Assessing grain damage and weight loss under varying (LGB) (*Prostephanus truncatus* Horn*)* (*Coleoptera*, *Brostichidae*) initial infestation densities and storage duration in stored maize grain

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Abstract
Larger grain borer (LGB) (Prostephanus truncatus Horn) (Coleoptera, Brostichidae) is a key maize (Zea mays L) grain storage pest in Zimbabwe. There is lack of information on initial infestation densities and storage duration on damage and weight loss by Prostephanus truncatus on maize grain. A laboratory experiment was carried out at Masvingo Christian College Biology Laboratory by utilising a Complete Randomized Design (CRD) with seven treatments and three replications for each treatment. Seven population levels used were: 0, 10, 20, 30, 40, 50 and 60 insects per 250g maize grain. On each assessment date (15, 30, 45, 60, 75 and 90 days) the plastic jars were opened and the contents separated into grains, insects and dust using 4.7 and 1.0 mm sieves.

The data collected included number of damaged kernels, weight of damaged kernels and number of insects from day 45. The results indicated that there were significant differences ($p<0.05$) on grain damage and weight loss in stored maize with increase in initial insect pest density and duration of storage. Farmers are recommended to immediately control LGB when maize has been put in storage.

Keywords: Larger grain borer (LGB), infestation, kernels, dust, post-harvest.

Introduction

Maize (*Zea mays L.*) is the most important grain produced worldwide and used as staple food in most southern African countries.[46,49] It is a basic staple food grain for large parts of world including Africa, Latin America, and Asia.[31,37] It is an increasingly important cereal crop grown and stored in almost all ecosystems in Sub- Saharan Africa. It is both a staple food and its use has increased tremendously in the poultry industry.[11,50]

The crop is grown throughout the country, even in areas best suited for the small grain production. In fact, in the smallholder sector ones prowess is measured from the hectares under maize and yield. Although maize production is mainly dominated by smallholder farmers[8,51], its contribution to food income of many developing countries deserves much more attention, particularly its storage. Losses due to stored pests are currently estimated to be between 35 and 40%.[36,42,45]

According to KILIMO/ GTZ[19], crop pests' infestations deprive farmers of significant parts of their production yearly. The ensuing losses in stored maize impact negatively the national food security in particular and the economy in general.[12]

Insects are the primary pests of maize in storage and the most troublesome pest is *Prostephanus truncates*.[43,47,48] (Verstraeten *et al*., 1987; Helbig, 1995; Ngom *et al*., 2020). Infestations of grains start in the field whereby adults attack whole or broken grains and flour during storage.[38,39,47] *Prostephanus truncatus* is a serious pest of economic importance causing about 30%[45] to 40% losses of total production in 6 months.[42] Pantenius (1988) reported dry weight loss of up to 45% of maize grain after eight months of storage in Togo. Grain moisture content and germination of maize are reduced[40,41] resulting in storage contamination by fungi and bacteria as reported by Lamboni et al.[44] The seriousness of *P. truncatus* damage to stored maize grain varies considerably among countries.

Post-harvest insect pests associated to grains such as maize are the first from the invasive forces to begin the interaction with the grain. Consequently, they are one of the major threats to the grains' quality maintenance during storage.[7] Besides, they are most damaging of all other pests and the most difficult to control due to their small size, feeding behavior and ability to attack grain before harvest.[33] Majority of these insect pests are cosmopolitan and polyphaguos in their feeding behaviors.[10] They cause their damage (loss) on stored grains mainly by direct feeding both in field and storage.

In addition to direct consumption, they also contaminate their feeding media through excretion, molting their own existence, leaving their dead bodies, body fragments, webbing and an unwanted odor or flavor.[30] In most cases, they (insect pests) also pre-dispose the stored grains like maize to secondary attack by disease causing pathogens such as fungi.[32] Besides, a major concern with the presence of insects in storage, is potential to various vector disease organisms. This is because many of them possess hairs and indentations on their exoskeletons that can serve for mechanical vectoring of pathogens. For instance, maize weevils have been reported to carry or vector several fungi species including *Aspergillus niger, A. glaucus, A. candidus, Penicillium islandicum, P. citrinum, Fusarium semitectum* and yeasts.[30]

Despite the various efforts directed towards storage, farmers still face significant losses resulting from storage insect pests. Management of postharvest losses due to insect pests in maize is critical for food security in Zimbabwe. Different storage methods predispose maize grain to pest infestations.

