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# A survey of post-harvest handling practices and pest control measures in stored maize in western Ethiopia

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**ABSTRACT:** This survey was conducted in western Ethiopia with 125 respondents using face-to-face interviews. Surveys evaluated farmers' post-harvest practices, losses from post-harvest handling, insecticide usage frequency, and management techniques for preventing storage pest infestations of maize. All of the farmers planted hybrid maize varieties. Post-harvest handling practices caused 24% of crop losses. Harvesting (2%), threshing (3%), transportation (2%), and storage (17%) were identified as major points of loss. Farmers employed several strategies to reduce pest damage in storage. Of these strategies, 81.6% of farmers used synthetic insecticides, with 31.62% using insecticides more than twice. In total, 5.6% of respondents used plants such as *Croton macrostachyus* and *Lantana camara* for controlling insects during storage, which were frequently mentioned. Sun drying, roofing, and regular cleaning were all adopted by 4% of farmers as cultural insect pest management strategies. About 6.4% of farmers used a combination of the above management tactics. Insect-resistant hybrid varieties are critical to developing and implementing sustainable pest management strategies. Local governments can develop more effective pest management strategies. The primary emphasis should be on IPM. This method is more efficient and long-lasting than single-method control strategies. This will help keep pest populations in check and minimize pesticide use.

**Key words/Phrases: Food insecurity, Insect pests, integrated pest management (IPM), post-harvest losses, *S. zeamais***

## INTRODUCTION

Maize is the first marketable agricultural crop and is a major income source for farmers in Sub-Saharan Africa (SSA) (Santpoort, 2020). Ethiopian farmers grow maize more than any other crop, and it is the nation's long-term food security. Due to favorable natural cultivation conditions, maize farming is the main agricultural activity in the western Oromia region. As a result of anticipated storage losses, many farmers in SSA are compelled to sell their maize grains as quickly as possible after harvesting. However, they often experience food shortages within a few months and must purchase maize or other grains at exorbitant costs during the lean season (Tibaingana *et al.*, 2022). Post-harvest losses threaten family food security and market income, prompting farmers to look for safe ways to store their grain (Sisay Debebe, 2022). Insects destroy more grain than they consume; they release metabolic wastes, such as uric acid, which can produce unpleasant odors and tastes; they develop harmful microorganisms; and most people dislike the smell and taste of the filth they create (Deshwal *et al.*, 2020). They cause significant economic losses to stored grains, and their effects are more pronounced in poor countries (Singh *et al.*, 2021). In Ethiopia, the most economically critical insect pests in storage include *Sitophilus zeamais* (maize weevil), *Sitophilus oryzae* (rice weevil), *Sitotroga cerealella* (Angoumois grain moth), *Tribolium spp*. (red flour and confused grain beetle), and *Ephestia cautella* (Almond moth) Muez Berhe *et al.*, 2022). They cause the most damage to stored maize and are abundant creatures of the arena. They also reduce product quality and quantity. Even if they do not produce clearly toxic substances or strong off-flavors like mold, their presence depreciates grain value, even in minor infestations (Malik *et al*., 2019).

The use of integrated pest management (IPM) strategies can help smallholder farmers to address food security and safety. IPM strategies focus on natural methods to control pests, combined with chemical interventions when necessary (Dara, 2019). These strategies can be tailored to smallholder farmers' specific needs. However, synthetic pesticides carry a number of risks, including environmental pollution, health hazards, and resistance development (Ngegba *et al*., 2022). Therefore, integrated pest management strategies that combine cultural, biological, and chemical control methods should be adopted to ensure sustainable pest management (Deguine *et al*., 2021).

