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Seasonal Changes in Field-to-storage Insect-pests of Maize and Implications for Their Control in South-Western Cameroon

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Authors' contributions

This work was carried out in collaboration between all authors. Author NNN designed the study and wrote the experimental procedures. Author DN performed the studies, did the statistical analysis and wrote the first draft of the manuscript. Authors NNN and EBF supervised the studies. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To identity and assess the seasonal population dynamics of field-to-store insect-pests of maize at various harvesting dates in South-western Cameroon.
Methodology: Maize was planted mid-monthly during the rainy season months of 2014 and 2015 in 16 plots. At physiological maturity 2 cobs per plot were harvested weekly. The harvesting was for four weeks for maize planted from March to May and five weeks for those planted from August to October. The different insects were assessed from maize cobs with intact husk at harvest, during de-husking after one month drying and subsequently during incubation at two and four weeks. Insect-pests from intact and bird-induced damaged cobs at harvest were also compared.
Results: The results showed that *Cryptolestes ferrugineus*, *Sitophilus zeamais, Ephestia cautella* and *Sitotroga cerealella* were the major field-to-store insect-pests at harvest. *C. ferrugineus* was

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present during all the months of harvest, *S. zeamais* only in cobs harvested during the dry season months of November, December and January while *E. cautella* and *S. cerealella* though present throughout the year showed a slight increase during the months of the dry season. As concerns harvest dates, the longer maize stayed in the field post physiological maturity, the higher the population of *S. zeamais* and *C. ferrugineus* while *E. cautella* and *S. cerealella* did not vary significantly. Cobs damaged by birds had significantly higher numbers of *C. ferrugineus* and *S. zeamais* compared to intact maize cobs while *E. cautella* and *S. cerealella* did not show any difference between the damaged and intact maize cobs.

Conclusion: Harvesting maize early and separating bird-induced damaged cobs from intact ones can therefore minimize stored insect-pest numbers and grain losses in storage.

Keywords: Cobs; maize; bird-induced; harvest dates; intact.

1. INTRODUCTION

Maize (*Zea mais*) is a widely grown crop and one of the most affordable cereals in terms of market price and cost of seeds in Africa [1,2]. In Cameroon, maize is produced countrywide and it contributes enormously to food security and employment since agriculture employs 73% of the workforce of the country [3]. It is the first most widely produced and consumed cereal in the country with over 700,000 families involved in its cultivation [4].

The South West region of Cameroon has the highest potential for maize production in the country but the region's current average yields of 1.67 tons/ha are still low compared to the potential of 6 tons/ha [4]. Despite this low yield, post-harvest insect-pests are also a major problem to the preservation of the harvested grain. Some of these stored product insects are acquired from the field to storage where their populations rapidly build up during storage period. Post-harvest maize insect-pests which include the 'field-to-store' and the 'store' pests are a major constraint to food security and income generation in Sub-Saharan Africa in general; they cause significant post-harvest losses in quantity and grain quality degradation [5].

Most of these stored grain insect-pests belong to the orders of Coleoptera and Lepidoptera. The most destructive tropical species for cereals that begin infestation in the field and continue in storage in most parts of African belong to genera *Sitophilus, Tribolium,* and *Sitotroga* [6,7,8]. Though most of these species can potentiate their entry into intact maize cobs, feeding on cobs in the field by other animals can cause an increase in the numbers of these field-to-store insect-pests besides acting as pests themselves. Birds for example have been noted to be serious pests of maize in the field [9,10] and they feed by opening the husk thus exposing the grains to varied group of insects, and microorganisms alike. It has been shown that a tight and long husk cover can reduce weevil entry and thus grain damage in maize cobs [11]. Also a good husk cover that is tight at the tip with many husk leaves that are extended above the ear contributes to reducing insect damage and attack by microorganisms in the field [12]. Consequently, the opening of cobs by birds poses a serious threat to preserving maize as this can increase the populations of pests of the harvested produce in storage.

To mitigate the damage inflicted by these varied post-harvest pests, farmers have resorted to using various methods. The most common method employed by most farmers worldwide to control insect-pests in the field and storage is through the use of synthetic residual insecticides. These chemicals although effective, pose many environmental threats such as pollution, human health hazards and the development of resistance in pests among others [13,14]. Furthermore, most farmers in Africa are resource-poor, coupled with low education and therefore do not have the means or skills and knowledge to obtain and handle pesticides appropriately. For instance most farmers in most areas of Cameroon when using insecticides often do not use appropriate protective clothing, nose masks or goggles and do not respect pre-harvest interval stipulated by manufacturers [15,16]. In view of the above, farmers need to resort to safe and more environmentally friendly methods of managing pre- and post-harvest pests. However, the vital first step in implementing any curative and sustainable pest management program are the proper identification of the pest involved and monitoring their population dynamics over time and/or seasons. Therefore the objectives of this study were to identity the various field-to-storage insect-pests of maize in South-western Cameroon, assess their population dynamics and the effect of bird-induced damaged cobs on their numbers in the target area.

2. MATERIALS AND METHODS

2.1 Study Site

This study was conducted at the Institute of Agricultural Research for Development (IRAD) Ekona, Cameroon located at 4.1327°N and 9.1923°E and 410 m above sea level and at the University of Buea, Cameroon located at 4.1537°N and 9.2920°E and 530 m above sea level. Ekona has a mean annual rainfall of 2,085 mm, monthly temperature range of 19-30°C and mean annual relative humidity of 86%. Buea has an annual rainfall of about 2,000 mm and a temperature range of 18-23°C; most of the rain is received between June and September. The soil types are basically volcanic making agriculturally productive [17].

2.2 Planting of Maize

The maize variety CMS 8704 was used and it reaches physiological maturity 90 days after planting. The maize was planted two seeds per hill mid-monthly from March to October in 2014 and 2015 in research plots of IRAD Ekona. The planting was done in sixteen plots of 5 m x 4.5 m each at spacing of 75 cm and 50 cm between and within rows respectively. Two weeks after planting, gaps were filled by replacing those that did not germinate and/or destroyed by pest. At four weeks post-planting NPK (20:10:10) fertilizer was applied at the rate of 5 grams per plant. Weed control by hoeing and manual weeding was done at 4 weeks after planting prior to the fertilizer application.

