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# A survey of systems of grain storage and management of insect pests in stored grain in Kebbi state

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***Abstract:*** *Grain storage losses due to insect pests threaten the livelihood of small-scale farmers in Kebbi state. The farmers various methods of grain protection are in adequate in providing good protection from pest damage, however, when improved might provide a better protection. A survey of 240 famers was conducted in three regions (Central, North and South) of Kebbi state to increase understanding of various methods employ by farmers to protect their important grain from damage by insect pests. Of all the grain, sorghum was stored in greater quantity (4,000 kilos/household, $p<0.001$) than other grains and a majority in south Kebbi stored sorghum threshed ($p<0.001$), even though this form is more vulnerable to infestation. The methods of storage practice by the respondents varied between the regions which affect the types of insects found. Tribolium castaneum and Rhyzopertha dominica were found as the major pest mentioned by almost all respondents in all the regions. Over 40% of the respondents from both north and central, and 20% from the South regions used synthetic pesticide as control measures. Over 30% of respondents from the South and 12% and 17% from the North and Central regions respectively use pesticidal plants, where Ocimum basilicum was the most frequently mentioned. That farmers use pesticidal plants indicates the prospect for improving pesticidal plants. This study highlights opportunity for improving and enhancing the value of pesticidal plant for use as grain protectants for small-scale farmers.*
***Key words:*** *Insects, Grain storage, Pesticidal plants, Survey*

## I. Introduction

Cereal grain such as sorghum has been an important food of small- scale farmers in Kebbi state, where after harvest more than 70% of the grain is stored in their various traditional storage structures, which is used to satisfy their immediate or feature food and other socio-economic needs throughout the rest of the year [1]. Grain storage on farms thus plays an important role in ensuring food security for local populations. However, high post-harvest losses due to insect pests and inadequate storage facilities are the main setback in realising this benefit [2]; [1]. However, no record of previous surveys have been published for Kebbi state to establish how methods of grain storage affect their grains, to identify the major pest species affecting stored grain, to estimate the extent of relative damage by the main insect pests or to characterise how farmers respond to grain storage losses. This study presents a survey of farmers conducted in three geo-political zones of the state (Kebbi North, South and Central). A farmer survey is a valuable tool for gaining an overview of the problems associated with preserving harvested grain, both during pre-storage processing and during the period of storage, as well as giving an insight into the socioeconomic situations of the communities investigated. The information gathered has been analysed to give a picture of the main storage problems. This information will be useful in providing a base for developing a new approach to controlling storage pests that is appropriate and effective for small-scale farmers in Kebbi State.
The aim of the survey was to gain a greater understanding of:
* The type of grain that small-scale farmers in Kebbi store most.
*Methods of grain storage used and how these affect the amount of insect pests and relative damage caused.
* How farmers respond to the insect problems and how they view the effectiveness of the methods they used to control the storage pests.

## II. Methodology

### 2.1 Study area

Socio-economic surveys and grain sampling surveys were carried out in June and August, 2011. At this time of year farmers are engaged in grain storage activities. The survey was carried out in three regions of Kebbi state: Kebbi South, Kebbi Central and Kebbi North. Four districts were selected in each region, with two villages each district, for a total of 24 villages, as follows:
**Kebbi South:** Danko-wasagu district (Villages selected: Wasagu, Tudun bichi), Bedi (Bedi, Tungandoro), Birnin-Yauri (Kimo, Makirin) and Shanga (Saminaka, Tungangiwa);

**Kebbi Central:** Bese district (Villages selected: Dogon-Karfe, Bashe), Mungadi (Gunbinkure, Sabonsara), Basaura (Kyande, Kangiwa), Kalgo (Bagarza, Langido);
**Kebbi north:** Gulma district (Villages selected: Bagaye, Lailaba), Alwasa (Sawa, Kaura), Kangiwa (Falde, Sabogari), Bayawa (Tigi, Kwaido). The location of these villages is given in Figure1.