Consumers are increasingly looking for organic produce and food products with fewer chemicals and pesticides (Rahman *et al*., 2021). Food safety regulations are also tightening, with governments introducing more stringent standards for pesticide residue limits. This has forced food producers to find alternative ways to manage pests and maintain food quality. IPM is an effective approach to pest control that reduces pesticide use. IPM assesses pest damage risk and combines various control methods, such as biological control and physical barriers, to reduce chemical control. This approach is more efficient and sustainable than relying solely on pesticides (Green *et al*., 2020). These packages should focus on the efficient use of cultural, biological, and chemical pest control methods. Additionally, farmers should be educated and trained on the safe and proper use of pesticides to minimize potential risks and environmental damage (Mubushar *et al*., 2019). This lack of information hinders more effective pest control strategies. Therefore, it is critical to assess local farmers' knowledge and management practices to develop more successful control strategies for storage pests in the region (Sabran and Abas, 2021). Understanding farmers' existing knowledge and practices can help design an effective pest management approach (Benaboud *et al*., 2020). To bridge this gap, active engagement and communication between researchers and farmers are necessary. Education and awareness programs can also help build capacity and foster more effective pest management. This approach has been proven to be more productive than top-down approaches, as it takes into account farmers' needs and preferences. Through this, farmers in SSA can be better equipped with more sustainable and effective pest control management strategies. This would also reduce post-harvest losses. Additionally, it could reduce food insecurity in the region.

The current survey was carried out to identify potential intervention points in the development of IPM strategies for maize storage pests. These strategies are appropriate for low-income smallholder farmers in western Ethiopia. The study specifically identifies farmers' post-harvest practices, losses related to post-harvest handling, maize crop infestation level, synthetic insecticide use frequency, and stored maize pest control methods other than synthetic insecticides as intervention opportunities for the development of efficient IPM approaches that would contribute to food security and income growth in western Ethiopia by addressing losses caused by post-harvest insect pests.

## MATERIALS AND METHODS

### *Description of the study areas*

This survey was undertaken in Ethiopia in five locations (Kebeles) in three districts. These were Dambi Dima and Tulu Sangota kebeles, which lie at (N 09°05' and E 037°03') and (N 9°04' and E 37°10') respectively, from Bako Tibe district; Sombo Kejo lies at (N 9°07' and E 37°09') from Gobu Sayo district; Darbes Gerado and Chali Jima lie at (N 9° 45' and E 35°17') and (N 9°15' and E 37°06') respectively, from Gudaya Bila District (Figure 1). The research areas are located between 1581 and 2425 meters above sea level, with annual rainfall ranging from 830 to 1950 millimeters. The area's climate is warm and humid, with average minimum and maximum air temperatures ranging from 15 to 30°C. The minimum, maximum, and average relative humidity in the area is 49, 75, and 62%, respectively.