2.3 Assessment of Field-to-store Insect-pests

To identify and quantify the various field-to-store insect-pests, 2 cobs from each of the sixteen plots were randomly harvested weekly after physiological maturity. The harvesting was done for four weeks for the maize planted from March to May and five weeks for those planted from August to October. The harvested cobs were placed in small fine mesh storage bags and taken to the Zoology Laboratory of the University of Buea where the cobs were observed and the insects collected, identified and counted. The identification was done with published pictorial guides and comparing with laboratory voucher specimens. After collecting the insects, the cobs were returned to their respective bags and those that were harvested in June, July and August (months of higher rainfall) dried for one month using a rotatory electric drier. During the drying, the cobs were placed at a distance of 26 cm from the source of heart in the drier to have a temperature of 35°C. Cobs harvested in November, December and January (dry season) were sun-dried also for one month. After drying, the cobs were de-husked and observed to collect, identify and count any insect therein that emerged during the drying period. After which, the cobs were maintained inside their storage bags in the laboratory and checked after two and four weeks of incubation to collect, identify and count any more insects that emerged. To compute the seasonal abundance of the different insects collected, the numbers collected during the first four weeks of a month were summed up to give the monthly abundance.

2.4 Insects from Maize Cobs with Intact Husk and those Opened by Birds

Based on the presence of cobs whose husks were opened by birds in each plot, two of these cobs were randomly harvested each week, put in fine mesh storage bags and taken to the laboratory. In the laboratory these cobs with opened husks were assessed for field-to-store insect-pests. The mean numbers of insects observed in these damaged cobs harvested each week were identified and compared with those from maize cobs with intact husks harvested during the same week.

2.5 Statistical Analysis

Data collected were analysed using MINITAB Package version 16. The number of insects collected was log-transformed ($\log_{10}(x + 1)$) in order to normalize the data before analysis; however, the original counts of insect-pests are presented in tables. Analysis of variance (ANOVA) was performed at 95% confidence level to compare mean number of insects collected during the various weeks of harvest. When the differences were significant, the means were separated using Turkey multiple range test. Insects obtained after two and four weeks of the laboratory incubation of the harvested maize were represented graphically. Paired t-test was used to compare the insect-pest counts from maize cobs with intact husks and those opened by birds (bird-induced damaged cobs).

3. RESULTS

3.1 Field-to-store Insect-pests at Harvest

Maize planted in March, April and May matured in June, July and August while those planted in August, September and October matured in November, December and January respectively. Maize planted in June and July was stunted and did not grow to produce mature cobs and as such is not further discussed. The main insect-pests acquired from the field into stores were *C. ferrugineus*, *Sitophilus zeamais, Ephestia cautella* and *Sitotroga cerealella.* During harvest, a total of 195 and 154 *C. ferrugineus* were identified in 2014 and 2015 respectively. For *S. zeamais*, a total of 188 and 200 were identified in 2014 and 2015 respectively while 8 and 15 *E. cautella* were identified in 2014 and 2015 respectively and *S. cerealella* was 1 and 4 in 2014 and 2015 respectively.

C. ferrugineus was present during all months of harvest and the highest population density per two maize cobs recorded in July (2.2±0.9) and June (2.7±1.2) of 2014 and 2015 respectively. Only the different weeks of harvest in July and August 2014 and August of 2015 respectively had significant differences in the number of *C. ferrugineus* (Table 1).

Throughout the study period, *S. zeamais* was collected only from cobs harvested during the dry season months November, December and January. The highest population densities of *S. zeamais* were recorded in December 2014 (6.3±3.7) and in January 2015 (5.0±2.5). There were no statistical differences among the different weeks of harvest for both 2014 and 2015; the population densities of *S. zeamais* increased in the maize cobs as harvest was delayed that is in the later weeks of harvest (Table 1).

Ephestia cautella was also more common during months of dry season though a few were also recorded during the rainy season. The population of *E. cautella* was lower than that of *S. zeamais* regardless of the month of harvest of the dry season. There were no significant differences in number of *E. cautella* observed over the different weeks of harvest for the various months of 2014 and 2015 (Table 1).

Sitotroga cerealella was observed in very small numbers and only seen during Vth week of January in 2014 and 2015; it was seen during the IInd week of July, IIIrd week of August, Vth week of November and Ist week of December where it all had a mean number of 0.1±0.1 per two maize cobs. Generally it was observed both in maize cobs harvested during the rainy and dry seasons but in very low populations compared to the other insect-pests.

3.2 Field-to-store Insect-pests Observed during De-husking

During de-husking of maize cobs thirty days after harvest, the same insect-pests observed during harvest were recorded, but in higher numbers. A total of 1,801 and 926 *C. ferrugineus*, 241 and 525 *S. zeamais*, 72 and 99 *E. cautella* and 16 and 11 *S. cerealella* were observed in 2014 and 2015 respectively.

The highest number of *C. ferrugineus* was collected from cobs harvested in July (27.1±9.3) and January (6.1±3.0) of 2014 and 2015 respectively. There were significant differences (P<0.05) among the different weeks of harvest for all the months of 2014 except November where cobs harvested during IVth or Vth week exhibited a higher number of *C. ferrugineus*. Also in 2015, the difference in the numbers of *C. ferrugineus* among the weeks of harvest in July, August and January was significant as cobs harvested during IVth or Vth week had a higher number of *C. ferrugineus* (Table 2).

As during harvest, *S. zeamais* was only seen in cobs that were harvested during the dry season (November, December and January). The highest densities 5.9±4.3 and 21.9±6.6 for 2014 and 2015 were respectively obtained in December and January. There were significant differences (P<0.05) in the numbers of this pest among the different weeks of harvest of December 2014 and November, December and January of 2015 with the lowest recorded during week I and the highest in week VI (Table 2).

