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Assessment of grain storage structures, pests and their management practices in Lesotho

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A survey was conducted among 218 farmers in 8 of the 10 districts of Lesotho. Data collection was conducted using a structured questionnaire uploaded on KOBO data collection software and it was also used for data analysis of descriptive statistics. Microsoft Excel was used to construct tables and chats while Statistical Package for Social Sciences (SPSS) was used to determine the relationship between selected dependent variables. The results showed that majority of farmers used their own living houses to store their grains (64.2%) and many farmers used non-hermetic bagging (78.6%) for packaging. Rodents (84.4%) and weevils (71.9%) were found to be major storage pests of grains in storage. For management of rodents, farmers mainly used cats (56%), while for weevils they used chemical fumigant, phostoxin (48%), cultural methods (37%), and indigenous methods (14%). There was no significant relationship between the educational background of farmers and their choice of the control of weevils and rodents at p=0.336 and p=0.996, respectively. There is a need to investigate proper storage methods and pest control methods that smallholder farmers can use to address postharvest losses.

Key words: Storage structures, weevils, rodents, postharvest losses.

INTRODUCTION

Maize, sorghum, wheat and beans are the key agricultural commodities produced in Lesotho. They occupy more than 65% of the arable land across all the agroecological zones which are the Lowlands, Foothills, Mountains and Senqu River Valley (Lesotho Bureau of Statistics, 2019). Maize is the number one staple food and the major source of energy in Lesotho. Common bean is a significant leguminous crop eaten as dry beans and immature pods. It acts as a vital source of protein to resource poor families that cannot afford meat and other livestock protein. Maize production is continually declining in Lesotho. For instance, in 2017/2018 agricultural year, there was a yield decline of 36.3% from the previous year. It further decreased by 77.3%. Production trends analyzed from 1961 to 2013 (54-year time period) reveal that maize production had declined by 12.5% but the

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yield remains constantly low at around 800 kg/ha (Morojele and Sekoli, 2016). On the other hand, production trends for beans for a period of 58 years (1961 - 2016) showed that bean production has increased by 44%, but the yield/ha had decreased by 2% (Morojele and Lelima, 2020). Low yields may be attributed to a number of factors. These include increased costs of production inputs and operations which impoverished farmers cannot afford, poor agricultural practices, reduced soil fertility and eroded soils, and climate change characterized by prolonged period of drought or continuous rains.

There is very little information on the storage systems farmers use, prevalence and type of pest farmers encounter and how they control them in Lesotho. Therefore, the purpose of this study was to (1) evaluate the type of grain storage methods used by farmers and (2) to assess the degree of damage by insects and rodents in farmers' stored grains and document the control methods used by the farmers.

Production of cereals is not only reduced by pre-harvest practices but it is also affected by postharvest losses. In Africa, postharvest losses were estimated to be in the range of 20 to 40%, which is extremely high considering the low production in most African countries (Abass et al., 2014). Post harvest losses occur at all stages of crop handling which include transportation from the field, storage, processing, packaging, and marketing (Befikadu, 2014). Storage losses are due to biotic factors which include insect pest, pathogens, and rodents and the abiotic factors like humidity, temperature, and rain (Abedin et al., 2012). A study conducted by Bhandari et al. (2015) showed that 61% of the respondents considered storage pest as the major pests while about 12% reported field pests as the main pests in the western hills of Nepal in Asia. The major pests of stored grains in most of the countries worldwide include weevils *Sitophilus* species (Tadesse and Ali, 2021) and bruchid, bean weevil (*Acanthoscelides obtectus*), which is the most devastating pest of stored beans across the globe (Ishimoto and Chrispeels, 1996).

Rodents (rats and mice) are also considered as destructive storage pest, causing huge amounts of losses and contamination of grains. Damage to stored grains can further be exacerbated by development of moulds and bacteria as a result of rodent and weevil feeding and excretions (Brown et al., 2013). These losses in quantity and quality affect human and livestock nutrition, food security and income of the smallholder farmers (Tadesse and Ali, 2021). The key factor behind the infestation of stored grain pests is the availability of favorable climates for their development and survival (Ahmad et al., 2021). Poor storage structures predispose grains to outbreaks by weevil and rodent pests, which cause a significant amount of losses in grain quality and quantity.

