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Loss Assessment of Stored Maize at Different Storage Durations and Maize Weevil Densities

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Authors' contributions

This work was carried out in collaboration between both authors. Author MJ designed the study, perform the statistical analysis, wrote the protocol and the first draft of the manuscript. Author OORP supervised the overall work. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: The extent of stored grain losses depends on varieties and duration of storage, and most of the quantitative losses are attributed to insect pest infestations. The study was conducted to determine the damage caused by *Sitophilus zeamais* on maize stored at different durations.
Methodology: *Sitophilus zeamais* at four varying population densities (5, 10, 15, 20 adults) and four storage durations (30, 60, 90 and 120 days) reared on 200 g sample of Jeka maize variety was kept in glass jars covered with muslin cloth in a 4 x 4 factorial fitted in a completely ramdomised design with four replicates at room temperature for 120 days.
Results: Weight loss, seed damage and weight of dust caused by *S. zeamais* on maize seeds at 5-insect and 20-insect levels were statistically similar at 30 and 120 days but show significant difference at 60 days after storage. *Sitophilus zeamais* population continued to grow exponentially on maize grains after 120 days of storage, indicating that factors are not limiting, thereby causing significant losses to stored grains. Temperature and

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relative humidity were found to affect insect population growth positively (r = 0.73 and r = 0.70, respectively).
Conclusion: The study concluded that *S. zeamais*, which is a major pest in The Gambia, in the absence of control measures at any number of infestations greater than 5 weevils could result to severe damage to stored seeds.

Keywords: Exponentially; Jeka; population densities; storage duration; Sitophilus zeamais; The Gambia.

1. INTRODUCTION

In The Gambia, about 6.8% of the farming households are maize growers and an estimated 434,769 fields were cultivated in 2012 out of which 72,532 (17%) were cultivated with maize [1]. Maize production increased by 20.82% in 2010 to a total production of 66,000 metric tonnes but decreased by 64.22% to 23,613 metric tonnes in 2011 as a result of poor rainfall, and in 2016 increased again from 10.50% to 39,463 [2]. Maize is a major food crop of The Gambia, contains excellent properties all over the world. It is an important staple food for about 1.2 billion people around the world, which provides over 20% of the total calories in human diets in 21 different countries in Africa, and also provide the food to more than 300 million people in the continent [3,4]. In The Gambia, maize grains are processed and consumed as "*Cherreh"*, porridge, boiled or roasted and serve as animal feed.

During storage, maize grains can be infested and destroyed by insect pests, especially when the grains are stored on-farm with no insecticide protection or control over moisture content [5]. The maize weevil, *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae), is among the most destructive pest of stored cereals in tropical and sub-tropical regions [6]. *Sitophilus zeamais* infests maize in the field before harvest and continues through transportation or storage, where the larvae feed and develop within grains [7,8,9]. It bores holes in the grain, consumes a large portion of the endosperm, destroys the germ and thus reduces the nutritive value and germination viability of the grain These activities produce moisture that aid in caking and fungal growth of the grain, which constitutes quality loss. Therefore, the objective of this study was to assess the losses caused by *S. zeamais* on stored maize seeds in order to establish the most suitable time for application of control measures.

2. MATERIALS AND METHODS

2.1 Culturing of Study Insects

The weevils used for cultures were obtained from infested maize samples collected from Brikama, Barra and Basse of The Gambia. Fifty adults of *S. zeamais* with both sexes were cultured on clean and disinfested maize seeds in 500 ml capacity plastic jars on 250 g of seeds. To prevent weevil escape, the jars were covered with muslin cloth tightened with a rubber band and placed in the laboratory at ambient temperature (25 ± 2ºC) and relative humidity (70 ± 5%). The weevils were allowed to oviposit for 7 days, thereafter; all adults were removed and placed in another set of jars, the newly emerged adults of *S. zeamais* were used for the study [10].

2.2 Source of Maize Seeds

Maize seeds obtained from the National Agricultural Research Institute (NARI) in The Gambia immediately after harvest were disinfested using cold shock treatment at -20 ± 2°C for two weeks after which the seeds were air-dried and kept in 500 ml air-tight plastic jars in the laboratory.