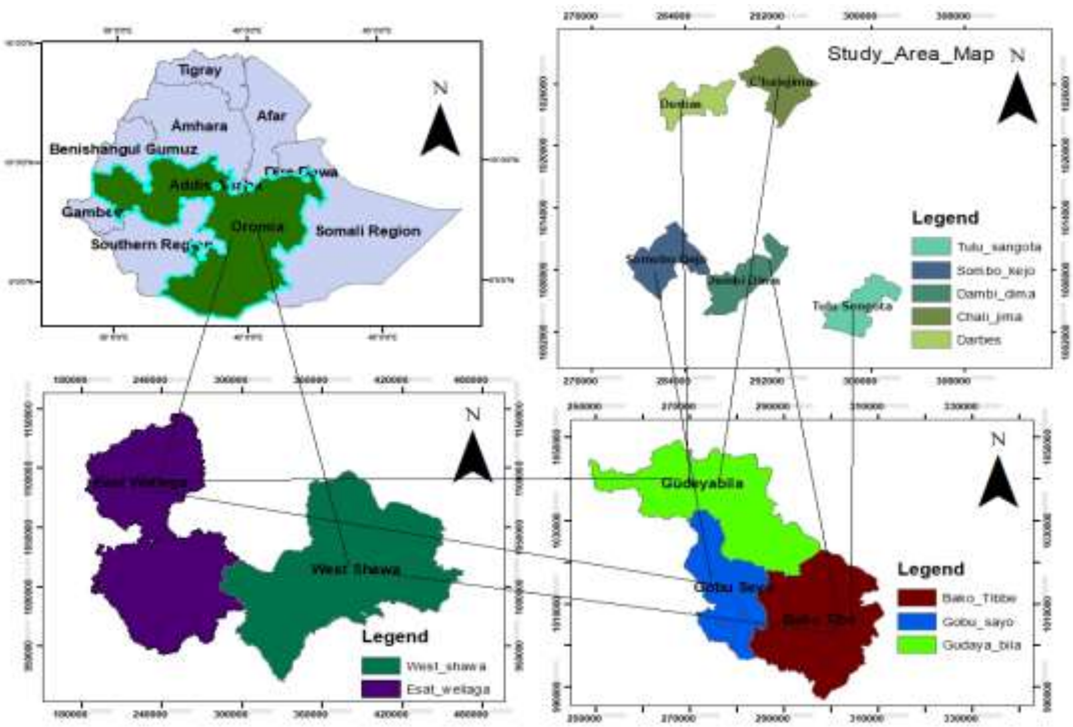


Figure 1 Map of study area

***Sampling procedure and sample size***

The three survey districts were purposively selected based on maize production potential. From these districts, five survey locations (Kebeles) were selected based on their long history of substantial maize production. Logistic reasons, such as trail availability and road accessibility, were also considered in the meantime. A kebele is the smallest administrative unit of a district in Ethiopia.

Multi-stage cluster sampling was employed in the study to ensure the selection of households from each Kebele that had the same chance of being selected. It is advisable to use multi-stage cluster sampling when there is a large and dispersed population. Based on the total number of households in the five Kebeles (1250), 10% of these were chosen randomly, resulting in a sample size of 125 farmers for the study. To accomplish these tasks, within each kebele, five clusters were formed. Five farmers were randomly selected for interviews from sampling lists obtained from each Kebele's agricultural office. Hence, 25 farmers were chosen from each kebele. As a result, 125 farmers were selected for interviews (5 kebeles x 5 clusters x 5 farmers).

Surveys were carried out from October 2021 to September 2022. In order to compile the relevant information, the researchers administered a pre-tested semi-structured questionnaire to the assigned farmers. All respondents were interviewed in Afan Oromo, the regional language. Most survey questions were "open" to avoid limiting farmers' responses (Midega *et al*., 2012). The questionnaire consisted of farmers' socio-economic background, maize varieties grown, losses related to post-harvest handling practices, storage technologies practiced, and insect control practices. The data was collected through face-to-face interviews.

***Data analysis***

Data was entered into an Excel spreadsheet, and quantitative and qualitative data were coded and analyzed using IBM Corp.'s Statistical Package for Social Sciences (SPSS, 2016). A one-way analysis of variance (ANOVA) was conducted to assess any differences between farmers' perceptions of pests and management practices. The chi-square independence test was used to test for significant differences between the variables. The significance level was set at 0.05, and means were compared by the Tukey HSD test.

## RESULTS AND DISCUSSION

### *Socio-economic background of farmers*

As the result shown in Table 1, 84.8 percent of the respondents were men, while women's made up 15.2%. Men typically make up the majority of smallholder farmers in Ethiopia. This gender disparity is consistent with the findings of other studies conducted in Ethiopia, which have found male smallholder farmers to outnumber female farmers (Girma Gezimu *et al*., 2021). Over fifty percent of the farmers (58.4%) had completed elementary school education (grades 1–8), and 19.2% of the respondents could not read or write, indicating that the sampled population had high illiteracy. Similarly, a study in the Central Rift Valley of Ethiopia found that many Ethiopian farmers are still illiterate (Daniel Jaleta, 2023). The respondents across all kebeles had an average age of 43 and 22 years of farming experience. Yemane Asmelash *et al*. (2021) recently made a similar observation in northwest Ethiopia.

The average land size was 1.83 ha, of which 1.34 ha were used for maize cultivation, showing that most farmers were smallholders. In Ethiopia's regional states, households have access to land ranging from less than 0.5 hectares to more than 2 hectares. Official data on landholding size support this (Table 1). However, even 2 hectares of land are insufficient to feed a typical family (Gebissa Yigezu, 2021; Gebeyanesh Zerssa *et al*., 2021), and there was no significant difference in respondents' land sizes across kebeles, F (4,120) = 0.859, P<0.491.

