Evaluation of Metal Silo Performance for On-Farm Maize Grain Storage Structure in Ethiopia

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Abstract

In Ethiopia maize suffers serious postharvest losses in storage due to different factors among which insect pests are the most important. To address this problem, Sasakawa Global 2000 – Ethiopia (SG 2000) in collaboration with the International Maize and Wheat Improvement Center (CIMMYT) introduced and demonstrated hermetically sealed metal silo as maize grain storage device to farmers in Amhara, Oromia and SNNP regions in a participatory approach. This study was conducted to evaluate the performance of the technology at six months of storage and assess farmers' perception on the technology in order to decide whether the technology can be disseminated for wide scale use. Farmers reported that weevils and moths followed by rodents were the major storage problems and cause much loss. Physical analysis of samples revealed that the metal silo provided complete protection with only 0.6 % weight loss while the control treatment (polypropylene bag) did not protect the maize grain from infestation by storage insect pests leading to 5.2 % weight loss. After evaluating the treatments farmers also unanimously concluded that the metal silo was very effective in addition to its merits of avoiding chemical hazard, saving of money and increasing income. As a result farmers showed interest in using the metal silo technology. Metal silo technology can, therefore, help farmers safely store their produce and is worth demonstrating and disseminating.

Keywords: Metal silo, insect pests, weight loss, postharvest loss

Introduction

Maize (*Zea mays* L.) is one of the major cereal crops in Ethiopia, making up the largest production. In the year 2011/12 main season crop production, maize covered the largest area of about 2,054,723.69 hectares (21.4 %) next to teff and made up the largest record in production of 6.1 million metric ton (MT) which is about 32.3 % of the total cereal grain production with a productivity of 3.0 MT/ha (CSA 2012). The crop is cultivated by 7.96 million smallholder households (CSA 2011). It is also the least-cost source of cereal calories. According to crop utilization survey of the CSA (2011), of the total national production, 76.03 % was utilized for household consumption, 10.22 % for sale and the balance for seed, wage in kind, animal feed and others. According to the Ethiopian Commodity Exchange, close to 95 % of the marketed quantity comes from smallholders and the rest from commercial and state farms (ECX 2009). The International Food Policy Research Institute (IFPRI 2010) indicated the country's good potential of further improving current productivity levels much higher than other cereals. Increases in smallholders' production as well as incomes from maize can also be obtained from improvements in postharvest handling including storage and marketing. However, grain crops produced by subsistence farmers are stored in traditional ways that make them vulnerable to attack by several storage pests.

Tsedeke Abate *et al.* (2000) reported that the grain weevils, *Sitophilus* spp. (Coleoptera: Curculionidae) and the Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) are the most important pests of stored grain cereals in Africa. The dominant species on maize in Ethiopia is maize weevil (*Sitophilus zeamais Motsch.)* followed by Angoumois grain moth (*S. cerealella),* rice weevil (*S. oryzae L.)* and flour beetle (*Tribolium confusum)* (Abraham 1997; Waktole & Amsalu 2012). Abraham (1997) collected numerous species of arthropods associated with stored maize grain in Ethiopia of which the most important were maize weevil, Angoumois grain moth and flour beetles. Emana (1993) also reported *S. cerealella* followed by *S. zeamais*, as the two most important pests of stored maize in southern Ethiopia.

In 2011, the Food and Agricultural Organization of the United Nations (FAO) reported annual food loss in Sub-Saharan Africa exceeding 30 % of the total production (FAO 2011).The rapid assessment conducted in Ethiopia by IFPRI in 2010 suggests a slightly lower level of 15 to 30 percent; with losses concentrated at the farm level. According to Dereje (2000) the magnitude of Post Harvest Loss (PHL) in the country has been tremendous, ranging from 5 % to 26 % for different crops. In particular to maize the author reported storage loss of 5.8 % when harvested, threshed and stored in a traditional way while grains managed in a similar way but stored by treating with an insecticide dust reduced the loss to as low as 0.5 %. According to Abebe and Bekele (2006), majority of the farmers (93.3 %) perceived imminent risk of grain loss due to attack by storage pests and/or other factors if crops are stored for longer period and reported a 12 % loss in 12 months of storage. Abraham and Senayit (2013) reported estimated storage loss of 30-35% in *Enebse Sar Midir* and *Enarj Enawga* woredas of East *Gojam* Zone of *Amhara* Region in Ethiopia.