2.3 Damage Caused by *S. zeamais* on Maize at Different Grain Storage Times

A sample of 200 g of disinfested maize, Jeka variety was placed in 1 L glass jars, covered with muslin cloth in four replicates arranged in a 4 x 4 factorial fitted into a Completely Randomized Design at the National Agricultural Research Institute laboratory. Each replicate was infested with 5, 10, 15, 20 adults of unsexed *S. zeamais* for a duration of 30, 60, 90 and 120 days in the following combinations: $5_{30,}$ $5_{60,}$ $5_{90,}$ $5_{120;}$ $10_{30,}$ $10_{60,}$ $10_{90,}$ $10_{120;}$ $15_{30,}$ $15_{60,}$ $15_{90,}$ $15_{120,}$ $20_{30,}$ $20_{60,}$ $20_{90,}$ 20_{120}. Temperature and relative humidity were recorded daily to determine the influence of weather factors on the damage and reproductive parameters of the weevil.

2.4 Data Collection

On each assessment date, 30, 60, 90, 120 days after seed storage, the content of the glass jars (treatments) was separated into seeds, insects and dust using 1.0 and 4.7 mm sieves. Number of live and dead insects, number and weight of damaged seeds, number and weight of undamaged seeds and weight of the dust produced were recorded. Weighing was done with a digital electronic scale (XY-8006 model). Percentages were calculated using equation 1 (percent damaged grain) and equation 2 (percent weight loss).

$$\%\ \text{Grain damage} = \frac{\text{Total number of bored grains}}{\text{Total number of grains}} \times 100 \quad 1$$

$$\%\ \text{Weight loss} = \frac{(\text{Wu}\times \text{Nd})-(\text{Wd}\times \text{Nu})}{\text{Wu}(\text{Nd}+\text{Nu})} \times 100 \quad 2$$

Where

Wu = weight of undamaged;
Nd = number of damaged;
Wd = weight of damaged
Nu = number of undamaged [11]

2.5 Statistical Analysis

Data collected on insect count were subjected to square root transformation (√x+1), whilst percent grain damage, dust weight and weight loss were angular transformed (arcsine √proportion). The transformed data were analysed using analysis of variance (ANOVA) with SAS (JMP 14) method. Means were separated with Student's Newman-Keuls tests at 5% probability. Correlation and regression analysis were also carried out using MS Excel.

3. RESULTS

3.1 Final Insect Density

There were no significant differences in the final insect density (FID) at 30 (*P* = 0.09) and 120 days (*P* = 0.82) after seed storage, however, significant differences were observed at 60 (*P* = 0.02) and 90 days (*P* = 0.03) after seed storage for all treatments (Table 1). Initial Insect Densities (IID) of 5, 10, and 15 were not significantly different from each other in the FID at all storage durations, but IID of 20 was significantly different from the others in FID with 9.50 ± 1.43 and 49.75 ± 6.68 at 60 and 90 days after grain storage, respectively (Table 1). All the IID showed an exponential population growth curve during the 120 days storage period (Fig. 1).

3.2 Grain Damage

There were significant differences between the IID in percent grain damage at 30 (*P* = 0.002), 60 (*P* = 0.001) and 90 (*P* = 0.01) days after seed storage. At 120 days after seed storage, the IID of 5, 10, 15 and 20 showed no significant difference (*P* = 0.62) in percent grain damage. Percentage grain damage started rising at 90 days after seed storage, with the least (3.48) and highest (7.88) percent grain damage recorded at IID of 5 and 20, respectively (Table 2). Grain damage severity increased as the storage duration extents as indicated by the grain damage curves (Fig. 2).

3.3 Weight of Dust

Significant differences were observed in the weight of dust produced at 60 days (*P* = 0.002) after grain storage (Table 3), dust produced was found to increase with an increase in storage period (Fig. 3). The least mean amount of dust (0.01 ± 0.005g) was produced by IID 5 at 30

Table 1. Mean values of final insect density in 200 g maize seeds with different levels of infestation of *Sitophilus zeamais*