Ephestia cautella in 2014 and 2015 was highest in cobs harvested in January and December. There were no statistical differences in the number of this pest among the different weeks of harvest (Table 2).

Sitotroga cerealella was also observed in very low numbers with the highest in cobs harvested in January in 2014 (0.6±0.4) and December in

2015 (0.5±0.3). There was no difference among the different weeks of harvest. *S. cerealella* during de-husking in 2014 and 2015 was seen in very low numbers and during few weeks of harvest with the highest week having a mean of 0.2±0.1.

3.3 Field-to-store Insect-pests during Incubation

During the laboratory incubation of the maize cobs, *S. cerealella* was not seen. *C. ferrugineus* was present in cobs harvested during all the different weeks of the various months of June, July, August, November December and January of 2014 and 2015. In contrast, *S. zeamais* and *E. cautella* were present only from maize cobs harvested during dry season months of November, December and January of both years. *C. ferrugineus* and *S. zeamais* numbers increased in cobs that were harvested late post physiological maturity; that is maize cobs harvested after one week post physiological maturity had significantly lower numbers than those harvested during the fourth and fifth weeks. The insect population also increased as the numbers of weeks of laboratory incubation increased (Fig. 1).

Table 1. Mean number (±SEM) of various field-to-store insect-pests per two maize cobs at various weeks of harvest

Months of harvest	Weeks of harvest	Field-to-store insect-pests					
		C. ferrugineus		*S. zeamais*		*E. cautella*	
		2014	2015	2014	2015	2014	2015
June	I	0.1±0.1a	0.8±0.3a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	II	0.4±0.3a	0.8±0.3a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	III	0.4±0.2a	0.5±0.3a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	IV	0.7±0.3a	0.6±0.3a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	Total	1.6±0.9	2.7±1.2	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
July	I	0.1±0.1a	0.7±0.3a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.1±0.1a
	II	0.2±0.1a	0.4±0.2a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	III	0.9±0.3b	0.8±0.3a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.1±0.1a
	IV	1.3±0.4b	0.6±0.2a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	Total	2.2±0.9	2.5±1.0	0.0±0.0	0.0±0.0	0.0±0.0	0.2±0.2
August	I	0.2±0.1a	0.0±0.0b	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.1±0.1a
	II	0.2±0.1a	0.4±0.2ab	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	III	0.4±0.2ab	0.4±0.2ab	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	IV	0.8±0.3b	0.9±0.3a	0.0±0.0a	0.0±0.0a	0.1±0.1a	0.1±0.1a
	Total	1.6±0.7	1.7±0.7	0.0±0.0	0.0±0.0	0.1±0.1	0.2±0.2
November	I	0.1±0.1a	0.1±0.1a	0.0±0.0a	0.0±0.0a	0.1±0.1a	0.1±0.1a
	II	0.0±0.0a	0.3±0.2a	0.0±0.0a	0.1±0.1a	0.0±0.0a	0.1±0.1a
	III	0.1±0.1a	0.2±0.1a	0.0±0.0a	0.1±0.1a	0.0±0.0a	0.0±0.0a
	IV	0.1±0.1a	0.5±0.3a	0.0±0.0a	0.4±0.3a	0.0±0.0a	0.0±0.0a
	V	NH	0.4±0.3a	NH	0.2±0.2a	NH	0.1±0.1a
	Total	0.3±0.3	1.1±0.7	0.0±0.0	0.6±0.5	0.1±0.1	0.2±0.2
December	I	0.1±0.1a	0.1±0.1a	0.2±0.2a	0.1±0.1a	0.0±0.0a	0.2±0.1a
	II	0.2±0.1a	0.1±0.1a	0.5±0.4a	0.6±0.4a	0.1±0.1a	0.1±0.1a
	III	0.3±0.2a	0.1±0.1a	1.0±0.7a	0.4±0.3a	0.0±0.0a	0.0±0.0a
	IV	0.4±0.3a	0.4±0.2a	4.6±2.4a	0.4±0.3a	0.0±0.0a	0.1±0.1a
	V	0.6±0.3a	0.6±0.3a	5.4±2.3a	2.1±1.4a	0.0±0.0a	0.2±0.1a
	Total	1.0±0.7	2.2±0.5	6.3±3.7	1.5±1.1	0.1±0.1	0.4±0.3
January	I	0.2±0.1a	0.2±0.1a	0.1±0.1a	0.3±0.2a	0.0±0.0b	0.1±0.1a
	II	0.5±0.4a	0.3±0.2a	0.1±0.1a	1.2±0.7a	0.0±0.0b	0.0±0.0a
	III	0.0±0.0a	0.7±0.3a	0.0±0.0a	2.1±0.9a	0.1±0.1b	0.0±0.0a
	IV	0.6±0.3a	0.6±0.3a	0.0±0.0a	1.4±0.7a	0.1±0.1b	0.0±0.0a
	V	0.8±0.5a	1.0±0.6a	0.0±0.0a	3.2±1.5a	0.2±0.1a	0.0±0.0a
	Total	1.3±0.8	1.8±0.9	0.2±0.2	5.0±2.5	0.2±0.2	0.1±0.1

Means that do not share a letter in a column are significantly different. NH = no harvest

Table 2. Mean number (±SEM) of various field-to-store insect-pests per two maize cobs observed during de-husking

