Effect of Interspecific Competition between the Larger Grain Borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrychidae) and the Maize Weevil, *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae) on Grain Damage and Progeny Production in Stored Maize (*Zea mays* L)

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ABSTRACT: This study investigated the effect of the interaction between *Prostephanus truncatus* (Horn) (LGB) and *Sitophilus zeamais* (Motschulsky) (MW) on grain damage and progeny production in stored maize. 50g maize grains replicated four times was placed into 250ml Kilner[®]. 10 and 5 pairs of 1-3 day old adult LGB and MW were introduced into each Kilner[®] jar in single and simultaneous infestation and placed in a completely randomized design (CRD) in the laboratory at 27±1°C and 75-80% RH. There was increase in the number of emerged insects from F1 to F2 for both insects. The percentage change in the number of emerged LGB was 18.7% and 9.0% in single and simultaneous infestation respectively, while in MW, it was 13.2 % and 16.8% respectively. There was a significant reduction in the reproductive performance of the two insects during simultaneous infestation when compared with single infestation. The weight loss and damage caused by LGB were 4.31 and 7.21% while that for MW were 2.55 and 5.85% respectively for single infestation and 5.0 and 9.67% for simultaneous infestation at F1. For F2 generation weight loss and damage to grains was 6.90 and 11.14% for LGB and 3.78 and 7.79% for MW during single infestation while for simultaneous infestation it was 8.33 and 13.33%. There was a positive correlation between the number of LGB and MW and the grain weight loss and weight damage of stored maize. The result of the study indicated the potential of LGB and MW to cause huge weight loss and damage in maize grains which can lead to serious storage losses.

Keywords: *Prostephanus truncatus*, *Sitophilus zeamais*, grain damage, reproductive performance, grain weight loss.

INTRODUCTION

Insect pest damage to store grains result in major economic losses to farmers throughout the world (Obeng-Ofori, 2008). It is estimated that approximately one-third of the world food crop is destroyed by insects at various stages including storage. This constitutes a major constraint to

food security and income generation in sub-Saharan Africa (Abebe *et al.*, 2009; Osipitan *et al.*, 2011). Up to 20-30% loss of maize can be experienced because farmers often lack effective post-harvest storage technologies (Mwoko *et al.*, 2012) especially in rural regions where maize is typically stored in bags or other containers (Abass *et al.*, 2014; De Groot *et al.*, 2013), and these losses are due primarily to two internally feeding postharvest insect pests namely, maize

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weevil (MW) *Sitophilus zeamais* (Motschulsky) and the larger grain borer (LGB) *Prostephanus truncatus* (Horn) (Omondi *et al.*, 2011; Tefera *et al.*, 2011). *Prostephanus truncatus* and *S. zeamais* are primary insect pests of maize (Meikle *et al.*, 1998) resulting in severe damage and great weight losses in stored maize. Once the crop has attained maturity and is drying in the field, both insects infest the standing crop but most damages occur in storage. The insects cause characteristic damage to maize by making holes in which the adult female deposit her eggs on the grain. Being internal feeders, early detection of infestation by these insects is very difficult (Sahaf *et al.*, 2008). The damages caused result directly in loss of food (reduced grain weight) ready for consumption or loss of cash from farmers' pocket ready to buy other valuable resources for the family (Boxall *et al.*, 2002). The damage also reduces the viability of the seeds (Cornelius *et al.*, 2008) as the larvae and adult consume the embryo affecting maize production of farmers who plant grains of the last season as seed. Apart from the physical damage, there is also the health risk associated with the consumption of infested maize kernels as it has been reported to have relatively higher levels of aflatoxin contamination than non-infested maize kernels (Dhliwayo and Pixley, 2003, Golob, 2002, Kankolongo *et al.*, 2009).