The use of scientific storage methods can reduce insects' pests and rodent losses to as low as 1 to 2% (Kumar and Kalita, 2017). The metal silo technology has demonstrated to be effective in preventing attack in the harvested grains not only from the rodents but also from insects pests (CIMMYT, 2009). Kumar and Kalita (2017) also indicated that the use of hermetic storage can be used as a storage method for cereals. The method generates an automatic altered atmosphere of increased carbon dioxide concentration using sealed watertight bags or structures.

METHODOLOGY

Description of the study area

Lesotho is situated in Southern Africa between 28° and 31° south of the equator and 27° and 30° east of the Greenwich meridian, and it is located at the highest part of the Drakensburg escarpment with altitude ranging from 1500 to 3482 m above the sea level. The study was conducted in the eight districts of Lesotho; Mafeteng, MohalesHoek and Quthing which are in the southern lowlands, Berea, Leribe and Botha Bothe found in the northern region, Maseru in the central and Mokhotlong in the mountains. Mafeteng district, has the lowlands and foothills, consists of largely marginal lands with poor soil fertility, and high rates of soil erosion. Mohale'sHoek and Quthing districts are in the southern lowlands, with minimal arable land and little vegetation cover. The Northern districts, Berea and Leribe have relatively good fertile soils and better yields than other districts in the country. Botha Bothe and Maseru have the lowlands, foothills and mountains and they have medium yields. Maize, sorghum, wheat and beans are major crops grown in the lowlands and the foothills. Mokhotlong as a mountain district is dominated by rangelands and the main crop produced is wheat. However, there are some places where maize is grown.

Data collection and analysis

The study was conducted in July 2022. Data collection was done using a structured questionnaire, administered by graduate students from the National University of Lesotho. KOBO data collection software was used and the numerators were trained on the use of the software and the questionnaire. A total of 218 farmers, twenty eight from each district and twenty two from Mokhotlong were interviewed. Mokhotlong had low number of respondents because of low maize and bean production in the district. Sesotho which is the local language, was used to interview the respondents and the enumerators were trained on how to ask the questions in the local language to avoid variation. The questionnaire was designed to collect data on farmers' socio-economic information, type of storage used, duration of storage of grains, monitoring of storage pests, farmers' perceptions of problems associated with stored grain insects pests and rodents, the degree of damage by these pests, management practices including indigenous ones, and safety measures taken in administering phostoxin (Aluminium phosphide).

Sampling

A purposive stratified sampling method was used to obtain a representative sample, whereby villages were chosen from each of eight districts. The villages were chosen based on the list provided by the area extension offices. Villages with known history of maize and bean production were selected. Farmers were then randomly selected in the villages and interviewed at their farms.

Table 1. Socio-economic characteristics of farmers.

Profile of farmers	Characteristics	Frequency	Percentage
Gender	Female	110	50.1
	Male	108	49.5
Age range	21-30	12	5.5
	31-40	20	9.2
	41-50	41	18.8
	51-60	65	29.8
	61-70	51	23.4
	71-80	18	8.3
	81+	11	5.0
Educational background	Primary school	120	55.1
	Secondary school	61	28.0
	High school	17	7.8
	Tertiary	13	6.0
	Informal education	6	2.8
	Did not go to school	1	0.5
Types of main grains grown	Maize	203	93.1
	Beans	156	71.6
	Sorghum	124	56.9
	Wheat	56	25.7
Size of the land	<1 acres	4	1.8
	1-3 acres	43	19.7
	4-6 acres	65	29.8
	7-9 acres	50	22.9
	≥10 acres	54	24.8

Data analysis

Frequencies and percentages of variable occurrences were calculated using KOBO software and they were presented in tables and charts. Some farmers gave multiple responses to the same questions, so percentages may not add up to 100. Chi-square test using SPSS Statistics was used to determine the relationship between selected dependent variables (rodents and weevil control methods) and sociological parameters of respondents (educational background).