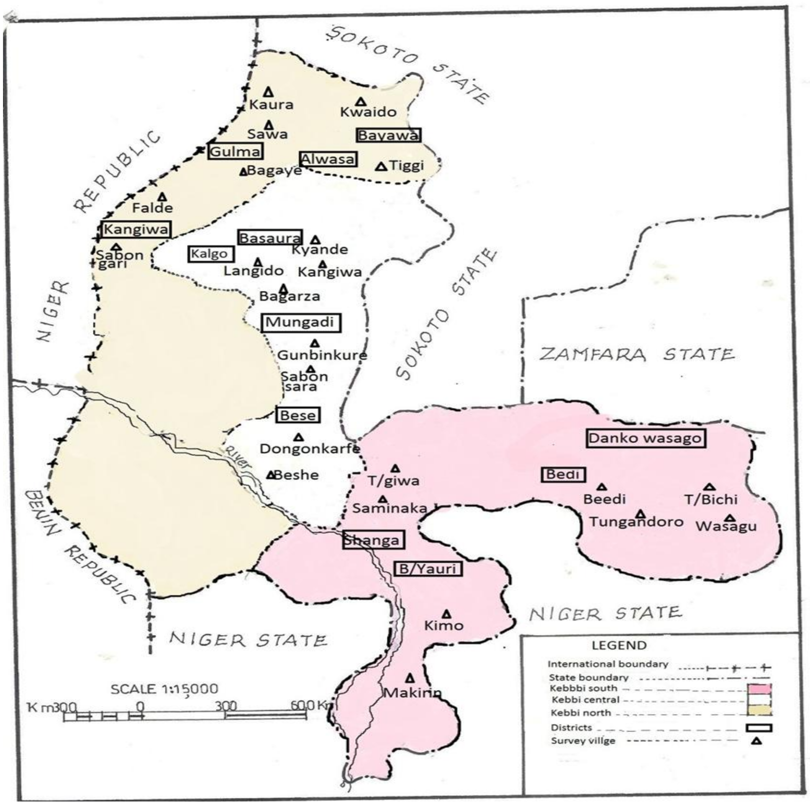

Figure 1 Map of Kebbi state showing districts and survey villages

**2.2 Survey methodology**
**Data collection**

The relevant information was collected using a structured questionnaire, which was personally administered by the author to 240 farmers, ten from each of the 24 villages between July and October, 2012. Hausa, the local language, was used to interview all the respondents in their villages. The questionnaire was designed to collect information about farmers' perceptions of problems associated with stored grain insect pests, the types of insect species damaging their grain, the quantity of grain typically stored, the amount of loss due to stored insect pests, the maximum period of insect pest attack, the type of storage structure used and pest management practiced. In addition, socio-economic information, such as the respondent's sex, family size, farm size, age and educational level were collected. A poster (NRI, Insects in a tropical store) containing images of different types of storage insects were presented to the respondents to help in identifying the type of insect pest species in their stores. The data obtained were summarized using simple percentages and, where necessary, subjected to statistically analysis as outlined in Section 3.3.

**Village sampling**

A purposive stratified sampling method was used to obtain a representative sample, whereby two villages were chosen from each of eight districts in each of the three regions. Village agricultural extension agents in each district provided a list of villages that grew and stored grain. Two villages were selected at random from the list for each district (See map, Fig..1).

**Respondent selection**

Wealth ranking, following the method of Hodges (2005) was used to identify sub-samples of farmers to be interviewed. Ten households, including both male and female heads of household, were chosen, to make a total of 240 farmers for the study as a whole.

## III. Statistical Analysis

Data from the questionnaires were summarized in cross-classifying responses, such as levels of infestations against region, or method of storage and storage structures against level of infestations sampled. The Chi-square test of independence was used to test for significant differences between the variables. The test was run using the R statistical software package (version 2.10.0) [3].

## IV. Results

### 4.1 Socio-economic characteristics of the farmers in the surveyed area

Table 1 shows the educational background, age, occupation, family size and farm size of the respondents in the surveyed area. The majority of the respondents (97%) were male household heads. The low number of female respondents could be due to the procedure used for selection of respondents, as only the head of a household was interviewed. [4] reported that in northern Nigeria female heads of household are rare. In the survey area women are mostly confined to the domestic area, where their main responsibility is cooking and taking care of the young. It is the responsibility of a male head of the household in the area surveyed to procure and manage grain when needed by women for cooking, with the exception of widows who manage their own grain supplies. However, this does not mean that women do not take part in post-harvest operations; the preparation of grain for storage by threshing and winnowing is undertaken by women. In northern Nigeria, women's participation in agricultural activity is very low, (~16 %), and focuses mainly on post-harvest activities [5]. This is related to religious and cultural norms, prevalent among the Hausa-Fulani Muslim community across the north [6].

The majority of the respondents had no formal education (~68%), with relatively few having attended primary or secondary school (Table 1). The mean age of the respondents was 42 years. The majority of the respondents (~82%) considered farming as their main occupation, followed by those whose main occupation is trading. A very small percentage considered their paid job (civil servant) to be their main occupation. This indicates that agriculture is the main livelihood of the people surveyed.

The mean family size of the respondents was relatively large (> 13.4) which is reflected in the mean farmland holding size, which must be big enough to support the family with enough food. The majority of the respondents (~ 90 %) possessed their own farmland and very few borrowed (~ 8%) or rented land (~ 2%). The majority of the farmers (~ 64%) sourced their seed from their previous harvest, ~20% purchased seed from an open market, ~12% sourced seed from friends and only ~ 4% sourced seed from the government (KARDA).

