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Original Research

Assessing storage insect pest infestation and post-harvest loss of wheat in major producing Kebeles of Tiyo district, central Ethiopia

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Abstract

This study examined wheat insect pests and post-harvest loss in Tiyo district's main wheat villages. This study randomly collected 600 quintal sample points from 20 households to determine wheat insect infestation. Wheat samples were obtained with a 50cm bag spear. Postharvest storage management and wheat pest control were assessed by ten key informants in a focus group. The 600 quintal sample bag stores had 30% wheat pest infestation. One-way ANOVA showed that wheat grain weight decrease was statistically different. This created a statistically significant weight drop in the middle of the bag store, unlike the bottom and top. Most householders employed synthetic insecticides to combat wheat bugs in sack storage. A 600-quintal sack store sample has 30% wheat insect infestation. Wheat weight decrease at the bag store's bottom, middle, and top was statistically significant. District wheat producers employed chemical pesticides as their main control technique.

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INTRODUCTION

One of the main cereal crops grown worldwide, wheat (Triticum aestivum L.) is a staple grain and a part of most peoples' daily meals. With an annual production of 750 million tonnes (MT) over roughly 220 million hectares (Mhas) in 2017, it is a grain of life. As part of the Neolithic revolution, which signaled a move away from hunting and gathering food and toward settled agriculture, wheat was first grown about 10,000 years ago (FAO, 2017). From a 10 Mha area, Africa produces more than 25 MT of wheat (FAO, 2017). Sub-Saharan Africa (SSA) produced 7.5 MT on 2.9 Mha of total area, according to FAO, which accounted for 1.4% and 40% of global and African wheat production, respectively (FAO, 2017). After South Africa, Ethiopia is the second-largest producer of wheat in the SSA. In Ethiopia, the Oromia region accounts for roughly half of the total area covered by wheat farms. From Oromia Regional State, Arsi, Bale, and Shoa are all part of the wheat growing belt of the country. Wheat ranks third in total production, after teff and maize, and fourth in area coverage, trailing only teff, maize, and sorghum (CSA, 2013).

In Ethiopia, the average wheat yield per hectare was 26.75 quintals, 29.65 quintals in Oromia, and 32.09 quintals in Arsi. The influence of altitude on rainfall, temperature, and disease is significant in wheat production. Rainfall distribution was good in most wheat growing areas from the end of June to the end of September. Wheat was once a pesticide-free crop in many parts of the world; however, times have changed. Biological and abiotic stresses are currently putting all crop production practices to the test. Wheat yield and quality losses are primarily caused by insect pests and diseases. Pests cause 20–37 percent yield losses on average worldwide, amounting to approximately $70 billion per year. In developing nations like Ethiopia, biological spoiling is the main reason for postharvest crop losses (Hodges et al., 2011). Irrespective of the reasons, postharvest crop loss in underdeveloped nations during storage varies from 5 to 10% overall (Hodges et al., 2011) and from 14 to 23% in Ethiopian wheat during different handling phases (Dessalegn et al., 2017).

Many biotic and abiotic factors have had a significant impact on wheat yield and output in Ethiopia and throughout Africa. Pests that gnaw and suckers damage wheat. Then, one of the most difficult biotic limitations during storage is insect pests. The rice weevil (Sitophilus oryzae L.) is the most common pest of stored wheat, causing 2-5 percent grain damage. The majority of the damage occurs during the rainy season. It feeds internally, reducing weight and degrading grain quality. For example, the grain may become humid and hot, rendering it unfit for human consumption.

