

Assessment of Crop Storage Structures in Swaziland

By

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ABSTRACT

A survey was carried out to identify the types of crops popularly stored, the structures commonly used and problems experienced with produce storage in the Kingdom of Swaziland. Respondents included operators of government storage facilities, non-governmental organizations providing food relief, millers, large-scale farms, homesteads and artisans who fabricate metal tanks.

Maize, the national staple food, was stored by all homesteads essentially for family consumption. It was the commercial staple crop, the major raw material for the millers and the produce commonly distributed as food aid by the non-governmental organizations. Significant quantities of groundnut, beans, sweetpotatoes, jugobeans and cowpeas were also stored.

The crop storage structures found in use were metal silos, bags, platforms, cribs, metal tanks, concrete tanks, warehouses/rooms/old houses, metal/plastic drums, earthen/metal pots, plastic/metal buckets, bottles and tins. Metal silos and warehouses were the predominant structures used for large scale storage. The most common storage structure for maize by small-scale farmers was the metal tank as reported by 78.8% of respondents followed by cribs for both drying and storage (76.3%) and bags for the storage of maize, beans and groundnuts (65.7%)

Moisture penetration and condensation, moulding, caking, insect infestation and rusting were some of the problems experienced with metal silos and tanks. In addition to these, the cracking of the solder used at the joints was a common problem with metal tanks. Bags often got torn by rodents that infested the produce. The absence of rodent guards in platforms and cribs encouraged rodent attack on produce stored in these structures. The use of inadequate -sized members and overloading often resulted in buckling and collapse of cribs and platforms. Losses of produce through these sources are a major problem.

Remedial measures adopted towards solving these problems included the use of weevil and other types of tablets for produce storage, replacement of rusted and broken parts. The use of rodent glue and cats were also employed as control measures.

About 48.2%, 35.7%, 70.3% and 81.2% of the respondents expressed satisfaction with the use of bags, platforms, cribs and metal tanks respectively. These groups and those who rated them as

unsatisfactory requested for intervention by way of arresting the problems identified with existing storage structures and provision of new ones.

The use of rat guards on cribs and platforms should be emphasized; riveted joints on metal tanks should be appropriately spaced to provide structural stability and the amount of solder to minimise or eliminate cracking used.

Keywords: Crop storage structures, food relief, food security, metal tank, postharvest losses, subsistence agriculture, Swaziland

1. INTRODUCTION

Swaziland is located between latitudes $30^{\circ} 30'E$ and $32^{\circ} 30'E$ of the Greenwich and between longitudes $25^{\circ} 30'S$ and $27^{\circ} 30' S$ of the Equator. The country is bounded in the north, west, south and south - east by the Republic of South Africa and to the north - east by the Republic of Mozambique. (Figure 1). The country covers a total area of $17,363\text{km}^2$, out of which $17,203\text{m}^2$ is land and the remaining 160km^2 is water.



Figure 1. Location map of Swaziland

The vegetation of the country varies from short grassland with forest patches in the Highveld region of the north to savannah in the Lumbobo region of the south. Annual rainfall varies from 500mm in the lowveld to a maximum of 2300mm in the highveld. Temperatures are between 11°C and 29°C . (Anon, 2005)

About 70 % of the populace are engaged in subsistence agriculture producing both crops and animals while agriculture accounts for about 17% of the country's gross domestic products (GDP) (Wikipedia 2005). The major staple crops are maize, groundnut, beans, sweetpotatoes, jugobeans and cowpeas.

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Although a large percentage of the country is engaged in agriculture, Swaziland remains a food deficit country, a situation which has been aggravated in recent times by severe droughts. Food self-sufficiency in the kingdom declined from 96% in 1997 to 47% in 2002, resulting in ever increasing importation. (NMC, 2004)

The increasing need for crop storage cannot be overemphasized. Besides ensuring family food supplies at later dates, farm produce where possible is becoming an increasing source of income for the peasant farmers and produce merchants. The needs to ensure continuous production by agro-industries and price stabilization in order to ensure political stability have increased industrial and government participation in produce storage (FAO, 1994)

Majunder (2005) observed that although many tropical and sub-tropical regions have great potentials for food production because of the enabling climatic conditions, they have not been able to achieve food self-sufficiency because pests, diseases and other agents compete with humans in their struggle to ensure that adequate food is available to meet the population requirements. Efficient storage of food plays a vital role in the attainment of food security.