**Table 1. Characteristics of respondents in the different regions.**

| Kebeles | CJ | DD | DG | SK | TS | Total | F-test | χ2 |
|---|---|---|---|---|---|---|---|---|
| Gender (%) | | | | | | | | 19.9* |
| Males | 20 | 16 | 19.2 | 12 | 17.6 | 84.8 | | |
| Females | 0.0 | 4 | 0.8 | 8 | 2.4 | 15.2 | | |
| Level of education (%) | | | | | | | | 27.68 |
| Illiterate | 7.2 | 1.6 | 2.4 | 4.8 | 3.2 | 19.2 | | |
| Informal education | 0.0 | 0.0 | 2.4 | 0.8 | 0.8 | 4.0 | | |
| Primary (1-4) | 7.2 | 8 | 1.6 | 7.2 | 4.8 | 28.8 | | |
| Primary (5-8) | 3.2 | 5.6 | 10.4 | 4 | 6.4 | 29.6 | | |
| Secondary (9-10) | 1.6 | 3.2 | 2.4 | 2.4 | 2.4 | 12 | | |
| College 10+ | 0.8 | 1.6 | 0.8 | 0.8 | 2.4 | 6.4 | | |
| Average age of the farmers (years) | 45.3 (1.62) | 43.0 (2.09) | 38* (2.36) | 46.2* (2.16) | 42.1 (1.78) | 42.9 (0.92) | 2.551* | |
| Average farming experience (years) | 15.0* (1.37) | 24.6* (2.17) | 25.6* (2.13) | 19.8 (2.08) | 23.6* (2.07) | 21.7 (0.94) | 4.812* | |
| Average land size (hectares) | 2.0 (0.18) | 1.9 (0.11) | 1.8 (0.13) | 1.74 (0.15) | 1.68 (0.19) | 1.83 (0.07) | 0.859 | |
| Average area of farm land under maize (hectares) | 0.98 (0.14) | 2.04* (0.45) | 0.89 (0.12) | 1.74 (0.15) | 0.85* (0.06) | 1.34 (0.14) | 0.004* | |

***Figure in parenthesis are Standard errors. *The mean difference is significant at the 0.05 level. Kebeles: CJ= Chali Jima, DD= Dambi Dima, DG= Darbes Gerado, SK= Sombo kejo, TS= Tulu Sangota***

### *Post-harvest practices and losses related to post-harvest handling*

Across the entire area being studied, farmers planted hybrid maize varieties such as BH660 (12.5%), BH661 (36.44%), Damot (1.36%), Limmu (30.72%), and Shone (18.98%); all of the farmers (100%) use hybrid maize varieties (Figure 2). Farmers prefer hybrid maize because it yields more grain, increases household food production and consumption, and produces more surplus grains for sale (Tripathi *et al.*, 2023).