The lesser grain borer (Rhyzopertha Dominica) is another damaging pest that causes damage throughout the country. Adults and larvae consume the grain. This reduces weight while degrading quality. The lesser grain borer is most common in humid climates and when wheat moisture content is high. The Khapra beetle (Trogoderma granarium) is a sporadic but widespread pest. In conditions of high humidity and moisture content, it causes extensive damage. Wheat is also severely harmed by the red flour beetle (Tribolium castaneum) and the rice moth (Sitotroga cerealella). Similar to this, Sitophilus granarius (L.), rice weevil Sitophilus oryzae (L.), maize weevil Sitophilus zeamais Motschulsky, R. Dominica, and S. cerealella are the main storage insect pests in Ethiopia that are linked to stored wheat (Tadesse et al., 2008). Major secondary storage pests in wheat include Oryzaephilus spp., Tribolium castaneum (Herbst), confused flour beetle, Tribolium confusum Jacquelin du Val, and almond moth, Cadra cautella Walker (Tadesse et al., 2008). Although they are rare in Ethiopian grain warehouses, psocids are also becoming serious pests and gaining attention internationally (Athanassiou & Arthur, 2018). (Tadesse et al., 2008). As a result, it is critical to understand the biology of insect pests alongside crop biology in order to determine when, where, and what chemical should be used to control specific insects or pests more effectively.

The Tiyo district is the focus of this investigation. The district contains a large number of kebeles that are in the wheat belt, where 76% of farmers grow wheat and where households mostly rely on it for food and income. Farmers in the district have been confronted with a variety of issues, including storage insect pests, traditional storage practices, a lack of training in storage methods, particularly for wheat grain, and a lack of assessment of storage insect pests and other cereal grain. This is the primary motivation for conducting this research, which aims to identify the storage insect pests, storage structure, and assessment of storage losses in wheat.

In Eastern Arsi, particularly in Tiyo district, the majority of farmers cultivate wheat, and most of them produce the highest yield, which is used as a source of food, animal feed, and cash crops. Although it is used for different purposes, farmers face problems as they cannot store their crops for two or three years due to postharvest losses; the main cause of postharvest losses during storage is an infestation of wheat insect pests. The farmers may know that wheat is mainly damaged by pests. However, they do not know in which storage structure wheat pests more attack their wheat and cause great loss. The purpose of conducting this study was to investigate the infestation rate, weight loss, storage management, and control practices of wheat pests in the major producing kebeles of Tiyo district.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Tiyo district, Eastern Arsi zone of Oromia Regional State (Fig. 1). The capital of Ethiopia, Addis Ababa, is located 175 kilometers from the research area. Munesa borders Tiyo district on the south; Ziway Dugda borders it on the west; Hitosa borders it on the northeast; and Digelu and Tijo districts border it on the southeast. The governmental and commercial hub of the Arsi Zone and Tiyo region is Asella Town. According to a land survey, the Tiyo district has 40.2% arable land, 23.1% grazing land, 8.7% forest land, and the remaining 28.2% unusable, marshy, or hilly territory. The district has a total population of 86,761 people as of the National Census Report of 2015, 43,463 of whom were men and 43,298 of whom were women. Moreover, 6,525 people, or 7.52% of the total, live in cities. The estimated population density of Tiyo is 285.4 persons per km^2. There are 18 villages in the district. Furthermore, the zone is classified as a hotspot for climate change consequences based on the geo-ecological position and socio-economic activities (CSA, 2013). The district is one of the wheat belts in the Arsi zone, and several of the districts are situated in Ethiopia's Great Rift Valley, where climate change effects have been seen repeatedly.

The main route into the district is the Addis Ababa-Asella all-weather road. In terms of geography, Tiyo District is found approximately between 7° 45' 55" and 8° 02' 2" N latitude and 38° 56' 42" to 39° 18' 31" E longitude.