Efficient storage of produce depends on a number of factors one of which is the availability of the structures to hold the produce. There are a number of these and the choice depends on the type of produce, volume of storage, and technical and economic situations of the individual involved in the storage. (FAO, 1994, World Resources, 1998; Mijinyawa, 2002, Dlamini, 2003)

FAO (1994) reported that although efforts in the last two decades have resulted in the development of a number of storage systems suited to many local conditions, and also minimised post-harvest losses, the search for improved storage systems and structures should be a dynamic process. There is a continuous increase in storage volume because the output from the intensified efforts in food production in the rural areas must be conveyed to the urban centres, increasing livestock population would require more grains for feed which must be stored and the liberalization of grain marketing in countries such as Swaziland will encourage the emergence of produce merchants who must have places to store their produce. Some new varieties have been found not to be as amenable to the storage systems and structures of the existing varieties and it is necessary to provide appropriate storage structures for such harvests.

FAO (1994) reported that there has been a tendency to overestimate storage losses, and to base estimates on extreme cases or guess-work rather than on sound empirical testing. Figures of 30% or more are not uncommon for grains, 50% for roots and tubers and a complete loss in the case of perishable crops such as fruits and vegetables. Even if these figures are exaggerated, FAO (1994) suggests that food losses even if they are as low as 5%, should not be ignored. This is because such physical losses are usually accompanied by qualitative losses which affect the whole mass of the grain in store. Secondly, the losses are mainly experienced during the lean season before the new harvest is ready, thereby having an adverse effect on the food security of farming families at a particularly critical period.

Crop storage in Swaziland has received attention both in terms of research, extension and provision of physical structures. Ossom *et al.* (2004) recommended the use of bagged sawdust and pit for sweet potatoe storage in Swaziland. Attempts have also been made to popularize the use of ferrocement tanks for the storage of grains among Swazi farmers. (National Academy of Science, 1973; MOAC, Undated). Under the 1980 FAO programme on prevention of food losses, metal silos of 5 and 10 tonnes capacities were erected in various parts of the country while a number of equipment to assist in the monitoring of produce quality were also provided. (De Lima, 1982a and 1982b). The National Maize Corporation (NMC), the government maize marketing organ maintains a 2000 tonne silo complex at Mastapha and a 70 tonne capacity in each of the four regions of the country (NMC, 2004). The crop storage section located at Malkerns is an arm of the ministry of agriculture and cooperatives with the primary mandate to create awareness amongst farmers on the magnitude of post-harvest losses and develop programmes, strategies and techniques to curtail these losses. (Crop Storage Section, 1996)

The question has repeatedly been asked whether the issue of storage should be given attention in Swaziland when there is even not enough to eat. In the past, storage was perceived by many to be synonymous with keeping the excess after meeting the present need but at present the objective has changed and means keeping to ensure that it will be available all year round no matter the quantity. Storage is therefore very important in all circumstances whether there are surpluses or deficits. The food aid brought into Swaziland is distributed throughout the country and while awaiting distribution in the various locations, it must be well stored so that no part of the scarce commodity is lost to pilferage or other agents of spoilage. This underscores the special need for storage in Swaziland. An effective storage system is required to achieve this goal. Storage structures form the bedrock of any storage system and hence the need for this study.

The primary objectives of the survey reported in this paper were therefore to identify the various crop storage structures in use in Swaziland; identify the problems experienced with their use and make recommendations aimed at improving their efficiencies.

2. MATERIALS AND METHODS

The study was descriptive and primarily used data collected from small-scale farmers/households, large-scale farms, millers, NGOs and government storage facilities.

Three instruments, a questionnaire, interview schedule and observation form were used in the collection of primary data. These were prepared taking into account relevant social, demographic, economic and technical factors.