Initial insect density	Storage period (days)			
	30	60	90	120
5	2.75 ± 1.31a	1.75 ± 1.43b	21.50 ± 6.68b	98.25 ± 31.62a
10	3.25 ± 1.31a	6.75 ± 1.43ab	21.25 ± 6.68b	125.50 ± 31.62a
15	5.25 ± 1.31a	5.00 ± 1.43ab	27.00 ± 6.68b	142.25 ± 31.62a
20	7.50 ± 1.31a	9.50 ± 1.43a	49.75 ± 6.68a	133.25 ± 31.62a

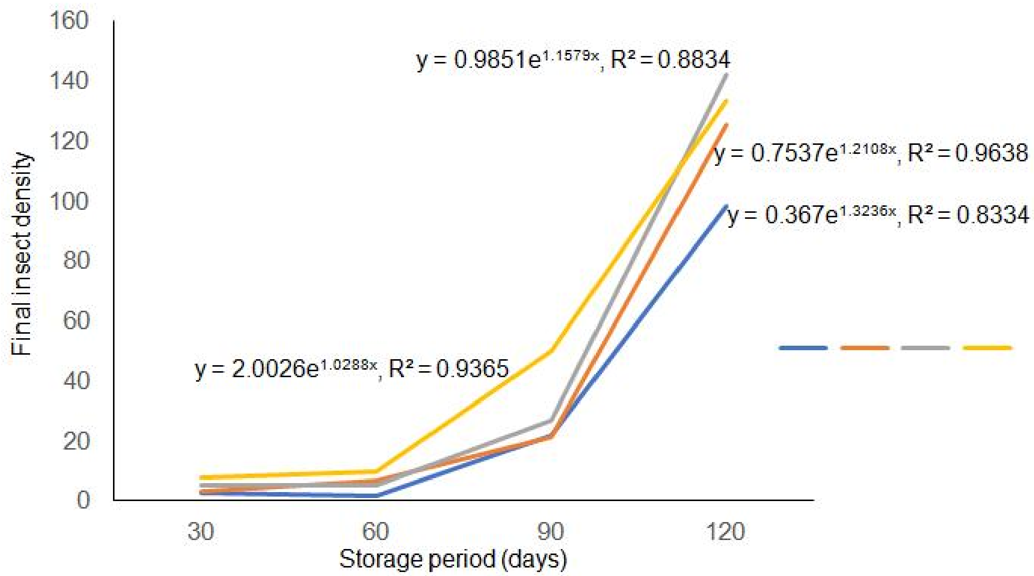

Fig. 1. Population growth curves for different IID fed on maize seeds for 120 days

And 60 days, while the highest mean dust weight (0.84 ± 0.20g) was produced by IID 15 at 120 days after seed storage (Table 3).

3.4 Weight Loss

Percent weight loss showed significant differences at 60 days *(P* = 0.007*)* after seed storage. A similar percent weight loss was observed at 30, 90, 120 days after seed storage with the least (0.07%) and highest (4.44%) percent weight loss registered at 30 and 120 days after storage, respectively (Table 4). Percent weight loss increased as the storage duration extended from 30 to 120 days (Fig. 4).