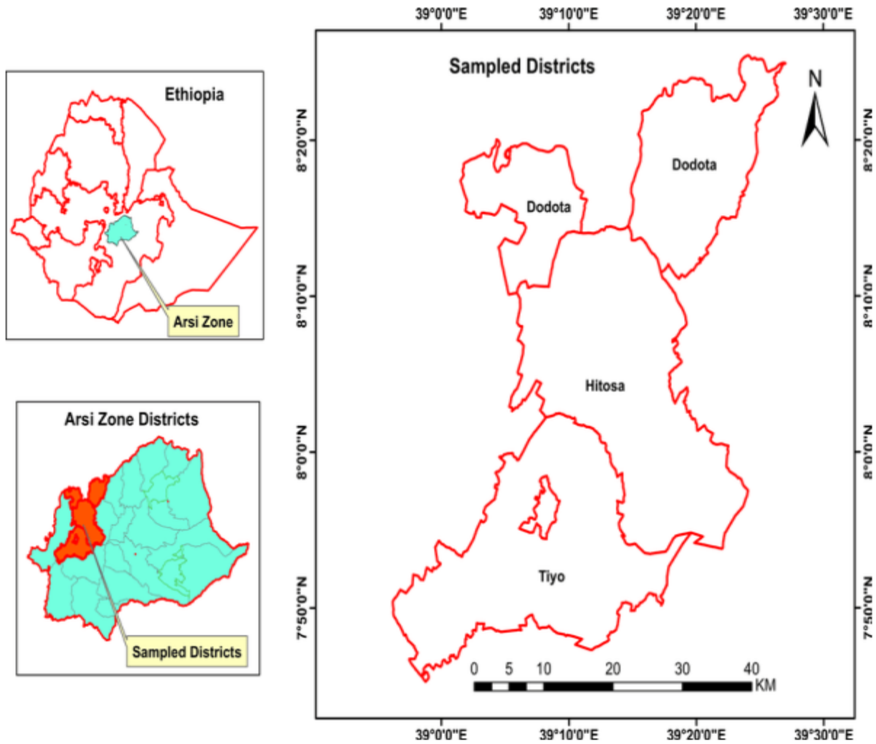

Figure 1 *Map of the study sites in Tiyo district, Oromiya Regional State, Ethiopia*

Research design and period

In the Tiyo district, a community-based, house-to-house cross-sectional descriptive survey was conducted between May and July of 2021. Samples of wheat were taken using a 50 cm bag sampling spear. The 50 cm sample spear was used to collect grain stored in bags and 200 seeds were taken randomly. The samples were taken from various parts of the store, specifically from the top, middle, and bottom of store bags that were chosen at random. Using the "count and weigh" method, weight loss was computed from a 100g subsample (Adams *et al*., 1978).

Sampling procedures and sample size

Every household in the Tiyo district that farmed wheat was included in the study. Sample homes served as the data sources. 15% of the total amount of wheat grown and stored by rural farmers in the research area was considered for calculating the infestation rate and grain loss. Every fifth home head was contacted in the systematic random sampling process used to choose the sample houses (Humanitarian Response, n.d.).

To evaluate wheat pest control methods and postharvest storage management among smallholder farmers in the study area, a sample size of 400 was used. The sample size was calculated using Table 1's sample size, n, for a 95% confidence level.

$n = N/(1 + N(e^2))$ where N is the population size and e is the level of precisions, N= 86761 study population, e=0.05

$n = 86761/(1 + 86761(⟦0.05⟧^2))$,

here n =398.1

A percentage of the sample size (10%) was added to the total sample size of 400 in order to reduce errors resulting from the possibility of noncompliance. Head households were chosen using a systematic selection technique that divided N by n (N/n = i). Each ith head of the household was chosen in order of its name from the list at their kebeles level. A lottery would be used to select the first household from each of the corresponding i ranges. The formula provided by Boyd et al. (1985) was used to calculate the percentage of the sampled population (C).

$C = n/N * 100$

Table.1

Tiyo District with Total kebeles, sampled, and percentage of households

Keble	Total farmers (N)	Number of selected farmers (n)	Percent (%)
Abosara Alko	2761	78	2.82
Tulu Cabi	3321	85	2.55
Oda Dhawata	2421	76	3.13
Murkicha kobo	2531	78	3.08
Katar	3256	83	2.54
Total	14290	400	2.799

Inspection of wheat storage structures for the infestation of insect pests

Visual examination was used to check wheat sack storage structures for insect infestations. In order to determine the rate of infestation of wheat pests, stored wheat was examined for the presence of wheat pests and their telltale signs (oviposition and emergency holes) in smallholder farming households' available storage structures, including up to 10 randomly chosen wheat sacks (bags) per household. For the purpose of observation and sampling, ten bags total from each residence were randomly chosen to represent the homeowners who store their wheat in those bags.