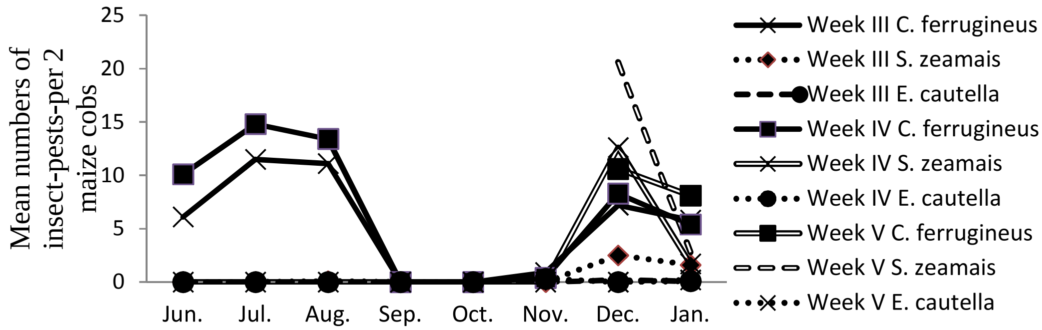
Months of harvest	Weeks of harvest	Field-to-store insect-pests					
		C. ferrugineus		*S. zeamais*		*E. cautella*	
		2014	2015	2014	2015	2014	2015
June	I	0.3±0.1a	0.5±0.2a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	II	0.6±0.4a	0.4±0.2a	0.0±0.0a	0.0±0.0a	0.1±0.1a	0.0±0.0a
	III	3.3±1.1a	0.9±0.4a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.1±0.1a
	IV	14.4±3.5b	1.6±0.5a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.1±0.1a
	Total	18.6±5.1	3.4±1.3	0.0±0.0	0.0±0.0	0.1±0.1	0.2±0.2
July	I	1.8±0.6a	0.1±0.1b	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	II	4.8±1.2ab	0.8±0.3ab	0.1±0.1a	0.0±0.0a	0.1±0.1a	0.0±0.0a
	III	6.5±2.1b	1.0±0.5ab	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	IV	14.0±5.4b	1.6±0.5a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.1±0.1a
	Total	27.1±9.3	3.5±1.4	0.1±0.1	0.0±0.0	0.1±0.1	0.1±0.1
August	I	1.3±0.7a	0.8±0.2b	0.1±0.1a	0.0±0.0a	0.0±0.0a	0.1±0.1a
	II	4.5±1.5ab	0.8±0.2b	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.1±0.1a
	III	6.8±2.8ab	0.9±0.3ab	0.0±0.0a	0.0±0.0a	0.2±0.1a	0.2±0.1a
	IV	10.4±3.2b	1.9±0.4a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.2±0.1a
	Total	23.0±8.2	4.4±1.1	0.1±0.1	0.0±0.0	0.2±0.1	0.6±0.4
November	I	0.5±0.3a	0.1±0.1a	0.0±0.0a	0.0±0.0a	0.1±0.1a	0.1±0.1a
	II	0.5±0.3a	0.6±0.6a	0.0±0.0a	0.1±0.1a	0.2±0.1a	0.2±0.1a
	III	0.8±0.4a	0.8±0.8a	0.0±0.0a	2.1±1.3ab	0.1±0.1a	0.3±0.2a
	IV	1.0±0.5a	0.7±0.7a	0.0±0.0a	1.2±1.1ab	0.1±0.1a	0.4±0.2a
	V	NH	1.1±1.1a	NH	2.6±1.3ab	NH	0.5±0.2a
	Total	2.8±1.5	2.2±2.2	0.0±0.0	3.2±2.5	0.5±0.4	1.0±0.6
December	I	0.2±0.1d	1.1±0.8a	0.1±0.1a	0.6±0.6a	0.1±0.1a	0.3±0.1a
	II	1.8±0.6cd	0.8±0.6a	0.5±0.4a	2.3±1.6a	0.3±0.1a	0.3±0.1a
	III	4.9±1.5b	2.7±1.4a	0.9±0.5a	2.0±1.9a	0.2±0.1a	0.7±0.4a
	IV	2.3±1.1cd	2.6±1.0a	4.4±3.3b	5.4±2.2b	0.1±0.1a	0.4±0.2a
	V	9.5±2.2a	3.6±1.6a	6.8±3.4b	4.8±2.5b	0.1±0.1a	0.6±0.3a
	Total	9.2±3.3	7.2±3.8	5.9±4.3	10.3±6.3	0.7±0.4	1.7±0.8
January	I	0.8±0.3c	1.4±0.6a	0.0±0.0a	4.6±1.7a	0.4±0.1a	0.3±0.2a
	II	1.9±1.0bc	0.9±0.6a	0.0±0.0a	4.8±0.2a	0.1±0.1a	0.3±0.1a
	III	5.7±1.9ab	1.2±0.8a	0.1±0.1a	4.6±1.4a	0.9±0.4a	0.3±0.1a
	IV	5.4±2.8ab	2.6±1.0a	0.1±0.1a	7.9±3.3ab	0.8±0.2a	0.4±0.2a
	V	8.8±5.1a	5.8±2.5b	2.1±1.9a	10.8±1.8b	0.7±0.3a	0.4±0.2a
	Total	13.8±6.0	6.1±3.0	0.2±0.2	21.9±6.6	2.2±0.8	1.3±0.6

Means that do not share a letter in a column are significantly different. NH = no harvest

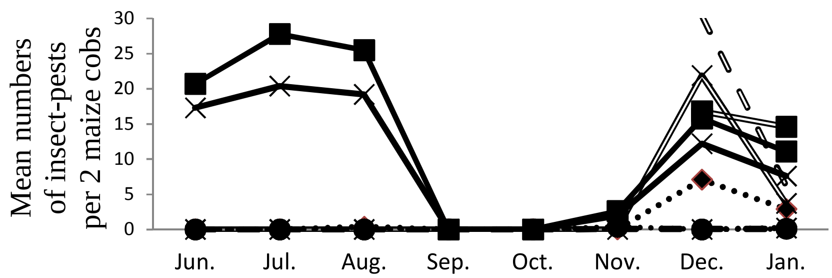
The population of *C. ferrugineus* was always double that of *E. cautella* irrespective of the month or week of harvest each year. The larvae of *Ephestia* produced a lot of silk and hence caused webbing the maize grains. These larvae also produced silken cocoons inside which they pupated. *Cryptolestes* often fed starting from broken areas of the grains created by *Ephestia* larvae. Hence *Cryptolestes* appears to be a secondary pest after the grains had been damaged by *Ephestia* larvae and/or *S. cerealella* larvae.