The LGB is rated as the most damaging postharvest insect pest of maize causing substantial losses and aggravating hunger and poverty (Nwololo *et al.*, 2010). Larger Grain Borer and MW are known to complete their development over a wide range of temperature, ranging from 27°C to 32°C and between 70% and 80% relative humidity conditions. The developmental period for both insects is approximately 30 days (Howard, 1984). The intrinsic rate of increase of LGB is reported by Cowley *et al.*, (1980) to be Λ 1.399 at optimum conditions on shelled maize grains and this apparently low rate may reflect a feature of inter-specific competition with more fecund storage pests like *S. zeamais*. It is therefore important to examine the interaction of LGB and *S. zeamais* from this point of view. As noted by Chapman and Resiss (2002), organisms differ in their ability to compete with each other and hence

varying impacts of one species on another. Regarding inter-specific associations, Weimerskirch *et al.*, (2003) observed that these can cause changes in reproduction since the effect of increasing intensity of competition among adult insects decreases fecundity or rate of reproduction after some generations. The objective of this study therefore, was to compare the F1 and F2 adults that emerged during single and simultaneous infestation as well as the damage and weight loss caused by the infestation of these insects in stored maize.

MATERIALS AND METHODS

Insect Culture

Prostephanus truncatus (LGB) and *Sitophilus zeamais* were obtained from a culture maintained on dried maize grains in separate 250ml Kilner® jars in the Entomology Research Laboratory of the Department of Zoology, Faculty of Science, University of Lagos. Several LGB and *Sitophilus zeamais* adults were introduced separately into the uninfested maize grains. For massive production of the two insect pests, *Sitophilus zeamais* was reared on shelled maize while LGB was reared on maize on the cobs (Hodges 1986, Kossou *et al.*, 1992). Frass generated by the feeding activities of the insects were sieved out on weekly basis using sieve of mesh size 0.25mm to prevent excessive grain moisture content and growth of mould. The jars were left undisturbed and emerged F1 adults were collected into vials containing disinfested maize grains.

Assessment of F1 and F2 *P. truncatus* and *S. zeamais* Numbers

The maize variety (Oba-Super 1) used for the study was obtained from the Crops Sub-Component of the Lagos State Agricultural Development Authority, Oko-Oba, Agege (LSADA). The maize grains were picked to remove unwholesome ones and disinfested by keeping them in the freezer at -20°C (cold shocking) for ten days, and then leaving them on the laboratory bench for 10 days to attain equilibrium condition of temperature and relative humidity (27±1°C and 75-80% RH). Thereafter, 50g maize grains were weighed into 250ml Kilner® jars and infested with 1-3 day old adult

LGB and *S. zeamais*. There were four treatments replicated four times and arranged in the laboratory in a Completely Randomized Design (CRD) as follows:

- Single infestation of maize grains with 10 pairs of LGB.
- Single infestation of maize grains with 10 pairs of *S. zeamais*.
- Simultaneous infestations of maize grains with 5 pairs of LGB and 5 pairs of MW.
- Control comprised only maize grains without insects, this serves to measure moisture gain or loss as a result of environmental factors.

All the treatments and control were replicated four times. After 7 days the adults were removed from each replicate, and left undisturbed for 13 days for F1 generation. Thereafter, the grains were inspected daily for emergence of F1 adults. Adults that emerged were removed and numbers recorded. The exercise continued until no adult emerged for three days. Similarly, a number of dead insects was also recorded. In the separate set ups for the F2 generation, F1 adults were left to mate and lay eggs in the maize samples for two weeks and the F2 adults were then removed and recorded as they emerged.

Determination of Grain Damage and Weight Loss of Maize Grains

At 70 days after infestation, each sample replicate was sieved to remove the resultant maize dust, and weighed to determine the weight losses of the maize grains at both F1 and F2. Damage was assessed after the complete emergence of adult insects. This was done by separating grains into damaged and undamaged grains and calculating percentage damage according to Baba-Tieto (1994) and Adedire and Ajayi (1996). The actual weight loss (%) of the maize grains due to insect attack and grain damage (%) were calculated according to Baba-Tieto (1994) and Yusuf and Ahmed (2005) using the formula:

$$WL(\%) = (IWs - FWs) / IWs \times 100\%$$

Where WL = Weight

loss

IWs = Initial weight of sample before

infestation

Fws = Final weight sample after infestation

GD% = $WD / TW \times 100\%$

Where GD = Grain damage

WD = Weight of damage grains

TW = Total weight of damage and undamaged grains

Data Analysis

Data were subjected to analysis of variance (ANOVA) and means were separated using Duncan's New Multiple Range Test (DNMRT) at $p < 0.05$. The t-test was carried out to compare the changes in the numbers of emerged F1 and F2 progeny of *P. truncatus* and *S. zeamais* and their mortality during single and simultaneous infestation. Damage indices for both F1 and F2 of the two insects were correlated using SPSS software.