Measuring wheat grain loss (damage) by insect pests

With the use of a 50-cm sample spear (plate 1), weight loss and damage from wheat insect pests were calculated from grain samples taken from farmers' stockpiles. 200 seeds were counted when the 50 cm sample spear was used to gather wheat grain that was kept in bags. Three distinct depths within the bag were used to gather the samples: the top, middle, and bottom.

Plate 1: *A 50 CM Wheat Sampling Spear*

Survey of wheat storage pest management practices

The following techniques and instruments for data collection were used to obtain the information needed for this study to be successfully completed. Observation Check Sheet: The visual observation differentiated between damaged and undamaged wheat seed and also infested stored wheat seed by wheat pests.

Questionnaire

It was believed that relevant information would be collected using a closed and open-ended questionnaire that is personally administered by the author to the 400 farmers.

The structured questionnaire was composed of both closed-ended and open-ended types of questions. The purpose of the questionnaire was to gather data on postharvest storage management and wheat pest control procedures by small holder farmers. The questionnaire was prepared in English and translated to the local language, Afan Oromo, to get enough information from the respondents.

Focus Group Discussion (FGD): To gather data about postharvest storage management and wheat pest control practices among the small holder farmers, 10 key informants that included five model farmers, three extension workers, and two religious leaders employed for FGD. Discussion points were prepared, and the discussion was conducted in Afan Oromo.

Methods of Data Analysis

After the data were collected by the data gathering tools, analysis and interpretation were done b using both quantitative and qualitative methods. The data entry and analysis were done by using statistical software, SPSS version 20.

The infestation rate was calculated by using the following equation:

$$Infestation\ rate = \frac{Number\ of\ store\ structures\ pest\ positive\ \times 100}{Total\ number\ of\ store\ structure\ observed}$$

Count and weight loss assessment. The pest damaged and undamaged wheat grains in the sample were first counted and then weighed. The percentage weight loss was then calculated using the following equation:

$$Weight\ loss\ \% = \frac{Nu(Nd \times Wu) - (Wd \times Nu)\ x\ 100}{(Nd\ +\ Nu)\ Wu}$$

Where, N_d = Number of damaged grains in the sample, N_u = Number of undamaged grains in the sample, W_d = Weight of damaged grains in sample, W_u = Weight of undamaged grains in the sample.

The storage management and wheat pest control practices were assessed using a questionnaire and a focus group discussion.

Mean comparisons using one way ANOVA

Let the mean weighted grain loss be U_j, where j^{th} group, and j= 1, 2, 3. We took the sample wheat from the top, from the middle, and from the bottom to see whether there was a difference in the wheat loss caused by wheat pest from these different positions in the sack store. We applied one- way analysis of variance (ANOVA) to see whether there was statistical difference in the wheat loss taken at different position. The hypothesis for one-way ANOVA:

H_o: $U_1=U_2=U_3$ (the mean loss of wheat sampled from three different positions is the same).

H_1: At least one is different from the other.

Pairwise comparison

We also applied pairwise comparisons to see which pair of wheat losses is statistically different from the other after we got statistical differences in the ANOVA test. We have three pairwise comparisons to see their respective grain loss differences. We put the three different hypotheses as follows:

To see the difference between the grain loss at the top and in the middle

H_o: $U_1=U_2$ (grain loss at the top and in the middle is the same).

H_1: U_1 U_2 (grain loss at the top and at the middle is different)

To see the difference between the grain loss in the top and at the bottom

H_o: $U_1=U_3$ (grain loss at the top and in the bottom is the same).

H_1: U_1 U_3 (grain loss at the top and at the bottom is different).