**Table 1 Socio-economic background of respondents**

The percentage (%) or mean and standard deviation (St Dev) for some of the socio-economic variables derived from the questionnaire data. Total sample size (N) = 240 farmers.

| Variable | Mean | St Dev |
|---|---|---|
| Age (year) | 42.3 | 11.6 |
| Farm size (ha) | 4.7 | 2.3 |
| Family size | 13.4 | 7.5 |
| Occupation (%): | | |
| Farming | 82.5 | |
| Trading/farming | 12.5 | |
| Civil servant/farming | 5.0 | |
| Education (%): | | |
| Non-formal | 68.3 | |
| Primary | 17.9 | |
| Secondary | 12.9 | |
| Tertiary | 0.8 | |

Figure 2 shows that the age distribution of the respondents within the different regions was quite similar, and followed a normal distribution. The majority of the respondents in the north were in the 41-50 and 51-60 age categories, whereas in the south and central region the majority was in the 41-50 age range. The proportion of respondents in all regions in the 20-30 age range and over 70 years was minimal. The difference in age of all respondents in the different regions and age categories was found not to be significant ($\chi^2$ =7.4, df=10, p<0.6843).

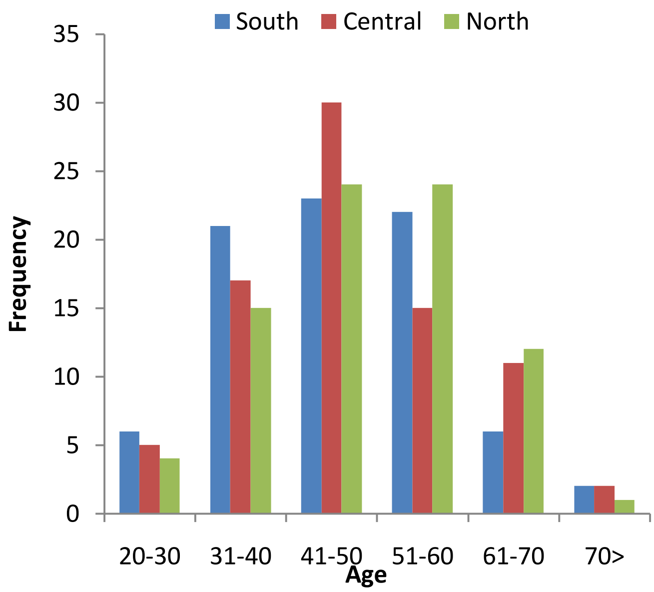


**Figure 2 Frequency distribution of respondents by age in the different regions (N = 240 farmers, 80 farmers per region).** There was no difference in the age of respondents in each age category between the regions ($\chi^2$ =7.4, df=10, p=0.6843).

**4.2 Types of grain grown and stored by farmers surveyed**

The respondents listed sorghum, millet, maize and rice (in rank order, highest to lowest) as the major cereal grains grown and stored. The time at which farmers in the surveyed area harvest and store their grain varies by crop and region.

Table 2 shows that the proportion of farmers that grew and stored a given type of grain varied between grain types and regions. More farmers in the north grew and stored a combination of millet plus sorghum than in the central or south regions. More farmers in the southern region grew and stored sorghum and millet alone. Similar proportions of farmers grew and stored maize plus millet in the south and north with greatest proportion in the central. As similar pattern was true for maize grown on its own in all the regions; more farmers in the south grew and stored maize than in the central or north regions and the range of proportions between regions was least for this type of grain. The chi-square test of independence confirmed that for the results given in Table 2, there was a significant difference in the proportion of farmers that grew and stored each grain type in the three regions ($\chi^2$= 44.7, df = 8, p < 0.0001).

**4.3 Method processing of grain for storage, duration of drying and levels of infestation**

Response of farmers regarding processing of grain for storage: Respondents stored their grain in both threshed (sorghum and maize) and un-threshed (sorghum, millet and maize) forms. Overall, a large proportion of respondents (56%) stored their grain un-threshed, with higher proportions of farmers practicing this form of storage in the north and central regions (Table 3). The remaining farmers (44%) stored their grain in the threshed form, with a high proportion in the south and similar proportions in the central and north regions. The differences between choice of form of storage and location were significantly different ($\chi^2$ = 31.391, df = 2, p < 0.00002). Most farmers (45%) mentioned reduced insect pest damage as their reason for using the unthreshed form for storage, followed by economic reasons (37%), and easy to handle (19%). For those that stored threshed, 89% mentioned easy bagging and handling as their reason, while 11% mentioned reduced insect infestation.

Table 4 shows that a greater proportion of the respondents said that un-threshed grain had low levels of infestation, compared to the respondents reporting threshed grain to have low levels of infestation. It is interesting to note that even though unthreshed grain had lower infestation levels, a majority of farmers stored their grain in the threshed form. It would be interesting to know why they do this, because they could reduce losses by simply leaving their grain unthreshed. This is worth future investigation. Similarly, the proportion of respondents who stored threshed grain reported high levels of infestation, which was higher than for those storing un-threshed grain. Only a few of the respondents using un-threshed and threshed grain, respectively, reported no infestation. The difference in levels of infestation between the forms of storage was statistically significant ($\chi^2$ = 11.1574, df = 3, p < 0.0109).