3.4 Number of Field-to-store Insects in Maize Cobs Opened by Birds and Intact Cobs

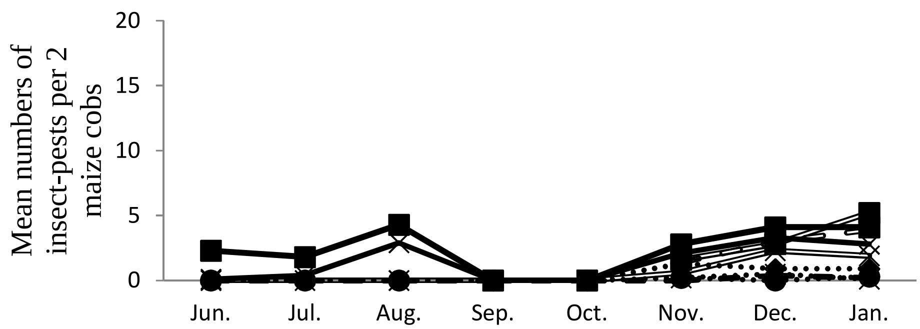
Maize cobs with the husk opened by birds (bird-induced damaged) generally had higher numbers of the different insect compared to intact ones. In 2014, 59 and 218 *C. ferrugineus* as well as 100 and 569 in 2015 were obtained from intact and bird-induced damaged cobs respectively. There were 29 and 104 *S. zeamais* from intact and bird-induced damaged cobs in 2014 respectively but



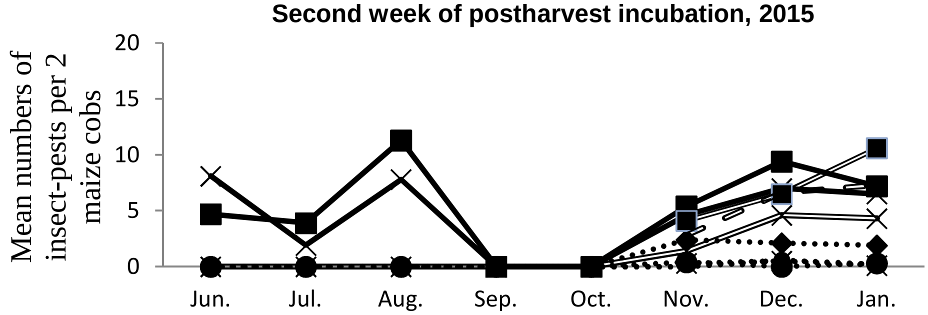
Second week of postharvest incubation, 2014



Fourth week of postharvest incubation, 2014



Second week of postharvest incubation, 2015



Second week of postharvest incubation, 2015

Fig. 1. Cumulative number of field-to-store insects pests during incubation (weeks in legend represent when maize was harvested after physiological maturity)

77 and 465 in 2015. *E. cautella* had 3 and 8 from intact and bird-induced damaged cobs respectively in 2014 while in 2015 there were 10 and 14 respectively. *S. cerealella* in 2014 was

absent in intact cobs but 1 was observed in damaged ones while in 2015 both intact and bird-induced damaged cobs had 3 of this pest each.

With respect to the different weeks of harvest, the numbers of *C. ferrugineus* and *S. zeamais* were significantly higher in bird-induced damaged maize cobs compared to the intact maize cobs in 2014 and 2015. In contrast, the numbers of *E. cautella* and *S. cerealella* did not show any significant difference regardless of the week of harvest (Tables 3 and 4).

4. DISCUSSION

The results showed that the major insect-pests of maize gotten from the field into storage in South-western Cameroon were *Cryptolestes ferrugineus* and *Sitophilus zeamais* which belong to the order Coleoptera as well as *Ephestia cautella* and *Sitotroga cerealella* in the order Lepidoptera*.* Similar results were obtained by Hill [18]; Lale and Ofuya [19] who reported over 1195 insect species associated with stored products in the tropics most of which belong to the orders Coleoptera and Lepidoptera. These are typical insects found in most tropical stores thus suggesting that most are carried from the field to stores. *C. ferrugineus and S. zeamais* were more abundant right from harvest to when the maize was incubated. This corroborates the findings of Nansen et al. [20] who conducted sampling in a maize facility for 13 consecutive weeks and found high densities of the rusty grain beetle, *C. ferrugineus* and the maize weevil, *S. zeamais*.

For the seasonal abundance*, C. ferrugineus* was present during all months of harvest and *S. zeamais* during dry season months from November to January while *E. caitella* and *S. cerealella,* though present during all the months of harvest were more abundant during the dry season months. The presence of *C. ferrugineus* during all the months of harvest was probably due to the ability of this pest to feed on a variety of substrates like detritus, fungi and flour from broken cereals. It has been reported that *C. ferrugineus* feeds on detritus [8] which is often abundant during the rainy season. *Cryptolestes* has also been reported to occur under bark of hardwood logs and are apparently fungivorous [21]. Detritus and fungi are abundant during rainy months as a result of heavy rains that hinder proper drying of maize cobs. This causes maize to decay and provide a good trophic niche for *Cryptolestes*. The presence of *C. ferrugineus* during the dry months might be partly due to the presence of *S. zeamais, S. cerealella* and *E. cautella* which are primary feeders that fed on maize grains first thus producing powder that favoured the growth and reproduction of *Cryptolestes* usually known to be a secondary pest that feeds on damaged grains, dried fruits, nuts and other stored plant materials [22].

The presence of *Sitophilus zeamais* during dry season months from November to January might possibly be due to increase in temperatures during the dry season compared to wet and cold rainy season months. Increased temperature is known to speed up the life cycle of insects leading to faster increases in pest populations. It has been estimated that a 2℃ increase in temperature has the potential to increase the number of insect life cycles by one to five times [23,24]. The higher population of *S. zeamais* during dry season months which is when maize is allowed to get dry in the field in South-western Cameroon increases the risk of carrying some of these weevils during harvest into storage. This maize weevil is the most important post-harvest insect-pest of maize in Cameroon and is largely responsible for most post-harvest losses [25,26] with losses of up to 90% registered after 5 months of storage [27]. Consequently farmers need to apply control measures to suppress this pest during these dry season months as it is these cobs harvested during the dry season that are often allowed to get dry in the field and later harvested for storage in Buea and its environ.

