is grown in about 0.8 million ha with total production of about 1.33 million tons. The crop is also emerging as an industrial crop in accessible areas. Maize loss during drying and storage has been reported as high as 51% of total post harvest loss. Studies conducted in Nepal and a few other studies from other countries, related to maize loss, dryers/drying methods and maize storage bins/methods are listed.

Traditional maize drying/storage methods at the farmer level are sun drying, outdoor raised open bamboo structure (Thankrol Suli); indoor natural aerated bamboo structure (Meera); hanging on ropes and placing above the kitchen. Storage method/structures are piling (Kuniu); sundried mud structures (Dehari); baked mud structures (Ghyampo, Ghyampi etc.); baked brick or stone structures (Dhikuti) and timber structures. Traditional storage structures are neither airtight nor rodent proof. They need to be modified or replaced by simple improved methods. Metal bins are being distributed/sold at 25% subsidy to the farmers.

Available technologies, research priorities and present constraints for research work on maize drying and storage are listed. Also, methods to improve outreach research activity have been pointed out. Coordinated research programs aimed at women friendly technologies and outcomes aimed at farmer groups have been stressed. Finally, farmer to farmer exchange of information/experience, an effective mechanism for technology transfer, are stressed to be arranged by the concerned authorities to improve outreach research activity.

Introduction

The agricultural worker including farmers, scientist, extension workers and other technicians put hard labor to produce more and more food to meet the ever increasing demand of the growing population. A major share of the food so produced is lost even after harvest till it reaches to the consumers. Reducing post harvest losses is, therefore, the main concern of the whole world today.

In Nepal, maize is a second major crop after rice. It is the significant staple food for the mid-hills, which covers 70 percent of total maize area. The Nepalese farmers therefore have a serious concern regarding the success and failure of the maize crop in any year.

Maize covers about 27 percent of the total cereal production, and nearly 30 percent of the total cultivated land. The crop is grown in an area of 791,700 ha with a total production of about 1.33 million tons (NMRP, 1997). The terai, which has high potential for spring as well as winter maize, occupies 20 percent of the maize production area and the trend is on the rise particularly in the winter.

Among maize harvesting seasons in Nepal, summer maize has the most difficult situation during which simple mechanical drying is probably needed for its safe storage. The harvesting season coincides with the late monsoon season. The bulk of the maize is generally harvested between mid September to early October. The harvested maize cobs have, therefore, relatively high moisture content, generally more than 30%. Under such condition, the cobs are susceptible to insect infestation, if not properly dried and stored. In spite of hard effort, farmers in Nepal are not in a position to control considerable amount of maize losses in post harvest operations including storage and drying. Therefore, new grain drying technologies should be explored.

Additionally, maize is emerging as an industrial crop in accessible areas of Nepal. It is used for the production of oil, animal feed, glucose, etc. Verma (1997), described the popularity of baby corn for salad's vegetable - on its tremendous export potential too in canned form, and also as food and fodder. Moreover, the future demand for maize in Nepal is expected to grow by 4 percent per year over the next 20 years driven by an increase in demand for food in the hills and feeds in terai (Adhikary, 2000). Statistical data (1994/95) shows that the requirement of maize in the country is 13.7 percent more than the production. Drying of this crop would help in the reduction of storage losses fulfilling a part or even whole of the required balance.
Importance of Drying before Storage

Maize is a priority crop under Nepal Agriculture Perspective Plan (HMG/N; 1996). Emphasis on accelerating the production of the agricultural products alone will not solve the problem. Whatever is produced should be saved too. The rate of growth of stored pests, as well as the rates at which chemical and physical changes take place, increase greatly with the moisture content as well as with the ambient temperature of the product. It is reported whenever the moisture content and temperature of the stored grain go higher than 13 percent and 70°F (21°C), respectively, grain in storage starts deteriorating rapidly. The moisture content of the harvested crop ranges from 23-38 percent (RSGP, 1986). It should be reduced at least to 18 percent or less for the winter maize storage or to 13-14 percent for the spring maize. So, appropriate and economical/mechanical methods should be applied for quick drying of the products to store well for about 6 months.

Drying is a pre-requisite for proper storage of any crop. Muir, W.E. explained, as was determined by Saul and Associates (without considering insect and mite infestation), that reducing MC from 25 to 20% causes an increase in storage life of 3 times, but if it could be reduced from 25 to 15%, storage life would be increased 30 times.

Review of Literature on Losses

K.C. (1992) reported 19.5% total post harvest weight loss of maize of which 2.50% occurs during drying while 7.4% occurs during storage. In another report, he also pointed out maize loss due to rodents, insects, and mold to be 4.6, 3.1 and 0.2% respectively (K.C., 1987-1997). However, Boxali and Gillett (1984), on the basis of a study carried out in the eastern hill of the country, reported total weight loss of maize of 5.7% during a period of 6.1 months. Of this, 3.7% was due to rodents, 0.6% due to insects and 1.4% due to mold. Different weight loss figures obtained by these authors could be probably due to different methodology applied during the study or due to different ecoclimatic condition of the study area. The ecological belt-wise storage loss in maize has been, however, reported by Anon (1982), which indicated total weight loss due to various agents including rodent, insect and mold as 8.0% in the mountain, 7.4% in the hill and 13.0% in the terai. Storage loss of 7.4% in the hill seemed to agree with the figure reported by K.C. (1992). However, storage losses for the mountain and tarai are at the higher side than that reported by K.C. (1992).

In addition, some authors have also observed the weight loss of maize in the thankro, an outside wooden structure used for storing maize cobs in husks. Shivakoti (1984) found a weight loss of 0.8 to 6.1% in thankro covered with 250 gauge plastic sheet. Similarly, Anon (1980/81–1995/96) reported average weight losses of 6.5% and 11.6% in thankro, respectively, with and without rodent baffles. Besides the storage of newly harvested maize cobs, Kiss and Farkas (1977) reported that shelled maize at 31.2% moisture content (MC) could be stored in jute bags at 5°C for only 2 weeks.

Sinha (1971) listed the important variables in a grain bulk ecosystem as temperature, moisture, oxygen, geographical location, storage structure, physical, chemical and biological properties of grain bulk and biological enemies. Analyses were based on simultaneous observations on 35 variables.

Muir, W.E. (1971) presented an equation for max. storage life of corn as:

\[ T = T_x \times M_x \times M_M \times M_D; \]

where: \( T \) = estimated max. storage life for a loss of 0.5% dry matter, hours; \( T_x \) = time for corn at 25% MC (w.b.) and 30% mechanical damage stored at 15.6°C to lose 0.5% dry matter = 230 hr; \( M_T \) = temperature multiplier; \( M_M \) = moisture multiplier and \( M_D \) = mechanical damage multiplier.

Review of Literature on Crop Drying/Dryers

Soponronnarit et al., 1999 investigated the performance of a continuous cross-flow fluidized bed dryer with recycled air. Maize, at 19% to 40%, was dried at an inlet air temperature of 130–175°C, the bed depth was 17-22 cm, superficial air velocity of 2.7 m/sec. At initial moisture contents (MC) higher than 28% (dry basis), drying efficiency (DE) increased with the increase of air temperature. Thermal and electrical energy consumption were 4.7-6.7 and 0.3–0.6 MJ/Kg of water evaporated, respectively. However, when initial MC was lower than 23% (dry basis), DE slightly decreased with the increase of air temperature. Thermal and electrical energy consumption was 15.2-27.8 and 0.8-2.0 MJ/Kg of water evaporated, respectively. Breakage, stress cracks and color was maintained except in the case of MC reduction from 21.1% to 14.2% (d.b.) at 170°C, where the stress cracks increased rapidly to 32% by mass as compared to reference samples.

Mekvanich (2000) tested dryers with a mobile corn cob brick and cement furnace (1.22 m x 1.52 m; 300 kg corn cob/hr), a heat exchanger (2.4 m long, 30 cm φ. 10 m high smoke stack; 122 cm outer φ.) and a blower mounted on a mobile frame. It contains an auxiliary grate 15 cm x 61 cm in the opposite direction of the main fire grate. The back wall of the furnace is
connected to the fire tube of the heat exchanger. The blower was driven by a 7.5 Hp electric motor. The second prototype has a furnace with 65 x 85 cm main fire grate and 65 x 15 cm auxiliary grate. The blower is driven by an 8 HP diesel engine. Field-testing of mobile heaters has shown that drying cob maize in the farmer's crib is technically and economically viable system for drying maize in the wet season.

Manolito Bulaong et al. (1991) conducted trials for maize in 1989/90 using an in-store drying bin of one meter diameter and 2.5 m height equipped with a 1000 cfm centrifugal blower. Maize samples were pre-dried to about 18 to 20% MC (wet basis) using either sun drying or flatbed drying and pre-cleaned before loading into the in-store dryer. Drying air temperature of about 31°C and RH of about 67% with air velocity of 6 m/min (static pressure of 1.40 inch of water) was used. Grain MC was reduced to about 11% within about 141 hrs of total fan operation. The drying rate was 1.10 kg of water per hour and energy consumption of 8.3 Kw hr was calculated.

Phan Hieu Hien et al. (1999) while studying the drying of cob maize they designed a dryer (SRR-1; Vietnam). The moisture content (MC) of cob maize was reduced from 34.5 to 24.7% in 96 hours using 68 kwhr of electricity and 126 kg of coal. Similarly, in an experiment with maize kernels, MC was reduced from 31.2 to 14.1% in 39 hours using 26 Kw hr of electricity and 41 kg of coal, respectively. In a second set of experiments with maize kernels at 24.7% MC, they were reduced to 13.8% in 36 hrs; power consumption was 25 kwhr of electricity and 36 kg of coal. Ambient temp. (temperature) was increased by about 7-10°C. The final moisture differential was within 2.5%. The cost of drying cob-maize and shelled maize, each per ton of dried product was found to be $ 19.52 and $ 6.28, respectively.

Manandhar, et al. (2000), tested a simple grain dryer based on the design from Vietnam in the 1999 wet season. The dryer consisted of locally available materials; bamboo mat (Chitra) for the drying bin, an axial fan, and its support frame and simple room electric heater and/or charcoal heater along with a metallic pipe for heat transfer (for charcoal heater operation). The dryer was loaded with 580 kg of a mixed variety of maize-on-cob with average kernel MC of 32.9%. Three sets of experiments were conducted, all from the same crop. The drying rates were found to be about 0.045% per hr, 0.042% per hr, and 0.17% per hr, in cob maize with electric heater, cob maize with charcoal heater, and maize kernel with electric heater respectively. Total cost of drying per ton of cob maize by electric heater, cob maize by charcoal heater, and maize kernel by electric heater were found to be Rs 1140.0 (US $ 15.83), Rs 806.4 (US $ 11.2), and Rs 886.6 (US $ 12.31), respectively.

According to Padua (1976), drying rate is influenced by the temperature of drying air, relative humidity of drying air, availability of moisture at surface of grain from where it could be evaporated and velocity of air moving through the grain mass. He added that increasing the temperature of air by 11°C would reduce the relative humidity to half its original value.

Boxall et al. (1985) reported that drying with heated air with either low temperature/high volume (5-10°C above ambient temperature) or high temperature/low volume type. Maximum drying time using low temperature air will depend upon grain type, its physical condition and its MC and temperature, all of which equate to the food supply and condition for mould growth. He also mentioned that modifications needed to improve the fuel efficiency of grain dryers are likely to have a positive bearing on grain quality.