**4.4 Farmers' perspective on storage practices and storage structures**

***Response of farmers on choice of storage structures:*** The granaries used by farmers in the three regions generally measure 7.9 – 35.4 $m^3$ and are made of mud and wood with a thatched roof. Stones are used to raise the floor above the ground for aeration and rat control. Some have side openings (hatches) to provide access to the stored grain, while others are windowless with access to the grain only from the top of the structure. Grain is stored either loose or in bags. The second most frequently used storage structure is a storeroom within the main dwelling, which is made of mud with a thatch or zinc roof. Storerooms are generally used to store grain and other types of food and domestic belongings. Unlike granaries, the floor of a store room is not raised above the ground. Grain is generally stored in storeroom either loose or in bags which are loaded into, and emptied out, of the room through a small door. The bags used for storage hold 60 kg of grain, and are made from woven polyethylene strips.

The results in Fig. 3 indicate that farmers often use more than one type of structure to store their grain. The users of the different structures were evenly distributed between regions. For instance it indicates that <35% of respondents use each of the two structures in each region, except for storeroom that have a greater proportion of users (>40) in the south). However, the difference between the high proportion of farmers that used rooms in the south and other regions was not significant ($\chi^2 = 4.238$, df = 3, $p > 0.375$).

Farmers mentioned different reasons for choosing particular storage structures. The majority of farmers (64%) using granaries mentioned reduction in insect damage as their reason for choosing granaries, followed by better control of how grain is used (22%), because they inherited the granaries (9%), and ease of storage (4%). Of farmers that chose rooms for storage, 39% reported ease of storage, followed by 'had no access to a granary' (32%) and rooms can accommodate more grain (20%) and reduced insect infestation (9%).

**Table 2 Relative distribution of the amount of grain stored in each region by grain type**

| | Percentage of respondents in each category | | | | | |
|---|---|---|---|---|---|---|
| | maize | sorghum | millet | maize/millet | sorghum/millet | Total |
| South | 8.8 | 37.5 | 20.0 | 18.8 | 15.0 | 100 |
| Central | 5.0 | 13.8 | 26.3 | 31.2 | 23.7 | 100 |
| North | 1.3 | 13.8 | 6.2 | 21.3 | 57.5 | 100 |

**Table 3 Proportion of farmers using different methods of preparing grain for storage in different regions**

| | Threshed | Un-threshed | Total |
|---|---|---|---|
| South | 68.7 | 31.3 | 100 |
| Central | 35.0 | 65.0 | 100 |
| North | 27.5 | 72.5 | 100 |

**Table 4 Comparison of methods of processing grain for storage and level of infestation during storage**

| | Percentage of respondents in each category<br>Level of infestation | | | | |
|---|---|---|---|---|---|
| | None | Low | Medium | High | Total |
| Threshed | 10 | 24 | 30 | 36 | 100 |
| Unthreshed | 13 | 53 | 23 | 11 | 100 |

**Table 5 Percentage of insect species farmers observed in their grain stores according to the type of storage structures used**

| Percentage of respondents reporting different number of insects species in their store | | | | | | | |
|---|---|---|---|---|---|---|---|
| Number of insect species | | | | | | | |
| | 0 | 1 | 2 | 3 | 4 | 5 | Total |
| Granary | 48.6 | 31.1 | 0.0 | 13.5 | 5.4 | 1.3 | 100 |
| Room | 13.0 | 39.7 | 6.0 | 24.5 | 13.4 | 3.6 | 100 |

**Table 6 Percentage of all respondents within a region that used a particular form of insect control**

| Percentage of farmers using each control method | | | | | |
|---|---|---|---|---|---|
| Control method | None | Chemical | Botanical | *Chm/bot | Total |
| South | 37.3 | 20.0 | 30.2 | 12.5 | 100 |
| Central | 28.8 | 45.0 | 17.5 | 8.7 | 100 |
| North | 35.0 | 43.2 | 12.0 | 10.0 | 100 |

***Chm/bot indicates a combination of chemicals and botanicals**

**Table 7 Distribution of respondents according to infestation level and control method used**

| Percentage of farmers reporting infestation level in each control method | | | | |
|---|---|---|---|---|
| | None | Chemical | Botanical | Chm/bot |
| Infestation level | | | | |
| None | 21.4 | 27.6 | 30.3 | 20.0 |
| Low | 21.4 | 50.0 | 39.4 | 36.0 |
| Medium | 27.1 | 6.3 | 6.1 | 36.0 |
| High | 30.0 | 16.1 | 24.2 | 8.0 |
| Total | 100 | 100 | 100 | 100 |

*Duration of storage and its effect on levels of infestation:* The majority of farmers in all the areas surveyed begin to fill in their stores with grain in December- January, and store for as long as one year, depending on the farmer's circumstances. The majority (67%) gave 'home consumption' as their main reason for storing grain, and 22% gave 'trading' as their main reason. Only 11% combined both consumption and trading as their main reason for storing grain. In all regions, most respondents stored their grain for seven months; 73%, in the north, 45% in the central and 38% in the south (Fig. 4). Some respondents stored grain for up to a year: 30% in the south, 25% in the central and only 8% in the north. In all regions, very few of the respondents stored grain for only 4 months. There was a significant difference between the time of storage and different locations ($\chi^2$ = 33.569, df = 6, p < 0.0001). This appears to be due mainly to farmers in the north who tend to store their grain for only 7 months, whereas in the central and south regions there is a tendency for equal proportions of farmers to store their grain for 7, 10 and 12 months.