Other workers reported grain losses of 20–30 % (Tadele *et al.* 2011; CIMMYT 2012). Losses of 10-20% are reported three months after maize storage, and this goes up to more than 50 % after six months due to the maize weevil and the larger grain borer (CIMMYT 2012). Smallholder farmers end up selling their grain soon after harvest at lowest price in order to avoid significant storage losses. More than 30 % food loss in Sub-Saharan Africa that represent more than USD $4 billion every year (FAO 2011) far exceeds the total amount of international food aid provided to these countries (Costa 2014). Similarly, Ethiopia for instance imports over a million MT of grain per annum to supplement the food shortage.

Among the major factors that contribute to the huge losses in storage include poor construction, maintenance and management of storage structures used in Ethiopia. Therefore, it is believed that improvement in storage structures alone would help reduce storage losses significantly, and contribute much to the efforts in acquiring food security at large and increasing income of the farmers in particular.

Over the last two decades the metal silo technology was developed and deployed in numerous developing countries in Africa, Asia and Latin America, by the Swiss Agency for Development and Cooperation (SDC), Food and Agricultural Organization of the United Nations (FAO), and the International Maize and Wheat Improvement Center (CIMMYT) (Dawn 2012). World Bank research report (2011) on the impact of the use of metal silos in Central America found a variety of benefits: families had to buy less food and had greater flexibility to decide when to sell their surpluses, rather than being forced to sell it all right after threshing. This has resulted in higher incomes to the farming households and a steadier market supply. The metal silo technology significantly improved food security; is ecologically friendly hence safeguarding the agro-ecosystems. An action research trial conducted in Uganda and Burkina Faso also revealed excellent performance of metal silos and super grain bags and the new technologies and procedures enabled food loss to be reduced by more than 98 % regardless of the crop type and duration of storage (Costa 2014). The author also reported that utilization of such improved storage technologies represents a potential 64 % gain in household income.

Based on the above mentioned experiences, Sasakawa Global 2000 (SG 2000) -Ethiopia in collaboration with the CIMMYT jointly introduced and demonstrated the use of metal silo technology in three major maize producing Regional States; *Oromiya, Amhara* and *Southern Nations, Nationalities and Peoples* (SNNP). Therefore, this assessment was done to evaluate the performance of metal silo technology at six months of maize storage.

Materials and Methods

Performance assessment of metal silo technology

SG 2000 distributed 10 metal silos of 300 kg to 1000kg capacities in nine selected sites of the three major maize production regional states; *viz*, *Oromiya* (*Rafu Hargisa* and *Oda Anshura* Kebeles), *Amhara* (*Merawi* and *Wegdad* kebeles) and *Southern Nations, Nationalities and Peoples Regional State* (SNNPRS) (*Jara Karero* and *Shofedi* kebeles). The silos were filled with dried maize grain that had low natural infestation with storage insect pests. A candle was lit and placed on the grain surface in each metal silo for oxygen depletion (Figure 1). The silos' openings at the top and at the bottom spout were sealed by tying with a rubber band to create a hermetic condition. The silos were placed on a wooden pallet and kept in Primary Cooperative stores for demonstration to member farmers. The pilot farmers were briefed about the technology and the utilization procedures. One hundred kilo gram of similar grain was kept in polypropylene sack as control treatment. As the grain used for the demonstration was purchased from farmers it had initial low level of infestation by storage insect pests, though effort was made to use as clean grain as possible. Six of these silos, two each in the three regions, were assessed at six months of storage. About 300 g maize sample was taken from the top, middle and bottom part of each metal silo and the control treatments to determine the extent of damage and weight loss. Percentage damage was determined by computing the proportion of damaged grains to the total sample. The sample grains were separated into damaged and undamaged categories, and each category was counted and weighed separately to compute weight loss using the count and weigh method as follows (Harris & Lindblad 1978).

$$\text{Weight loss (\%)} = \frac{(UNd)-(DNu)}{U(Nd+Nu)} * 100$$

Where; U = weight of undamaged grains, Nu = number of undamaged grains, D = weight of damaged grains, Nd = number of damaged grains.