The pest complex of stored maize in Zimbabwe and most Sub- Saharan Africa compromises of *Sitophilus zeamis* (maize weevil), *Prostephanus truncatus* (larger grain borer), *Sitrologa cereallela* (Angoumois grain moth).[9,20,23-25] and *Sitophilus oryzate* (lesser grain weevil)[35]. Two of the most important stored produced insect pests that cause heavy qualitative and quantitative losses are *Sitophilus zeamais* and the recently introduced *Prostephanus truncatus*.[3,9,21,29] Insect pest damage to stored maize results in macroeconomic losses in Zimbabwe where subsistence grain production is the backbone of the livelihoods of the majority of the population.

Damaged grain has been reported to have reduced weight, market value, nutritional value and low percentage germination.[34,35] Makundi et al[21] highlighted that losses due to postharvest insect pests' infestation could be influenced by the storage duration and population density of the infesting insect pests. Storage insect pests cause greater losses of maize particularly in storage where it is kept for a relatively longer time for future utilization. Therefore, the objective of the study was to assess grain damage and weight loss under varying (LGB) (*Prostephanus truncatus*. Horn*)* initial infestation densities and storage duration in stored maize grain.

Experimental site: The experiment was conducted in 2020 in the biology laboratory from February to May 2020. Masvingo Christian College is located south-west of Masvingo town at approximate geographical coordinates of latitude and longitude of 20º5' S and 30º50' E. It is in agro-ecological zone IV. Mean annual temperature ranges from 15^0C to 25^0C.[22] The average rainfall ranges from 450-650mm per year. The study site is in agro-ecological region IV.[53]

Mugandani et al[52] reported that the study area has a mean minimum temperature range of 11-20 ºC, mean maximum temperature range of 19-26 ºC and a mean annual temperature range of 18-24 ºC.

Collection of maize grain and mass culturing of insect pest: The procedure according to Tefera et al[34,35], Makundi et al[21] and Ngom et al[47] was followed for the collection of maize grain and mass culturing of the insect pest. A susceptible maize variety (Pannar 413) was obtained from the researcher's home area. The *P. truncatus* was obtained from the researcher's stored maize infested with *P. truncatus*.

Experimental design and procedure: Complete Randomized Design (CRD) with seven treatments and three replications was used. Seven varying population levels of adult insects of *P. truncatus* were used for the experiment. Population levels used were: 0, 10, 20, 30, 40, 50 and 60 insects per 250g maize grain. The *P. truncatus* was introduced into each jar containing 250g maize grain. The plastic jars were covered with a perforated lid and mesh cloth (1mm) to prevent the escape of the insects and allow gaseous exchange for survival.[34,35] The jars were stored in a laboratory and incubated for 15, 30, 45, 60, 75 and 90 days at room temperature 25-35^{0}C and relative humidity of 70-80%.[47]

Data collection: On each assessment date (15, 30, 45, 60, 75 and 90 days), the plastic jars were opened and the contents separated into grains, insects and dust using 4.7 and 1.0 mm sieves. The data collected included number of damaged kernels, weight of damaged kernels and number of insects from day 45. Weight loss was computed by removing the dust and measuring damaged kernels from the initial weight of 250g after the dust has been removed. The procedure of collecting data was adopted from Harris and Lindblad[17] and Boxal[4].

Data analysis: The data were subjected to Analysis of Variance (ANOVA) using GenStat version 14. The data was also transformed using square root transformation. Means which were significantly different were separated using Bonferroni at 5% significance level.

Results

Effects of Larger grain borer *(P. truncatus)* initial population density on damaged kernels 15, 30, 45, 60, 75 and 90 after infestation: There were significant differences ($p<0.05$) in the mean number of damaged maize kernels at 15, 30, 45, 60, 75 and 90 days after infestation for *P. truncatus* across all treatment levels (Table 1). Pest population of 60 had the highest mean number of damaged kernels at all-time points which was comparable to pest population of 10 at 15 days after infestation and to pest population of 10 at 90 days (Table 1).