Most respondents reported highest levels of infestation occurring in grain stored for 7 months, followed by grain stored for up to 10 months (Fig. 5). Grain that had been stored for 4 months had the lowest levels of infestations (none + low). The highest proportion of respondents that reported infestations in grain stored for one year had only medium levels of infestation. The data also suggest that if grain is stored well, it can be kept for one year with only medium levels of infestation developing. According to chi-square test of independence there was highly significant correlation of storage duration and level of infestations ($\chi^2$ = 91.74, df = 9, p < 0.00002).

4.5 Farmers' perspectives on insect pest identification and levels of infestation in stored grain

Farmers were able to identify some of the insects that were found in their stores using the NRI poster showing different types of storage insects. However, those with moth infestations could not identify which type of moth was found in their stores and did not know moths produce larvae that also cause grain losses. However 52% of respondents were able to identify *Tribolium castaneum* (Herbst) (Coleoptera: Tenobrionidae) and *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae) as the pest found in their store using the poster; and 26% identified *Sitophilus zeamais* (Motsculski) (Coleoptera: Curculionidae), 16% identified *Lasioderma serricorne* (Fabricius) (Coleoptera: Anobiidae) and 6% indentified *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae) in their grain. Table 5 shows that number of insect species varied by the storage structure used. The greatest percentage of farmers reporting no insect infestations was those using granaries (~49%), while only 13% of farmers using rooms had no infestations. A relatively high percentage of farmers using room (~47%) reported three, four or five insect species in their grain, while only ~20% using granaries reported more than three insect species. Overall, there was a significant difference between the number of insect species reported and types of storage structures used by the farmers. ($\chi^2$ = 19.4826, df = 10, p < 0.03454).

The results in Fig. 6 show that there was a significant difference between the regions in level of damage by insect pests ($\chi^2$ =16.6847, df=6, p<0.01051). Overall, a relatively high proportion of respondents (> 40%) reported medium or high levels of damage, especially in the south (~48%).

4.5 Farmers' perspective on pest management practices

In all the surveyed regions, farmers used a variety of pest control methods, including synthetic chemical products (permethrin, cypermethrin, organophosphorus, phostoxin and Gamalin 20), botanicals (*Ocimum basilicum*, *Erythropleum guineeses*; wood ash mixed with pepper (*Capsicum frutescens*), *Nuclea diderrichii* dried flowers from tamarind (*Tamarindus indicus*) and *Vernonia amygdalina),* while some used no insect control measures at all.

Table 6 shows that there was a significant difference between the regions and the control methods used ($\chi^2$ = 19.7713, df=6, p<0.034). The most frequently used methods of insect control in each region were either the application of chemical pesticides (Central and North regions) or nothing (South region). Although in every region > 20 percent of respondents used botanicals on their own or in combination with chemical pesticides. However, overall, ~ a third of respondents used no control at all. The type of control method used varied with regions; almost half in the north and central regions used only chemicals, while in the south ~ 30% used only botanicals.

Figure7 shows that among those that used botanicals in all regions, *O. basilicum* (Sweat basil) was the most widely used, with the highest number of respondents in the south, followed by central and north regions, in rank order. Wood ash mixed with pepper was used by 29% of farmers, with the highest number of respondents in the south, followed by central and the north. Only 9% of respondents used *N. diderrichii*, which was only found in the central and north regions. The other botanicals mentioned included *E. guineeses* and tamarind flower, which were both reported by 8% of respondents, and *V. amygdalina*, mentioned by 3% of respondents. However, the difference in types of botanicals used and the region was not statistically significant ($\chi^2$ = 5.7289, df = 10, p > 0.8375).

When farmer were asked on their view on the effectiveness of the plant materials used as grain protectant, overall, there was a discrepancy in the way farmers perceived how botanicals work. A majority (67%) of respondents that used botanicals reported that botanicals are an effective method of pest control, as against 33% that reported the method was not effective, which needs to be confirmed

The majority of respondents that used botanicals (75%) sun-dried the plants for two to three days, and then applied them to the grain. The leaves of the plants only were crushed to powder using a pestle and mortar and then mixed with the grain before loading it into the store. The whole (un-ground) sun-dried plant was used by 25% of the respondents, who placed the whole plants in layers between and on top of the grain.

The results in Table 7 show that the type of insect species recorded in grain and levels of infestation depended on the form of insect control used. For instance, most of the respondents that reported their grain had none to low levels of infestation had used a chemical control method (~78%), followed by those using botanicals (~70%). The majority of respondents reporting medium to high infestations were those that had not used any control measures (~57%), followed by those that had used botanicals (~ 30%). Respondents reporting the lowest percent of high infestation were those that had used a combination of botanical and chemical control (8%). It is interesting to note that respondents using only chemical or botanicals appear to belong in two groups: those with None or Low infestations and those with High infestations, with a dip to only ~ 6% with Medium infestations. This suggests that the High infestations may have been due to misuse of the respective control treatments. Overall, there was a significant difference between control method applied and presence of insect infestations ($\chi^2$ = 48.689, df = 9, p< 0.001).