Golob et al. (1984), studied the effect of traditional store diameter on the rate of drying of maize stored on the cob with the sheathing leaves intact in Malawi. Four different diameters were considered; 0.6 m, 1.2 m, 1.8 m, and 2.4 m. The rate of drying of grain was related to the diameter of the store and the position of the cob within it.

**Review of Literature on Maize Storage/Structures**

Rana and K.C. (1977) conducted comparative studies on concrete bin, asbestos bin, polythene sandwiched bin, and local bin (Bery). They reported the best result from the concrete bin among the structures tested. The loss of grain in the local bin was as high as 25 percent while it was less than 5 percent in the concrete bin.

Wilson (1974) also reported the superiority of the concrete bin over the mud bin. He found the storage grain loss of 4.4 percent in the concrete bin as compared to 14.9 percent in the mud bin over a storage period of 10 months.

Shivakoti (1984) conducted studies with indoor (Bhakari, Kunew, Ghyampo and Poly lined bags) and outdoor maize storage structures (Thankro and Suli) including the use of plaster and celphos tablet and of plastic sheet in outdoor structures. The study indicated that polylined bag with or without fumigation was the
best among the indoor structures. Similarly, among outdoor structures, Thankro covered with 250 gauge plastic was found to be better than Suli.

Upadhyaya et al. (1999) studied the storage of maize seed at 12.7% moisture content (MC) under ambient conditions in four storage structures; Dehari, Ghyampo, Metal bin and Polylined gunny bags in 1997/98 for 8 months. Among the structures, polylined gunny bag was found better in terms of germination capacity and insect infestation.

Osunade and Lasisi (1995) looked into the suitability of laterized concrete (1:1.5:3 of cement: lateritic soil: crushed granite) as a construction material for silos and compared it to the metal silos. The study was conducted with white hybrid maize at 11.75% MC. Laterized concrete silos maintained uniform temperature of about 26°C, while there was high temperature fluctuation within metal silos. The results showed that laterized concrete silos are better than metal silos.

Multon (1989) described the use of stabilizers (organic acids) for temporary protection of damp grains.

Sabio et al. (1988) reported on the efficacy of a long term seeded storage technique based on CO₂ or Phosphine atmospheres for maize. Fourteen bags stacks of white maize were stored from 61 to 281 days. Eleven stacks were sealed, of which nine of them were treated with CO₂ and two with phosphine. Other three stacks remained unsealed and were surface treated with protectant insecticides to serve as controls. It was concluded that safe long-term storage of dry bag-stacked maize is possible in sealed plastic enclosures.

Breth (1976) mentioned that insects destroy cob-maize stored in cribs made from maize stalks in Guatemala within six months. The local metal silos, however, can protect maize for at least two years.

Hyde et al. (1973) mentioned that airtight storage of any agricultural commodity is known mainly for its simplicity and pest control without the use of toxic chemicals. However, grain MC should be reduced as far as possible to use airtight storage methods.

**Traditional Drying and Storage Practices and Suggested Improvements**

Sun drying is the cheapest traditional practice to dry any agricultural commodity including maize. Cob maize is dried with or without its sheath. However, bamboo/straw mat or a plastic sheet or other local mats should be used to spread the cobs or kernels, for which many farmers do not apply, especially for cobs. Black polythene sheet is preferable to be used as a mat. One person stand-by is required to take care of bird, insect and rodents and for spreading, turning regularly and collecting or covering to protect against unexpected bad weather conditions. Otherwise, he or she could have used the time for other fruitful work also. As summer maize harvesting is done during the rainy season, which results into rewetting of cobs or kernels. Moreover, it has other disadvantages such as non-uniform final moisture content of the product, low quality of the product due to various environmental contaminations (Hendriada, Agung et al. 1997) and the fact that this system is restrictive to bad weather.

**Thankro/Suli** - Thankro consists of a wooden platform (2.5 to 3.0 m high) raised on wooden or bamboo poles. It has a capacity of 1.5 to 5 quintals. Suli is another structure in which unhusked maize cobs are stored. It is similar to the thankro but there is a problem of aeration in this structure than in thankro. These outdoor structures are mostly popular in the hills and mountains. In these structures, as cob maize is exposed to air/wind, drying and storage take place side by side.

Both structures are not rodent proof. Metallic rodent baffles should be kept on all poles/timber posts erected to support the platform to get rid of rodents. Instead, local materials like cocklebur (Xanthium strumarium), pine needles (Pinus roxburghii or P. wallichiana), bamboo sheaths etc. can be used as the rodent baffle. To protect the stored cobs from rain, a thatch roof need be provided in both structures. Application of coal tar paint at the pole bottom to be inserted inside the ground will help for termite proofing. For good aeration in thankro, cob maize can be piled in such a way that every second layer of the cobs is perpendicular to the first layer. Such structures should be made at least 3 m away from the nearest building. For effective drying in thankro, perforations in the platform will work better if only bamboo is used, spacing should be about 25 mm apart while making the thankro platform.

**Meera** - It is similar to chitra-ko-bhakari (discussed below) as far as the size, shape and capacity are concerned. It is basically designed for the storage of cob maize but the only difference is that it is loosely woven so that drying could also be taken place by natural aeration during favourable weather condition. As it is an indoor structure, drying is slower so comparatively dried cob maize is stored in it. To make it rodent proof, at least 45cm wide metal sheet, with small perforations, should be used to cover the peripheral bottom surface of the structure. Also, it should be covered from the top by a metallic lid.
Hanging on Ropes—Cob maize are hung on ropes (nylon or jute) by tying the sheaths together (in Jhutais) either inside the house or in verandahs. This method of drying/storage is economical, provided cob maize could be saved from rodents and rain.

There should be sufficient hanging in the roof of the verandah to protect from rainwater. To protect the cobs from rodents, baffles similar to those used on Thankro poles could be used at the ends of the ropes. Rodent proof plant materials like cocklebur (Xanthium strumarium) or pine needles (Pinus roxburghii or P. wallichiana) can also be used.

Above the Kitchen—Cob maize is dried and stored, simultaneously, by placing them above the kitchen. The technique of utilizing the smoke generated during cooking is very common so that drying takes place only when food is cooked. When there is no smoke/heat, heated cob maize would absorb moisture from the atmosphere again. Moreover, chances of rodent attack are high. If the cobs are placed inside a rectangular wire mesh structure and it is again covered by the same wire mesh with a gap of about 25 mm between the two, it could be saved from rodents. Special designs to utilize heat/smoke from the kitchen to dry cob maize on the top floor of the house is an option to explore.

Kuniu—Kuniu is the method of storing sheathed maize cobs with their tips towards the center by stacking them directly on the floor or on a wooden platform. It is usually built at a room corner. For this, the uppermost floor is more preferred to the ground floor. The size of kuniu depends upon the quantity to be stored, size of room and the strength or load carrying capacity of the floor etc. Rodents are the major problems with the kuniu.

Dehari—It is a cylindrical or rectangular indoor structure built by the farmers from a mixture of mud, straw pieces and cowdung. To give more strength, the structure is sometimes reinforced with the stalks of morning glory bush (Ipomoea fistulosa) locally known as basharam or bisarma weed. It is made in a wide range of capacity varying from one to as large as 20 quintals. These structures are usually meant for storing paddy, wheat and maize kernel. To assure rodent proofing, it could be raised on a platform with rodent baffles. A tight lid should also be kept on it. The structure is not airtight. The outer surfaces of dehari could be plastered with moisture proof paint or bitumen to make it sufficiently airtight and to facilitate fumigation. Almost every farmer in the Terai can make this structure. So, no cost is involved to construct it.

Bhakari (chitra-ko-bhakari) — Split bamboos are interwoven to make bamboo mats known as chitra or mandro. These bamboo mats are generally used for the construction of bamboo bins called chitra-ko-bhakari, one of the most popular storage structures in Nepal. Sometimes gundri, a straw mat is used in place of bamboo mats to make a bhakari. These tightly woven bhakaris are used for storing paddy and wheat as well as shelled maize. These structures can hold 14 to 21 quintals.

The structure is neither rodent proof nor airtight. To make it rodent proof, it should be covered from its outer bottom periphery by at least 45cm wide metal band. Also, it should be covered from the top by a tight metallic lid. Farmers have the practice of plastering the structure with mud or oil cakes. Plaster of oil cake prevents the entry of migrating insects. It would be better to treat the soil with some chemical before plastering. Waterproof paint all over the outer surface of the mud plastered Chitra-ko-bhakari would help to make it sufficiently airtight.

Small Bamboo Structures—Bamboo structures like thunche, thungilo, doko, dalo are sometimes used for the storage of maize in smaller quantity. These structures have the maximum of 50-70 kg capacity. Tin containers could easily replace such small structures.

Earthen Pots—Ghyampo, ghyampi, gagro etc. are the baked clay structures. They are used for the storage of maize seeds. These structures hold about 30 to 70 kg. They are rodent proof, but not moisture-proof. Fumigation is possible if a tight lid is used.

Dhikuti—Dhikuti, also known as wall bhakari, is constructed from bricks and the mud mortar utilizing two sides of a room. It is also made from stone and mud mortar in the high hills and the mountains. It is found in the range of 1.5 to 14 quintals capacity. This is neither rodent proof nor moisture proof. As this structure is not airtight, fumigation is not possible. To make it rodent proof, it should be plastered by cement mortar and a tight lid should also be kept on it.

Timber Bin—It is a rectangular indoor structure made of wooden planks. Rich farmers generally prefer to keep this type of timber bin called kath-ko-bhakari or kothi to store their grains. Depending upon the capacity of an individual farmer, it can be of 7.5 to 50 quintal capacity. Farmers generally make use of planks of whatever is available. To make it rodent proof, there should not be any gap between the planks and a tight lid should also be placed on it.
Metal Bin - Farmers are using metal bins of different sizes/capacities since Rural Save Grain Project started distributing at nominal rates. District Agricultural Development Offices (DADO) and Post Harvest Loss Reduction Division (PHLRD) first collected demands from farmers and bins are distributed at subsidized rates according to the available resources. Three different sets, each with five different capacities were fabricated ranging from about 75 to 200 kg. Plain galvanized iron sheet (4' x 8' size; 24 gauge) is being used for the fabrication. More than 2000 metal bins were distributed each year at 25% subsidy. Use of metal bins should be intensified, as it is rodent proof and fumigation is possible for dry maize kernels. Moreover, training of blacksmiths should be arranged in all districts of the country in fabrication of metal bins. They also should be provided with a set of most necessary tools to fabricate bins at a nominal rate.

Potential Drying Technologies

There is no simple rule for the choice of one particular drying method over the others, but a number of things influence the economy or overall satisfaction of each. These include:

- Quantity of crop to be dried
- Moisture content of grain and ultimate use of grain
- Drying rate
- Climatic condition during harvest
- Availability of power and fuel
- Rate of fuel consumption
- Total cost of the system and its operational cost etc.

Out of several methods of mechanically drying agricultural crops each has its own advantages. All depend on moving air through the grain. None of these is the “best,” but one may be better adapted to a given situation than another. Common methods of mechanically drying shelled corn were:

- Batch drying in a self-contained dryer
- Batch drying in a storage bin
- Drying in storage with unheated air
- Drying in storage with supplement heat
- Layer drying in storage

A number of dryers which were used for other crops could also be tested for maize. These include flat bed or vertical bin batch type; cabinet/tray type or drum dryers; the mechanism of transporting heat energy may be conduction or convection heating type; source of fuel may be electricity, kerosene, LP gas, agricultural waste, solar energy or combination of any two of them. Hot air may be blown to the drying grain by an electric motor, manually or by using another source of prime mover like a power tiller (two-wheel tractor). A short description of some of the dryers tested in various countries was presented in Table 1.