The number of damaged kernels was highest after 90 days at the highest initial density of 60 insects per 250g grain. The mean number of damaged kernels increased with increase in initial insect density.

Effects of LGB *(P. truncatus)* initial population density on weight loss of damaged kernels 15, 30, 45, 60, 75 and 90 days after infestation: Significant differences in the mean weight loss were observed at 15, 30, 45, 60, 75 and 90 days after infestation across initial insect densities ($P< 0.05$) as shown in table 2. After 75 days, only the highest density of 60 insects had a significantly higher (P< 0.001) mean weight loss than the control with 0 initial densities. *P. truncatus* density of 90 had the highest mean weight losses which were significantly different (P < 0.001) from lower densities at all-time points. The mean weight loss increased with increase in initial insect density and storage duration and this was evidenced by the dust produced.

Effects of LGB (*P. truncatus)* initial population density on final effect density 45, 60, 75 and 90 days after infestation: Generally, there were significant differences (P< 0.05) in final insect densities at all-time points across the initial insect density (Table 3) compared to the control. Final insect densities increased with an increase in initial insect densities and duration of exposure. The insects were busy tunneling in maize kernels and only insects that showed up during the experiment were recorded.

Discussion

This demonstrated the potential grain damage, weight loss and final insect density increase for *P. truncatus* at varying population densities over storage duration of 90 days. The mean number of damaged kernels and mean weight of loss increased with an increase in initial pest density and duration of exposure of the maize grain. The LGB tended to remain inside the grain causing more damage to the grain as well as weight loss. This was also observed by the amount of dust produced due to the extensive tunneling to the kernels by *P. truncatus.*

Table 1
Effect of Larger grain borer *(P. truncatus*) initial population density on damaged kernels 15, 30, 45, 60, 75 and 90 after infestation

Initial insect density per 250g grain						
Number of days	**15**	**30**	**45**	**60**	**75**	**90**
0	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a
10	14.33ab	19.67b	22.67b	27.33ab	40.00b	58.67b
20	21.33bc	31.00bc	42.33bc	51.67bcd	64.00bcd	79.00bcd
30	24.33bc	31.33bc	41.00bc	47.33bc	60.67bc	74.00bc
40	25.33bcd	40.33cd	48.00c	62.67cde	82.00cde	103.00cde
50	31.67cd	49.67de	55.33cd	80.00de	95.67de	120.00de
60	42.00d	60.33e	69.67d	90.33e	111.67e	135.33e
Grand mean	22.7	33.2	39.9	51.3	64.9	81.4
p-value	<.001	<.001	<.001	<.001	<.001	<.001
LSD	9.79	8.28	12.25	18.24	19.69	24.7
CV%	24.6	14.3	17.5	20.3	17.3	17.3

Means followed by the same letter within a column are not significantly different from each other at 5% significance level.

Table 2
Effect of LGB *(P. truncatus)* initial population density on weight loss of damaged kernels 15, 30, 45, 60, 75 and 90 days after infestation

Initial insect density per 250g grain						
Number of days	**15**	**30**	**45**	**60**	**75**	**90**
0	200.2e	200.3d	200.0c	200.2c	200.0d	200.0d
10	199.6de	199.8cd	198.9bc	198.5bc	198.4cd	196.7cd
20	199.1cd	199.8bcd	198.2bc	197.3b	196.9bc	195.0bc
30	199.0cd	199.7bcd	198.1b	197.3b	196.9bc	194.3bc
40	198.2bc	199.3abc	196.7a	195.2a	194.5ab	190.1ab
50	198.0ab	199.1ab	196.5a	194.5a	193.5a	189.4a
60	197.3a	198.7a	195.5a	193.4a	192.2a	187.7a
Grand mean	198.77	199.533	197.7	196.61	196.06	193.32
p-value	<.001	<.001	<.001	<.001	<.001	<.001
LSD	0.5223	0.4044	0.7557	1.133	1.641	2.823
CV%	0.2	0.1	0.2	0.3	0.5	0.8

Means followed by the same letter within a column are not significantly different from each other at 5% significance level.

Table 3
Effects of LGB (*P. truncatus*) initial population density on final insect effect density 45, 60, 75 and 90 days after infestation.