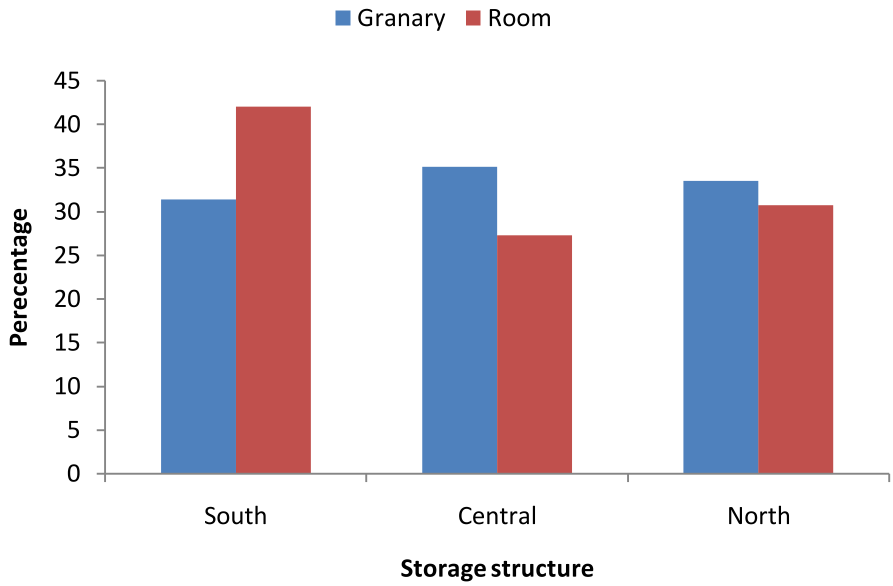


**Figure 3 Distribution of respondents according to location and storage structures used, n=240, 80 per region.** No significant difference in the distribution of farmers that used a particular storage structure between the regions ($\chi^2$ = 4.238, df = 3, p=0.375).

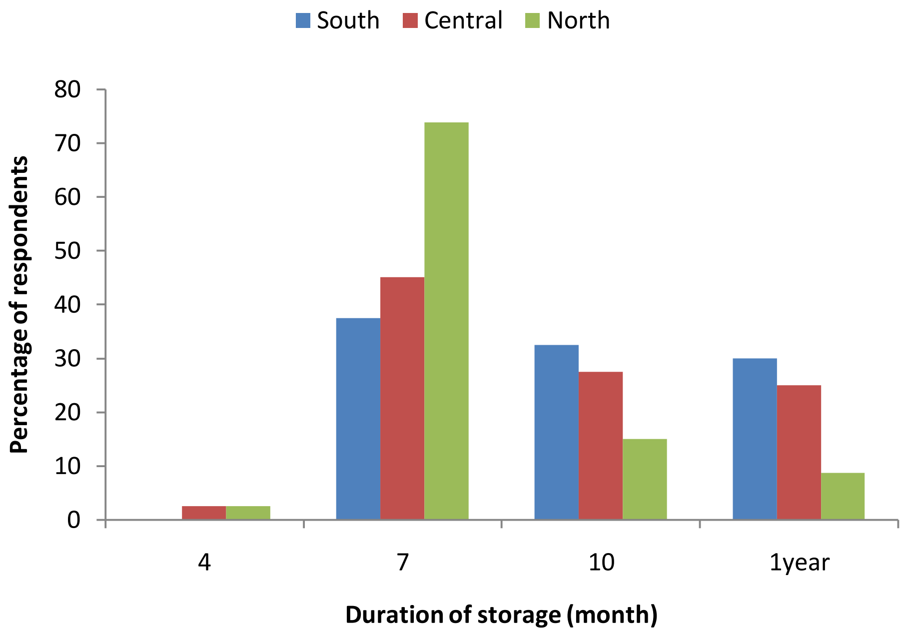


**Figure 4 Distribution of respondents according to location and duration of grain storage, n=240, 80 farmers per region.** There was a significant difference in the duration of storage between the regions ($\chi^2$ = 33.569, df = 6, p<0.001).

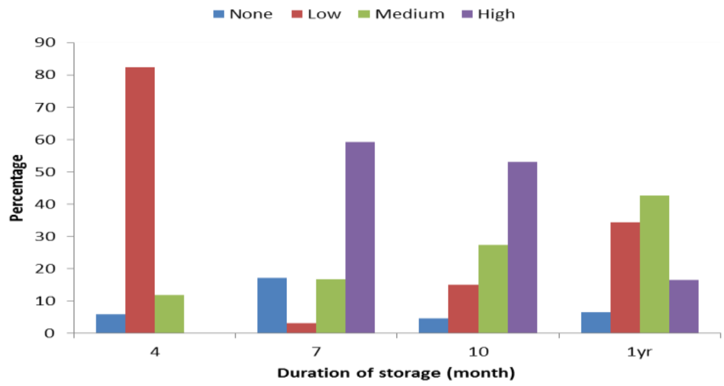


**Figure 5 Relationship between levels of insect infestation and storage duration, n=240, 80 farmers per region.** There was a significant association of duration of storage on level of infestations ($\chi^2$ = 91.74, df = 9, p<0.001).