Maize Crib

Though not known as a dryer, maize cribs do allow for natural air-drying during storage. Crib whether circular or rectangular, can be constructed from bamboo, timber, wire mesh or other similar materials. There should be some gap between each bamboo or timber of small width. A platform needs to be raised on four or more poles with rodent proofing baffles. It should have a roof with sufficient overhanging to avoid contact with rainwater. The cribs are being used traditionally in many countries.

Further improvement in the maize crib is possible by keeping a pipe at the center of the crib and providing a small wind driven (cyclone) fan at the top. It would help to have good aeration during non-rainy days. To store de-husked cobs at higher moisture content in adverse condition, there should be layers of about 60cm width only. It could be increased to 100-150 cm in favorable conditions. A rectangular structure is preferable to a round structure as increasing its length can expand its capacity.

Potential Storage Technologies

The choice or suitability of the improved storage methods for any crop depends on many factors. It will apply to maize crop also. Major Factors to determine the type of storage facility can be listed as:

- Quantity of crop to be stored;
- Moisture content of the crop and its ultimate use;
- Climatic condition during storage period;
- Natural resources and the traditional storage methods;
- Purpose and duration of storage;
- Type of rodents, animals and insect-infestation present in the surrounding area;
- Total cost of the system and its operational cost etc.

A structure good for one region may not be good for another agro-climatic region. So, it should be chosen and tested in the specific climate condition to confirm...
Table 1: Crop dryers (Maize Drying Tech.) for possible adoption to Maize

<table>
<thead>
<tr>
<th>Name of dryer</th>
<th>Country/ Institute</th>
<th>Dryer type, size &amp; capacity;</th>
<th>Power source &amp; type of blower</th>
<th>Drying air temp/Drying Rate</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Banos Rice Dryer</td>
<td>IRRI</td>
<td>1.8 m x 3.6 m; 1700 kg/hr</td>
<td>5 hp diesel or gasoline; 58 cm fan (truck radiator)</td>
<td>43°C</td>
<td>Rice (26-14%)</td>
</tr>
<tr>
<td>Rotary Flash Paddy Dryer (RFD-80D)</td>
<td>Dept of Agri Engg, Central Philippine Uni.</td>
<td>80 cm dia x 250 cm; 10-15 sacks/hr; cooler oscillating 60 cm x 250 cm</td>
<td>8 hp prime mover; 30 kg rice hull or coconut husk/hr; radial-type centrifugal</td>
<td>Heating grain to 70°C-90°C &amp; immediate cooling to 30-40°C for 100 sec; reduction of MC from 25-30% to 14-16% in a single pass</td>
<td>Could be tested for cob maize; Initial dryer cost = US $ 4265 (1990) $ 0.16/sack of grain drying</td>
</tr>
<tr>
<td>Multicrop Dryer</td>
<td>Los Banos, Philippines</td>
<td>floor area 1.83 m x 1.83 m; 84-168 kg of paddy/6 hr; 4-8 bags of shelled corn &amp; 10-15 bags of cob maize in 10-12 hrs</td>
<td>Corn cobs, peanut hull, wood chip etc.; 14 kg coconut shell/5-6 hr</td>
<td>MC reduction of cob maize &amp; shelled corn from 25-14%</td>
<td>Copra, corn, paddy, pine apple etc.</td>
</tr>
<tr>
<td>Agri. Waste Fuelled Metal Bin Dryer</td>
<td>Dept of Agri. Processing, Tamil Nadu Agri. Uni., India</td>
<td>Batch bin dryer; furnace with heat exchanger</td>
<td>Agri. Wastes (coconut husk &amp; shell)</td>
<td>Upto 90°C</td>
<td>Cereal, pulse, oilseed</td>
</tr>
<tr>
<td>Solar Fruit &amp; Grain Drying System</td>
<td>Farm Machinery Institute, Pakistan</td>
<td>Flat plat solar collector; 15 sq. m.; 1 ton fruit or 2 ton vegetable per month</td>
<td>Solar energy</td>
<td>Could be tested for cob maize</td>
<td></td>
</tr>
<tr>
<td>Drying-Storage (DS) System</td>
<td>Center for Agri. Machinery Development, Indonesia</td>
<td>1.5 – 2 ton</td>
<td>Axial type blower 50 cm dia; airflow 102 cu m/min</td>
<td>6°C above ambient air temp 0.4%/hr</td>
<td>US $ 3.85/ton of grain drying (1997)</td>
</tr>
<tr>
<td>Agro-waste fuelled root crop dryer</td>
<td>Phil. Root Crop Res. &amp; Training Center</td>
<td>100 kg root crop/7-8 hr</td>
<td>50-60 kg of coconut husk</td>
<td>60°C</td>
<td>Dryer size could be increased for cob maize</td>
</tr>
<tr>
<td>IGSI Grain Dryer</td>
<td>IGSI, Hapur, India</td>
<td>Batch type; 1.16 m x 1.764 m; 6.5 quintal/batch</td>
<td>1 hp electric motor with blower; 1 kg of coal/hr</td>
<td>Paddy, maize</td>
<td></td>
</tr>
</tbody>
</table>

IRRI – International Rice Research Institute; IGSI – Indian Grain Storage Institute; RNAM - Regional Network for Agricultural Machinery

*1 sack of paddy = 42 kg
its storability. While selecting a storage structure, the following points should be considered:

- Limitation of height and diameter of bin
- Availability of local construction materials, mason and labour
- Ease of loading/unloading
- Indoor/outdoor
- Flexibility of the structure required etc
- Construction material with less thermal conductivity for maize (Shelled maize has higher thermal conductivity compared to wheat); wood has the lowest thermal conductivity among major construction material
- Physical properties of grain and construction material
- Chemical reaction with construction material
- Cost of storage system/construction material and value of produce
- Strength and life
- Farmer level, trader/middle men, mill owner, consumer or government level.

A number of storage structures/bins/methods are available which were used for agricultural crops including maize. The structure may be outdoor or indoor; underground, semi-underground, rested on the ground or raised on a platform. Irrespective of the type of structure chosen, grain should be dry and free from dust and other unwholesome particles, and the structure used should also be free from dust, spillage and old grain residues, to minimize loss during storage.

Many food grain storage structures from different construction materials have been tried in Nepal and elsewhere. These include mud structure, clay rings, sundried bricks, baked bricks with mud mortar, brick-in-cement, reinforced brick, reinforced concrete, RCC rings, metal bins (plain and corrugated G.I. sheets) of different designs (flat or hopper bottom raised on legs or brick masonry base; flat or sloped top lid), rubberized cloth, wooden planks, bamboo splits, stone, asbestos sheet, LDPE films, jute cloth/bags or use of coal tar drum etc. Controlled atmosphere storage techniques may also be used. There are structures used especially for wet grains (e.g., Dehydrobin); for urban; for cob maize (e.g. cribs etc).

The method of sandwiching polyethylene for moisture retention capacity; structure which can be dismantled easily (like Collapsible bin); zero energy cool chamber which could be tried for seed storage; air tight storage methods, use of plastic sacks are some other improved methods available for selection. Few storage structures that could be tested/used for maize crop were presented in Table 2.

### Suggested Research Areas

- Study harvesting time with respect to drying characteristic/performance, maize yield and storability of grain,
- Study on natural convection dryers for cob-maize,
- Use of solar collector with power storage facility for crop drying,
- Design of a cob maize drying system using domestic kitchen smoke/heat,
- Modification of SRR-1 dryer (Vietnamese design),
- Rack storage inside the house for maize cobs covered by wire mesh,
- Study of maize cribs,
- Modification of Zero-energy Cool Chamber to store seeds temporarily,
- Design of small wooden/bamboo container for seed storage,
- Study on laterized concrete as a construction material for maize storage bins,
- Airtight storage of grain kernels,
- Study on storage of baby corn.

### Power Options

- Peltric Set Technology,
- Use of PV-Cells and Solar Energy Storage Batteries,
- Use of Hydrams for Operation of Fan,
- Traditional water mills as power source for drying purpose.

### Present Constraints for Research

- Lack of co-ordination among various national institutes and international organizations involved in loss prevention (research, training and extension).
- Lack of trained personnel at all levels in post-harvest engineering technology,
- Lack of information on post-harvest technologies that have been found effective elsewhere.
### Table 2: Storage methods for possible adoption to maize

<table>
<thead>
<tr>
<th>Name of Storage bin</th>
<th>Country/Institution</th>
<th>Type of storage bin/Size</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crib</td>
<td>ICRISAT, India</td>
<td>circular or rectangular; bamboo, wiremesh or similar materials; raised on four poles with rodent proof baffles</td>
<td>Needs sufficient roof overhanging; Provision of a perforated pipe at the center of crib with exhaust fan</td>
</tr>
<tr>
<td>Ferrocement Bin</td>
<td>SERC/tested at CFTRI</td>
<td>On the ground structure with curing period of 3 months; 1, 2 &amp; 3.14 m high; $\phi = 1.2$ m</td>
<td>Needs to surround inner surfaces with pol. Sheet before storing; underground bin is not suggested</td>
</tr>
<tr>
<td>Dehydro Bin</td>
<td>CFTRI</td>
<td>MS sheet; hemispherical outdoor structure; Bin is about 1 m high and is raised on legs</td>
<td>Good for wet grain for few days; works better under larger temp. fluctuation during day and night</td>
</tr>
<tr>
<td>Urban Bamboo Storage Bin</td>
<td>IPRI</td>
<td>Rectangular made of 0.3cm thick bamboo splits (2 layers) with top lid; 4.5 cu. Ft. = 0.13 cu. m. at CFTRI</td>
<td>Outer surface of bamboo should be exposed</td>
</tr>
<tr>
<td>Welded Wiremesh Bin</td>
<td>IGSI</td>
<td>GP Sheet floor; 7.6cm x 2.54cm wiremesh with inner hessian cloth lining; circular steel evetuated base (0.8m); with roofing; 1.5-2.8 ton</td>
<td>Used for wet paddy when dryer was lacking; fumigation using rubberised cloth or pol. Sheet is possible</td>
</tr>
<tr>
<td>Improved Bhakari/ Pol. Sandwiched Bamboo Structure</td>
<td>RSGP-N/IGSI</td>
<td>Metallic top lid; bottom spout with lid; metal trough at bottom; polythene sandwiched between 2 bamboo bins; Dia =76cm; Ht = 107cm</td>
<td></td>
</tr>
<tr>
<td>Pusa Bin/ Pol- Sandwiched mud Bin</td>
<td>IARI/ RSGP-N</td>
<td>Pol-sandwiched mud brick structure; outer walls with baked bricks upto 45 cm height: 1.22m x 1.22m x 1.37m height; 700 gauge plastic sheet</td>
<td>US $ 33.75 (1981); Jute cloth with pol. Sheet inside may be used instead of costly rubberized fabric.</td>
</tr>
<tr>
<td>Collapsible Bin</td>
<td>RSGP-N</td>
<td>Could be dismantled if needed; use of rubberized fabric bag; bamboo poles, metal base; 2m high, 0.5m high metal trough</td>
<td></td>
</tr>
<tr>
<td>Zero-energy Cool Chamber</td>
<td>IARI; RSGP-N</td>
<td>Sand (7.5 cm) between 2 layers of baked brick wall; single brick layer on floor. Top is covered by gunny bag in a bamboo frame</td>
<td>Could be used for seed storage in pol. Bags; Rs 1000 for 1 MT (1981); During summer (outside temp. at 44°C), Chamber temp was max of 28°C Min. Rh was 84 %, Rs 250/100 kg of fruit and veg.</td>
</tr>
<tr>
<td>Metal Bin</td>
<td>IGSI/RSGP-N</td>
<td>Flat bottom, raised; 0.2 to 1.0 tonnes; 75 kg to 252 kg in Nepal</td>
<td>Rs 1200 for 1 tonne (1981); hopper bottom bins could be demonstrated</td>
</tr>
</tbody>
</table>