RESULTS

Table 1 shows the socio-economic characteristics of farmers. Number of males and females respondents surveyed was almost similar about 50%. Majority of the interviewed farmers were at the age range of 51-60 at 29.8%. 55% of the farmers had a basic primary educational level, followed by farmers with secondary educational level of 28%, very few farmers had a tertiary education at 6%. The four major grains produced by farmers include maize, beans, sorghum and wheat, with maize being the most produced grain by farmers at 93.1% and wheat being the least produced grain at 25.7%. The size of the land owned by farmers for cereal production ranged from less than 1 acre to more than 10 acres. The area of land that was mostly owned by farmers ranged between 4 and 6 acres at 29.8% with few farmers that owned a relatively small area of land <1 acres at 1.8%.

The storage practices and structures used by farmers are shown in Table 2. Majority of farmers (92.6%) indicated that they store the grains after threshing and very few farmers (1.3%) store their grains with cobs still attached to their stalk. A huge number of respondents used non-hermetic bags as means of storage, followed by the farmers that used silos at 78.6 and 12.4%, respectively. Most of the farmers (64.3%) did not own storage structures, rather they used some of their rooms or houses for storing of grains, only about 29.6% of the farmers had their own storage for grains. In terms of duration of grain storage, majority (59.2%) of the farmers indicated that their produce can only sustain them for a

Table 2. Storage structures and storage practices used by farmers.

Storage practices	Farmers response	Frequency	Percentage
Ways of storing grains	Store after threshing	213	92.6
	Store in cobs	14	6.1
	Store with cobs still attached to stalks	3	1.3
Material used for storing grains	Silo	26	12.4
	Non-hermetic bagging	165	78.6
	Hermetic bagging	19	9.0
Common structure used as storage facilities for grains	Own living house	137	64.3
	Own storage	63	29.6
	Outside (grain bags put under shade structure or covered with tarpaulin)	12	5.6
	Community storage structure	1	0.5
Duration of storing grains	6 - 12 months	129	59.2
	3 - 6 months	43	19.7
	1 - 3 months	22	10.1
	1 - 2 years	21	9.6
	>2 years	3	1.4
Monitoring of pest and rodent occurrence in storage	Yes	199	91.7
	No	18	8.3

period of 6 to 12 months. A very small percentage of farmers stored their grains for a period between 1 and 2 years (9.6%) and 2 years (1.4%).

Grain storage insect pests

A huge percentage of farmers (91%) monitor their storage for pest infestation, this occurs mostly while cleaning their houses and only a few proportions (9%) do not carry out the inspection (Table 2). Majority of farmers (82%) performed weekly pest inspection with only few farmers (4%) that reported that they performed monitoring fortnightly. Farmers in the surveyed districts considered rodents (84.4%) and weevils (71.9%) to be the major pests affecting grains in storage. A small percentage of farmers did not consider rodents (15.6%) and weevils (28.1%) as a problem in their farms.

Degree of damage by rodents and weevils

Farmers were asked to rank the degree of damage caused by the rodents and the weevils on their grains in storage as shown in Figure 1. The degree of damage caused by the rodents was very high at 43% while that caused by weevils was 39%. A lower percentage of farmers encountered moderate damage by weevils (18%) and rodents (13%). Some farmers did not experience huge losses due to the rodents and weevils at 9 and 2%, respectively.

Table 3 shows the control measures used by farmers on rodents and weevils. Majority of farmers used biological control methods in the form of cats at 56% to control rodents followed by use of rodenticides at 35%. Very few farmers used traps for rodents at 9% as a means of control. Phostoxin tablets were the most dominantly used control method for weevil at 48% followed by exposing the infested grains to sunlight at 21%. Other farmers used indigenous methods (14%) to control the weevil while very few did not employ any control measures (1%).