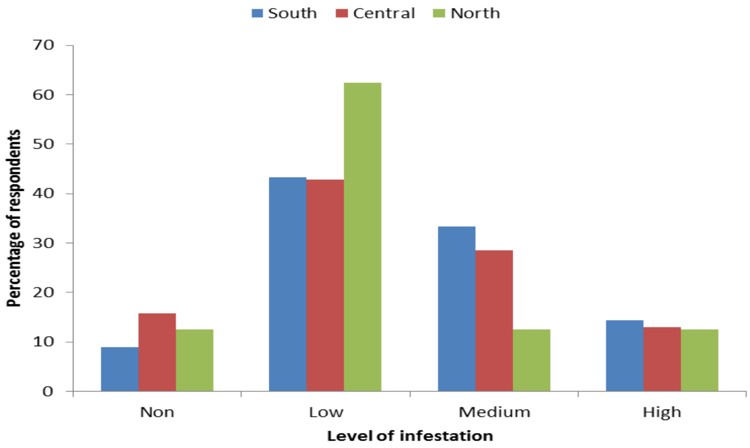


**Figure 6 Levels of insect infestation (damage) in the three regions of the study area, n=240, 80 farmers per region.** There was a significant difference between the regions in level of damage by insect pests ($\chi^2$ =16.6847, df=6, p<0.01).

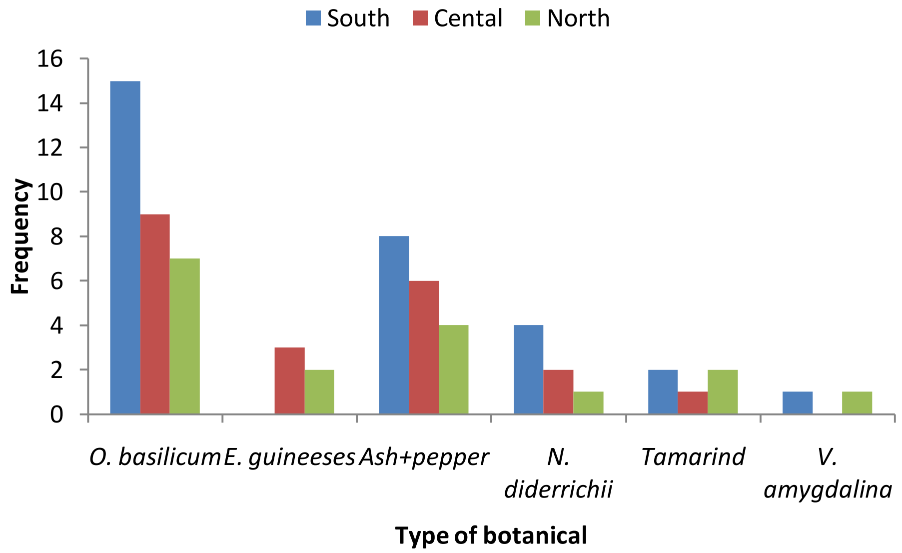


**Figure 7 Frequency of respondents applying specific plants for pest control in different regions, n=68.** There was no statistical significant between types of botanicals used and the regions ($\chi^2$ = 5.7289, df = 10, p=0.837).

## V. Discussion

Use and maintenance of good storage systems is the key to minimizing losses. Small-scale farmers often use traditional systems for storing their grain after harvest. The grain types and the systems used by farmers vary from place to place, depending on the local environment and cultural practices. In Kebbi state, a survey of farmers was conducted to understand and obtain basic information from the farmers' perspective about their systems of storage, the insect pest species that cause damage and the different management practices used by the farmers. The results confirm that their stored grain is attacked and damaged by a variety of storage insect pests. The level of infestation and amount of damage caused was found to be influenced by many factors, including the grain type, storage system, length of time stored and pest management practices.

*Profile of main stored crop and insect pests:* Of all the variety of staple grains grown and stored in all regions surveyed by the author (sorghum, millet and maize), sorghum was found to be the staple crop grown and stored most abundantly (overall, >40% of respondents mentioned sorghum) especially in the south with over 40% respondents grew and stored sorghum. The respondents perceived sorghum as the grain that suffers the greatest proportion of loss to insect pests, mainly *T. castaneum*. *Tribolium castaneum* is a serious pest commonly found in Nigeria attacking most stored cereals [7]. This species thrives in the study area probably because it is well adapted to the weather conditions of the area during the storage season, i.e., temperatures between 22 and 32$^{o}$C [8], within which they survive a long time and reproduce successfully [9].