The instruments were validated for face and contents by specialists in this area. They were further pre-tested at the Ngwempisi RDA by interviewing farmers who did not form part of the final respondents. The pre-testing was very useful as it enabled the researchers to revise the instruments.

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Since the main thrust of the research was storage structures, it was considered necessary that whoever was to be interviewed must own and use crop storage structures. The respondents were grouped into operators of government storage facilities, large and small-scale millers, large-scale farms, non-governmental organizations involved in food relief and the small-scale farmers/households. All the five government storage centres were selected for the survey. Also selected for the administration of questionnaires were 11 non-governmental organizations providing food relief, 11 large-scale farms/farmers, ten small-scale millers and ten large-scale millers. Sixty small-scale farmers/households who were known to have storage structures were interviewed in each of the four regions of the country through the assistance of the extension staff of the Ministry of Agriculture and Co-operatives in the rural development areas (RDAs) and four agriculture graduates who were recruited as research assistants. A total of 240 homesteads were interviewed nationwide.

Arising from the observations made on maize tanks during the field work, the study was extended to include visits to artisans who fabricate the metal tanks. These were spread all over the country and many of them were visited.

The data were analyzed quantitatively and qualitatively using the Statistical Package for the Social Sciences (SPSS) version 10.0 to derive statistics of frequencies and percentages. The results were presented in tables and charts.

3. RESULTS AND DISCUSSION

3.1 Crops Stored

Crops storage in the kingdom is done at two levels. Large-scale storage is done by the government, millers and non-governmental organizations providing food relief for the purposes of price stabilization, industrial raw material and as food aid respectively. Small-scale storage is done at the household level mainly to meet family food requirements and feeding livestock, and only in a few cases were there surpluses for sale. Maize was found in almost all the storage locations and was the only crop stored in large quantities. Besides maize, significant quantities of beans, jugobean, groundnut, cowpea and potatoes were also stored at the household level. Table 1 shows the percentages of respondents who stored the various crops and the range of quantities stored at the household level. As expected, the higher values were for maize with the maximum quantity stored reported at about 8.5 tonnes.

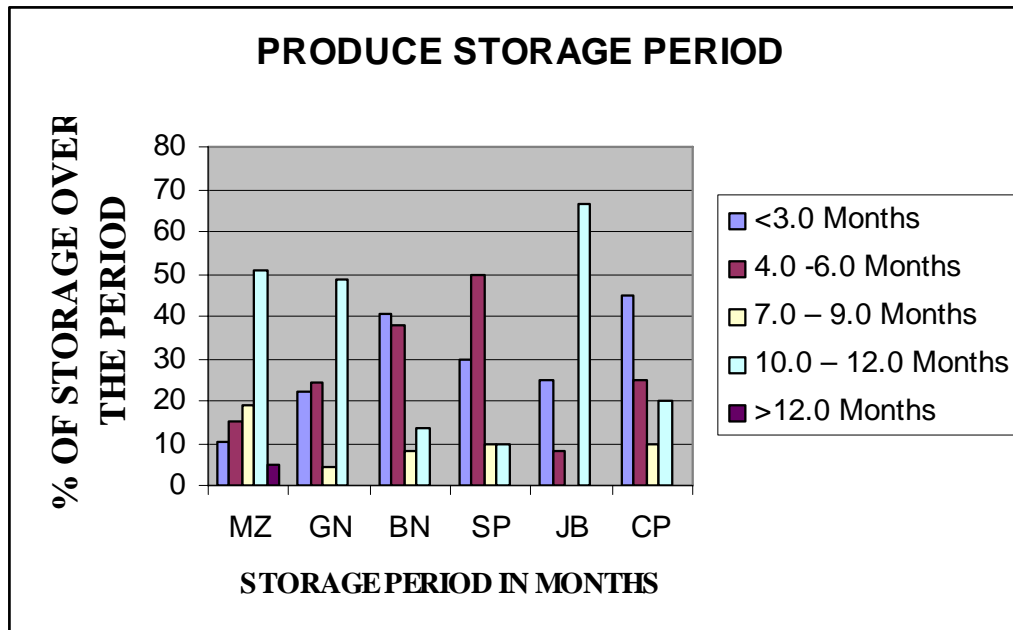
Table 1: Major crops, population storing them and quantities stored at household level