Initial insect density per 250g grain				
Number of days	**45**	**60**	**75**	**90**
0	0.000a	0.000a	0.000a	0.000a
10	3.333ab	3.6667b	4.667ab	8.333b
20	5.333bc	4.667b	6.333bc	7.667b
30	4.000ab	4.333b	6.000b	8.667b
40	5.667bc	6.667bc	8.000bcd	8.333b
50	9.333c	9.333cd	11.000cd	14.333bc
60	14.677d	12.333d	12.333d	16.333c
Grandmean	6.05	5.86	6.9	9.1
p-value	<.001	<.001	<.001	<.001
LSD	2.702	1.986	2.729	2.047
CV%	25.5	19.4	22.6	27.6

Means followed by the same letter within a column are not significantly different from each other at 5% significance level.

The tunneling allows the insect to convert grain into dust/ flour within a short period of time as the *P. truncatus* mostly survives within the maize grain. The *P. truncatus has* a very aggressive boring and feeding habit resulting in high losses even with fewer insects.

The highest density of 60 LGB insects per 250g caused a total weight loss of 6.2% in 90 days. Damaged grain had reduced weight, market value, nutritional value and low percentage germination.[34,35] This observation was also consistent with that made by Makundi et al[21] who concluded that losses due to postharvest insect pests' infestation could be influenced or affected by the storage duration and population density of the infesting insect pests.

Though the figures slightly vary, this could be attributed by the different experimental conditions, variability of climatic conditions, difference in number of insect pests and susceptibility of the hybrid used. The current study revealed that smallest initial density (10 insects 250g-1 grain) of *P. truncatus* caused high grain damage and weight loss. This indicates that small initial population of the *P. truncatus* in stores at the beginning of the season suffices to cause high infestation levels at the end of the storage period since maize can be stored for more than 90 days.

In the present study, mean weight loss recorded after 90 days was 193.32grams. This implies that in the absence of control measures, post- harvest losses due to LGB during storage can be severe. Although not experimentally tested individual farmers reportedly suffering high losses of up to 34% dry weight and in very extreme cases, 70 to 80% of the maize grains were damaged. Dry weight loss of up to 45% of maize grain was reported after eight months of storage in Togo. Several authors reported that *P. truncatus* is a serious pest of economic importance causing about 30%[45] to 40% losses of total production in 6 months.[42] The dust produced consists of the insects' eggs, excreta and exuvia and is therefore unfit for human consumption due to its unattractive taste.[34,35]

In addition to direct consumption, they also contaminate their feeding media through excretion, molting their own existence leaving their dead bodies, body fragments, webbing and an unwanted odor or flavor.[30] In most cases, they (insect pests) also pre-dispose the stored grains like maize to secondary attack by disease causing pathogens such as fungi.[32] The increase in damaged kernels and weight loss after 30 days indicates that insect numbers would have multiplied and the first generation will be active in terms of grain damage within 45days in addition to their parents.

According to Tefera et al[34,35] the final insect densities, percent grain damage, flour (dust) produced and weight loss due to *P. truncatus* exceeded that of *S. zeamais.* Some studies on maize losses in Ghana estimated about 15% to 45 % market value loss due to damage by LGB. Abass et al[1] reported that after six months of maize storage, LGB was responsible for more than half (56.7%) of the storage losses.

Conclusion

Grain storage insect pest *P. truncatus* is of economic importance on maize storage. The results of this study proved that grain damage and weight loss in stored maize increased with increase in initial insect pest density and duration of exposure. This implies that in the absence of control measures, post-harvest losses due to the LGB during storage can be severe. The figures highlighted that there is need for control measures to be put in place when storing maize after harvest in order to prevent storage losses due to LGB.

Recommendations

Once a crop has been placed in storage, the story does not end there. The farmers have to regularly monitor and sample the grain, ensuring that any infestation is not arising. If they do notice any infestation, then steps must be taken. Survey of post-harvest generally focuses on detection and monitoring. The study showed that in order to safe guard the maize grain against larger grain borer, scouting for storage pest is very critical and control measures must be implemented in the presence of even a single pest. There is need for farmers to regular inspect their stored grains in order to detect and deal with insect storage infestation. Therefore, it is recommended that control measures should be put in place on the onset of grain storage if grain is to be stored for more than 15 days.

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