*CFTRI Central Food Tech. Res. Institute; SERC Structural Engg Res. Center; IARI Indian Agr. Res. Institute; IPRI Indian Plywood Research Institute; RSGP-N Rural Save Grain Programme, Nepal; IGSI Indian Grain Storage Institute*
Suggestions to Improve Outreach Research Activity

- Participatory technology development: dialogue and partnerships with stakeholders in evaluating research priorities and strategy.
- Distribution/sale of metal bins from Post Harvest Loss Reduction Division (PHLRD) at subsidized rate need to be intensified.
- Subsidies should be provided to the farmers to purchase small grain dryers also.
- Training on fabrication of metal bins should be arranged for blacksmiths.
- PHLRD should start fabrication of metal bins raised on 4 legs, with conical bottoms.
- Make a data base of information available on drying and storage of cob maize/kernel.
- Coordinated research followed by training of technical assistants and fresh graduates.
- Selection of farmer groups to conduct outreach research activities on drying/storage and for demonstration of related equipment.
- Development of women friendly dryers/storage structures
- Women farmers in Nepal contribute as much as 88% of labor inputs in producing maize and millet. Therefore, special training should also be organized for the women farmer groups.
- Regular exhibition of post harvest equipment at district level.
- Development and improvement of women friendly traditional tools/technology.
- Farmer to farmer exchange of information/experience would be an effective mechanism for technology transfer.
- Networking with other institutes and countries to enhance technology transfer.

Conclusion

Sun drying is the only existing method of maize drying at the farmer level. Studies on cob maize and kernel drying should first be conducted at major growing areas to reduce storage loss and also to minimize cost of study on storage bins.

Traditional maize storage structures are neither airtight nor rodent proof. They should be modified or replaced by improved methods. Locally available bamboo or timber structure should be given preference for study as thermal conductivity of maize kernel is higher than that of other cereals, e.g. wheat.

Distribution/sale of metal bins to the farmers at subsidized rates should be intensified. Such subsidies should be provided for small dryers too.

Present constraints for research work on grain drying and storage are lack of manpower, facilities, information and coordination. Consequently, coordinated research programs aimed at women friendly technologies should be conducted. The research outcomes should also reach farmer groups selected by the Department of Agriculture at different districts. Finally, farmer to farmer exchange of information/experience, an effective mechanism for technology transfer, should be arranged by the concerned authorities to improve outreach research activity.

Acknowledgement

The authors are highly thankful to Mr. Scott E. Justice, Affiliate Scientist, CIMMYT/Nepal for his untiring effort in giving comments. They are also thankful to Mr. S.K. Adhikary, Chief Agricultural Engineer, Agri. Engg. Division, NARC, Khumaltar for his valuable suggestions.

Literature Cited


USDA (United States Department of Agriculture). Drying shelled corn and small grains. Farmer’s Bulletin No. 2214.


Post-harvest Losses in Maize: Review Of The Findings Of The Rural Save Grain Project

Ganesh KC
Program Director, Industrial Entomology Development Directorate, DOA

Introduction

Post-harvest is the other half of the agricultural story. In the absence of appropriate post-harvest loss reduction technology, the effect of increased production will be of no economic benefit to the farmers at large. At the same time, the use of costly inputs, labor, risk and time for increasing production will also go waste. The concern for the development of post-harvest technology to reduce food losses started as human beings settled for growing food, along with the human instinct to gather and store food. But the scientific and technological development in this field is of recent initiation.

During late seventies about 203 projects on prevention of food losses to reduce losses by 50 percent were implemented globally of which about 26 percent were in Asia. Project emphasis was made especially in the following areas:

1. Identification of the magnitude and extent of losses in post-harvest systems and to plan and implement national food loss reduction programs.
2. Improve existing farm level storage structures.
3. Design and construct modern storage structures.
4. Improve and develop small scale grain driers.
5. Improve harvesting and processing facilities.

Nepalese Post-harvest Scenario

The above activities at the global level resulted in an upsurge of concern in the implementation of a loss-reduction program in Nepal. Consequently HMG/Nepal started the “Rural Save Grain Program (RSGP)” in collaboration with FAO and with an objective to assess the extent and magnitude of losses and demonstration of post-harvest loss reduction technologies. RSGP initially was designed for a period of 3 years and was extended till 1984. Later it was followed by a 5 years long-term project funded by the Government of Australia. The major activities carried out under RSGP were:

1. Post-harvest loss assessment of major cereals.
2. Evaluate existing structures and improve it as per requirement.
3. Carry out training and extension programs.
4. Establish a model village and introduce improved storage technology to at least 20 percent of the total households.
5. Carry out a survey of post-harvest losses, especially the storage losses in different structures, to provide a basis and justification for expanding the loss reduction programs and means of monitoring the impact of loss reduction technology where they have been introduced.
6. Assess the efficiency of village level grain processing methods and develop appropriate improvements.
7. Develop the capability for the further expansion of a national post-harvest loss reduction program.

Maize Post-harvest Systems in Nepal

1. Harvesting: Maize harvesting is done by detaching the cobs manually from the maize plant. In some locations topping of the maize stalk above the cob attachment is done before detaching the cob. The moisture content at harvest is in the range of 23-28 percent. It is transported to the house and piled up in some corner of the house and whenever the farmer get time they take out the outer husk and they store either in a kuniu or Thangro. The harvesting losses observed in maize was 2.21 percent (wt. loss) and the range was 2.63-3.79 percent.

2. Shelling: Maize is shelled either by beating the cobs or stripping the kernels using a metal sheller. The shelling losses observed during the shelling, in maize was 2.85 percent.

3. Drying: Solar drying is the most common practice of drying maize. The drying loss observed was 2.5 percent. Unshelled maize is dried in situ during storage.

4. Storage: More than 85 percent of the total maize produced is retained at the farm level for household consumption, wage payment, animal feed and seed.
purposes. Farm level storage structures are mainly indigenous types. Maize is stored with the sheath intact on “Thangros” (vertical/horizontal poles) or stacked on the floor or on a wooden platform or in a Suli. Hanging of maize cobs in bundles under the eaves is also very common. The shelled maize is stored in Gagro, Thunche, and Thangros. The average storage period of maize is 8 months. *Sitophilus oryze, Sitophilus zeamays, Sitotroga cereallia,* rodents and molds are some important pests in maize storage. The loss due to these pests is about 7.44 percent.

5. **Primary processing:** Quern, water mills, modern plate mills and Engleberg steel plate are common equipments used for maize processing. The recovery rate in maize is in the range of 95-97 percent. But the flour is coarse compared to the flour obtained from modern mills.

### Major Activity and Achievements of RSGP

1. **The activity carried out under RSGP can be broadly categorized under:**

   - Survey of Post-harvest systems and loss assessment.
   - Storage structure modification and improvement.
   - Training, demonstration and extension.

2. **Achievements:** (summary)
   
   RSGP carried out all its activities in close cooperation and coordination with various concerned Departments, Division and Research Centers.

   **a. Loss assessment and survey study:** It was carried out in 27 districts and the losses recorded in maize post-harvest systems were:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Loss percentage (wt. basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting</td>
<td>3.33</td>
</tr>
<tr>
<td>Transportation</td>
<td>1.04</td>
</tr>
<tr>
<td>Shelling</td>
<td>2.85</td>
</tr>
<tr>
<td>Drying</td>
<td>2.05</td>
</tr>
<tr>
<td>Storage</td>
<td>7.44</td>
</tr>
<tr>
<td>Processing/milling</td>
<td>2.30</td>
</tr>
</tbody>
</table>

   **b. Design, development and improvement of storage structures:**

   - Modification/improvement was made in local bamboo *Bhakari, Dheri and Thangros,* using plastic, cement, tins, coal tar and waterproof paints.

   - Metal bins of different capacities were tested and developed.
   - Corn shellers, serrated sickles were also tested and demonstrated.

   **c. Training, Demonstration and Extension activities:**

   - Training on various aspects of post-harvest loss reduction technologies were given to farmers, technicians, entrepreneurs and subject matter specialist.
   - Demonstration of scientific storage methods of different commodities through the model village development program.
   - Film, slides, posters, leaflets, pamphlets preparation and distribution.
   - Workshop, seminar and talk programs: Tailoring loss reduction technology messages for the agricultural extension system.
   - The model village development: Its approach was carried so that the farmers in the model village are encouraged to adopt improved storage structures as well as scientific methods of storage. Efforts were made so that at least 20 percent or more farm families in the village would adopt the improved technology.

### Overall Impact of the Project

- Metal bins in seed production program have been found very useful and effective.
- The magnitude and extent of post-harvest losses in major cereals and the areas of further technical intervention have been identified.
- Awareness of the project activities have been most apparent in the development, manufacturing and distribution of metal bins. Annually about 2000 pieces of metal bins are distributed and the demand is in increasing trend.
- A conservative estimation shows that about 15,000 households have been benefited from the post-harvest loss reduction activities and the project has been successful in creating awareness among the farmers about the post-harvest problems, issues and importance of minimizing the losses.

### Some Observations in Post-harvest Systems

- Lack of commonly agreed upon loss assessment methods and database on losses considering different agro-ecologies.
- Unavailability of commodity and post-harvest
operation wise and location specific appropriate loss reduction technology.

- Inadequate trained human resources for post-harvest technology generation and dissemination.
- Inadequacy of inputs for loss reduction technology application and extension.
- Economic incentive from application of loss reduction technology in cereal grains at the farm level is not very encouraging.
- Usually both men and women participate in maize harvesting, transportation, while women carry out the shelling, storage and processing activities.
- Maize post-harvest activities are mostly traditional which needs improvement.
- No aflatoxin is observed in green maize. Shelled maize is more prone to aflatoxin contamination than whole cobs. The aflatoxin contamination problem is more serious in the Terai than in hills during the rainy season.
- Aflatoxin content at the time of harvest is very low in percentage but could be serious in terms of quality.
- Rewetting of maize cobs from rain during storage can cause more weight losses due to mould damage.
- Farmers in general are aware of the post-harvest losses but there is an overall attitude of resignation as to what they could do to minimize the losses. To a certain extent the overall negligence towards improving the post-harvest system is also due to less tangible benefit than gains arising from increased crop production. Farmers, planners, and bureaucrats all are more responsive to immediate and visible gains than indirect saving by reducing post-harvest losses.
- Questions such as why post-harvest technologies have not been widely adopted? To what level these technologies can reduce the losses? Is the loss data so far presented reliable? Is there a need for further loss assessment to be carried out? Between now and 1952, dozens of studies on storage structures have been conducted but repeatedly the need for improvement come again and again, why?

