Species Composition and Status of Stored Sorghum Pests in Traditional Farmer’s Storages of Kena District of Koso Zone, Southern Ethiopia

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Authors’ contributions

This work was carried out in collaboration between both authors. Author AG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author BH managed the analyses of the study, managed, corrected and approved overall designing of the study and write up the final manuscript. Both authors read and approved the final manuscript.

ABSTRACT

Aim: To determine the species composition and status pests of stored sorghum under traditional storages of farmers in Kenna district of Konso Zone of Southern Ethiopia.

Study Design: From peasant association, about three sub-localities were randomly selected and from each sub-locality, three villages were selected at random with using a nested design.

Place and Duration of Study: Survey was conducted between 1, August to 27, December 2019 in four major sorghum growing peasant association of Kenna district of Southern Ethiopia.

Methodology: The study on determination of the species composition and status pests of stored sorghum was made from of half kilogram of wheat grain sample taken from 720 stores of randomly selected representative farmer’s storages of four peasant associations using key of books related to stored product insects.

Results: Fifteen arthropods species consisting of twelve primary and secondary pests and three natural enemies belonging to four insect orders with in nine families were recorded. Of which, nine species such as S. zeamais, S. oryzae, S. cerealella, T. castaneum, T. confusum, C. ferrugineus,
C. pusillus, R. dominica and P. interpunctella, respectively were found to be the most abundant as they appeared between 3.47 and 19.44 individuals per 100 g of sampled grains. They were also found to be the most frequently occurring as they occurred in the range between 63.89 and 94.44% per 100 g of sample grain collected from survey site and had major pest status.

Conclusion: The traditional methods and practices used by farmers were inefficient for providing adequate protection of their stored sorghum grain pests. Therefore, there is urgent need for designing effective management strategies against insect pest’s sorghum as well as improving the existing farmer’s traditional storage strictures in the survey site in order to reduce the loss of stored sorghum by insect pests and the associated food insecurity.

Keywords: Arthropod pests; stored sorghum; species composition; status.

1. INTRODUCTION

Sorghum is the fourth most important world cereal, surpassed only by wheat, rice and maize in area of production. The United States is the world’s largest producer of sorghum, followed by India. The bulk of energy, protein, vitamins and minerals have been derived from sorghum by millions of poorest people in India as well as in the African countries [1]. Sorghum is an important source of food, feed, forage and industrial raw material worldwide [2]. It is mostly cultivated in semi-arid tropics where water is scarce and drought is frequent [3,4]. The crop is environment-friendly as it is water efficient, requires little or no fertilizers and biodegradable organic matter [5]. In many parts of the world, sorghum has traditionally been used in food products and various food items [6]. 50% of sorghum is grown directly for human consumption [5].

Ethiopia is the second largest sorghum producer in Africa, after Sudan. Sorghum is one of the major staple crops grown in the poorest and most food-insecure regions of Ethiopia [7]. Nationally it provides one third of the cereal diet and is grown almost entirely by the subsistence farmers [2]. The crop is typically produced under adverse conditions such as low input use and marginal lands [8].

Despite all the aforementioned significances, the production and storage of sorghum has been affected by a range of abiotic and biotic constraints. Among biotic constraints, insect pests are the most important one to cause significant loss of stored grains such as sorghum during storage in developing countries, including Ethiopia [9,10]. In addition, insect pests were indicted to be the most successful and diverse arthropods from animal kingdom that have been closely associated and affecting the wellbeing of human being in diverse ways [11,12]. Grain storage pests are major concerns for farmers worldwide but especially in developing countries like Ethiopia, as they account to large percentage (10-50%) of grains loss after harvest that could not be compensated [13,14].

Accordingly, in Ethiopia, food security has been more threatened by excessive post-harvest losses of grains such as sorghum caused by storage insect pests, at household and at a nation level [15]. A married of insect pests are indicated to causes loss of sorghum grain in storage. Among these pests, the principal causes of losses of stored grains such as sorghum are maize weevil and Angoumois grain moth [10,14,15,16].

Consequently, these days, safe grain storage and prevention of post-harvest losses grains due to insect pests has arisen to be more a necessity than ever, so as to overcome scarcity of grains among resource poor farmers as well as to fight malnutrition and famine in study area, in particular and Ethiopia in general. This is central to ensure food security poor farmers and to nourish the ever-increasing population of the country where more than 85% of the population earns its livelihood directly or indirectly from agriculture. Reducing losses of grains under farmers traditional storages, therefore, becomes fundamental not only from the standpoint of improving food security, but also from the requirement to store harvested grain on which farmers have spent their knowledge, finance, labor and time [17].