| Crop | Percentages of respondents storing them | | Quantities of produce stored in (kg) | |
|---------------|---|--------|--------------------------------------|----------|
| | Frequency | % | Min | Max |
| Maize | 240 | 100.00 | 9.00 | 8,400.00 |
| Groundnut | 45 | 18.8 | 5.00 | 1,000.00 |
| Beans | 37 | 15.4 | 1.00 | 2,100.00 |
| Sweetpotatoes | 10 | 4.2 | 20.00 | 300.00 |
| Jugobean | 12 | 5 | 30.00 | 210.00 |
| Cowpeas | 20 | 8.3 | 8.0 | 350.0 |

Produce stored by the government storage facilities was procured from small-scale farmers and supplemented with importation, some millers own farms where the raw material was sourced from while others depended on the government storage depot and small-scale farmers and for the NGOs, it was substantially importation.

The primary source of stored produce at the household level was from own harvest. About 81.7% of the respondents stored only what was harvested from their farms while in addition to the produce harvested from their farms, the remaining 18.3% also stored produce purchased from local markets and those received as food donation.

The primary determinant of storage duration was the volume of harvest on which the family depended until it is exhausted. Fig 2 shows the percentage of respondents and the periods over which they are able to store farm produce. These are periods after which the produce in the store gets exhausted irrespective of what they were being used for. From figure 2, it can be seen that only a fraction of the households were able to have produce of one harvest in store till the following harvest which is usually twelve months. This was observed in about 50.8%, 48.8%, 13.5%, 10%, 66.7% and 20% cases respectively for maize, groundnut, beans, sweet potatoes, jugobean, and cowpeas. Many households have to buy food especially maize to cover the period between when the family store is empty and the following harvest.



MZ = Maize, GN= Groundnut, BN = Beans, SP = Sweetpotatoe, JB = Jugobeans, CP = Cowpea

Figure 2. Produce storage duration

3.2 Types of Crop Storage Structures

Large-scale storage is done using silos and warehouses while the various types of crop storage structures used in households are presented in Table 2 and figures 3 to 8. These included bags, platforms, cribs, metal tanks, concrete tanks, warehouses/rooms/old houses, metal/plastic drums, earthen/metal pots, plastic/metal buckets, bottles and tins.

Metal tanks were the predominant structure used for the storage of shelled maize. They are manufactured from corrugated galvanized metal sheets with a width of 650mm, thickness of between 0.4 and 0.6mm and of varied lengths. The sheets are folded and overlapped in both the vertical and horizontal planes to form the circular tank. The joints are riveted and then soldered to stop moisture migration into the tank. Metal tanks are made by artisans scattered all over the country.

Figs. 3 and 4 show some metal and concrete tanks on small-scale farms. Tanks manufactured from concrete are less common but are also used to store shelled maize. These were only identified at two locations during the survey. One of the concrete tanks shown in fig. 4 was not being used because the owner had reduced his maize production. This was because the low price paid for maize by the National Maize Corporation had made maize production unprofitable



Fig.3. Metal tank for maize storage



Fig.4 Concrete tank



Fig. 5 Traditional crib



Fig. 6 Clay pots for crop storage



Fig.7 The use of tree branches for crop storage



Fig. 8 Location of an abandoned underground pit

The crib is traditionally used as a drying structure and it is only on a few occasions that it is used for storage. The maize cobs, after harvesting, are left in the crib to dry for between one and three months after which they are shelled and put in the tank. For this reason, most of the cribs are constructed annually and after the maize is dried and removed, the structure is destroyed. The few that are used for storage are provided with a roof and are given minor maintenance. Fig.5. At present, the Crop Storage Unit is popularizing the improved cribs among farmers. The improved crib involves the use of durable wooden members, metal and wire mesh and is also provided with a roof made from corrugated roofing sheets. Besides drying, the structure is also being popularized for use in produce storage.