Critical Areas for Further Investigation

- Maize harvest time and methods, maize dryers, evaluation of rice husk briquette as substitute fuel for maize drying.
- Maize variety screening for storage pest resistance.
- Leader farmers' training to be developed to train the farmers in their respective VDC.
- Decentralized fabrication and distribution of metal bins and similar activities.
- Storage structure modification in such a way that it utilizes the environmental pest control measures.
- Development of a simple and low cost hand com sheller.
- Research on improved configuration of maize stacking to promote aeration and protective schemes from rain, birds and rodents.
- Loss assessment and a quick validation of loss data to understand the loss from the perspective of farmers.
- Develop appropriate loss assessment methodology and technology. It is still in evolving process, so depending upon the ecological niches, storage period and loss causing agents, loss assessment procedures needs to be verified.
- Use of pheromones for trapping storage pest.
- Examine thoroughly the relationship between aflatoxin in maize and storage structures and mould damage.

Suggestions

- Prior to implementing the Loss Assessment or Loss Reduction Program first the area to be studied must be identified keeping in mind the purpose, financial and logistic support.
- Farmers knowledge on the post-harvest operations needs to be taken into consideration.
- Loss assessment programs must be implemented in conjunction to loss reduction programs.
- Post-harvest loss calculation on the basis of yield, needs to be carefully analyzed while presenting and extrapolating the data.
- Climate data of the study area must be analyzed and only on this basis loss reduction technology should be developed for extension program.
- An ideal technology for small farmer would be HYV, that are resistant to storage pest.

Conclusion

The important cause for low adoption of recommended post-harvest technologies are economical and social. So the GO/INGOs or private sector involved in the agriculture development programs must work in close cooperation with farmers, to design and develop appropriate post-harvest loss reduction technology for the hill farmers.
Post-harvest: Current Extension Programme, Recommendations and Constraints to Effective Dissemination

S. Adhikari  
Chief, Post Harvest Loss Reduction Division, Shree Mahal Pulchowk

Background
His Majesty’s Government of Nepal launched the Rural Save Grain Project (RSGP) in 1984 with the mandate of saving food grain at the rural grassroots level. The RSGP was undertaken because of the positive impact during the two year (1980-82) implementation of the Prevention of Food Loss (PRL) project of FAO. The Australian Government, through FAO, technically as well as financially supported the project. RSGP devoted its activities mainly to rice, wheat and maize assessing losses at the farm level. The project initiated its work with some basic technologies on storage but the physical facilities, infra-structure and resources were inadequate to implement the activities at the national scale. HMG/N included post-harvest loss reduction in their eighth plan after the termination of RSGP in 1992. The mandate and task of reducing post-harvest loss was given to the Post-harvest Loss Reduction Division (PHLRD) under the Department of Agriculture (DOA). The Division is solely run by HMG/N’s budget. The volume and breadth of activities has been narrowed in accordance with the available budget and manpower.

Activities in Brief
During the RSGP period, both pre and post storage activities were emphasised on cereals. Now the PHLRD concentrates on post storage activities where the loss (7-10%) is relatively more. Anticipating future problems due to the increasing trend of intensive cultivation of fresh vegetables and fruit, (prioritised as high value crops by the Agriculture Perspective Plan), studies have been focused on post-harvest aspects of perishables. These market oriented perishable vegetable and fruit crops, needs to be handled carefully in post-harvest operations for maximizing returns by synchronizing supply when demand is high to ensure a higher market price for the farmers. The limited physical facilities and lack of well-trained manpower in this field, has restricted us to work on other aspects of post-harvest besides storage. Studies on local indigenous methods and local herbs for insect pest control in storage are tried. Laboratory experimental studies on the use of chemical, needs further investigation. Information is lacking on the effective application, procedure, exposure period and effect of temperature on the biology and ecology of a storage pests specifically on pest population, and feeding behaviour in relation to management effort. Hence, the biology of the insect like Bruchids has been studied for effective management in the division’s laboratory. In addition, sample collection from different parts of the country is done irrespective of the container and are analysed in the division’s laboratory for standard volume, weight, damage, percentage moisture content and for grain quality (broken, shrivelled, immature, foreign matter, etc). Based on the results of 2-3 years of studies conducted at the field level and the division’s laboratory and storage structures (cellar and zero-energy and normal room) the following recommendations have been made by the division.

Recommended Technologies

A. Four principles of food grain loss reduction
- Drying of food grains to 12% moisture content.
- Proper cleaning, maintenance and disinfecting the storage structures and go-downs before storing of new grains.
- Prevention of heating in storage structures and go-downs by storing food grains in dry, cool and well-ventilated places.
- Prevention of stored grains from insect and rodent attack.

B. Use of improved storage structures
- Use of improved metal bins and pucca kothi as well as improved local storage structures like bamboo mat bins, mud bins, etc.
- Use of zero energy storage structures for freshly harvested vegetables like carrot, radish, sweet pepper, cabbage and other leafy vegetables.

C. Use of chemicals
- Fumigation under airtight condition by using phosfume or phostoxin at the rate of 2-3 tablets per t or 2 tablets/m³ space for at least 72 hours.
- Disinfecting of storage structures and go-downs by malathion at the rate of 0.5-0.7% spray solution.
D. Use of botanicals/conventional practices

- Use of Neem seed powder at the rate of 1% in wheat, paddy and pulses against stored grain pests like weevils and moth for a period of six months.
- Use of Bojo rhizome powder at the rate of 0.3% to protect grains from stored grain pests.
- Use of Timmura powder at the rate of 0.3% to protect grains from stored grain pests.
- Titepati also can be used against insect attack.

Extension Activities

The findings of the studies are referred for recommendations to farmers, the target group. All the organizations under DOA are wholly or partially involved in extension of the post-harvest technologies but the District Agriculture Development Office (DADO) is the main extension agency at the grassroots level. Besides, Training Centres, DOA Ag. Farms and Services Centres are also involved in post-harvest extension activities. Recently 10 Assistant Plant Protection Officers from different districts were oriented with post-harvest technologies to be disseminated and activities in PHLRD so that they would be effective in the extension of the proven technologies at their respective districts. At present some of the technologies have been introduced into the districts of Bhaktapur, Lalitpur and Kathmandu.

The content of the message developed are provided to the DADO, training centres and services centres as a package of practices through visits, slide/film show, pamphlet, booklet, leaflets, radio, group monitoring activities, discussions and rodent control campaign. Recently, television has been also used as one of the media of dissemination of technology. Other activities of the project include using flip charts, participation in national and local exhibitions, agricultural fairs, demonstrations, training at service centre level on awareness of post-harvest losses and technologies to minimise them. Training exclusively for women are conducted every year considering their major involvement in post-harvest activities. Besides, blacksmiths or entrepreneurs engaged in this field are trained with an objective to develop resource persons for taking up the fabrication of metal bins, post-harvest hand tools and equipment. Rodent control campaign and model village concepts were used as extension tools.

Constraints to Effective Dissemination

For effective dissemination of technology, capacity for appropriate technology generation, competency in development of needed technology, effectiveness of extension workers and competency in the research-extension system as a whole is necessary. But in the present working environment, the competency is lacking at each level. As a result many technical and institutional constraints hinder effective dissemination.

Technological constraints

- Lack of awareness and information at the rural level for food security.
- Lack of trained manpower for technology generation and dissemination.
- Value addition of the crop by efficient post-harvest technology is not in the mind of the extension staff. As a result they only care for the production but do not care at all for quality of crops for marketing.
- Farmers have realised and often complain that the loss in post-harvest operations is serious but still they resist adopting the technology.

Institutional Constraints

The existing extension activities emphasise mostly the pre-production aspect. They rarely think the post-harvest problem as their work, hence motivation and services by technical staff is not up to the expected level.

Harvesting, drying, handling, transportation, processing, storage and marketing are different activities that are included in post-harvest operations. Hence for the success of any post-harvest program it is desirable to have a system approach with due attention to all components. An expanded national programme has to work in co-ordination with different line agencies like Central Food Research Laboratory, Directorate of Horticulture, Directorate of Marketing, Agri-engineering, District Agriculture Development Office, Ag. Farms and Stations, Nepal Agricultural Research Council and the Institute of Agriculture and Animal Science for the control of post-harvest loss reduction at the grassroot level.

Conclusion

APP's emphasis on production and prioritisation of the crops with the vision of poverty alleviation ultimately needs the market for which post-harvest technology is a must for value addition. The product to be marketed, must be of good quality to compete in market and size (in case of durables), fresh looking and undamaged. Vegetable and fruit products after harvest will need proper post-harvest technology in post-harvest handling, processing and marketing. The existing
structure of the Post-harvest Loss Reduction Division is not equipped to meet all these requirements in physical facilities and trained manpower in food science, agro-engineering, horticulture, agronomy, entomology, pathology, marketing, agro-industry and of course on farm management, extension and microeconomics. Success will depend upon coordinated and concerted efforts of all disciplines that need to work together for post-harvest technology generation, dissemination and adoption by the clients.
Advances in Post-harvest Research at CIMMYT

David Bergvinson
Maize Entomologist, CIMMYT, Mexico

A major contribution CIMMYT can make to the area of post-harvest technology for maize is to develop pest resistant maize. Through five years of cooperation with Canadian research centers under the UNDP project, three maize collections resistant to the larger grain borer (LGB) and grain weevil have been identified. This germplasm formed the basis of a source population for kernel resistance to storage pests that has now completed three cycles of recurrent selection. Additional germplasm has been identified and is under recurrent selection for post harvest resistance. With these resistant sources in place, the CIMMYT Entomology Unit was able to work towards identifying the resistance mechanism. One of the analysis consisted of adapting a force displacement meter to measure kernel hardness, a trait that has been considered important in post-harvest resistance but scientific support for this claim has been lacking. Using the force displacement we now have a repeatable technique for quantifying kernel hardness. We also developed a new 0.8mm probe that can withstand the 22 Kg force required for testing. The protocol involves a two-week calibration period to standardize the grain moisture content. This is a critical step as hardness is closely related to grain moisture content. We have tested the protocol on our segregating populations and it will now be used as a pre-screening tool to reduce the number of entries included in insect bioassays, enabling us to focus on those families with promising levels of insect resistance.

Using the above protocol, we have been able to identify families in our source populations with improved resistance to weevils and LGB. Moreover, as CIMMYT is now in the process of releasing more Quality Protein Maize (QPM) to our NARS partners, this technique is proving useful in separating the most promising entries for post-harvest resistance. One of the major criticisms of the early QPM maize was the severe loss associated with post-harvest pests. We are now able to identify those with the best endosperm modifications (i.e. those varieties that have an endosperm hardness similar to normal maize grains) (Fig. 1). We will be validating this technique with a grain quality lab in Texas A&M during 2000.