To see the difference between the grain loss at the middle and at the bottom

H_o: $U_2=U_3$ (grain loss at the middle and at the bottom is the same)

H_1: U_2 U_3 (grain loss at the middle and at the bottom is different)

Where: U1, U2 and U3 are the mean weight loss of wheat at the top, middle, and bottom of the sack store.

RESULTS AND DISCUSSION

Results

Infestation Rate and weight loss of wheat by insect pests

The overall infestation percentage of wheat pests in sack stores was 30% from 600 sack stores, and the percentage of pest-free bags was 70%. As it is presented in Table 2 the mean weight loss of wheat grain at the top, middle and bottom of the sack store is 2.80±0.15, 7.94±0.26, and 6.04±0.12, respectively. The minimum and maximum weight loss of wheat grain at the top is 1.64and 3.50, respectively. Based on the results of the present study, the overall weight loss of wheat by the wheat pest was 5.6%. On the other hand, the coefficient of variation on the top of the sack store is 5.4%, which showed that there is more variability or less consistency between the observed weight losses of stored wheat compared to the other positions. But the coefficient of variation of the mean weight loss of stored wheat at the bottom of the sack store is 1.9%. This showed that the observed weight loss of stored wheat at the bottom of the sack is more consistent or showed less variability between the weight losses of the wheat as compared to the other positions. Finally, the coefficient of variation of the mean weight loss of stored wheat in the middle of the sack store is 3.2%. This is more consistent than the coefficient of variation at the top of the sack store and less consistent than at the bottom of the sack store.

Table 2

Weight loss of stored wheat at different positions of the sack stores in Tiyo district in 2021

Position	N	Range	Minimum	Maximum	Mean		St. deviation	Coefficient of variation(CV)
					Statics	Std. error		
Top	10	1.90	1.64	3.50	2.80	.15151	.52483	5.2
Middle	10	2.92	6.52	9.47	7.94	.25606	.88701	3.2
Bottom	10	1.44	5.20	6.66	6.04	.11508	.39866	1.9

There was significant difference in the weighted loss of wheat taken at different positions in the sack store. Based on these findings, a pair-wise comparison was performed to determine the pairwise weighted wheat loss difference, and the middle portion was found to be more affected than the other portions. This could be due to an inappropriate habitat for the wheat pest to live at the top of the sack store due to high temperatures and low humidity. The ideal temperature and humidity for wheat pest growth is frequently found, which increases the weight loss of the wheat in the middle.

Table 3

ANOVA for weight loss of the wheat

	Sum of Squares	DF	Mean Square	F_{cal}	P-value
Between Groups	161.590	2	80.795		
Within Groups	13.433	33	0.407	98.486	0 .000
Total	175.023	35			

As it can be seen from Table 3, the weighted wheat loss at the top was significantly different as compared to the weighted wheat loss in the middle. This decision was supported by the p-value, which is zero. This rejected the null hypothesis, which suggested that the weight of the wheat loss in the middle and top positions is the same. This conclusion could also be confirmed by using the 95% confidence interval, which doesn't contain zero in the confidence interval. Since the p-value is zero and the 95% confidence interval doesn't include zero, the same conclusion can be drawn for the weighted wheat loss at the top and the weighted wheat loss at the bottom. Similarly, the wheat weight loss at the middle and bottom sack stores was statistically different as listed in Table 4.

Table 4

Pair-wise comparison of weighted wheat loss taken at three different positions (Top, Middle and Bottom positions of store structures).

(I) grouping factor	(J) grouping factor	Mean Difference (I-J)	Std. Error	Sig.	95% confidence interval Lower Bound	Upper Bound
Top						
	Middle	-5.12917*	0.26047	0.000	-5.6591	-4.5992
	Bottom	-3.24833*	0.26047	0.000	-3.7783	-2.7184
Middle	Bottom	1.88083*	0.26047	0.000	1.3509	2.4108

Dependent Variable: wheat weight lost, *. The mean difference is significant at the 0.05 level.