RESULTS

Number of Emerged Adult LGB and *S. zeamais*

The results showed different reproductive performances of the two insects during single and simultaneous infestation in maize grains. The mean number of emerged LGB and *Sitophilus zeamais* at F1 and F2 is shown in Table 1. In the F1 generation, the mean number of *S. zeamais* that emerged (174) during single infestation was significantly higher ($p < 0.05$) than the number of emerged LGB (109). Similarly, for the simultaneous infestation, the number of emerged *S. zeamais* (99) was significantly higher ($p < 0.05$) than the number of LGB (77). Same trend were obtained in F2 generation.

There was a change in adult insect numbers from F1 to F2 for the two insects. The result indicated that there is a significant increase in the numbers of emerged LGB and *S. zeamais* during single and simultaneous infestation at both F1 and F2 respectively. Each insect exhibited higher but not significant number of emergence from F1 to F2. The percentage change in numbers of LGB during single infestation (18.7) was greater than during simultaneous infestation (9.0) (Table 1) when

Table 1: Mean number of adult insects that emerged and change (%) in adult numbers from F1 to F2 in single and simultaneous infestation

Insect spp	Infestation Type	F1	F2	% Change
<i>P. truncatus</i>	Single	109.0±15.6 ^b	169.0±73.4 ^c	18.7±14.7 ^c
	Simultaneous	77.0±21.5 ^a	92.0±23.1 ^a	9.0±3.0 ^a
<i>S. zeamais</i>	Single	174.0±67.3 ^c	223.0±68.5 ^d	13.2±3.7 ^b
	Simultaneous	99.0±1.7 ^b	125.0±52.7 ^b	16.8±10.3 ^b

Means followed by the same letter in each column are not significantly different ($P < 0.05$) according to Duncan New Multiple Range Test (DNMRT).

Weight and Damage Assessment During Single and Simultaneous Infestation of LGB and MW

There was an increase in the damage and weight loss of grains from F1 to F2 (Table 2). The mean weight of dust, weight loss and grain damage increased significantly from F1 to F2 during single and simultaneous infestation for the two insects. The weight loss and grain damage caused by LGB was significantly higher ($P < 0.05$) than that caused by *S. zeamais* under similar conditions. In single species infestation at both F1 and F2, significantly higher ($p < 0.05$) maize damage was caused by LGB (7.21 and 11.4%) compared to *S. zeamais* (5.85 and 7.79%). Weight loss on the other hand was (4.31 and 6.90%) as well as (2.55 and 3.78%) respectively, for LGB and MW. Weight loss (5.0 and 8.33%), and grain damage (9.67 and 13.33%) recorded during simultaneous infestation was significantly higher ($p < 0.05$) when compared with the values recorded during single infestation of the individual

insect. The mean weight of dust recorded during single infestation of the individual insect (2.39 and 3.63) and (1.43 and 2.40) though significantly high ($p < 0.05$) is not as high as the dust recorded during simultaneous infestation of both insects (4.03 and 4.67) at both F1 and F2.

Mortality of Adult *Prostephanus truncatus* and *Sitophilus zeamais* at F1 and F2

Mortality of LGB was significantly higher ($p < 0.05$) at both F1 and F2 than the mortality recorded from *S. zeamais* during single and simultaneous infestation (Table 3).

Correlation of LGB and *Sitophilus zeamais* and the Damage Indices at F1 and F2

The correlation of the weight of dust, weight loss and damage was significantly positive ($p < 0.05$) (Tables 4 & 5) during single infestation for both LGB and *S. zeamais* at both F1 and F2. Same trend occurs in simultaneous infestations (Table 6) for the two insects.