Therefore, reducing the post-harvest losses of stored grains like sorghum due to insect pest’s needs great attention by any concerned bodies such as researchers, policy makers, farming community and students at graduate level. Accordingly, the need for maintenance of the nutritive and other qualities of food grains through improved storage methods and/or
appropriate management strategies is unquestionable and timely.

To develop such improved facilities as well as design effective management strategies that could be easily adopted by farmers, assessing the current status of insect pests of stored grain like sorghum under farmer’s traditional storage condition is very vital and key step. Therefore the current study was designed with the objective of determining the species composition and status arthropod pests of stored sorghum under traditional storages of farmers in Kenna district of Konso Zone of Southern Ethiopia.

2. MATERIALS AND METHODS

2.1 The Study Area and Period

Survey was conducted in four major sorghum growing kebeles or peasant associations (PAs) of Kenna Districts of the Konso Zone (Fig. 1). The kebeles or peasant associations (PAs) are namely Fasha, Debeno, Buso and Fuchucha kebeles of Kenna district in the Zone. Survey was conducted between 1, August to 27, December 2019. Besides, sorghum grains stored for 12 months under farmers traditional storages of pervious year (1 December 2018–30 December 2019) were also considered for this study.

2.2 The Study Design and Sampling Protocol

From each kebele (peasant association), about three sub-localities were randomly selected and from each sub-locality, three villages were selected at random with the assistance of the Ministry of Agriculture (MOA) sub-kebele staff using a nested design as adopted by earlier researchers [14,16]. Kebeles were selected purposefully based on abundance of sorghum
production, such that all villages of the kebeles growing sorghum were selected for the survey, while villages, representative farmers and their storages were selected randomly.

2.3 Determination of the Species Composition and Status of Arthropod Pests of Stored Sorghum under Farmer’s Traditional Storages

Half kilogram of sorghum grain was sampled from each stores (a total of 720 stores; two store from each villages of 360 randomly selected villages of four PAs were considered) using a nested design, such that District was nested under Zones and Kebeles were nested under District, and sampling stores were nested under Kebeles. Kebeles, District and Zone were purposively selected, while selection of villages and sampling stores were done randomly as indicated in section 2.2 as adopted by previous researchers [14,16]. The samples were taken from top, sides, center and bottom of the storage structures using different sampling tools such as sampling spear, sampling scoop and human hands among others. Samples taken from different positions of the stores were thoroughly mixed and half kg was taken as a final working sample.

Each sample at each sampling date from the different storage methods at each villages of the sampling site was collected in sampling bag, labeled with necessary information and kept for further identification of insect pests. The samples at each sampling date from the different farmers’ traditional storage structures of each villages of each PAS were sub sampled further after thoroughly mixing them to come up with a standard of 100 g sample.

The sub sample from stores of each village of each PAS was sieved (using sieves of different size) for separating the adult insects from the sample grains in Entomology laboratory of Arba Minch University. Alive and dead insects from samples of farmer’s traditional methods were collected and immediately preserved in 100 ml capacity bottles or plastic jars and kept for further identification. The subsampled grains were also putted in 1 L glass jars and kept under laboratory conditions (27±3°C and 55-70% RH) to determine species from internal infestation.

The procedures and keys of the books related with stored product insect pests and other arthropods by different authors [18,19,20,21,22,23] were used for identification purpose. Then after, insects were sorted according to their orders, families and species, and counted for each subsample grains from each of different farmer’s traditional storage methods in each case noting the number.

The status insect pests of stored sorghum were determined using the formulas indicated below [24]. The average of the sum total of species of arthropods (insect pests) collected from sub-samples from each village each PAS was used to determine the status of insect pests. For assessing pest’s infestations, the main variables have been included abundance, relative abundance and Constance (frequency) of species found in samples as suggested by previous scientist [24]. Abundance refers to the total number individuals of a species divided by the total number of samples (in this case the total number of kilograms) and it is expressed

$$\text{Abundance of species} = \frac{\text{Total number of individuals of species}}{\text{Total number of samples}}$$

The relative abundance of species is calculated as the following formula:

$$\text{Relative Abundance of species} = \frac{\text{Number of individuals of a species}}{\text{Total number of observed individuals}} \times 100$$

Constance (frequency) expresses the percentage of species occurrence. It is obtained by the following formula.