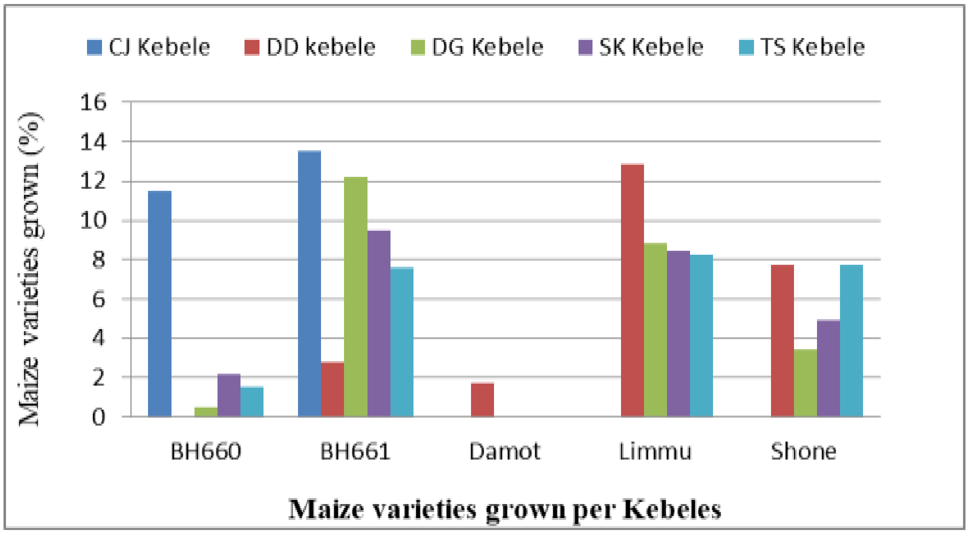


**Figure 2. Types of hybrid maize varieties grown in the study area in 2021.**

Table 2 shows post-harvest practices and losses related to post-harvest handling. According to these findings, 68% of farmers harvested maize in December, while 24% and 8% harvested maize in November and January, respectively. And this result agrees with Negasa Fufa *et al.* (2021). The chi-square test of independence indicated that maize harvesting times in the five kebeles differed significantly ($\chi^2 = 19.451$, df = 8, $p < 0.013$). Most farmers (76.8%) store maize in shelled form, while 22.4% store both cob and shelled maize. Only 0.8% of farmers store maize on cobs. A previous study in Jimma Zone, Ethiopia, indicated that the majority of farmers reported shelled maize storage; even if unshelled maize storage resulted in fewer pest attacks, only a small percentage reported unshelled maize storage (Nezif Abamecha, 2021). The chi-square test of independence confirmed that for the results given in Table 2, there was no significant difference in the methods of keeping maize in the five kebeles ($\chi^2 = 12.976$, df = 8, $p < 0.113$).

Human labor was used for post-harvest tasks in the study area. Most farmers (79.2%) responded that threshing activities were performed by human labor; only 20.8% of respondents trashed their maize crops using machinery. The chi-square test of independence indicated that the threshing methods in the five kebeles differed significantly ($\chi^2 = 12.335$, df = 4, $p < 0.015$).

According to the findings, farmers experienced maize crop losses due to post-harvest handling practices. Post-harvest handling accounts for 24% of crop losses. The estimation of the post-harvest loss proportion significantly varied across kebeles, ranging from 15% to 32% (Derbes Gerado and Dambi Dima, respectively). Africa's post-harvest maize losses are between 20% and 40% (De Groote *et al.*, 2023). According to Table 2, manual processing, such as harvesting, accounted for on average 2% of post-harvest losses; human and animal labor wasted 2% of the maize crop during transportation from the farm to the residence; threshing/winnowing destroyed 3% of the maize crop, which was lost due to mechanical breakage; and in storage, 17% of the maize crop was lost.

**Table 2. Post-harvest practices and losses related to post-harvest handling.**

| Kebeles | CJ | DD | DG | SK | TS | Average | F-test | χ2 |
|---|---|---|---|---|---|---|---|---|
| Maize harvesting time % | | | | | | | | 19.451[a] |
| November | 0.0 | 4.8 | 7.2 | 4.0 | 8.0 | 24.0 | | |
| December | 18.4 | 12 | 12.8 | 15.2 | 9.6 | 68.0 | | |
| January | 1.6 | 3.2 | 0.0 | 0.8 | 2.4 | 8.0 | | 12.976 |
| How do you store maize (%) | | | | | | | | |
| Cob | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 0.8 | | |
| Shelled | 14.4 | 18.4 | 17.6 | 15.2 | 12 | 76.8 | | |
| Mixed | 5.6 | 1.6 | 2.4 | 4.8 | 7.2 | 22.4 | | |
| Methods of threshing (%) | | | | | | | | |
| Manual | 20.0 | 14.4 | 17.6 | 13.6 | 13.6 | 79.2 | | |
| Machinery | 0.0 | 5.6 | 2.4 | 6.4 | 6.4 | 20.8 | | |
| Mean proportion of post-harvest loss during different activities (%) | | | | | | | | |
| Harvesting | 2.0 | 2.0 | 2.0* | 2.0* | 2.0* | 2.0 | 3.60* | |
| Threshing/winnowing | 2.0 | 3.0 | 3.0* | 2.0* | 3.0 | 3.0 | 2.53* | |
| Transportation | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.03 | |
| Storage | 14.0 | 25.0 | 13.0 | 14.0 | 21.0 | 17.0 | 0.72 | |
| Overall sample | 20.0 | 32.0 | 15.0 | 16.0 | 25.0 | 24.0 | | |