Figure 1: Kernel hardness of Quality Protein Maize (QPM) varieties compared to normal endosperm maize, Morelos, Mex., 1999.
Studies were conducted to identify the grain moisture content at which the kernel hardness breakdowns to better understand the limitations to a kernel hardness resistance mechanism. A resistant (Pop. 84) and a susceptible (CML244xCML349) maize was calibrated at 5 different relative humidities, which represent a range of storage conditions, to look at the relationship between kernel hardness, relative humidity and insect resistance. A strong negative correlation was found between grain moisture content and hardness \((r>0.95)\) and resistance \((r>0.9)\). From Figure 2 we see that kernel resistance against *Prostephanus truncatus* breaks down under high humidity conditions. Similar results were obtained for *Sitophilus zeamais*. For kernel hardness

<table>
<thead>
<tr>
<th>Table 1: Treatments tested using experimental tropical maize varieties, Poza Rica 1999.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Control</td>
</tr>
<tr>
<td>Reidan®</td>
</tr>
<tr>
<td>Protect-It DE</td>
</tr>
<tr>
<td>Pool DE</td>
</tr>
<tr>
<td>Green Pea (Chuchan)</td>
</tr>
<tr>
<td>Crotalaria</td>
</tr>
<tr>
<td>Canavalia</td>
</tr>
<tr>
<td>Mucuna</td>
</tr>
<tr>
<td>Neem leaves</td>
</tr>
<tr>
<td>Pea Protein</td>
</tr>
<tr>
<td>Pea Protein and Top dress</td>
</tr>
</tbody>
</table>

Figure 2: Kernel damage by *Prostephanus truncatus* after 2 months and kernel force as a function of grain moisture content, Mex., 1999.
to be effective, grain moisture content must be below 16 percent for the existing resistant sources.

CIMMYT, in collaboration with Agriculture and Agri-Food Canada, has also been testing "soft" technologies under small farm storage conditions in the tropics. A study was carried out at CIMMYT’s tropical field station (Poza Rica, Veracruz, 60masl). Twenty-five kg of maize was placed into polyethylene bags for each treatment. Moisture content was measured and samples were taken to verify homogeneity of grain infestation from the field. A total of 12 treatments were tested (Table 1). Two diatomaceous earth formulations were tested (Pool DE, Mexico; Protect-IT, Canada) which control insects by damaging the cuticle which result in desiccation. Another technology developed by Agriculture Canada is the pea protein extract but its mode of action has yet to be determined. Mexican farmers use Crotalaria, Canavalia and Mucuna as rotation crops with maize to increase soil fertility; the seeds of which are thought to be insecticidal. Reldan® (chlorpyrifos-methyl) was used as a chemical control treatment which is used by farmers to control stored-product insects in maize.

After treatment, the bags were stored with open access to enable natural infestation by post-harvest pests. After 3 months, 1-kg maize samples were taken from the bag and the number of live and dead insects of each species noted, the weight and number of insect damaged kernels was recorded. From these preliminary results, the most effective control was the Protect-It, a commercial product produced in Canada (Table 2). The Reldan® treatment was one of the least effective treatments as it likely killed off biological control agents and did not provide residual control of pests. For 2000 we plan to look at the interaction between the best “soft” technologies and resistant maize varieties as the “soft” technologies alone do not provide a satisfactory level of control in tropical ecologies.

Table 2: Damage to maize and insect numbers after 3 months (21 June to 28 Sept) at Poza Rica of 25 kg lots of maize treated with various natural products and chemical insecticide.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Kernel Damage (%±SE)</th>
<th>Weight Loss (%±SE)</th>
<th>Flour Weight (g)</th>
<th>Sitophilus (X±SE)</th>
<th>Lepidoptera (X±SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>44±7</td>
<td>3±1</td>
<td>0.7±0.2</td>
<td>12±10</td>
<td>0±0</td>
</tr>
<tr>
<td>Reldan</td>
<td>65±12</td>
<td>13±4</td>
<td>2.3±0.8</td>
<td>7±2</td>
<td>33±11</td>
</tr>
<tr>
<td>Protect-IT DE</td>
<td>38±8</td>
<td>6±2</td>
<td>0.2±0.02</td>
<td>2±1</td>
<td>15±5</td>
</tr>
<tr>
<td>Pool DE</td>
<td>65±11</td>
<td>10±3</td>
<td>0.5±0.1</td>
<td>2±1</td>
<td>14±6</td>
</tr>
<tr>
<td>Green Pea</td>
<td>39±7</td>
<td>5±2</td>
<td>1.9±0.6</td>
<td>10±3</td>
<td>2±1</td>
</tr>
<tr>
<td>Croptalari</td>
<td>78±6</td>
<td>10±4</td>
<td>0.5±0.02</td>
<td>5±2</td>
<td>2±2</td>
</tr>
<tr>
<td>Canavalia</td>
<td>80±4</td>
<td>13±3</td>
<td>0.6±0.1</td>
<td>7±2</td>
<td>3±2</td>
</tr>
<tr>
<td>Mucuna</td>
<td>48±10</td>
<td>6±3</td>
<td>0.9±0.1</td>
<td>7±2</td>
<td>0±0</td>
</tr>
<tr>
<td>Neem</td>
<td>61±6</td>
<td>7±3</td>
<td>0.7±0.1</td>
<td>5±1</td>
<td>0±0</td>
</tr>
<tr>
<td>Pea Protein</td>
<td>68±10</td>
<td>11±3</td>
<td>2.4±0.8</td>
<td>6±2</td>
<td>1±1</td>
</tr>
<tr>
<td>Pea Protein+DE</td>
<td>54±17</td>
<td>10±5</td>
<td>4.7±1.1</td>
<td>3±2</td>
<td>12±4</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>56±3</td>
<td>8±1</td>
<td>1.2±0.2</td>
<td>6±1</td>
<td>7±2</td>
</tr>
</tbody>
</table>

For flour weight, this would include the dust from the treatment, which was 0.15g for DEs, 1% for the legumes and 2% for top dressing with pea protein and none for control and Reldan treatments.
Phytochemical Characterization of Maize Resistant to Storage Pests

Recent research has shown that cell wall bound phenolic acids are correlated with kernel resistance to *Sitophilus zeamais* and *Prostephanus truncatus* (Serratos et al. 1997).

Pytochemical analysis was conducted on seven varieties: Sinaloa 35, Yucatan 7, 1780 Ejura (QPM resistant to *S. zeamais*), 1784 (resistant to *P. truncatus*), 1784 x P47, P47x1784, and CML 244xCML349 (highland single cross). Kernels were partitioned into pericarp, endosperm and germ and milled using a cyclone mill. Base hydrolysis (4 h shake in 20 ml of 2N NaOH under N₂) was used to cleave the ester bond between the phenolic acids and the arabinoxylan moiety of the cell wall. Samples were analyzed by a standard HPLC protocol and peak identity was confirmed using absorption spectra, retention times and spiking of extracts with authentic phenolic standards.

The results from this analysis are summarized for only the pericarp tissue that showed the strongest correlation with insect resistance (Table 3). A good correlation was observed between and kernel force (Force) and diphenolic acids (DFA) which are known to strengthen plant tissue through cross-linking arabinoxylan moieties. Moreover, these chemical components also correlated well with insect resistance. Based on this preliminary data, we believe the cross-linking in the pericarp to be a very important trait. Protein quality was not negatively affected by the presence of high levels of diphenolic acids. We believe this trait should not impose a yield drag nor should it alter the food processing or quality of maize grain.

### Table 3: Correlation between different biochemical components of the pericarp and *Sitophilus zeamais* resistance using seven different CIMMYT varieties, 1999.

<table>
<thead>
<tr>
<th></th>
<th>Comaric</th>
<th>DFAS5</th>
<th>DFA804</th>
<th>DFA85</th>
<th>DFAB85</th>
<th>Damage</th>
<th>Fiber</th>
<th>cisFA</th>
<th>transFA</th>
<th>TotDFA</th>
<th>TotPA</th>
<th>Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFA5</td>
<td>0.49</td>
<td>0.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DFA804</td>
<td>0.76</td>
<td>0.94</td>
<td>0.08</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DFA85</td>
<td>0.81</td>
<td>0.70</td>
<td>0.84</td>
<td>0.05</td>
<td>0.13</td>
<td>0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DFAB85</td>
<td>0.80</td>
<td>0.91</td>
<td>0.99</td>
<td>0.85</td>
<td>0.06</td>
<td>0.01</td>
<td>0.00</td>
<td>0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damage</td>
<td>-0.52</td>
<td>-0.91</td>
<td>-0.89</td>
<td>-0.85</td>
<td>-0.87</td>
<td>0.29</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiber</td>
<td>0.47</td>
<td>-0.38</td>
<td>-0.10</td>
<td>0.34</td>
<td>-0.07</td>
<td>0.19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cisFA</td>
<td>0.34</td>
<td>0.45</td>
<td>0.86</td>
<td>0.51</td>
<td>0.89</td>
<td>0.71</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>transFA</td>
<td>-0.15</td>
<td>0.75</td>
<td>0.50</td>
<td>0.06</td>
<td>0.44</td>
<td>-0.52</td>
<td>-0.84</td>
<td>0.24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TotDFA</td>
<td>0.77</td>
<td>0.09</td>
<td>0.32</td>
<td>0.92</td>
<td>0.38</td>
<td>0.29</td>
<td>0.03</td>
<td>0.64</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TotPA</td>
<td>0.73</td>
<td>1.00</td>
<td>0.85</td>
<td>0.99</td>
<td>-0.91</td>
<td>-0.12</td>
<td>0.18</td>
<td>0.51</td>
<td>0.10</td>
<td>0.00</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>0.10</td>
<td>0.00</td>
<td>0.03</td>
<td>0.00</td>
<td>0.01</td>
<td>0.82</td>
<td>0.73</td>
<td>0.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Force</td>
<td>0.37</td>
<td>0.97</td>
<td>0.87</td>
<td>0.53</td>
<td>0.84</td>
<td>-0.80</td>
<td>-0.51</td>
<td>0.29</td>
<td>0.85</td>
<td>0.88</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.46</td>
<td>0.00</td>
<td>0.02</td>
<td>0.28</td>
<td>0.04</td>
<td>0.06</td>
<td>0.30</td>
<td>0.58</td>
<td>0.30</td>
<td>0.03</td>
<td>0.03</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>0.52</td>
<td>0.84</td>
<td>0.83</td>
<td>0.82</td>
<td>0.84</td>
<td>-0.97</td>
<td>-0.20</td>
<td>-0.09</td>
<td>0.43</td>
<td>0.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.29</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.00</td>
<td>0.70</td>
<td>0.87</td>
<td>0.40</td>
<td>0.03</td>
<td>0.03</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>0.34</td>
<td>0.92</td>
<td>0.81</td>
<td>0.42</td>
<td>0.79</td>
<td>-0.69</td>
<td>-0.56</td>
<td>0.27</td>
<td>0.85</td>
<td>0.82</td>
<td>0.97</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>0.51</td>
<td>0.01</td>
<td>0.05</td>
<td>0.41</td>
<td>0.06</td>
<td>0.13</td>
<td>0.25</td>
<td>0.61</td>
<td>0.03</td>
<td>0.05</td>
<td>0.00</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Note: Bold numbers indicate significant correlations between intersecting traits.
Table 4: Regression equations for grain damage and grain weight loss in different maize ecologies within Mexico.