Though *E. cautella* and *S. cerealella,* were found during some months of the rainy season, they were more frequent during the dry season months possibly because of the higher temperatures which dried up the maize faster to render them suitable for these xerophilic stored insect-pests.

Regarding the various harvest dates, the longer maize remained in the field post-physiological maturity, the higher the numbers of *C. ferrugineus* and *S. zeamais* while *E. cautella* s and *S. cerealella* did not show significant increases with delayed harvesting. This is consistent with the findings of Storey [28]; Bruns and Abbas [29] who reported that delayed harvesting in humid sub-tropical environment to allow grain to get dry in the field increased the risk of pest infestation and could result in serious grain losses during storage [30].

Table 3. Mean number (±SEM) of field-to-store insect-pests per two each of bird-induced damaged and intact maize cobs at various weeks after physiological maturity in 2014

Months of harvest	State	I	II	III	I	II	III	I	II	III
		C. ferrugineus			*S. zeamais*			*E. cautella*		
June	Intact	0.1±0.1a	0.4±0.3a	0.4±0.2a	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	Damaged	2.6±0.9b	3.4±1.1b	0.4±0.3a	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	t-value	3.17	4.17	0.18						
	P-value	0.006	0.001	0.86						
July	Intact	0.1±0.1a	0.2±0.1a	0.9±0.3a	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	Damaged	1.3±0.8a	3.0±0.9b	0.7±0.4a	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
	t-value	1.75	4.57	0.30						
	P-value	0.13	0.01	0.78						
August	Intact	0.2±0.1a			0.0±0.0			0.0±0.0		
	Damaged	6.0±1.9b	NH	NH	0.0±0.0	NH	NH	0.0±0.0	NH	NH
	t-value	5.78								
	P-value	0.01								
November	Intact	0.1±0.1a			0.0±0.0			0.1±0.1a		
	Damaged	0.0±0.0a	NH	NH	0.0±0.0	NH	NH	0.0±0.0a	NH	NH
	t-value	1.00						0.99		
	P-value	0.33						0.34		
December	Intact	0.1±0.1a	0.2±0.1a	0.3±0.2a	0.2±0.2a	0.5±0.4a	1.0±0.7a	0.0±0.0	0.1±0.1a	0.0±0.0a
	Damaged	1.5±0.4b	2.2±0.8b	3.4±0.7b	0.6±0.3a	10.3±4.0b	26.0±6.6b	0.0±0.0	0.2±0.2a	0.2±0.2a
	t-value	3.60	2.85	2.70	1.09	3.80	7.24		0.52	1.00
	P-value	0.006	0.04	0.05	0.29	0.002	0.04		0.61	0.37
January	Intact	0.2±0.1a	0.5±0.4a	0.0±0.0a	0.1±0.1a	0.1±0.1a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.1±0.1a
	Damaged	1.1±0.5b	1.1±0.4a	0.3±0.3a	0.3±0.2a	1.4±0.6b	2.0±1.2a	0.1±0.1a	0.3±0.2a	0.0±0.0a
	t-value	2.11	1.54	1.00	1.53	3.11	1.73	1.00	1.45	1.00
	P-value	0.05	0.14	0.39	0.14	0.01	0.18	0.33	0.18	0.33

Means that do not share a letter in a column are significantly different. NH = no harvest

Table 4. Mean number (±SEM) of field-to-store insect-pests per two each of bird-induced damaged and intact maize cobs at various weeks after physiological maturity in 2015

Months of harvest	State	I	II	III	I	II	III	I	II	III
		C. ferrugineus			*S. zeamais*			*E. cautella*		
June	Intact	0.8±0.3a	0.8±0.3a	0.5±0.3a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	Damaged	5.0±0.9b	3.4±0.9b	2.0±0.7a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.0±0.0a
	t-value	6.32	2.63	4.87						
	P-value	0.00	0.01	0.00						
July	Intact	0.7±0.3a	0.4±0.2a	0.8±0.3a	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.1±0.1a	0.0±0.0a	0.1±0.1a
	Damaged	2.3±0.8b	1.5±0.8a	8.8±2.2b	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.1±0.1a	0.0±0.0a	0.0±0.0a
	t-value	2.60	1.28	3.63				0.32		1.00
	P-value	0.02	0.25	0.02				0.76		0.33
August	Intact	0.0±0.0a	0.4±0.2a		0.0±0.0a	0.0±0.0a		0.1±0.1a	0.0±0.0a	-
	Damaged	12.0±5.2a	2.7±1.2a	NH	0.0±0.0a	0.0±0.0a	NH	1.3±0.9a	0.0±0.0a	
	t-value	6.15	2.93					1.61		
	P-value	0.03	0.10					0.25		
November	Intact	0.1±0.1a	0.3±0.2a	0.2±0.1a	0.0±0.0a	0.1±0.1a	0.1±0.1a	0.1±0.1a	0.1±0.1a	0.0±0.0a
	Damaged	2.4±1.0b	3.9±1.7b	4.4±1.1b	0.8±0.5a	2.8±1.0b	4.9±5.0b	0.3±0.3a	0.0±0.0a	0.1±0.1a
	t-value	2.38	2.84	6.51	1.49	3.31	3.11	0.65	1.00	1.00
	P-value	0.05	0.03	0.00	0.18	0.02	0.02	0.53	0.33	0.36
December	Intact	0.1±0.1a	0.1±0.1a	0.1±0.1a	0.1±0.1a	0.6±0.5a	0.4±0.3a	0.2±0.1a	0.1±0.1a	0.0±0.0a
	Damaged	3.2±1.1b	5.5±2.0b	6.2±1.8b	4.9±2.1b	8.2±3.0b	15.0±3.9b	0.3±0.2a	0.2±0.2a	0.4±0.3a
	t-value	3.18	3.96	6.86	2.75	3.66	9.95	0.76	0.59	1.63
	P-value	0.01	0.01	0.002	0.03	0.01	0.00	0.46	0.58	0.18
January	Intact	0.2±0.1a	0.3±0.2a	0.7±0.3a	0.3±0.2a	1.2±0.7a	2.1±0.9a	0.1±0.1a	0.0±0.0a	0.0±0.0a
	Damaged	7.4±1.3b	8.3±1.1b	10.0±2.1b	9.6±3.1b	10.0±3.5b	17.3±4.2b	0.0±0.0a	0.0±0.0a	0.0±0.0a
	t-value	10.90	13.0	7.94	3.76	3.65	6.37	1.00		
	P-value	0.00	0.00	0.00	0.005	0.007	0.00	0.33		