***a.Significant at 1%. *. The mean difference is significant at the 0.05 level. Kebeles: CJ= Chali Jima, DD= Dambi Dima, DG= Darbes Gerado, SK= Sombo Kejo, TS= Tulu Sangota***

***Maize crop infestation levels and synthetic insecticide use frequency***

Table 3 indicates maize crop infestation levels and pesticide use frequency during the 3–9 months of storage. Above 30% of respondents reported that the level of infestation is low during the first three months of storage (1-3 months), about 29% reported that the level of infestation is medium during the second three months of storage (3-6 months), and 31.1% said the level of infestation is high during the last three months of storage (6–9 months) (Table 3).

To manage insect pests in maize, more than 70% of smallholder farmers in developing nations use synthetic insecticides (Quellhorst *et al*., 2020). In the study area, many farmers (81.6%) used synthetic insecticides to manage maize storage pests, and of these, 31.62% applied synthetic insecticides more than twice. The results are in line with Negasa Fufa *et al*. (2021) reported that over 80% of Ethiopian farmers employed chemical insecticides to control maize storage pests (which included fumigant insecticides such as Aluminium Phosphide tablets, as well as Malathion 5% dust and Malathion EC). Because the effectiveness of many synthetic insecticides declines after six months of storage periods, some respondents applied synthetic insecticides twice in storage structures, while others used them more than twice (Table 3). Maize farmers and grain traders in Kenya are forced to apply synthetic insecticides twice or more over the usual storage period due to efficacy limitations and the possibility that locally available synthetic insecticides are of low quality or impure (Mobolade *et al*., 2019). The majority of respondents (46.9%) cited effectiveness as the primary reason for using synthetic insecticides, while some respondents (34.70%) cited low cost as the main reason. However, using synthetic insecticides have a negative impact on the environment and can cause health issues (Ngegba *et al*., 2022). Hence, alternative pest control methods should be considered.

**Table 3. Maize crop infestation level and insecticides use frequency.**

| Parameters | Infestation level[1], reasons[2], and insecticides use frequency[3] | | | | | χ2 |
|---|---|---|---|---|---|---|
| [1]The level of insect pest infestation on stored maize grain 3-9 months (%) | | | | | | 333.99 |
| | | High | Medium | Low | | |
| 1-3 months | | 0.0 | 3.1 | 30.2 | | |
| 3-6 months | | 4.4 | 28.9 | 0.0 | | |
| 6-9 months | | 31.1 | 2.2 | 0.0 | | |
| Overall | | 35.6% | 34.2% | 30.2% | | |
| | | [2]Reasons for using synthetic insecticides (%) | | | | 12.318 |
| | | | | [3]Insecticides use frequency (%) | | 1.82 |
| Kebeles | Synthetic insecticides used (%) | Effectiveness | Low cost | twice | > twice | |
| Chali Jima | 17.6 | 11.70 | 5.90 | 9.15 | 8.45 | |
| Dambi Dima | 14.4 | 8.64 | 5.76 | 9.22 | 5.18 | |
| Darbes Gerado | 17.6 | 10.56 | 7.04 | 9.86 | 7.74 | |
| Sembo Kejo | 16.0 | 3.2 | 12.8 | 10.88 | 5.12 | |
| Tulu Sengota | 16.0 | 12.8 | 3.2 | 10.88 | 5.12 | |
| Overall | 81.60% | 46.9% | 34.70% | 49.98% | 31.60% | |