<table>
<thead>
<tr>
<th>Duration</th>
<th>Ecology</th>
<th>Storage</th>
<th>Regression equation</th>
<th>R-Squared</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 months</td>
<td>Winter</td>
<td>Grain</td>
<td>PD= 9.668 - 0.340 (Tmaxmin) + 0.054 (Tx)</td>
<td>0.617</td>
<td>0.035</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TD= 9.152 - 2.287 (Tmaxmin) + 3.123 (Tx)</td>
<td>0.483</td>
<td>0.099</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PL= 2.850 - 0.207 (Tmaxmin) + 0.161 (Tx)</td>
<td>0.909</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL= 6.167 - 1.046 (Tmaxmin) + 1.239 (Tx)</td>
<td>0.406</td>
<td>0.161</td>
</tr>
<tr>
<td>Ear</td>
<td></td>
<td></td>
<td>PD= 41.108 - 2.770 (Tmaxmin) + 0.096 (Tx)</td>
<td>0.716</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TD= 329.458 - 10.142 (Tmaxmin) + 9.319 (Tx)</td>
<td>0.258</td>
<td>0.350</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PL= 56.080 - 1.147 (Tmaxmin) - 2.058 (Tx)</td>
<td>0.216</td>
<td>0.426</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL= 144.839 - 3.158 (Tmaxmin) - 5.197 (Tx)</td>
<td>0.234</td>
<td>0.391</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Husk</td>
<td>PD= 107.266 - 2.692 (Tmaxmin) - 3.656 (Tx)</td>
<td>0.852</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TD= -42.497 + 0.073 (Tmaxmin) + 2.780 (Tx)</td>
<td>0.851</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PL= 14.671 - 0.442 (Tmaxmin) + 1.531 (Tx)</td>
<td>0.426</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL= 107.266 - 2.692 (Tmaxmin) - 3.656 (Tx)</td>
<td>0.852</td>
<td>0.001</td>
</tr>
<tr>
<td>6 months</td>
<td>Winter, ecol 1</td>
<td>Grain</td>
<td>PD= 52.300 - 0.369 (Tmaxmin) - 1.151 (Tx)</td>
<td>0.062</td>
<td>0.937</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TD= 726.019 - 20.659 (Tmaxmin) - 8.336 (Tx)</td>
<td>0.923</td>
<td>0.076</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PL= 56.711 + 1.687 (Tmaxmin) + 1.531 (Tx)</td>
<td>0.499</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL= 333.497 + 9.164 (Tmaxmin) + 8.459 (Tx)</td>
<td>0.981</td>
<td>0.018</td>
</tr>
<tr>
<td>Ear</td>
<td></td>
<td></td>
<td>PD= 1.187 + 0.310 (Tmaxmin) - 0.184 (Tx)</td>
<td>0.937</td>
<td>0.052</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TD= -310.668 + 0.626 (Tmaxmin) + 1.015 (Tx)</td>
<td>0.975</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PL= -1.705 - 0.171 (Tmaxmin) + 0.191 (Tx)</td>
<td>0.856</td>
<td>0.143</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL= -2.451 - 0.271 (Tmaxmin) + 0.293 (Tx)</td>
<td>0.778</td>
<td>0.221</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Husk</td>
<td>PD= 2.811 - 0.187 (Tmaxmin) + 0.046 (Tx)</td>
<td>0.219</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TD= -10.699 - 0.148 (Tmaxmin) + 0.608 (Tx)</td>
<td>0.959</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PL= -3.605 - 0.050 (Tmaxmin) + 0.185 (Tx)</td>
<td>0.772</td>
<td>0.227</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL= -3.632 - 0.232 (Tmaxmin) + 0.312 (Tx)</td>
<td>0.882</td>
<td>0.117</td>
</tr>
<tr>
<td>Winter, ecol 2</td>
<td>Grain</td>
<td>PD= 80.91 - 1.928 (Tmaxmin) - 1.710 (Tx)</td>
<td>0.715</td>
<td>0.284</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TD= -62.382 + 2.308 (Tmaxmin) + 3.634 (Tx)</td>
<td>0.999</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PL= 23.962 - 0.204 (Tmaxmin) - 0.660 (Tx)</td>
<td>0.535</td>
<td>0.464</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL= -34.959 + 1.017 (Tmaxmin) + 1.788 (Tx)</td>
<td>0.994</td>
<td>0.005</td>
</tr>
<tr>
<td>Ear</td>
<td></td>
<td></td>
<td>PD= 1.001 + 0.772 (Tmaxmin) - 0.422 (Tx)</td>
<td>0.837</td>
<td>0.162</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TD= 30.26 + 0.913 (Tmaxmin) - 1.386 (Tx)</td>
<td>0.529</td>
<td>0.470</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PL= 91.622 + 2.666 (Tmaxmin) + 3.912 (Tx)</td>
<td>0.969</td>
<td>0.030</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL= 50.073 + 1.077 (Tmaxmin) + 2.172 (Tx)</td>
<td>0.993</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Husk</td>
<td>PD= 17.911 + 2.799 (Tmaxmin) - 2.102 (Tx)</td>
<td>0.839</td>
<td>0.160</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TD= -75.022 + 2.873 (Tmaxmin) + 2.647 (Tx)</td>
<td>0.968</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PL= 1.074 + 0.899 (Tmaxmin) - 0.415 (Tx)</td>
<td>0.474</td>
<td>0.525</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL= 44.993 + 1.045 (Tmaxmin) + 1.826 (Tx)</td>
<td>0.938</td>
<td>0.016</td>
</tr>
<tr>
<td>Summer 1&amp;2</td>
<td>Grain</td>
<td>PD= 288.167 + 5.395 (Tmaxmin) + 9.443 (Tx)</td>
<td>0.385</td>
<td>0.615</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TD= 219.628 - 7.971 (Tmaxmin) - 10.470 (Tx)</td>
<td>0.921</td>
<td>0.078</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PL= 39.338 + 1.671 (Tmaxmin) + 1.057 (Tx)</td>
<td>0.351</td>
<td>0.648</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL= 191.879 + 2.028 (Tmaxmin) - 7.731 (Tx)</td>
<td>0.970</td>
<td>0.029</td>
</tr>
<tr>
<td>Ear</td>
<td></td>
<td></td>
<td>PD= 300.736 - 9.383 (Tmaxmin) - 7.799 (Tx)</td>
<td>0.355</td>
<td>0.644</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TD= 1481.57 - 25.938 (Tmaxmin) - 48.424 (Tx)</td>
<td>0.999</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PL= 222.914 + 5.395 (Tmaxmin) - 6.655 (Tx)</td>
<td>0.627</td>
<td>0.373</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL= 673.53 - 10.502 (Tmaxmin) - 22.758 (Tx)</td>
<td>0.999</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Husk</td>
<td>PD= 389.39 - 10.362 (Tmaxmin) - 11.199 (Tx)</td>
<td>0.626</td>
<td>0.373</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TD= 1393 - 24.378 (Tmaxmin) - 45.999 (Tx)</td>
<td>0.987</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PL= 115.121 + 2.018 (Tmaxmin) - 3.392 (Tx)</td>
<td>0.913</td>
<td>0.086</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TL= 462.199 + 6.787 (Tmaxmin) - 15.841 (Tx)</td>
<td>0.994</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Note: PD=partial damage, TD=total damage, PL=partial grain weight loss, TL=total grain weight loss, Tmaxmin is the difference between Tmax and Tmin, Tx is mean monthly temperature.
conducted. Storage losses and damage are commonly cited between 0 and 80%, which are not based on detailed surveys. This project is focused on quantifying storage losses in Mexico across several environments and storage practices to generate a database over time. Mexico offers a unique range of maize environments and storage practices for the purpose of this study. This information will then be incorporated into a GIS to predict the damage curve of maize in storage in tropical, mid-altitude and highland environments. The second phase will involve validation and testing in other regions of the world. The methodology involves preparing three ear equivalents as shelled (300g), ears with and without husk cover. Within each region, collaborators collect samples (3 reps) on a monthly bases from each site and send them to the Entomology Unit for evaluation. In one or two sites within each region, a composite sample is tested to relate the relative susceptibility of the different storage options within the region. We opted to use a common hybrid (CML244xCML349) as this is a popular female for seed production in Mexico. We also wanted to reduce the phenotypic effect and the effect of growing environment which are confounding factors in traditional survey work. Before samples were located in a site, the farmer was interviewed to characterize his storage practice and to document their perception of post-harvest losses. At each site the objective of the trail was explained to the farmer and the results will be returned along with a summary of the best storage option reported within the region.

Apart from just quantifying losses, we are also interested in identifying the pest storage options used in different maize ecologies so this information can be circulated to farmers in similar, but distant, ecologies. One storage intervention which is very popular with farmers is the small (1.2 T) silo. This silo costs approximately $100US to manufacture and is being sold by small-scale entrepreneurs for $150US. Despite the cost of these structures, they are becoming very popular with farmers in Oaxaca. The silos originated from the coast of Oaxaca are different from other silos in the use of screwed caps at both the top orifice for filling and the bottom orifice for grain removal. The Entomology Unit plans to test these silos in 1999 in Veracruz, as grain moisture content is a concern in this region.

Storage sites will reflect both variations in climate as well as popular storage practices for that region. Emphasis will be placed on humid environments. The project will initially focus on 10 key sites in Mexico, though Zimbabwe and Kenya will also be included as collaborators are identified. Each site will be monitored for temperature and humidity within the store and outside using HOBO® data loggers to record temperature and relative humidity on an hourly basis. Losses will be assessed using 300g grain samples randomly located within the grain store. GIS maps for temperature and rainfall were used in selecting the above regions as well as their importance to maize and the availability of collaborators.

Based on two years of data, regression equations have been developed to estimate partial weight loss of grain for different ecologies and storage practices for Mexico (Table 4). These equations will now be used in generating GIS grids for storage losses in Mexico and could be applied to other regions where GIS grids for monthly minimum and maximum temperatures exist. As you can see from Table 5, good correlations are found using these simple climate parameters to estimate storage losses.

References

Report of the Working Group Meeting on Developing and Disseminating Technology to Reduce Post-harvest Losses in Maize

September 25-27, 2000
Organized by the Hill Maize Research Project (NARC/CIMMYT/SDC)

Background and Objectives to the Meeting

Post-harvest loss of maize has been identified in recent RRA surveys as one of the major concerns of farmers in the hills of Nepal. With the exception of limited areas usually in valley bottoms, maize is grown during the summer months in the hills and is harvested before the end of the monsoon rains. Under these conditions, it is difficult for farmers to dry the harvested maize to a safe level therefore the crop is usually predisposed to losses from insects and diseases. Developing and disseminating recommendations to reduce post-harvest losses has been selected as a priority area within the Hill Maize Research Project (HMRP). Both globally and within Nepal there has been substantial research on controlling post-harvest losses of maize. The purpose of this working group meeting was to build upon existing information and establish a strategy for addressing the post-harvest problem within the HMRP and the National Maize Research Program.

The specific objectives of the meeting were:

1. To review past and on-going research related to post-harvest losses of maize.
2. To define priority areas for research that will address problems of post-harvest losses.
3. To review new research approaches and methodologies.
4. To develop a strategy for implementing research directed towards reducing post-harvest losses and extending promising technologies.
5. Develop a plan for improving the dissemination of existing post-harvest technologies.

Program

The program consisted of eleven invited papers, small group discussions and a final plenary discussion (see Annex 2 for a complete program). The presented papers will be published by the HMRP later in the year as part of a working paper series (these proceedings).

A few important points arising from the various presentations include:

1. Post-harvest losses were estimated to ranged from 5-40 percent with most researchers estimating losses to be 20%.
2. The major obstacles to storage relate to time of harvest (during the late monsoons in August-September), limited drying facilities and storage structures.
3. The most common practices for harvesting and storing maize includes:
   - Detasseling and stripping the maize plant of its lower leaves prior to physiological maturity.
   - Harvesting ears close to physiological maturity.
   - Freshly harvested ears are piled usually within a room of the house or a porch with the husk left on.
   - Small ears, those with poor husk cover and those that are obviously damaged are dehusked and shelled for immediate use for human consumption with rotten grain being set aside for livestock (mostly buffalo and cattle).
   - Larger ears are tied into bunches (jhutta) using the outer husk leave. Bunches typically consist of 2 groups of 3 ears.
   - Bunches are hung from various parts of the house to facilitate air drying for a minimum of 5-10 days before being placed into traditional storage structures.
   - Bunches are combined and tied with husk leaves into one of two main storage structures: the “suli”, which is round with ca 1.5 m diameter and the “thankro”, which is narrow (usually 4 to 6 cobs thick) and long (as long as
needed but 10-15 m lengths are commonly observed).