The cross-tabulation between educational backgrounds and weevil management methods is shown in Table 4. All the farmers with informal education used chemicals (100%) to control the weevils. A greater proportion of tertiary education level incorporated cultural and indigenous knowledge to manage weevils with the lowest being percentage of primary school level (1.3%) that used similar methods. In the integrated management of weevils, where cultural, indigenous and chemicals were used, both high school educated and primary levels were slightly similar. Majority of primary educated farmers used indigenous methods (55.6%). Table 5 shows the Chi-square tests for the cross-tabulation of the educational background and weevil control. There was no significant relationship between the educational background of farmers and their choice of the control of weevils with the

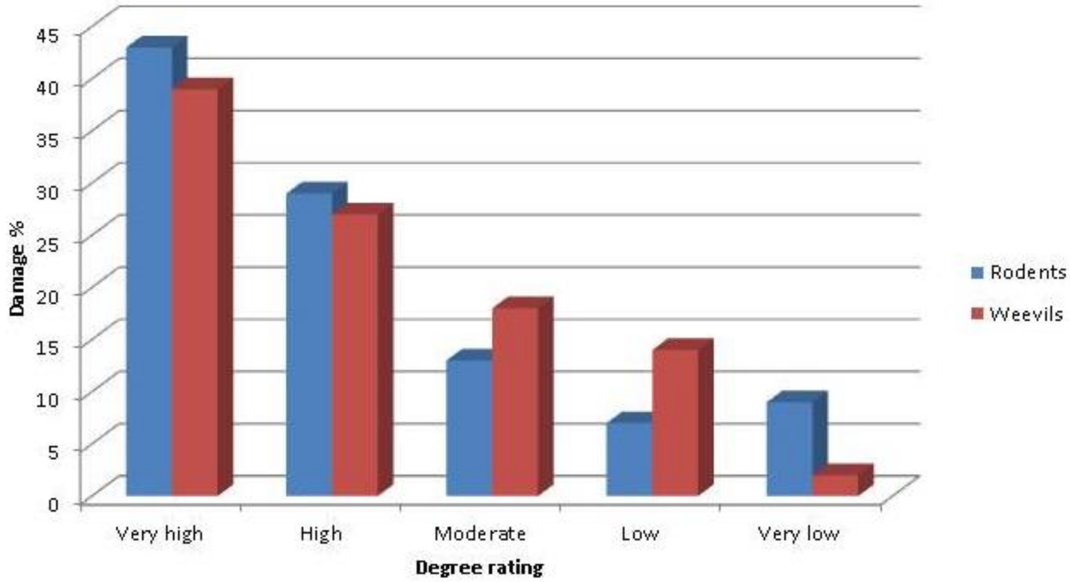

Figure 1. Farmer’s perception on degree of damage by rodents and weevils rating.

Table 3. Control methods used for rodents and weevils.

Pests	Control methods	Frequency	Percentage
Rodents	Use of cats	125	56
	Rodenticides	76	35
	Traps	19	9
	Phostoxin tablets	107	48
Weevils	Expose infested grains to sunlight	47	21
	Clean the storage	36	16
	Use indigenous methods	27	14
	No measures	3	1

p value of 0.336.

Educational background and rodents control cross-tabulation is shown in Table 6. Informal educated farmers used cats and rodenticides to control the rodents with a greater percentage using cats (83.3%) than rodenticides (16.7%). Integration of cats and traps was only used by primary and secondary level with 1.1 and 2.1%, respectively. A greater percentage of tertiary level attendees used the rodenticides (40%) while the lowest was the high school and the informal educated farmers with both at 16.7%.

The Pearson Chi-square test is shown in Table 7, and it indicates that there was no significant relationship between the educational background of farmers and their choice of control of rodents with the p value of 0.996.

Farmers were also interviewed on how they administered phostoxin to control weevils. Most farmers (69.5%) placed the phostoxin tablets in an enclosed grain storage bags followed by the farmers that put them between the storage bags at 15.2%. Very few farmers (1.9%) reported that they cover the tablet with a cloth before placing it in the storage bags.

During application of phostoxin, majority of farmers (66%) used protective clothing. However, farmers mainly used masks (49%) as shown in figure 2, which were mostly surgical masks obtained during covid 19 pandemic. They also used gloves (48%) and those that could not get proper gloves (2%) used plastic bags to cover their hands. A very small percentage (1%) used safety googles during administration of the tablets (Figure 3).

Indigenous methods of controlling weevils in storage structures are reflected in Table 8. Majority of farmers used shoats droppings cakes and hot chilli pepper at 27

Table 4. Educational background × weevil control cross-tabulation.