Germination test was undertaken to see the effect of the technology on viability of the seeds. Twenty seeds were randomly taken from each sample grain and plotted on tissue paper in a Petri dish and moistened with distilled water. They were then kept in the laboratory at Debre Zeit Agricultural Research Center under room temperature for ten days. The number of germinated and non-germinated seeds was counted and the germination percentage computed.

Farmers' perceptions on the metal silo technology

The pilot farmers who were trained on the metal silo technology and its utilization procedures were invited to evaluate the status of the technology after three months of storage. For the current assessment, ten of these farmers from each demonstration site (total of 60 respondents) were randomly selected to observe the performance of the silos after sixth month of storage and interviewed to collect their feedback on the technology. In Ethiopia, women, in addition to household chores and management, play significant roles in postharvest handling such as processing, marketing and household food security. The importance of integrating gender in a post-harvest loss reduction (PHL) projects cannot be overemphasized. Assessing gender roles is thus critical in determining the effectiveness of the proposed solutions to PHL. Though effort was made to address much female respondents in this study, it was possible to interview only 5 % women farmers. Frequency analysis of the collected information was undertaken using descriptive statistics with SPSS software.

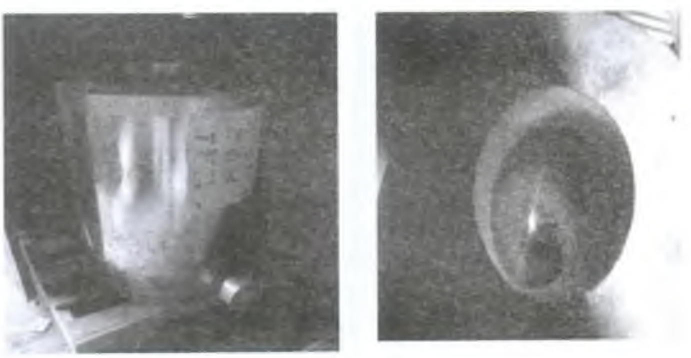

Figure 1. Metal silo grain storage (left) and candle light over the grain surface for oxygen depletion (right)

Results and Discussion

Physical Analysis of Samples

As earlier indicated in the methodology maize grain on which storage insect pest infestation has started was used for the evaluation of the technology. After six months of storage no live insect was found in the metal silo while the control treatment, grain in polypropylene bag, had live insects of weevils (*Sitophilus* spp.) and Angoumois grain moth (*S. cerealella*). The grain in the metal silos had an average damage of 5.6 %, ranging from 1.2 % at *Merawi* in *Amhara* region to 10.6 % at *Jara Korero* in SNNP region (Figure 2). On the other hand, the control treatments had an average infestation of 35.6 % ranging from 9.2 % at *Rafu Hargisa* in *Oromiya* region to 70.1 % at *Merawi* in *Amhara* region.

Figure 3 shows weight loss of maize grain stored in the metal silo and polypropylene bags after six months. Samples in the metal silos showed an average weight loss of 0.6 % ranging from 0.1 % at *Jara Korero* in SNNP region to 1.3 % at *Wegdad* in *Amhara* region. The control treatment suffered an average weight loss of 5.2 % ranging from 1 % at *Rafu Hargisa* in *Oromiya* region to 11.8 % at *Jara Korero* in SNNP regions. The estimated low level of damage and weight loss encountered in the metal silo could be attributed to the initial infestation before the treatment. These findings corroborate the findings of Costa (2014) where average losses of only 0.59 % and 0.74 % were recorded in Uganda and Burkina Faso, respectively, on grains stored in medium and large metal silos for more than nine months.