- Maize is not usually extracted from these storage structures until January to guard against food shortages. Any short fall between September and January are met by borrowing/buying maize from neighbors.

- Maize is stored in these structures until the beginning of the monsoons at the end of March. At this time the remaining grain is stored in the house. Shelled grain is stored in wicker baskets or clay containers.

4. More accurate estimates of post-harvest losses are needed and could be obtained through a more thorough and systematic way to reflect different storage strategies in different agro-ecologies within the country, especially the Terai and hills.

5. A Vietnam drier (SRR-1) tested in Khumaltar could dry grain on ears or shelled within 96 hours (32 to 14% GMC) at a cost of 12USD/ton. The major limitation to this technology is the capital investment of ca. 60 USD with the fan (30USD) being the most expensive component and the lack of electricity in many maize growing areas of the country. Modifications to the suli structure that would facilitate drying were suggested. Another option would be bamboo racks, which could be covered or relocated during heavy rains.

6. The status of the grain moisture content during the different stages of drying and storage are not well documented and should be the focus of further research efforts. Drying is a major limitation, which not only affects grain susceptibility to insects but also molds if GMC can not be lowered below 14%.

7. Storage structures are varied, with the predominant structures being the suli and thangro. Clay bins containing a layer of plastic called "cuescomate" have been tested for shelled grain but high GMC is a limitation. High GMC is also a problem for metal silos which have become popular with larger farmers in the Terai who store more grain for longer periods. By modifying the suli to increase ventilation and drying in the core holds considerable promise and may have application to other regions of the world where harvest occurs during a wet season.

8. Results from a rapid rural assessment and baseline studies indicate that farmers practice a high level of hygiene (87% of the farmers sweep out old stores before harvest and separate small or damaged ears for direct consumption) and that larger farmers tend to experience higher losses (est. 18%) than smaller farmers during extended storage.

9. Ear rots common to Nepal were reported to include Fusarium graminearum, F. moniliforme, and Aspergillus flavus. Some mycotoxin work had been conducted through USDA-Peoria (USAID project) which found the highest levels of fumonisins in the cob. Some selection for ear rots has been conducted in the development of Nepal varieties and this activity was encouraged to continue. Surveys have found Ganesh-2 and Pop. 22 to have 18% ear rot infection while Rampur composite was very susceptible at 84% (mostly F. graminearum)

10. The use of botanicals and other "soft" technologies have been tested extensively in Nepal. Nepalese farmers have a long tradition of using indigenous plant materials to protect standing crops and post-harvest agricultural products. The material found to be most effective was powdered prepared from sweet flag (Acorus calamus) rhizomes called "bojo". This plant is locally available in the hills of Nepal and can be prepared by farmers to control weevils in maize stores. No toxicology or taste studies have been conducted which may be a concern if the powder is applied to the grain. Some research has also been conducted on inert material such as diatomaceous earth and wood ash, which act by absorbing wax from the insects cuticle and causing desiccation. Further research will look at how bojo can be effectively incorporated into existing storage practices.

11. Extension of post-harvest technologies has met with limited success, as farmers are reluctant to change from their traditional storage practices. Their recommendation was to find ways to improve existing practices and to provide germplasm with resistance to weevils, especially good husk cover.

Recommendations

The following recommendations with regards to research directed toward controlling post-harvest losses were made.

I. Additional adaptive research on storage/drying structures is justified with an emphasis on

1. Improving the rate of dry down (early dry down through the use of new technology).

Some suggested areas that could be considered under this research theme include:

- Bending/doubling of the maize stalks in the field to accelerate grain drying.
- Developing a temporary crib for early dry down after harvest.
• Protecting grain from rain by adding a plastic sheet to existing structures.
• Developing a forced air system for drying (possibly through modification of suli by adding a mud base to avoid incineration of maize husks and a fire pit to reduce the height requirement of the wooden supports).
• Bamboo racks as an early drying process (possibly under a thatched roof).

2. Improving existing storage structures
• Monitoring moisture levels in different structures and locations within structures.
• Improving aeration within the suli (possibly creating a hollow core using bamboo).

II. Screen varieties for insect resistance/ear rots:
• Variety screening for resistance to weevils.
• Characterization of husk cover for husk thickness, silk channel length and tightness.
• Kernel characterization for endosperm hardness, a trait associated with resistance.
• Artificial inoculation for ear rots using Fusarium graminearum and Aspergillus flavus.
• Assessment of mycotoxin levels in grain sorted for livestock feed (i.e. that which was not deemed suitable for human consumption).

III. Obtain additional information on post-harvest losses that focus on the grain use profile after harvest.
This would include key pests, diseases and how they affect quality. This will require the use of improved methodologies. GIS may be used to extrapolate monthly survey data to cover all maize growing areas throughout the storage period.

IV. Socio-economic validation of biopesticides.
Cost or availability may be prohibitive for adoption by farmers, neem is one example that may be too costly for the hills but may have application in the Terai where it can be cultivated. Emphasis should be placed on bojo that can grow in the hills. Additional biopesticides include asuro and titipati (Artemesia spp.).

V. Use of locally available materials in the control of insect pests.
Such technologies could include household lime and wood ash (characterize the efficacy of different wood species grown in the hill region). Monitoring the current strategies used by innovative farmers in controlling post-harvest pests and to verify those technologies under experimental conditions.

VI. Develop more extensive information on insecticides that can be used for post-harvest insect control.
This information can serve as a reservoir of information for those farmers who want to use insecticides. For example, malathion is not effective and should be replaced by newer insecticides with improved safety and efficacy. This information could be used by those who wish to preserve seed as well as assist with crop establishment.

VII. Studies into the non-adoption of seemingly viable recommendations.
Sometimes the technology will work but it does not fit into the household system. Why are technologies that are inexpensive and effective not adopted?

VIII. Compile an extension publication that uses a decision tree approach for summarizing options for different types of farmers (i.e. farmer that store >12 months, <4 months, monkey problems, save seed, etc.). Given the range of farmers, not all technologies are relevant and this would be put out as an extension bulletin. A draft could be prepared based on a thorough synthesis of the reports on exiting technologies that were describe in the present meeting.

IX. CIMMYT’s Entomology program and the Post-harvest Loss Division of DOA were identified as key partners to HMRP in developing and implementing a research and dissemination program on controlling post-harvest losses of maize. The group did not identify a project or NGO that is specifically dealing with issues of post-harvest at the present time.
Annex 1.

List of Participants:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name</th>
<th>Designation/institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>G. P. Koirala</td>
<td>Director Finance, NARC</td>
</tr>
<tr>
<td>2</td>
<td>Ajaya Bajracharya</td>
<td>ARS Pakhrribas</td>
</tr>
<tr>
<td>3</td>
<td>Ram Paneru</td>
<td>Entomology Division, Khumaltar</td>
</tr>
<tr>
<td>4</td>
<td>Binaya Batsa</td>
<td>NMRP, Rampur</td>
</tr>
<tr>
<td>5</td>
<td>Khadga Shrestha</td>
<td>AED, NARC</td>
</tr>
<tr>
<td>6</td>
<td>Ganesh KC</td>
<td>IED, DOA</td>
</tr>
<tr>
<td>7</td>
<td>Shashi Adhikari</td>
<td>Post harvest Loss Div., DOA</td>
</tr>
<tr>
<td>8</td>
<td>Bhim Nath Adhikari</td>
<td>ARS, Dailekh</td>
</tr>
<tr>
<td>9</td>
<td>Roshan Manandhar</td>
<td>ARS, Lumle</td>
</tr>
<tr>
<td>10</td>
<td>K. Adhikari</td>
<td>NMRP, Rampur</td>
</tr>
<tr>
<td>11</td>
<td>Yamuna Prashad Sah</td>
<td>ARS Pakhrribas</td>
</tr>
<tr>
<td>12</td>
<td>Govind Koirala</td>
<td>NARC</td>
</tr>
<tr>
<td>13</td>
<td>Gautam Manandhar</td>
<td>AED, NARC</td>
</tr>
<tr>
<td>14</td>
<td>Gopal Shivakoti</td>
<td>Entomology Division, Khumaltar</td>
</tr>
<tr>
<td>15</td>
<td>B.P. Mainali</td>
<td>Entomology. Div., Khumaltar</td>
</tr>
<tr>
<td>16</td>
<td>Dhruba N. Manandhar</td>
<td>Entomology. Div., Khumaltar</td>
</tr>
<tr>
<td>17</td>
<td>I. P. Upadyay</td>
<td>NMRP, Rampur</td>
</tr>
<tr>
<td>18</td>
<td>Gyanu Manandhar</td>
<td>Plant Pathology Div, Khumaltar</td>
</tr>
<tr>
<td>19</td>
<td>David Bergvinson</td>
<td>CIMMYT, Mexico</td>
</tr>
<tr>
<td>20</td>
<td>Joel Ransom</td>
<td>CIMMYT, Nepal</td>
</tr>
<tr>
<td>21</td>
<td>N. P. Rajbhandari</td>
<td>CIMMYT, Nepal</td>
</tr>
</tbody>
</table>
Annex 2.

Working group program

25 September

1.0 Opening Session
9:00 Welcome
9:15 Objectives of the Working Group Meeting and Introduction of Participants K. Adhikari

2.0 Defining the Problem
9:45 Global Overview of Post Harvest Losses in Maize D Bergvinson
10:45 Tea
11:15 An Overview of the Post-harvest Problem in Maize in Nepal G.P. Shivakoti/D.N. Manandhar
12:15 Results of a Recent RRA Relative to Post-harvest Losses in Maize N.P. Rajbhandari
12:45 Lunch
1:45 A Review of Factors Affecting Post-harvest Losses J.K. Ransom

3.0 Review of Past and On-going Research and Extension Activities
2:30 Review of Research in Nepal on the Control of Post-harvest Pests (Insects and Rodents) of Maize D.P. Mainali/D.N. Manandhar
3:30 Tea
4:00 Botanicals and Other Indigenous Knowledge Systems for the Control of Post-harvest Insects R.B. Paneru/Y.P. Sah
4:30 Review of Research in Nepal on Disease Related Post-harvest Losses in Maize B.K. Batsa/G. Manandhar

26 September

9:00 Storage and Drying Structures to Control Losses K.B. Shrestha/G.B. Manandar
9:45 Review of the Findings of the Rural Save Grain Project on Post-harvest Losses with Special Reference to Maize Ganesh KC
10:30 Current Extension Program and Recommendation and Constraints to More Effective Dissemination S. Adhikari
11:15 Tea
11:45 Review of CIMMYT's Research on Controlling Post-harvest Losses (i.e. Breeding for resistance), Research Methodologies Used and Promising Research Areas D. Bergvinson
12:30 Lunch
2:15 Small Group Discussions

27 September

9:00 Small Groups
11:30 Report of Small Groups
12:30 Lunch
1:30 General Discussions and Conclusion of the Meeting

Post-harvest Maize Losses - Working Group Meeting