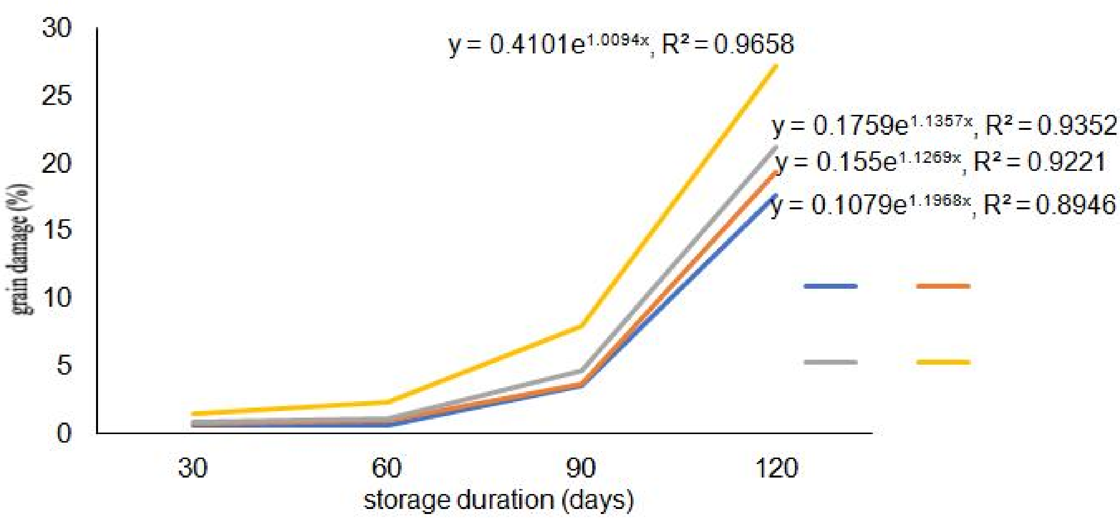

Fig. 2. The relationship between percent grain damage and storage duration for different IID fed on maize seeds

Table 2. Mean percent of damaged seeds in 200 g of maize seeds with different levels of *Sitophilus zeamais* infestation for 120 days

Initial insect density	Storage period (days)			
	30	60	90	120
5	0.59b	0.59b	3.48b	17.64a
10	0.71b	0.92b	3.59b	19.30a
15	0.79b	1.05b	4.67b	21.17a
20	1.42a	2.26a	7.88a	27.09a

Table 3. Mean values of weight of dust produced in samples of 200 g of maize seeds with different infestation levels of *Sitophilus zeamais* for 120 days

Initial insect density	Storage period (days)			
	30	60	90	120
5	0.01 ± 0.005a	0.01 ± 0.007b	0.11 ± 0.03a	0.59 ± 0.20a
10	0.02 ± 0.005a	0.03 ± 0.007b	0.10 ± 0.03a	0.69 ± 0.20a
15	0.02 ± 0.005a	0.03 ± 0.007b	0.15 ± 0.03a	0.84 ± 0.20a
20	0.03 ± 0.005a	0.07 ± 0.007a	0.24 ± 0.03a	0.71 ± 0.20a

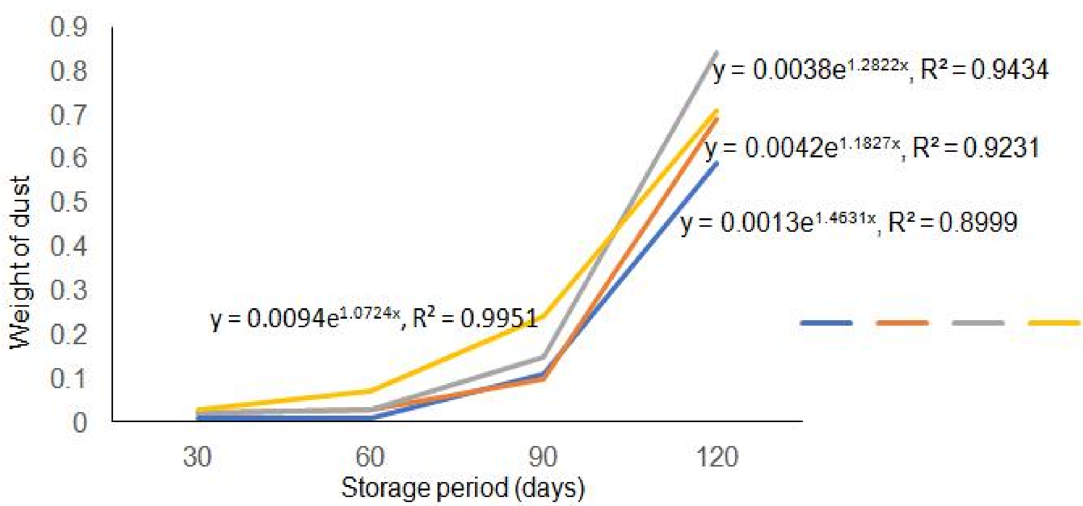

Fig. 3. Relationship between weight of dust and storage duration for different IID fed on maize seeds

Table 4. Mean percent of weight loss in samples of 200 g of maize seeds with different infestation levels of *Sitophilus zeamais* for 120 days

Initial insect density	Storage period (days)			
	30	60	90	120
5	0.07a	0.09b	0.50a	2.79a
10	0.08a	0.14b	0.42a	3.57a
15	0.16a	0.16b	0.67a	3.44a
20	0.09a	0.37a	1.13a	4.44a