Parameter			Weevil control							Total
			Chemical methods	Cultural and chemical methods	Cultural and indigenous methods	Cultural methods	Cultural, indigenous and chemical methods	Indigenous and chemical methods	Indigenous methods	
Educational Background	Informal education	Count	1	0	0	0	0	0	0	1
		% within Educational Background	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
	Primary school	Count	37	16	1	7	5	4	5	75
		% within Educational Background	49.3	21.3	1.3	9.3	6.7	5.3	6.7	54.7
	Secondary school	Count	20	9	2	4	1	3	1	40
		% within Educational Background	50.0	22.5	5.0	10.0	2.5	7.5	2.5	29.2
	High school	Count	5	2	1	2	1	1	1	13
		% within Educational Background	38.5	15.4	7.7	15.4	7.7	7.7	7.7	9.5
	Tertiary	Count	5	0	2	0	0	0	1	8
		% within Educational Background	62.5	0.0	25.0	0.0	0.0	0.0	12.5	5.8
Total		Count	68	27	6	13	7	8	9	137
		% within Educational Background	49.3	19.6	4.3	9.4	5.1	5.8	6.5	100.0

Table 5. Chi-square tests.

Test	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-square	32.697[a]	30	0.336
Likelihood ratio	23.940	30	0.775
No. of valid cases	138	-	-

a. 36 cells (85.7%) have expected count less than 5. The minimum expected count is 0.04.

and 19%, respectively. Very few farmers used sagewood at 3%.

DISCUSSION

The storage structures and management practices used by the respondents is reflected in Table 1. Majority of the farmers used their own homes (64.3%) to store their grains. These results are similar to those obtained in Kenya, by Njoroge et al. (2019), who also found that most farmers (55.6) stored their grains in rooms in their house. Addo et al. (2002) also noted that in West Africa, farmer used different ways and storage structures. This included storing in homes, on the field, in the open, jute or polypropylene bags, conical structures, raised platforms, clay structures and baskets.

A greater percentage of respondents used non-hermetic bagging (78.6%) than hermetic bags (9.0%). According to De Groote et al. (2013) storage of grains in hermetic bags, minimize post harvest losses from fungal and insect's pest

Table 6. Educational background × rodents control cross-tabulation

Parameter			Rodents control							Total
			Cats	Cats and rodenticides	Cats and traps	Rodenticides	Traps	Traps and rodenticides	Traps, cats and rodenticides	
Educational Background	Informal education	Count	5	0	0	1	0	0	0	6
		% within Educational Background	83.3	0.0	0.0	16.7	0.0	0.0	0.0	3.6
	Primary school	Count	49	17	1	18	1	3	4	93
		% within Educational Background	52.7	18.3	1.1	19.4	1.1	3.2	4.3	55.4
	Secondary school	Count	23	5	1	12	1	2	3	47
		% within Educational Background	48.9	10.6	2.1	25.5	2.1	4.3	6.4	28.0
	High school	Count	6	2	0	2	1	0	1	12
		% within Educational Background	50.0	16.7	0.0	16.7	8.3	0.0	8.3	7.1
	Tertiary	Count	5	1	0	4	0	0	0	10
		% within Educational Background	50.0	10.0	0.0	40.0	0.0	0.0	0.0	6.0
Total		Count	89	25	2	37	3	5	8	168
		% within Educational Background	52.7	14.8	1.2	21.9	1.8	3.0	4.7	100.0

Table 7. Chi-square tests.

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-square	13.475[a]	30	0.996
Likelihood ratio	14.997	30	0.990
No. of valid cases	169	-	-

a. 34 cells (81.0%) have expected count less than 5. The minimum expected count is 0.01.

infestation and the technology has become a priority in Africa. The advantage of using this system was outlined by Villers et al. (2008), where he indicated that super grain bags, which is a hermetic technology, consist of a single or double high density polyethylene plastic liner with low oxygen permeability and housed inside a polypropylene bag to provide extra protection to the liner against damage. According to the study by Likhayo et al. (2018) moist grains (18% moisture content) recorded the lowest population density of *Prostephanus truncatus* (7 adults/kg grain) in hermetic bags while polypropylene bags had the highest (1273 adults/kg grain). However, this technology is not well known and adapted in