Wheat pests' management and control practices

Wheat production and purpose of storage

From a total of 400 respondents, 395 (98.75%) said they acquired their food from farming, while the remaining 5 (1.25%) said they got it from the market. After harvest, all respondents said they store wheat. 99 (24.75 %) of the 400 farmers said they keep wheat for personal consumption, while 301 (75.25%) said they store wheat to sell at a higher price (Table 5).

Table 5

Source of food to feed their family, production and storage of wheat and purpose of storing

Variables	Categories	Frequency	Percent (%)
Source of food	Farming	395	98.75
	Market	5	1.25
Do you store wheat	Yes	400	100.0
	No	-	-
The purpose of storing of wheat	for household consumption	99	24.75
	To sell a higher price	301	75.25

Wheat storage structures used by subsistence farmers

As shown in Table 6, the most frequently used storage structures were bag storage (96.25%) followed by Gota (3.5%) and the least used storage was clay pot (0.25%).

Table 6

Main storage structures used by wheat subsistence farmers at Tiyo district

Storage structures	Frequency	Percent	Valid Percent	Cumulative Percent
Bag	385	96.25	96.25	96.25
Clay pot	1	0.25	0.25	96.5
Gota	14	3.5	3.5	3.5
Total	400	100.0	100.0	100.0

Wheat production rate by the subsistence farmers

The majority of (341, 85.25%) farmers got and stored above twenty quintals in the most recent harvest season in Tiyo district (Table 7).

Wheat grain loss by the subsistence farmers

From the total of 400 farmers 295(73.75%) farmers lost their stored wheat due to wheat pests, 5(1.25%) farmers lost their wheat due to theft, and 100(25%) farmers lost their wheat due to rodents (Table 8).

Table 7

The amount of wheat obtained and stored in one harvest season in Tiyo district

Quintal wheat per year	Frequency	Percent	Valid Percent	Cumulative Percent
5-12	4	1	1	1
13-20	55	13.75	13.75	14.75
Above20	341	85.25	85.25	100.0
Total	400	100.0	100.0	

Table 8

The major causes of stored wheat grain loss in Tiyo district.

Causes of wheat grain loss	Frequency	Percent	Valid Percent	Cumulative Percent
Wheat pests	295	73.75	73.75	73.75
Theft	5	1.25	1.25	75
Rodent	100	25	25	100.0
Total	400	100.0	100.0	

Wheat pests control methods in Tiyo district

From the total of 400 farmers, 398 (99.5%) used chemicals to protect stored wheat from wheat pests, and 2 (0.5%) farmers used cultural methods to protect stored wheat from wheat pests (Table 9).

Table 9

Methods of protection of wheat grain from loss by wheat pests

Methods of pest control	Frequency	Percent	Valid Percent	Cumulative Percent
Chemical method	398	99.5	99.5	99.5
Cultural method	2	0.5	0.5	100.0
Total	400	100.0	100.0	

Results obtained from a focus group discussion (FGD)

Results from FGD indicate that the majority of the farmers protect their stored wheat from pest infestations mainly by applying chemical pesticides such as actellic 2% liquid for 3–4-month, Malathion 5% powder for 3-4 month, diazinon 60% liquid for 1-2 years, and ciliphon tablets by fumigation. The storage structures of wheat grain for householder were sacks, gota and cribs. The best storage structure for wheat grain was a sack, and the major wheat pests control practices used by the farmers were chemical pesticides. The wheat pest management practices of farmers include mixing grain with salt, pepper powder fumigation of gota before storage, and cleaning storage structures before storing new grains.

Discussion

Results show that the infection rate of wheat pests in sack stores was 30% in a sample of 600 quintals. The weevil infestation rate was found to be 79.5 % from 200 bag store samples in other parts of Ethiopia (Nibret et al., 2020) which is much greater than the present finding. Because of the advent of modern storage structures, bag storage materials, and the availability of chemical insecticides, the wheat pest infestation rate recorded in this study is lower than in prior studies.