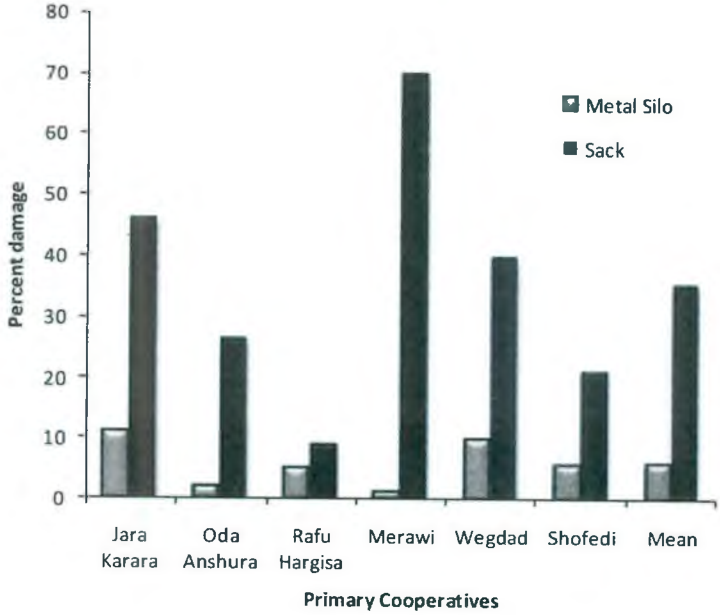

Figure 2. Percent damage of maize grain stored in metal silo and sack.

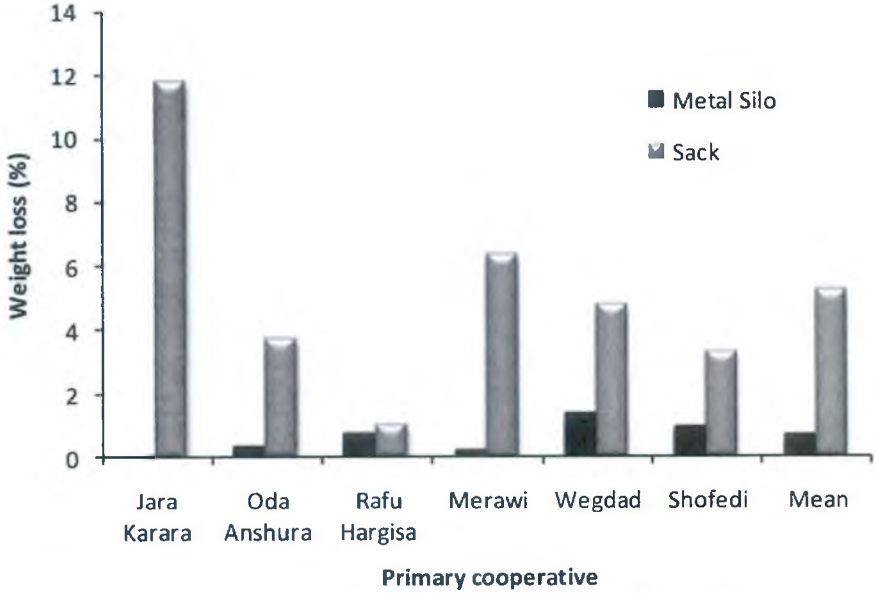

Figure 3. Weight loss of maize grain stored in metal silo and sack

Regarding the germination test, results of the test revealed that depletion of oxygen in the metal silo had no effect on viability of the seeds while damage due to storage insect pests on the control treatment showed considerable effect (Figures 4). Average germination of maize grain stored in metal silo for six months was 86.7 % while the control was 50.8 %. Complete germination of grains in the metal silo was recorded at *Merawi* and *Wegdad* cooperatives stores of the Amhara region while the least germination (55 %) was encountered at *Shofedi* in SNNP region. The loss in viability of seeds in the control treatments was found to be proportional to the degree of damage suffered. For instance, higher damage of grains in the control treatments at *Merawi* (70.1 %) and *Jara Karero* (46.3 %) cooperative store resulted in corresponding lower germination rates of 15 % and 25 %, respectively On the other hand, grains that had lower damages at *Rafu Hargisa* (9.2 %) and *Shofedi* (21.5 %) came up with better germination of 60 % and 85 %, respectively.