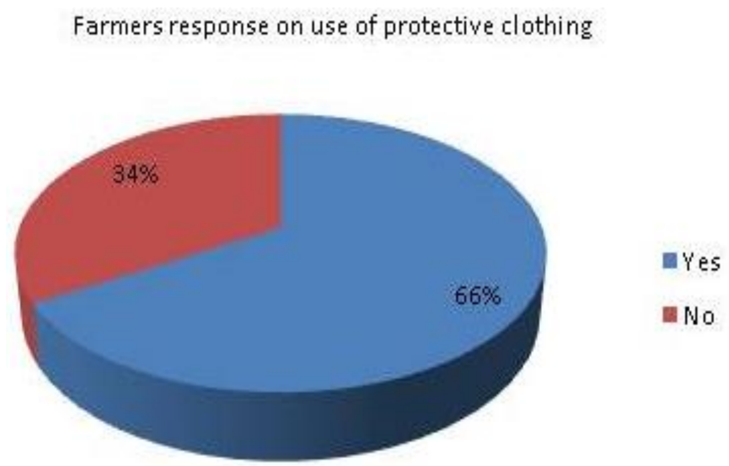

Figure 2. Farmer's responses on use of protective clothing.

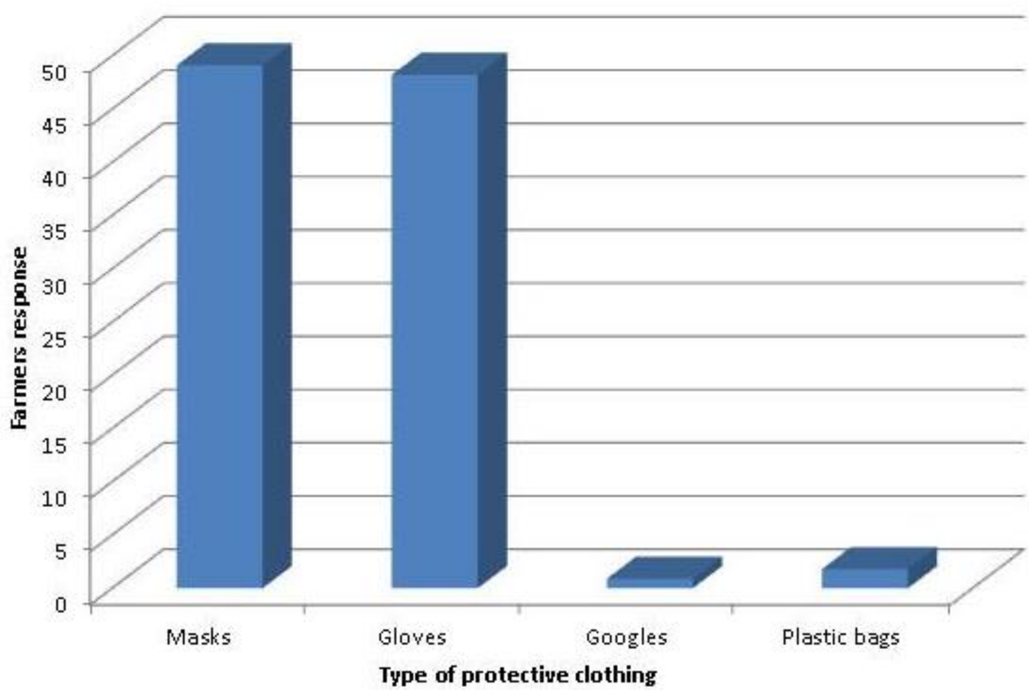

Figure 3. Type of protective clothing used by farmers.

Lesotho as only few farmers (9.0%) used hermetic bagging. The average time that many of the farmers interviewed stored their shelled grain was six to twelve months at 59.2%. These results are in line with those obtained by Chigoverah and Mvumi (2016) who also showed that farmers in Southern Africa store grain meant for household consumption for at least eight months.