Means that do not share a letter in a column are significantly different. NH = no harvest

This is because the longer maize remains in the field, a greater opportunity exists for stored grain insects to infest the grain and then be carried into storage. The fact that *E. cautella* and *S. cerealella* did not have differences with respect to delayed harvesting is presumably because these two insects though present are not serious pests of stored maize in South-western Cameroon. This was supported by the low numbers and complete absence of *S. cerealella* during incubation which is in line with Seck [31] who reported that infestation by *S. cerealella* was observed to start in the field, but during storage they were never detected beyond 30 cm depth within bulk deposited grains after threshing. Harvesting maize immediately after physiological maturity can thus reduce the risk of insect-pests like *C. ferrugineus* and *S. zeamais* being carried from the field-to-storage. This will intend advert the use of synthetic insecticides which are often associated with problems such as increasing cost of application, insect-pest resurgence and resistance to insecticides as well as lethal effects on non-target organisms in addition to direct toxicity to applicators [32] if inappropriately used. Minimizing or avoiding insecticide use will satisfy the main purpose of storage by small-scale farmers in Africa which is to ensure household food supplies and seed for planting [33] without endangering humans and the environment with potentially hazardous synthetic insecticides.

The results also showed that maize cobs opened by birds had higher numbers of *C. ferrugineus* and *S. zeamais* than intact husked maize cobs. The husks of maize cobs act as physical barriers which prevent the easy access of maize grains inside the cobs by insects and other pests. Therefore cobs whose husks have been opened by birds attract more stored product insects in South-western Cameroon which is in line with Bosque-Perez [12] and Zhou et al. [34] who reported that the degree of field infestation of maize by insects largely depends on the completeness of husk cover of the maize cobs. Also a good and long husk cover that is tight at the tip with many husk leaves extended above the ear contributes to reduce insect damage and attack by microorganisms in the field which might subsequently be carried into storage [13]. The higher numbers of *C. ferrugineus* and *S. zeamais* in maize cobs opened by birds is detrimental to maize storage since some farmers do not often separate these bird-induced damaged cobs from intact ones during drying and storage. This intend increases the population of these insect-pests in storage because they end up migrating from the damaged cobs to feed on the intact ones. Harvesting maize early and separating bird-induced damaged cobs from intact husked ones during storage will reduce *C. ferrugineus* and *S. zeamais* populations carried from the field into storage and may also reduce post-harvest rot/decay of maize. This seems obvious because infestation of maize by insects does not only cause significant losses due to consumption of grains but It also results in elevated temperature and moisture conditions that lead to accelerated growth of moulds including mycotoxins production [35]. The presence of mycotoxins such as aflatoxins is often correlated with other attributes that facilitate or result from fungal growth, including physical damage to the protective outer layer of the kernel, discoloration, and compromised taste quality [36].