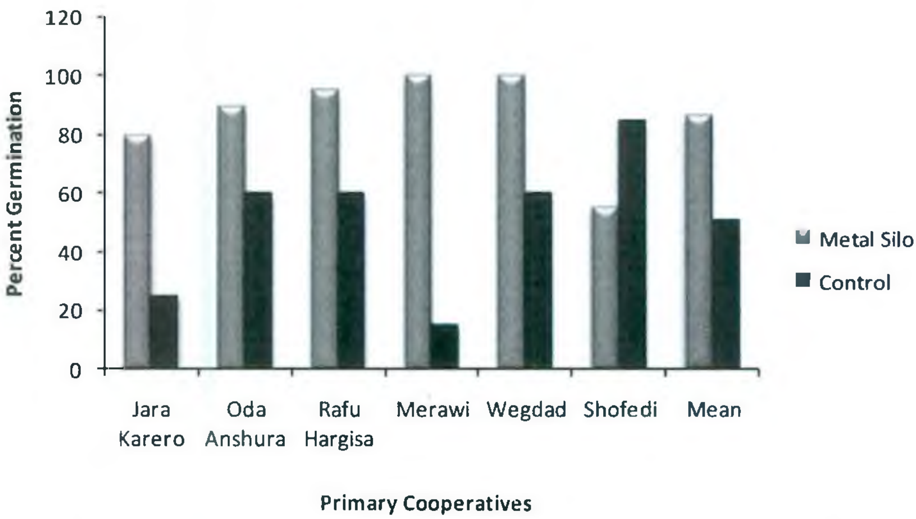

Figure 4. Percentage germination of maize grain stored in metal silo and polypropylene bag

Farmers' Opinion on Metal Silo Grain Storage

Farmers' opinion on the purpose and benefit of the metal silos under demonstration is depicted in figure 5. All the respondent farmers perceived that the metal silo provided effective protection of the grain from insect pests and rodents in comparison to the controls, polypropylene bags. About 16.7 % of the respondents reported that the technology avoids the hazards associated with pesticide use and 1.7 % mentioned the advantage of metal silo occupying less space compared to storing in polypropylene bags.

After evaluating the grain in the metal silo and the control treatments, all of the farmers concluded that the metal silo is very effective in protecting the grain from insect pest attack. They were highly surprised to see maize grain as fresh as a new harvest after six months of storage without chemical treatment. Because the farmers saw that the grain had minimum infestation when initially stored, they found it highly astonishing that storing in metal silo resulted in complete kill of the pests. Most of the farmers witnessed that they could not get such protection even with their experience of using chemical pesticides. Concomitantly, all the respondent farmers showed high interest to use the metal silo technology. This is because they found it to be effective, has no chemical hazard risk and saves money to buy pesticides, or buy back grain for domestic consumption, in addition to increased income from later sales of good quality produce at premium price.

This finding is supported by earlier works that showed the effectiveness of the metal silo technology in protecting losses in grain storage and recommended their promotion and scaling up to small scale farmers. Simon and Hugo (2010) evaluated new storage technologies, Actellic super, super grain bag and metal silo in Kenya and reported that a one ton metal silo had negligible percent crop loss and abated US $100 in 12 months. Zachary *et al.* (2012) also stated that households that do not adopt metal silo sell much of their grain within the first month after harvest at low prices while adopters store and sell most of their maize five months after harvest when prices are attractive. Metal silo adopters save on average US $134 worth of grain and US $18 on cost of storage pesticides compared to non-adopters. Tadele and Adebayo (2012) reported that the metal silo is proven effective hermetic storage for grains and recommended it's scaling up and out, to reach large number of farmers and the need of conducting economic analysis; identifying policy gaps, incentives and disincentives that affect adoption of the technology. On series of field days held in Malawi and Zambia to raise awareness and demonstrate the efficacy of metal silos in protecting stored grains against weevils and the larger grain borer of maize farmers compared the good-quality grain stored in a silo to the damaged grain stored in traditional structures and gunny bags (CIMMYT 2014).

The respondent farmers in this study, however, expressed their worry concerning the affordability of the technology, especially to buy with a cash-down payment. It seems that farmers could not realize the long term advantage they will be reaping. Therefore, efforts should be made in creating awareness and educating farmers on the long term economic and food security advantage of the technology, including facilitating and implementing credit opportunities and incentive mechanisms.