Table 2. Types of crop storage structures used by households
(n = 240)

| Structure | Frequency | Percentage |
|-----------------------------|-----------|------------|
| Metal tank | 189 | 78.8 |
| Cribs | 183 | 76.3 |
| Bags | 92 | 65.7 |
| Metal/plastic drums | 28 | 11.7 |
| Platforms | 27 | 11.3 |
| Plastic/metal buckets | 19 | 7.9 |
| Warehouses/rooms/old houses | 16 | 6.7 |
| Concrete tanks | 2 | 0.8 |
| Bottles | 2 | 0.8 |
| Tins | 1 | 0.4 |

The platform differs from the annual crib in that there are no side walls. Platforms, where available, are used for drying groundnuts before shelling. These structures are also annual structures and are destroyed after the produce is removed.

Metal and plastic drums are popularly used for the storage of maize. Their popularity lies in the possibility of effective closure eliminating pest infestation and rodent attack. Earthen pots are used for the storage of produce such as beans, groundnut and jugobeans which are in most cases stored in small quantities and serve as planting materials. (Fig. 6)

Plastic buckets are used for the storage of less popular crops such as beans.

Maize cobs with some of the sheath can be knotted and suspended from tree branches (Fig.7). This is used mainly for maize intended to serve as planting material.

Silos are used mainly by the government storage centres, millers and some large-scale farms. Most of the silos identified were essentially of metal types of different sizes except in places such as Mabuda Farm in Siteki where a concrete silo was identified.

Warehouses were used for storage by millers and non-governmental organizations providing food relief. In the case of millers, besides the storage of produce; the warehouses also accommodated the milling equipment. In the warehouses, maize which is the common raw material is kept in bags which are arranged on pallets. Most of the small-scale millers are engaged in contract milling and very little storage is done. The warehouse in such situations is more for the accommodation of the milling equipment rather than produce storage.

Bags of assorted materials are popularly used for the storage and transportation of produce. Hessian bags are used for beans while poly-sacks are used for maize and mealie meal or maize meal.

In the past, underground pits were popularly constructed near the kraals and used for maize storage. Sikhondze (1987) reported that the inability of the underground pits or dug-out tanks in cattle byres to maintain the quality of the maize had made the structure less attractive and as a result attention was on the use of metal tanks. The pit has become an unpopular structure for crop storage and it was at only one location that an abandoned pit was identified during the survey (Fig.8).

3.3 Problems Experienced with Structures and Produce Stored in them.

The problems experienced with the various crop storage structures and produce stored in them are presented in Tables 3 and 4, and figs. 9 and 10. These included leakages, buckling or bending/collapse, rusting, joint failure and moisture condensation, insect infestation, moulding, caking and germination.



Fig. 9 Caked and moulded maize at the bottom of a metal tank



Fig.10 The corroded bottom of a maize tank, a common problem in many households.



Fig. 11 Failed joint in metal tank, re-soldered and painted over as shown by the white vertical and horizontal strip. Also shown are metal drum and assorted containers which are also used for storage

The most common problem with bags was leakage which occurs when the bag gets torn and was reported by about 61.5% of the respondents. Bag tearing could be as a result of rodents that gnaw through them or during handling when the bags are pressed against sharp edges. Holes in bags are points through which produce fall out of the container and are lost. Such points are also avenues for rodents that feed and defecate on the produce reducing both the quality and quantity.

Buckling, bending or total collapse was the common problem reported for platforms and cribs. Because most cribs and platforms are constructed annually, in most cases the expected produce is underestimated while constructing the structure to receive the new harvest. When the harvest begins, it might be discovered that the structure constructed is not adequate to accommodate the harvested produce but because it is a bit late to start a new construction, the farmer decides to load the structure with all the harvest. Secondly the selection of components is done with experience and not based on any design and the size of members selected in some cases may not be of adequate strength to resist the imposed loads. About 42% of the respondents reported to have experienced complete collapse of their cribs while 41% have had buckled but not completely collapsed cribs which they have had to replace some of the components. About 90.5% and 9.5% respectively experienced the same problems with platforms