$$\text{Constance of species} = \frac{\text{Number of samples in which the species occurred}}{\text{Total number of sample}} \times 100$$

2.4 Data Analysis

Data collected from survey were managed and performed using Microsoft Excel version 2013 and Statistical Package for Social Sciences (SPSS) version 16. Descriptive statistics (mean and percentage) were used for compiling and computing data on the species composition and status of insect pests of stored sorghum under farmer’s traditional storage conditions. Significant difference between Means separated by Tukey’s honestly significant difference (THSD) test at 95% confidence interval level.
3. RESULTS AND DISCUSSION

3.1 The Species Composition and Status of Arthropod Pests of Stored Sorghum in Kena District

Tables 1 and 2 revealed the various categories of insects and mites recorded on sorghum grain stored in different storage structures of Kena district. Accordingly, fifteen arthropods species consisting of twelve primary and secondary pests and three natural enemies belonging to four insect orders with in nine families were recorded. Among these arthropod species identified from farmers traditional storages, nine species such as S. zeamais, S. oryzae, S. cerealella, T. castaneum, T. confusum, C. ferrugineus, C. pusillus, R. dominica and P. interpunctella, respectively were found to be the most abundant as they appeared between 3.47 and 19.44 individuals per 100 g of sampled grains. They were also found to be the most frequently occurring as they occurred in the range between 63.89 and 94.44% per 100 g of sample grain collected from survey site and had major pest status.

Following the aforementioned nine species, other similar species of Tribolium (non-specified or not distinguished), Anisopteromalus calandrae, Cynaeus angustus, Cephalonomia species and Pteromalus species, respectively were found to be the next abundant and the next frequently occurring as they appeared in between 1.19 and 1.58 individuals per 100 g of sampled grains and as they occurred in between 30.56% & 44.44%, respectively per 100 g of sample grain collected from farmers stores of the study area and were intermediate insect pests. However, Acarus siro was found to be the least abundant and the least frequently appearing as they occurred in < 1 individuals per 100 g of the sampled grain (in average) and as they appeared in < 22.5% per 100 g sample grain, respectively (Table 1).

Generally, in terms of abundance, relative abundance, frequency of occurrence and status (economic importance), the 15 arthropod species were found to be in the following orders, i.e., S. zeamais > S. oryzae > S. cerealella > T. castaneum > T. confusum > C. ferrugineus > C. pusillus > R. dominica > P. interpunctella > other similar species of Tribolium > Anisopteromalus calandrae > Cynaeus angustus > Cephalonomia species > Pteromalus species > Acarus siro.

The current study regarding abundance, frequency of occurrence and economic importance of the aforementioned pests justifies the actual knowledge of ecology and high economic importance of these insect pests, which is in agreement with study findings several authors [18-23] which indicated that these are cosmopolitan pests in the world.

Similarly, it was also reported that Sitophilus zeamais, Sitotroga cerealellam Tribolium castenun,Cryptolestes feruginus and Oryzaephilus surinamensis were recorded from farmers Traditional Underground Pit sorghum Grain Storages in Eastern Ethiopia [13]. It was also revealed that a total of six species belonging to three different orders i.e. Coleoptera, Lepidoptera and Hymenoptera were recorded sorghum storages in Dera Ismail Khan and its adjacent Punjab province areas. Of which the maize weevil (Sitophilus zeamais) was the most abundant species, followed by confused flour beetle (Tribolium confusum), Angoumois grain moth (Sitotroga cerealella), (Rhizopertha dominica) and rice weevil (S. oryzae) [25]. In similar manner, it was also reported that 37 species of arthropods associated with stored maize grain were recorded in Ethiopia. Among which Coleopteran Sitophilus sp., Tribolium sp., Cryptolestes sp., and Carphophilus sp. and Lepidopteran Sitotroga cerealella, Plodia interpunctella and Ephesia cautella were indicated to be widespread and common [26]. It was also shown that maize in storage has been attacked by numerous Coleopterous and Lepidopterous insect pests [16].

Most of the pest species (8 species out of 15) (Table 2) identified and recorded in the present study were from the order of Coleoptera (beetles) which implies great economic importance of beetles in grain storages than moths and mites, which is in agreement with reports previous researchers [27,28], in which beetles were shown to be the more diversified and highly destructive than moths, among post-harvest pests.

The classification of arthropods species in to nine primary and secondary pests, twelve primary and secondary pests and three natural enemies in the present study, is in accordance with the works or reports of previous scientists [18-23].