Approaches such as preventive measures, monitoring, sanitation, and identification of pests help to reduce grain losses in storage (Ahmad et al., 2021). A huge percentage (91%) of farmers performed insect pest monitoring in their storage. Majority of them (82%) performed weekly pest inspection with only a few farmers (4%) that said they performed pest inspection fortnightly.

The current study found rodents and weevils to be major insect's pest problems in grain storage structures. A greater percentage of farmers encountered rodents more than did the weevils at 84.4 and 71.9%, respectively. Only a small portion of the interviewed farmers did not have rodents (15.6%) and weevils (28.1%) in their storage. In the study conducted in Tanzania, by Abass et al. (2014), grain weevil (*Sitophilus*

Table 8. Indigenous methods used by farmers to control weevil in storage.

Common name	Vernacular name	Botanical name	Frequency	Percentage
Shoats droppings cakes*	Lisu	-	59	27
Hot/chili pepper	Chilisi	*Capsicum annuum*	41	19
Hardy aloe	Mohalakane	*Aloiampelos striatula*	28	13
Wild garlic	Konofolo	*Allium ursinum*	24	11
Khaki bush	Lechuchutha	*Tagetes minuta*	17	8
Dogwood	Mofifi	*Rhamnus prinoides*	17	8
Tobacco	Koaeea Sesotho	*Nicotiana tabacum*	15	7
Gum tree	Boleikomo	*Eucalyptus* spp.	9	4
Sagewood	Lelothoane	*Buddlejas alviifolia*	7	3

*Shoats droppings cakes refer to cubes formed trembling of sheep and goats droppings that are kept under one kraal.

granarius) was among the major pests identified in the storage areas of most farmers in Tanzania. Chapman et al. (2016) also indicated that insect species that were found from stored grain samples were the coleopteran species sawtoothed grain beetle, flat grain beetle, and minute mould beetles.

Control measures used by farmers for both the rodents and weevils are shown in Table 3. A greater percentage of farmers (56%) used biological control agent such as cats to control rodents while very few farmers used rodenticides (35%). Tomass et al. (2020) found that farmers in Southern Ethiopia were mostly using rodenticides (76%) and only a few farmers (6%) used cats. However, a similar study conducted by Legese and Bekele (2023) in Central Ethiopia showed that farmers mainly use cats (53.7%) for rodent control. For control of weevils, farmers mainly used Phostoxin (Aluminium Phosphide) tablets (48%) followed by the cultural practices such as exposing the infested grains to sunlight (21%). Other farmers used indigenous methods (14%) to control the weevil while the lowest percentage did not apply any control measures (1%). In the study by Makaza and Mabhegedhe (2016) in Zimbabwe, the farmers also reported that they used ethno-botanicals and other locally available options like cow dung and wood ash to control grain storage pests. Majority of the farmers incorporated their grains together with the shoat faeces cakes in storage bags at 27% as a method to prevent infestation by grain weevils, some farmers used locally available botanical pesticides like hardy aloe and wild garlic at 13 and 8%, respectively.

CONCLUSION AND RECOMMENDATIONS

Rodents and weevils were major pests of grains in storage. Rodents were the most destructive and inducing higher degree of damage to the stored grains than loses due to weevils. Management of rodents was predominantly biological by use of cats. As for the control of weevil, farmers mostly relied on chemicals where they applied a fumigant Phostoxin (aluminium phosphide). Many farmers stored their produce in the same room where they leave and very few had proper storage structures for the grains. This exposed family members to Phostoxin which is very toxic and volatile insecticide. Moreover, some farmers did not even use any protective clothing when applying it; they only relied on the surgical masks and gloves. As a result of inappropriate storage houses some farmers are forced to keep their grains for a short period of time to avoid weevil and rodent infestation. Therefore, there should be a study to determine small storage structures and that will be affordable and accessible to smallholder famers. These structures should also prevent entry of both rodents and weevils. The farmers should also be introduced to more ecofriendly control of weevils like use of hermetic backs to reduce reliance on pesticides.

The limitation of this study is that some information given by farmers may not be real. Smallholder farmers always perceive interviews conducted using project vehicles as need assessment studies for donations. Therefore, they will always give answers that will make them appear vulnerable.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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