Joint failure and hence the entry of moisture and rusting were the commonly reported problems for metal maize tank. (Figs. 9 and 10). Moisture penetration was reported in 33%, rusting in 25% while joint failure was reported in 21% of cases. Two factors are responsible for this observation. One is poor workmanship and the other has to do with management. As a result of

poor workmanship, the soldering is poorly done and this tends to crack with time allowing moisture penetration through the joint. This was observed during visits to artisans fabricating metal tanks. It was noted that the spacing of rivets holding together the tank vertically and along the circumference were varied between artisans. The spacing between rivets varied from 0.5 m to 1.00m vertically and 100 mm to 150 mm along the circumference. It is expected that if the rivets are far apart, the structural stability would be affected. Considering that solder does not have any strength, cracks would result. Another observation was that the solder was applied thinly and any slight structural instability would result in the appearance of cracks. Metal tanks should ideally be indoor or under a roof and raised above ground level to ensure adequate ventilation underneath. It was observed that in about 60% of cases, the metal tanks were unprotected from the inclement weather. Many of them were rested on the ground and where attempts were made to raise them, the supporting platform did not make provision for ventilation underneath. Besides the entry of moisture through cracked solder, the outdoor tanks were subjected to severe temperature fluctuations which resulted in the condensation of moisture on the walls of the tank and its migration to the core of the stored material over time. Rusting especially at the bottom is also a common problem with the maize metal tank.

Attack by rodents on stored produce was experienced in bags, platforms and cribs. This was reported by 20.7%, 59.2% and 76.0% of respondents respectively for bags, platforms and cribs. Rodents can easily gnaw through various bag materials creating little holes which expand with time as they repeat their attack especially if the bags are not regularly inspected. It was observed that no platform had any rat guards while only 24% of the cribs had rodent guards. Rodents therefore had very easy access to these structures.

While metal tanks provided adequate screen against rodent attack, insect infestation, moulding, germination and caking were experienced in 41.3%, 21.2%, 2.3% and 6.3% of cases respectively.

During the field work, efforts were made to obtain information on storage losses through a comparison between the amount of produce stored and the quantity lost irrespective of the sources. Most respondents reported that they had no idea as it was not important to them to take account of losses while for those who had such information, it was only for maize. Although there were isolated cases of where the whole contents of a maize tank had been lost, it was estimated that storage losses for maize using the maize tank as a storage structure was between 7.5 and 10%.

3.4 Remedial Measures

Towards the protection of their produce, those involved in storage attempt to find solutions to the problems experienced. Table 5 shows some of the common problems and attempts often made to solve them

3.5 Users' Perception and Necessary Intervention

The opinion of the users was sought on what they felt about the structures they use especially the four most popular ones. About 48.2%, 35.7%, 70.3% and 81.2% of the respondents expressed satisfaction with the use of bags, platforms, cribs and metal tanks respectively. The unsatisfactory perception was as a result of the inherent problems which have earlier been highlighted. Most of the respondents requested for intervention by way of arresting the problems identified with existing storage structures and provision of new ones

Table 3. Problems experienced with some of the storage structures

| Type of problem | Types of storage structures | | | | | | | |
|-----------------------|-----------------------------|------------|--------------------|------------|---------------|------------|----------------------|------------|
| | Bags (n=92) | | Platforms (n = 27) | | Cribs(n =183) | | Metal tanks(n = 189) | |
| | frequency | percentage | frequency | percentage | frequency | percentage | frequency | percentage |
| Leakages | 26 | 28.3 | | | | | 35 | 18.5 |
| Collapse | | | 19 | 70.4 | 50 | 27.3 | | |
| Buckling /bending | | | 2 | 7.4 | 43 | 23.5 | | |
| Cracking of soldering | | | | | | | 25 | 13.2 |
| Rusting | | | | | | | 26 | 13.8 |