Table 2: Mean Weight (Wt) of dust, % Weight loss and % Grain damage at F1 & F2

Insect spp	Infestation type	Dust	%Weight loss	% Grain damage
<i>P. truncatus</i>	Single(F1)	2.39±0.63 ^b	4.31±1.12 ^c	7.21±3.13 ^b
<i>S. zeamais</i>	Single(F1)	1.43±0.29 ^a	2.55±0.81 ^a	5.85±2.33 ^a
	Simultaneous(F1)	4.03±1.18 ^d	5.00±1.73 ^d	9.67±3.48 ^c
<i>P. truncatus</i>	Single(F2)	3.63±1.38 ^c	6.90±1.07 ^c	11.14±2.60 ^d
<i>S. zeamais</i>	Single(F2)	2.40±0.84 ^b	3.78±0.90 ^b	7.79±2.63 ^b
	Simultaneous(F2)	4.67±1.45 ^d	8.33±3.76 ^f	13.33±3.76 ^e

Means followed by the same letter in each column are not significantly different ($P < 0.05$) according to Duncan New Multiple Range Test (DNMRT).

Table 3: Mortality of Adult LGB and *Sitophilus zeamais* at F1 and F2

Insect spp	Infestation type	LGB	<i>S. zeamais</i>
<i>P. truncatus</i>	Single(F1)	4.31±1.12 ^c	2.39±0.63 ^b
<i>S. zeamais</i>	Simultaneous(F1)	2.55±0.81 ^a	1.43±0.29 ^a
<i>P. truncatus</i>	Single(F2)	5.00±1.73 ^d	4.03±1.18 ^d
<i>S. zeamais</i>	Simultaneous (F2)	6.90±1.07 ^a	3.63±1.38 ^c

Means followed by the same letter in each column are not significantly different ($P < 0.05$) according to Duncan New Multiple Range Test (DNMRT).

Table 4: Correlation matrix of *Prostephanus truncatus* and damage indices at F1 and F2 (single infestation)

	F1 DUST	F1 LOSS	F1 DAMAGE	F2 DUST	F2 LOSS	F2 DAMAGE
F1 DUST	1					
F1 LOSS	0.000 ^{**}	1				
F1 DAMAGE	0.000 ^{**}	0.000 ^{**}	1			
F2 DUST	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	1		
F2 LOSS	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	1	
F2 DAMAGE	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	1

^{**}Correlation is significant at the 0.01 level

Table 5: Correlation matrix of *Sitophilus zeamais* and damage indices at F1 and F2 (single infestation)

	F1 DUST	F1 LOSS	F1 DAMAGE	F2 DUST	F2 LOSS	F2 DAMAGE
F1 DUST	1					
F1 LOSS	0.26 [*]	1				
F1 DAMAGE	0.26 [*]	0.000 ^{**}	1			
F2 DUST	0.26 [*]	0.000 ^{**}	0.000 ^{**}	1		
F2 LOSS	0.26 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	1	
F2 DAMAGE	0.26 [*]	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	1

^{*}Correlations are significant at 0.01 and 0.05 levels

Table 6: Correlation Matrix of Both *Sitophilus zeamais* and *Prostephanus truncatus* at F1 and F2 (Simultaneous Infestation)

	F1 DUST	F1 LOSS	F1 DAMAGE	F2 DUST	F2 LOSS	F2 DAMAGE
F1 DUST	1					
F1 LOSS	0.000 ^{**}	1				
F1 DAMAGE	0.000 ^{**}	0.000 ^{**}	1			
F2 DUST	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	1		
F2 LOSS	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	1	
F2 DAMAGE	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	0.000 ^{**}	1

^{*}Correlation is significant at the 0.01 level

DISCUSSION

The results showed the different reproductive performance of the two insects at four different treatment levels. Inter specific competition is normally more frequent and symmetrical among

species feeding internally than among species feeding externally. Competition generally is assumed to have only negative effects on both (all) competing species. Competitions among individuals of a given population represent a

major negative feedback mechanism for regulation of population size. Similarly, competitions among species represent a major mechanism for regulations of the total abundance of multiple species populations. It was deduced from the study that as the number of LGB and MW increased, each individual had access to a decreasing share of the resource(s) and since the competition is asymmetrical, the superior species (MW) completely suppressed the population of LGB.