3.5 Determination of Insect Densities and Grain Damage for Days within the Storage Period

At IID of 5, the FID at x number of storage period is y = 30.625x - 45.5 and the percent grain damage is y = 5.404x - 7.935 at R^2= 0.74 and R^2= 0.73, respectively. At 10 IID, the FID at x number of storage period is y = 38.125x - 56.125 and the percent grain damage is y = 5.844x - 8.48 at R^2= 0.71 and R^2= 0.72, respectively. At IID 15, the FID at x number of storage period is y = 43.225x - 63.25 and the percent grain damage is y = 6.476x - 9.27 at R^2= 0.72 and R^2= 0.74, while at 20 IID, the FID at x number of storage period is y = 41.75x - 54.37 and percent grain damage is y = 8.263x - 10.995 at R^2= 0.83 and R^2= 0.79 (Table 5).

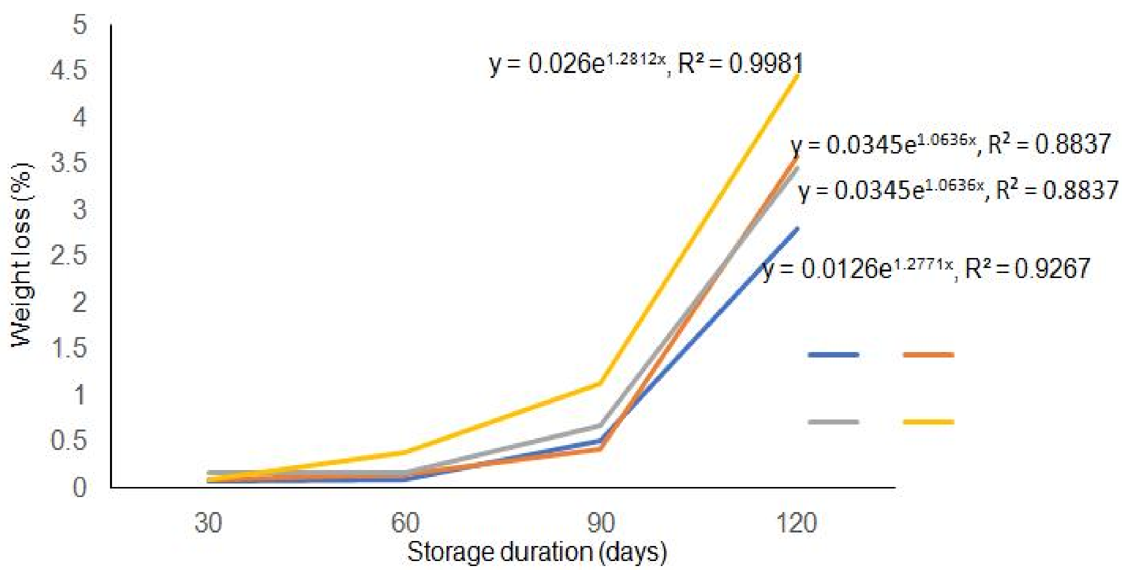

Fig. 4. Relationship between percent weight loss and storage duration for different IID fed on maize seeds

Table 5. Effect of storage period on final insect density and percent grain damage of *Sitophilus zeamais* (x axis) on (y axis)

Initial Insect density	Final insect density	R^2	Grain damage	R^2
5	y=30.625x-45.5	0.7483	y=5.404x-7.935	0.7313
10	y=38.125x-56.125	0.7185	y=5.844x-8.48	0.7223
15	y=43.225x-63.25	0.7235	y=6.476x-9.27	0.7485
20	y=41.75x-54.37	0.8399	y=8.263x-10.995	0.7946

Table 6 shows that temperature influenced FID positively (r= 0.73) which is proportional to the percent weight loss (r= 0.70), percent grain damage (r= 0.74) and weight of dust (r= 0.72). Relative humidity also showed a positive relationship with final insect density, percent weight loss, percent grain damage, and weight of dust. FID showed a strong positive significant relationship with percent weight loss (r= 0.91), percent grain damage (r= 0.93) and weight of dust (r= 0.99). Neither temperature (r= 0.03) nor relative humidity (r= 0.03) was significantly related to the number of dead *S. zeamais* recorded (Table 6).