Three species (Anisopteromalus calandrae, Cephalonomia species and Pteromalus species) out of 15 arthropods recorded were natural enemies, and they were commonly occurring and
### Table 1. The species composition and status of arthropod pests of stored sorghum in Kena district

<table>
<thead>
<tr>
<th>Species of pest</th>
<th>Total number of adult insect</th>
<th>Abundance (Average no. insects/100 g of grain sample)</th>
<th>Relative abundance (%)</th>
<th>Frequency (% of samples containing each species)</th>
<th>status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitophilus oryzae</td>
<td>670</td>
<td>18.61</td>
<td>15.65</td>
<td>94.44</td>
<td>Major</td>
</tr>
<tr>
<td>Sitophilus zeamais</td>
<td>700</td>
<td>19.44</td>
<td>16.35</td>
<td>97.22</td>
<td>Major</td>
</tr>
<tr>
<td>Tribolium castaneum</td>
<td>575</td>
<td>15.97</td>
<td>13.43</td>
<td>83.33</td>
<td>Major</td>
</tr>
<tr>
<td>Tribolium confusum</td>
<td>567</td>
<td>15.75</td>
<td>13.24</td>
<td>80.56</td>
<td>Major</td>
</tr>
<tr>
<td>Other similar species of Tribolium</td>
<td>78</td>
<td>2.17</td>
<td>1.82</td>
<td>38.89</td>
<td>Inter</td>
</tr>
<tr>
<td>Cryptolestes ferrugineus</td>
<td>300</td>
<td>8.33</td>
<td>7.01</td>
<td>72.22</td>
<td>Major</td>
</tr>
<tr>
<td>Cryptolestes pusillus</td>
<td>246</td>
<td>6.83</td>
<td>5.74</td>
<td>66.67</td>
<td>Major</td>
</tr>
<tr>
<td>Rhyzopertha dominica</td>
<td>154</td>
<td>4.27</td>
<td>3.6</td>
<td>58.33</td>
<td>Major</td>
</tr>
<tr>
<td>Sitotroga cerealella</td>
<td>630</td>
<td>17.5</td>
<td>14.71</td>
<td>91.67</td>
<td>Major</td>
</tr>
<tr>
<td>Plodia interpunctella</td>
<td>125</td>
<td>3.47</td>
<td>2.92</td>
<td>63.89</td>
<td>Major</td>
</tr>
<tr>
<td>Anisopteromalus calandrae</td>
<td>67</td>
<td>1.86</td>
<td>1.56</td>
<td>44.44</td>
<td>Inter</td>
</tr>
<tr>
<td>Acarus siro</td>
<td>25</td>
<td>0.42</td>
<td>0.35</td>
<td>22.20</td>
<td>Minor</td>
</tr>
<tr>
<td>Cynaeus angustus</td>
<td>45</td>
<td>1.25</td>
<td>1.05</td>
<td>36.11</td>
<td>Inter</td>
</tr>
<tr>
<td>Cephalonomia species</td>
<td>57</td>
<td>1.58</td>
<td>1.33</td>
<td>41.67</td>
<td>Inter</td>
</tr>
<tr>
<td>Pteromalus species</td>
<td>43</td>
<td>1.47</td>
<td>1.24</td>
<td>30.56</td>
<td>Inter</td>
</tr>
<tr>
<td>Total</td>
<td>4282</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Inter = intermediate*
Table 2. Taxonomic position of arthropod pests recorded from stored sorghum in Kena district