Wahinya (2013) reported that a farmer who adopted the technology in Kenya declared its eventual cost effectiveness, although the initial cost of a metal silo technology fabricated by local artisans is high. The author justified this by indicating the advantage of saving money since he does not buy pesticides and increase his income as he does not also have to sell his maize at a give-away price. According to the year 2011 World Bank report, incentive structures for the immediate beneficiary and the wider community must be in place to achieve successful adoption. In addition, learning alliances should be created to ensure the interactions of a diversity of key players (effectively the actors of the value chain), and socio-cultural issues should be carefully considered, especially those related to gender and diversity. This combines to highlight the need to evaluate all interventions from a technical, economic and social perspective if they are to be successfully adopted.

Farmers raised issues of guarantying material and manufacturing quality of metal silos of future distributions. This calls for a mechanism in place to control the standard of the metal silos. On the other hand, farmers in the *Amhara* region required modification of the metal silo such that it could be used to store two or more crop types in layers, because they commonly practice this method in their traditional storage system. Hence the need for design modification in the *Amhara* Region also deserves research attention.

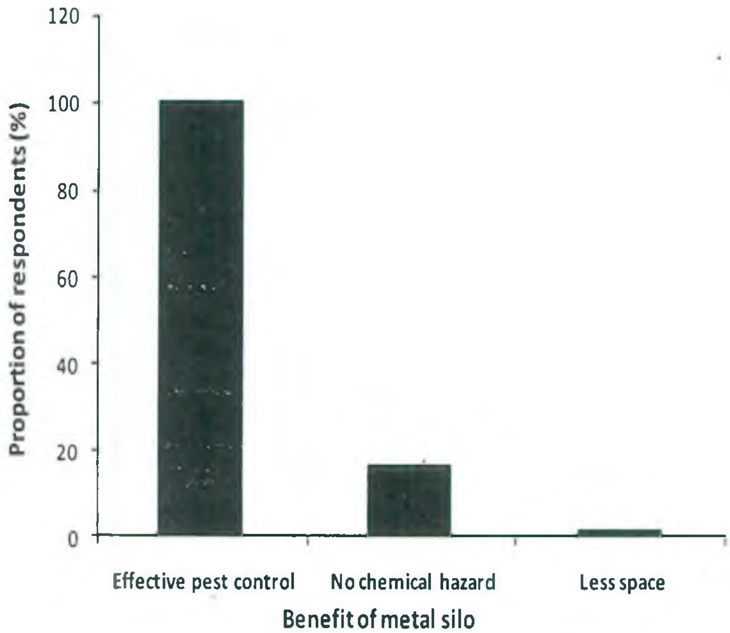

Figure 5. Farmers' opinion on the purpose of metal silo

Conclusion

Physical analysis of maize grains stored for six months indicated that no live insects were found in samples obtained from the metal silos while live weevils (*Sitophilus* spp.) and Angomois grain moth (*Sitotroga cerealella*) were detected in the control treatment. The maize grain stored in the metal silo suffered low damage and weight loss, which can be attributed to the minimum infestation at the start of the treatment. On the contrary maize grain stored in the control polypropylene bag suffered much damage and weight loss. Thus the results proved that metal silos provided effective protection. It was also found that maize grain stored in metal silo had good germination capacity while that stored in the control suffered much viability loss.

Farmers realized the importance of storage insect pests and rodents that cause serious damage and result in sever losses. Based on their evaluation of the maize grain stored in metal silos in comparison with that stored in polyethylene bags (control) after three and six months of storage, they witnessed that metal silos provided effective protection against storage pests. Other merits of the metal silo technology perceived by the farmers include avoidance of associated hazards from chemical use, storage cost savings and increase in income. As a result farmers showed interest in using the metal silo technology, posing concerns on its affordability, quality control of the product and possibility of design modification. It can therefore be concluded that metal silo technology help farmers safely store their produce and is worth demonstrating and disseminating.

Although considerable efforts have been made to increase crop productivity and production that resulted in increased production over the years, the postharvest sector has not been given the attention it deserves. As a result, the agricultural system continued to suffer huge postharvest loss. Therefore, strengthening the postharvest sector with a sound policy framework support is of prime importance. Moreover, establishment of an institution responsible to coordinate all activities in the promotion of the postharvest sector is critical. The first move into scaling out of the technology should focus on selected pilot farmers who would take responsibility of extending /disseminating/ the technology to fellow farmers. Rigorous training should be provided on the advantages, proper use and handling of a metal silo.

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