The survey results indicate that the proportion of loss caused by storage pests is related to the system of storage practiced, for instance, method of processing before storage. Although a large proportion of respondents overall (56%) stored their grain un-threshed, only 31% did so in the South region, in spite of the evidence that unthreshed grain had lower infestation levels. Further investigation is needed to discover why so many farmers store their grain in the threshed state. The observation that grain stored in an un-threshed form is less susceptible to insect attack is supported by [10] and [11]. However, this depends on the insect species and the host grain [12]. Since threshed grains are more susceptible to pest attack, these group of farmers may needs proper treatment with effective control measures.

The length of time grain is stored had affects levels of pest infestation during storage. The survey findings indicate that farmers stored their grain between four months and one year (i.e., from one crop season to another), with the majority storing their grain for seven months. Levels of insect infestation were reported to be significantly higher in grain stored for seven to ten months compared to that stored for four months. Several factors could contribute to this pattern of infestation. First, it takes time for insect populations to grow. Seven months of storage is long enough for an insect population to build-up, particularly with grain that is poorly treated against infestations or not treated at all. Also, the peak in infestations coincides with the rainy season, which reaches its peak in July and August. [10] reported that a combination of high temperature, relative humidity and moisture content provides favourable conditions for insect development. The survey also found that most farmers tend to dispose of their grain stores at about seven months for sale, possibly to avoid further losses to insect damage. The findings of this survey suggest that farmers need to be supported with improved storage methods so that they can extend the duration of storage without further loss of grain. It could be that farmers could not afford to procure enough grain treatment chemicals used to deter/kill insects and the storage structures themselves cannot protect grain adequately during longer periods of storage. A good combination of products developed from local pesticidal plant materials could be affordable and work effectively to increase the duration of storage.

Despite the fact that farmers used different storage structures in the different regions, insect infestation was found in all the types of structures used. Grain stored in storerooms had the highest levels of infestation. [13] reported that successful grain storage depends on the type of structure used, how the grain is handled and how well the grain is protected against environmental factors. It was observed that unlike a granary, the storerooms used by the respondents were usually a domestic room, with one or more windows, which were often observed to be open to the outdoors. The grains are stored in bags (Polypropylene bags). Bag storage provides a little extra protection against pest attack, and with good management bags can provide long term safe storage [10]; [13]. Thus, improvements to the main storage structure used by farmers, and using low cost inputs, i.e., locally-available repellent plant materials, could help improve farmers' food security. [14] confirmed that bags impregnated with plant extracts from *Chenopodium ambrosioides* and *Lantana camara* reduces legume damage by the insect pests *Acanthoscelides obtectus* and *Callosobruchus maculatus*. This method is simple and cost effective, particularly if the materials are locally available and inexpensive. The evidence from the survey in Kebbi suggests that there is an ideal opportunity to research the potential for improving the efficacy of polypropylene bags to store grain by treating them with locally available repellent plant material as a grain protectant against the most important pest, *T. castaneum*.

The majority of farmers responded to insect pests mainly by applying chemical pesticides, however, some farmers used no control and a minority used botanicals. Chemical pesticides were used by more farmers in the north than in the other regions and are the most popular method of pest control overall. However, evidence from the survey indicates that overall greater percent (over 30%) of respondents use no any control probably due to cost or difficult in accessing of treatment chemicals, which suggests the need for affordable and effective means of pest control. However, that over 20% overall respondents use plant material as grain protectant, suggests the opportunity to document, screen and improve plant products for use as grain protectants for small-scale farmers. *Ocimum basilicum* was the plant materials most used by the farmers as grain protectants, particularly in the southern region. However, it was apparent that farmers in the surveyed area did not have a standard method for preparing and applying repellent plant material to their grain stores, which could explain why botanicals did not appear to be very effective in reducing insect infestations. This could also be the reason for disagreements among the farmers as to whether botanicals are effective or not. [15] reported that the efficacy of plant materials depend on the pest species, the environmental location of the stores, the plant species and part of the plant used and the method of preparation and application used. Hence, an investigation of the optimal method of preparation and application of locally available materials is necessary in order to establish more promising and standard methods.

Evidences from this survey suggest that the approach used in the northern region stood out against the others for being significantly more successful at controlling insect pest infestations. The majority of respondents in the south either leave their grain untreated probably due to cost of treatment chemicals or use pesticidal plant materials as grain protectant. However, this survey found that the method of using botanicals was largely ineffective. Possible reasons for this may be that not all farmers prepared and applied the botanicals in an effective way. Therefore suggests an opportunity to research the potential for improving the efficacy of using the plant material. It is interesting to note that most of the respondents that reported using polypropylene bags to provide extra grain protection from pest attack were the one mostly affected. However, the finding of [14] and evidence from this survey provide ideal opportunity to research the potential for improving the efficacy of polypropylene bags (i.e double bagging) treated with locally available repellent plant material as a grain protectant against the most important pest, *T. castaneum***.**

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