According to a study conducted by Baidoo et al. (2010), pest activities in stored grains can result in a variety of losses, including weight loss, grain quality degradation, and mould development encouragement. The percent weight loss owing to wheat insect infestation ranged from 9.5 percent in the bottom to 15.3 percent in the middle in the present study. The weight loss of wheat grain held in sack stores near the middle was substantially greater than at the bottom, according to the study. It was also shown that the difference in weight reduction between wheat and other grains was not substantial. However, it was discovered in the current study that weight loss at the bottom and middle showed statistically significant differences at the 0.05 level of significance, just like in a previous study (Biadoo et al., 2010).

According to the findings of this study, weight loss was greatest in the middle of the sack store, which is consistent with a study conducted by (Biadoo et al., 2010) that indicated a higher pest number in the middle. Similarly, Niberat et al. (2020) higher weight loss of maize in bag stores from Ethiopia. This could be owing to the wheat pest's inability to live at the top of the sack because of the high temperature and low humidity. There is usually an optimum temperature and humidity for wheat pest growth, which results in increased wheat weight loss in the middle.

The small holder wheat farmers utilized a combination of cultural and chemical control strategies. Cleaning their storage two to three times a year, sanitation, drying the grains properly, and keeping the storage aerated are all cultural control strategies. In the assessed locations, about 99.5 percent of farmers utilized insecticides such as celphox and phosphotoxin fumigants, with a few using emulsion Malathion, Malathion dust, and Mographos fumigant tablets in their storage. Cleaning two to three times a year, sanitation, and pepper were utilized by the left 0.5 percent as cultural control methods. Insecticides, botanicals, ashes, salt, smoke, sanitation, and combining wheat seeds with pepper were among the pest management techniques used by farmers in the research area. Chemical pesticides were mostly used in the management and control techniques of smallholder farmers in our research.

Among the management options used to control storage insect pests of wheat are cultural control and sanitary methods, modified or controlled atmosphere techniques, temperature control or environment modification, chemical control, biological control, botanical insecticides, and host plant resistance (Nibret et al., 2020; Tefera, 2012).

0Pests can be treated directly by treating grain with inert dust such as ash from wood or rice husk (Wakeyo et al., 2014). In addition, applying 0.5–1 percent (0.5-1kg of rice husk ash to 100 kg of grains and 1 percent (1kg) of wood ash to 100 kg of wheat grains), removing grain from storage, drying for three days to kill pests, sieving to remove adult pests, burning the infested residues, and storing grain in undamaged sacks or airtight sacks are all direct control methods. Plant-resistant or tolerant wheat varieties such as hogolcho, timely harvest of mature cobs and selection of only uninfected cobs for storage, ensure that grains are dried properly before storage, use clean storage facilities, and seal cracks, crevices, and holes because insects can hide inside, according to a similar study.

In the end, this study is not without limitations. The target district has double wheat cultivation seasons in a single year, which means it has both summer and winter cultivated wheat on the same growing ground. During the winter season, some farmers in Tiyo district use irrigation systems to produce many quintals of wheat. However, in the previous two years, when Ethiopian governments declared a wheat irrigation scheme, farmers in Tiyo district have largely participated in the irrigation of wheat. Despite the fact that winter wheat is present; the study only includes summer cultivated wheat due to differences in storage times and insufficient funds.

CONCLUSIONS

The infestation rate of wheat pests in sack stores was 30% from the sample of 600 quintals of wheat. The weight loss of wheat at the bottom, middle, and top of the sack store had a statistically significant difference. The weight loss at the middle position of the sack store was greater than the weight loss at the bottom and top positions of the sacks.

Subsistence wheat producers primarily used sack storage structures to store wheat grain, while chemical and cultural pest control approaches were determined to be the most often used control methods against wheat pests. Pesticides were most widely used in the management and control of wheat pests by the smallholder farmers in the study setting.

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DECLERATION

The authors declare that they have no conflicts of interest regarding the publication of this paper.

DATA AVAILABILITY

The data used to support the findings of this study are included within the article.

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