***Stored maize pest control methods other than synthetic insecticides***

In addition to synthetic insecticides, farmers in SSA use botanicals to manage insect pests (Ratto *et al*., 2022). This study found that 5.6% used plants such as *Croton macrostachyus and Lantana camara*, which were the most frequently mentioned. Crushed powder derived from the plants *C. macrostachyus* and *L. camara* suppresses maize weevils (Cosmas *et al*., 2018; Daniel Getahun and Mulatwa Wondimu, 2020). Plant powders repel adult weevils, resulting in high mortality rates in immature stages (Quellhorst *et al*., 2020). Sun drying, roofing, and regular cleaning were all adopted by 4% of farmers as cultural insect pest management strategies. According to Muez Berhe *et al*. (2022), some farmers use sun drying, up-roofing, and frequent cleaning of agricultural fields, which are common grain preservation practices in developing countries. About 2.4% of farmers employed no insect pest management techniques, and 6.4% employed a combination of the above management tactics (Figure 3).

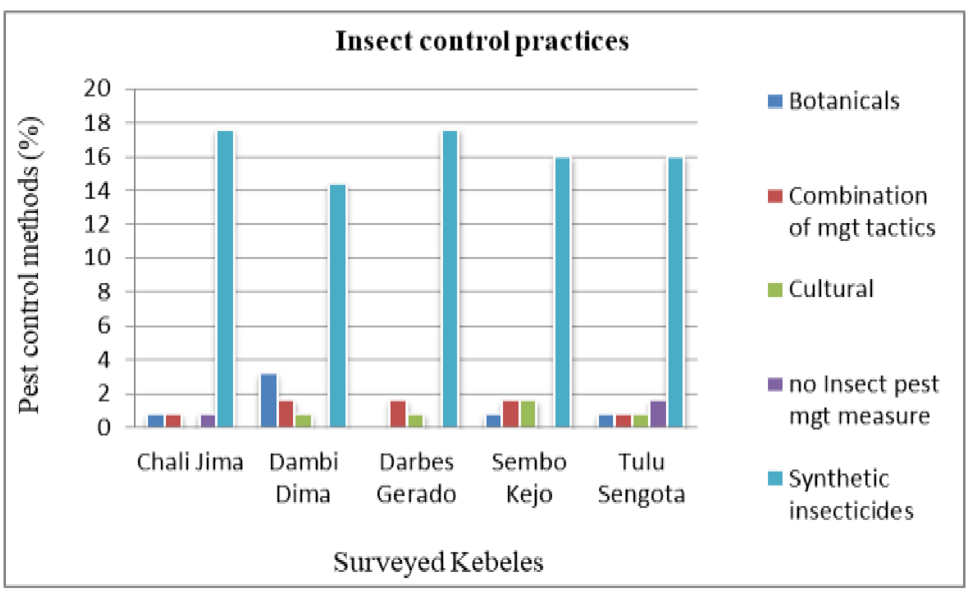


**Figure 3. Insect control practices in the study areas.**

## CONCLUSION

Farmers in western Ethiopia's Bako area of Oromia region prefer growing hybrid maize varieties, because it yields more grain and produces surplus grains for sale. However, their post-harvest handling practices lead to crop losses. We identified harvesting, threshing/winnowing, transportation, and storage as major losses. Farmers employed several strategies to minimize pest damage in storage. The strategies included synthetic insecticides, botanical treatments, and cultural methods. Overall, more than eighty percent of the sampled farmers applied synthetic insecticides. A rise in infestation levels in maize crops has led to an increase in synthetic insecticide use in recent years. This has resulted in more effective pest control, but also in the buildup of harmful chemicals in the environment. These issues can be resolved by developing sustainable pest control strategies. Use of plants having pesticidal property and smoke reduce pest populations and protect stored maize. However, their use as components of an Integrated Pest Management (IPM) approach requires further investigation due to the potential for smoke and plant residue to linger on the grain and affect its taste and smell.

The survey results will assist local governments in developing more effective pest management strategies. The main focus should be on IPM. This method outperforms single-method control strategies in terms of efficiency and longevity. This will help to control pest populations and reduce pesticide use.

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