5. CONCLUSION

The results showed that *C. ferrugineus*, *S. zeamais, E. cautella* and *S. cerealella* were carried from the field-to-storage especially in maize harvested during dry season months. Maize harvested early after physiological maturity had fewer or no insect-pests. Therefore farmers should harvest their maize immediately after physiological maturity in order to reduce their stored pest problems. Also since *S. zeamais* was absent in maize harvested during the rainy season months, it implies that harvesting during this period can minimise the pest problem provided that farmers have appropriate and adequate drying facilities and also clean their stores before storing maize. Bird-induced damaged cobs had higher numbers of *C. ferrugineus* and *S. zeamais* and should therefore be separated from healthy ones during drying and storage in order to reduce the introduction of more insect-pests from the field into storage. Also maize harvested during the dry season should always be solarized as a sustainable method of minimizing or preventing the carrying of insects from the field into storage.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. James TK, Rahman A, Mellsop J. Weed competition in maize crop under different timings for post emergence weed control. N. Z. Plant Prot. 2000;53:269-272.
2. Shi W, Tao F. Vulnerability of African maize yield to climate change and variability during 1961–2010. Food Sec. 2014;6:471–481.
3. Bella H. Agriculture and economic growth in Cameroon. Sub-Regional Institute of Statistics and Applied Economics (ISSEA), Final Thesis, Statistical Application Engineer. Available:http://www.memoireonline.com/10/09/2761/Agricultureet-croissance-economique-au-Cameroun.html
4. MINEPAT. Study report on the filler. 2008;110.
5. Abebe F, Tefera T, Mugo S, Beyene Y, Vidal S. Resistance of maize varieties to the maize weevil *Sitophilus zeamais* (Motsch) (Coleoptera: Curculionidae). Afr. J. Biotechnol. 2009;8:5937-5943.
6. Dal Bello G, Padin S, Lopez LC, Fabrizio MR. Laboratory of evaluation chemical-biological control of the rice weevil (*Sitophilus oryzae* L.) in stored grains. J. Stored Prod. Res. 2001;37:77-84.
7. Chimoya IA, Abdullahi G. Species compositions and relative abundance of insect pest associated with some stored cereal grains in selected markets of Maiduguri metropolitan. J. Am. Sci. 2011;7(4):355-358.
8. Tamgno BR, Ngamo TSL. Diversity of stored grain insect pests in the Logone Valley, from Northern Cameroon to Western Chad Republic in Central Africa. JAST. 2013;3:724-731.
9. Fayenuwo JO, Akande M, Olakojo SA, Amusa NA, Akinlosotu TA. Comparative study of vertebrate pests damage on open-pollinated and and hybrid maize plant. In-House-Research Review of IAR&T, Moor Plantation, Ibadan. 2002;65-70.
10. Mwanjabe PS, Sirima FB, Lusingu J. Crop losses due to outbreaks of *Mastomys natalensis* (Smith, 1834), Muridae, Rodenttia, in the Lindi region of Tanzania. Int. Biodeterior. Biodegradation. 2002;49: 133-137.
11. Demissie G, Tefera T, Tadesse A. Importance of husk covering on field infestation of maize by *Sitophilus zeamais* Motsch (Coleoptera: Curculionidea) at Bako, Western Ethiopia. Afr. J. Biotechnol. 2008;7(20):3777-3782.
12. Bosque-Perez NA, Buddenhagen IW. The development of host-plant resistance to insect pests: Outlook for the tropics. Proceedings of 8th International Symposium of Insect-plant Relationship. Dordrecht: Kluver Academic Publishers. 1992;235-239.
13. Subramanyam BH, Hagstrum D. Resistance measurement and management. In: Subramanyam, B.H., Hagstrum, D. (Eds.), Integrated Management of Insects in Stored Products. Marcel Dekker, Inc., New York. 1995;331–398.
14. Park IK, Lee SG, Choi DH. Insecticidal activities of constituents identified in the essential oil from leaves of *Chamaecyparis obtusa* against *Callosobruchus chinensis* (L.) and *Sitophilus oryzae* (L.). J. Stored Prod. Res. 2003;39:375-384.
15. Ntonifor NN, Monah MI. Use of three spices to protect stored maize against *Sitophilus zeamais*. Trop. Sci. 2001;41:74-77.
16. Ntonifor NN, Nsobinenyui D, Fokam EB, Fontem LA. Developing an integrated management approach for the fruit fly *Dacus punctatifrons* on tomatoes. AJEA. 2013;3(3):470-481.
17. Yerima BPK, Van Ranst E. Major soil classification systems used in the tropics: Soils of Cameroon. Victoria Canada, TRAFFORD Publishers. 2005;295.
18. Hill D. Agricultural pests in the tropics and their control. Cambridge University Press, London, UK; 1975.
19. Lale NES, Ofuya TI. Overview of pests problems and control in the tropical storage environment. In: Ofuya T.I. and Lale, N. E. S. (eds) pest of stored cereals and pulses in Nigeria. Dave Collins Publications, Nigeria. 2001;23.
20. Nansen C, Phillips TW, Palmer MW. Analysis of the insect community in a stored-maize facility. Ecol Res. 2004;19: 197-207.
21. Thomas MC. A revision of the new world species of Cryptolestes Ganglbauer (Coleoptera: Cucujidae: Laemophloeinae). Insecta Mundi. 1988;495.
22. CABI Crop Protection Compendium. *Cryptolestes pusillus*. 2008;868.

23. Bale JS, Masters GJ, Hodkinson ID, Awmack C, Bezemer TM, Brown VK, et al. Herbivory in global climate change research: Direct effects of rising temperatures on insect herbivores. Glob. Change Biol. 2002;8:1-16.
24. Petzoldt C, Seaman A. Climate change effects on insects and pathogens. Climate Change and Agriculture: Promoting Practical and Profitable Responses; 2010. Available:http://www.climateandfarming.org/pdfs/FactSheets/III.2Insects.Pathogens.pdf
25. Ngamo TLS, Goudoum A, Ngassoum MB, Mapongmetsem PM, Kouninki H, Hance T. Persistance of the insecticidal activity of five essential oils on the maize weevil *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae). Agric. App. Bio. Sci. 2004;69(3):145-147.
26. Akob CA, Ewete FK. The development and field infestation of *Sitophilus zeamais* Motschulsky (Coleopterea: Curculionidae) on maize in the western highlands of Cameroon. JCAS. 2007;7:77-84.
27. Boura AF. Sensitivity of different strains of *Sitophilus zeamais* to white corn CMS 85O4 and efficiency of traditional storage practices. Brief of DEA, ENSAI, University of Ngaoundéré. 2006;61.
28. Storey CI. Effect and control of insects affecting corn quality. In: S.A. Watson, P.R. Ramstad (Eds.), corn: Chemistry and technology. American Association of Cereal Chemists. St. Paul, MN, USA. 1987;185-190.
29. Bruns HA, Abbas HK. Effects of harvest date on maize in the humid sub-tropical mid-south USA. MAYDICA. 2004;49:1-7.
30. Kaaya AN, Kyamuhangire W, Kyamanywa S. Factors affecting aflatoxin contamination of harvested maize in the three agroecological zones of Uganda. J. Appl. Sci. 2006;6:2401-2407.
31. Seck D. Economic importance and development of an integrated pest management approach to insect pests of corn, millet and cowpea stocks in farmer environments. In: "Post-Harvest in Africa", Aupelf-Uref. 1992;155-160.
32. Zhou HN, Zhao NN, Shu Shan D, Yang K, Cheng FW, Zhi LL, Yan JQ. Insecticidal activity of the essential oil of *Lonicera japonica* flower buds and its main constituent compounds against two grain storage insects. J. Med. Plant Res. 2012;6(5):912-917.
33. Adetunji MO. Economics of maize storage techniques by farmers in Kwara State, Nigeria. PJSS. 2007;4:442-450.
34. Gwinner J, Harnisch R, Muck O. Manual on the prevention of post-harvest seed losses, post-harvest project, GTZ, D-2000, Hamburg, FRG. 1996;294.
35. AK, Prajapati V, Verma N, Bahl JR, Bansal RP, Khanuja SPS. Bioactivities of the leaf essential oil of *Curcuma longa* (Var. Ch-66) on three species of stored product beetles (Coleoptera). J. Econ. Entomol. 2002;95(1):183-189.
36. Hoffmann V, Mutiga S, Harvey J, Nelson R, Milgroom M. Aflatoxin contamination of maize in Kenya: Observability and mitigation behavior. Selected Paper Prepared for Presentation at the Agricultural & Applied Economics Association's. AAEA & CAES Joint Annual Meeting, Washington, DC; 2013.

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