<table>
<thead>
<tr>
<th>Scientific name of pest species</th>
<th>Order</th>
<th>Family</th>
<th>Common name</th>
<th>Pest type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitophilus oryzae</td>
<td>Coleoptera</td>
<td>Curculionidae</td>
<td>Rice weevil</td>
<td>Primary</td>
</tr>
<tr>
<td>Sitophilus zeamais</td>
<td>Coleoptera</td>
<td>Curculionidae</td>
<td>Maize weevil</td>
<td>Primary</td>
</tr>
<tr>
<td>Tribolium castaneum</td>
<td>Coleoptera</td>
<td>Tenebrionidae</td>
<td>Red flour beetle</td>
<td>Secondary</td>
</tr>
<tr>
<td>Tribolium confusum</td>
<td>Coleoptera</td>
<td>Tenebrionidae</td>
<td>Confused flour beetle</td>
<td>Secondary</td>
</tr>
<tr>
<td>Other similar species of Tribolium</td>
<td>Coleoptera</td>
<td>Tenebrionidae</td>
<td>Flour beetles</td>
<td>Secondary</td>
</tr>
<tr>
<td>Cryptolestes ferrugineus</td>
<td>Coleoptera</td>
<td>Cucujidae</td>
<td>Flat grain beetles</td>
<td>Secondary</td>
</tr>
<tr>
<td>Cryptolestes pusillus</td>
<td>Coleoptera</td>
<td>Cucujidae</td>
<td>Merchant grain beetles</td>
<td>Secondary</td>
</tr>
<tr>
<td>Rhyzopertha dominica</td>
<td>Coleoptera</td>
<td>Bostrichidae</td>
<td>Lesser grain borer</td>
<td>Primary</td>
</tr>
<tr>
<td>Sitotroga cerealella</td>
<td>Lepidoptera</td>
<td>Gelechiidae</td>
<td>Angoumois grain moth</td>
<td>Primary</td>
</tr>
<tr>
<td>Plodia interpunctella</td>
<td>Lepidoptera</td>
<td>Pyralidae</td>
<td>Indian meal moth</td>
<td>Secondary</td>
</tr>
<tr>
<td>Anisopteromalus calandrae</td>
<td>Hymenoptera</td>
<td>Pteromalidae</td>
<td>Pteromalid wasp</td>
<td>Parasitoid</td>
</tr>
<tr>
<td>Acarus siro</td>
<td>Acarina</td>
<td>Acaridae</td>
<td>Grain or flour mite</td>
<td>Secondary</td>
</tr>
<tr>
<td>Cynaeus angustus</td>
<td>Coleoptera</td>
<td>Tenebrionidae e</td>
<td>Larger black flour beetle</td>
<td>Secondary</td>
</tr>
<tr>
<td>Cephalonomia species</td>
<td>Hymenoptera</td>
<td>Bethylidae</td>
<td>Pteromalid wasp</td>
<td>Parasitoid</td>
</tr>
<tr>
<td>Pteromalus species</td>
<td>Hymenoptera</td>
<td>Pteromalidae</td>
<td>Pteromalid wasp</td>
<td>Parasitoid</td>
</tr>
</tbody>
</table>
had intermediate status in the current study, suggest the presence of possibility of using these natural enemies (predators & parasitoids) as safe pest management alternative to synthetic chemicals in storage ecosystem. Similarly, it was shown that the existence of considerable individuals of parasitoids and predators in stored maize were indications for the possibility of their use in stored grain insect pest management [29].

4. CONCLUSION

Fifteen arthropods species consisting of twelve primary and secondary pests and three natural enemies belonging to four insect orders with in nine families were recorded in present study. Of these arthropod species recorded, S. cerealella, T. castaneum, T. confusum, C. ferrugineus, C. pusillus, R. dominica and P. interpunctella species, respectively, followed by Tribolium species, Anisopteromalus calandrae, Cynaeus angustus, Cephalonomia species and Pteromalus species were the most abundant and important pests that were responsible for significant loss of stored sorghum in the study area.

As a result, the traditional methods and practices used by farmers were inefficient for providing adequate protection of their stored sorghum grains insect pests. Therefore, there is urgent need for designing effective management strategies against insect pest’s sorghum as well as improving the existing farmer’s traditional storage strictures in the survey site so as to reduce the loss of stored sorghum by insect pests and the associated food insecurity. Besides, provision of training to farmers and extension workers on safe handling of grains and management of insect pests of stored sorghum under farmer’s traditional storage conditions are urgently needed by any concerned bodies.

The three species (Anisopteromalus calandrae, Cephalonomia species and Pteromalus species) of natural enemies recorded in the current study confirmed the presence of possibility of using these natural enemies as safe pest management alternative to synthetic chemicals in storage ecosystem. The current study also confirmed that the great economic importance of beetles in traditional farmers grain storages than moths and mites.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Annex 1. Partial views of pictures of arthropods recorded from stored sorghum grains of farmer’s storages of Kena district of Konso zone during identification in Entomology laboratory of Arba Minch University

- Cryptolestes pusillus
- Tribolium confusum
- Rhizopertha domina
- Sitophilus oryzae
- Plodia interpunctella
- Sitotroga cerealella
- Anisopteromalus calandrae
- Pteromalus sp.
- Cephalonomia sp.
Acarus siro  Oryzaephilus surinamensis  Cynaeus angustus

a. Tribolium castaneum  b. Tribolium castaneum  c. Tribolium castaneum

a, b and c: Other similar species of Tribolium