Table 4. Problems experienced with produce stored in some of the storage structures

| Type of problem | Structure in which the produce is stored | | | | | | | |
|--------------------|--|------------|-------------------|------------|---------------|------------|----------------------|------------|
| | Bags (n=92) | | Platforms (n= 27) | | Cribs(n =183) | | Metal tanks(n = 240) | |
| | Frequency | Percentage | Frequency | Percentage | Frequency | Percentage | Frequency | Percentage |
| Attack by rodents | 19 | 20.7 | 16 | 59.2 | 139 | 76.0 | | |
| Insect infestation | 14 | 15.2 | 4 | 14.8 | 15 | 8.2 | 78 | 41.3 |
| Germination | | | 4 | 14.8 | 3 | 1.6 | 5 | 2.6 |
| Moulding | 1 | 1.1 | 2 | 7.4 | 1 | 0.5 | 44 | 21.2 |
| Caking | 1 | 1.1 | | | | | 12 | 6.3 |

Table 5. Problems and remedial measures

| Problem | Remedial measure |
|---|---|
| Joint failure in metal tanks or cracking of soldering | Solder and paint over (see fig. 11). |
| Insect infestation in various structures | Use weevil and other tablets, dry pepper and ash. |
| Moulded grains in metal tanks | Regularly inspect tank. Remove grains and clean tank for reuse, sun dry grains and use as possible |
| Leakage of metal tank | Solder points of leak, cover openings with rags |
| Rusting | Paint over rusted portion |
| Rodents attack in cribs | Use cats around the structure, use rodent glue, rattex and rat guards Clear surroundings where rodents may hide. |
| Collapse of platforms and cribs | Use treated poles and poles of bigger sizes Replace members and in some cases the entire structure is reconstructed after two or three years |
| Insect infestation in produce stored in bags | Winnow to remove powder and insect |
| Grains germinate in drums | Empty drum, remove germinated ones and feed to chicken and put the rest in the sun to dry and either used immediately or restored |
| Maize in crib get infested | Remove and take to tank |
| When caking takes place in metal tank | Open the tank to allow air circulates. |
| Leaking roof in warehouses/houses | Replace roofing sheets or increase thickness of thatching material. |

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The crop storage structures found in use were bags, platforms, cribs, metal tanks, concrete tanks, warehouses/rooms/old houses, metal/plastic drums, earthen and metal pots, plastic/metal buckets, bottles and tins. While the metal silo and warehouses were the predominant structures used for large scale storage, the metal tank, crib and platform were the predominant household produce storage structures.

Y. Mijinyawa, M. Mwinjilo and P.Dlamini. "Assessment of Crop Storage Structures in Swaziland". Agricultural Engineering International: the CIGR Ejournal, Invited Overview No. 22. Vol. VIII. October, 2006.

Moisture penetration and condensation, moulding, caking, insect infestation and rusting were some of the problems reported with metal silos and tanks. In addition to these, the cracking of the solder used at the joints was a common problem with metal tanks. Bags often got torn by rodents that infest the produce. The absence of rodent guards in platforms and cribs encouraged rodent attack on produce stored in these structures. The use of inadequate sized members and overloading often resulted in buckling and collapse of cribs and platforms. Remedial measures adopted towards solving these problems included the use of weevil and fumigant tablets for produce storage, replacement of rusted and broken parts. The use of rodent glue and cats were also employed as control measures.

The majority of the respondents expressed satisfaction with the use of bags, platforms, cribs and metal tanks.

Only about half of the respondents stored maize, the country's staple, for 10 to 12 months indicating very low household food security. Food aid and purchases meet the shortfall.

4.2 Recommendations

1. The use of rat guards in cribs and platforms should be vigorously promoted to minimise post harvest losses.
2. Metal tanks and other storage structures should be cleaned thoroughly and disinfected immediately they are empty and just before storing produce.
3. To minimise joint failure in metal tanks, the recommended rivet spacing should be adhered to while the amount of solder used should be that which would minimise or eliminate cracking.

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Y. Mijinyawa, M. Mwinjilo and P.Dlamini. "Assessment of Crop Storage Structures in Swaziland". Agricultural Engineering International: the CIGR Ejournal, Invited Overview No. 22. Vol. VIII. October, 2006.

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