It was noted from the study that MW produced more individuals at F1 and F2 than LGB. However, the number of progeny from both species was adversely affected by competitive interactions. As noted by Chapman and Reiss (2002) organisms differ in their ability to compete with each other and hence varying impacts of one species on another. Regarding inter-specific associations, Weimerskirch *et al* (2003) observed that these can cause changes in reproduction since the effect of increasing intensity of competition among adult insects decreases fecundity or rate of reproduction after some generations. Mortality of adult LGB was higher than that of MW during simultaneous infestation at both F1 and F2 generations. This is an indication that MW was the dominant competitor and had a significant suppressant effect on the activities of *P. truncatus* when in interspecific competition. As reported by Denno *et al.*, (2002) most competitive interactions were asymmetrical that is, one species is a superior competitor and suppressed the other.

The study revealed that *S. zeamais* would out-compete *P. truncatus* when they are both present together on shelled maize. This is in consonance with the report of Golob (1988) that *S. zeamais* thrives well on loose grains relative to LGB that thrives well on unshelled maize.

Dust production by *P. truncatus* during single and simultaneous infestation at both F1 and F2 exceeded that of *S. zeamais*. This is attributable to the extensive tunneling of the grain by *P. truncatus*. This tunneling by *P. truncatus* allows it to convert grains into flour within a very short period of time. This corroborates the position of Hodges *et al* (1983) that the most obvious cause of weight loss in *P. truncatus* infested grain is the conversion of the

grain to maize powder by the boring activities of both larvae and adults. The mean weight losses (4.31% and 6.90%), (2.55% and 3.78%) and the damage (7.21% and 11.14%), (5.85% and 7.79%) recorded for *P. truncatus* and *S. zeamais* (single infestation at both F1 and F2) during the course of the study implies that post harvest losses due to the two insects could be severe if adequate control measures are not put in place. The results reported here is consistent with those of earlier workers who reported that grain losses in maize caused by MW are 12-20% and 9-45% for LGB depending on periods of storage (Abdullahi *et al.*, 2011, Gueye *et al.*, 2008, Law-Ogbomo and Enobakhare, 2006, Markharm *et al.*, 1991; Panthenius, 1988, Tefera *et al.*, 2011). Similarly in Malawi, Singano *et al.*, (2007) reported that after the introduction of *P. truncatus*, harvested maize grain losses was up to 80% on shelled maize after six months. In very intense cases of infestation, the stored maize can practically be completely destroyed; resulting in total loss (Singano and Nkhata, 2004). Another reason that can be adduced for such damage could be that the two insects have mouthparts that are well adapted for chewing and grinding of maize grains into powder.

The final insect densities, grain damage, dust produced and weight loss for *P. truncatus* exceeded that of *S. zeamais* during single infestation. Greater damage and weight loss recorded in grain infested with LGB than those infested with MW was not unexpected considering the fact that LGB has been widely reported to be the most destructive insect pest of contemporary times (Anankwara *et al.*, 2012, Omondi *et al.*, 2011). The insect was noted to cause losses that exceeded those of other insects under similar conditions (GASGA, 1993). Storage losses in LGB-infested maize according to ADA (2010) varied between 15% and 30% depending on the regions. This agrees with the work of Golob and Hodges (1982) who reported that in Tanzania, the introduction of LGB elevated maize losses in store to 50% from the previous average of 5% damage. According to Magrath *et al.*, (1996), loss in maize due to *P. truncatus* was consistently higher than those due to other insect pest species. Although many

storage insect pests are ubiquitous throughout the sub-Saharan Africa, *P. truncatus* has been found to cause more than twice the weight loss in maize than infestation by *S. zeamais* (Stathers *et al.*, 2008).

CONCLUSION

It can be concluded that simultaneous infestations significantly reduced the reproductive performance of LGB and *S. zeamais* at both F1 and F2 generations. The result also revealed the ability of *S. zeamais* to suppress the activities of LGB when in competitive interaction. The result of the study indicates the potential of LGB and *S. zeamais* to cause huge weight loss and damage maize grains leading to serious storage losses. These losses and damage can result in food insecurity, threat to the livelihood of the poor people in Africa as well as health risk associated with the consumption of infested maize kernel, as it has been reported to have relatively high levels of aflatoxin contamination than non-infested maize kernels (Dhliwayo and Pixley, 2003; Kankolongo *et al.*, 2009). Considering the importance of maize as a major staple food crop in Africa, concerted effort should therefore be geared toward controlling the infestation of maize grain by LGB and *S. zeamais*.

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