Table 6. Correlation coefficients of the associations among damage characteristics and environmental factors obtained from the evaluation of different infestation levels of *Sitophilus zeamais* and storage durations

	Parameter		
Damage indices	**Temperature**	**Relative humidity**	**Final insect density**
% weight loss	0.70*	0.67*	0.91*
% grain damage	0.74*	0.71*	0.93*
Weight loss	0.72*	0.69*	0.99*
Final insect density	0.73*	0.70*	-
Dead *S. zeamais*	0.03	0.03	0.04

**-Significant at (P<0.05)*

4. DISCUSSION

This study shows the activities of *S. zeamais* at different insect densities (5, 10, 15 and 20) on maize grain damage, dust produced, weight loss and final insect population density over 120 days storage duration. *Sitophilus zeamais* final insect densities were relatively minimal and similar 60 days after storage and this could be due to the life cycle of the insect which last for about 35 days at optimal temperature of 27°C and up to 110 days at temperatures below 18°C [12], however, initial insect density of 20 recorded significantly higher insect density at 60 and 90 days after storage than the other treatments. As the storage duration extends to 120 days, the maize weevil exhibited an exponential form of population growth with no significant differences observed among the treatments. However, exponential growth is rarely observed in natural populations: several processes such as resource and space limitation, competition, disease, predation, and other factors control and limit population size [13]. In terms of population dynamics, density dependence means that the velocity at which population grows (i.e., growth rate) varies with time as a function of population density N. This is a nonlinear process that in the simplest models causes population to settle at some typical value such as the so-called carrying capacity K. If N is small relative to K, the population is, at least approximately, growing exponentially. This rapid growth can, for example, happen because in a small population, competition for resources might not be limiting. However, N rapidly approaches K, and the growth rate progressively decreases. When N is about K, the growth rate tends to zero and the population has reached the population size sustainable at the given environmental conditions (carrying capacity). If N happens to overshoot K, the growth rate becomes negative and N returns to K after a certain time [14]. In this study, the maize weevil population continues to grow 120 days after storage, meaning that factors such as food, oxygen and space were still available to support the population N. This indicates that the maize weevil population will continue to grow if factors are not limiting 120 days after grain storage, thereby causing significant losses to stored grains. [15] recorded higher population densities in a laboratory analysis than those obtained from the on-farm assessments.

A small initial population density (5 insects $200g^{-1}$) of *S. zeamais* can cause high grain damage, weight loss and infestation levels at the end of the storage period. Percent grain damage was minimal for up to 60 days after storage; however, by 120 days it was high with no significant difference among the various insect densities. [16] reported an increase in grain damage, weight loss, dust produced and final insect densities at 90 days after storage. Grain kernels were severely bored with holes due to infestation by the maize weevil. Dust production by the tunneling activities of the maize weevil was progressive, recording the highest weight of dust at 120 days after storage. This dust is hygroscopic and raise the moisture level of the grain environment, thereby causing fungal development in infested maize grains. The flour produce is not suitable for human consumption due to presence of insect eggs, excreta and exuviae and its unattractive taste. Weight loss due to *S. zeamais* was minimal at 30 days after storage with no significant difference among treatments, the percent weight loss increased at 120 days after storage without a significant difference. Therefore, the data shows that a population of insects three or 10 folds higher does not necessarily correspond to a weight loss, grain damage and dust produced of the same order. This implies that in the absence of control measures any number of infestations could result to severe damage to stored seeds.

This work looked at the damages caused by the maize weevil on four specific storage durations of 30, 60, 90, 120, however using the formulae on the line of best fit would help to determine the damages of each IID at any storage duration below 120 days of storage and this would help farmers determine whether or not to apply control measures outside of the storage durations studied in this work.

S. zeamais does not laid eggs if relative humidity is below 60% [17], and the life cycle could average 110 days at 18℃. Survivorship of all immature stages is highest at 25 ℃ [6]. Temperature and relative humidity were found to be key influencers of weevil population growth in this study, thereby resulting to quantitative and qualitative losses through weight loss, grain damage, and dust produced by the maize weevil, this indicates that temperature and relative humidity could be harnessed as a means of control against the maize weevil to suppress their population growth.

5. CONCLUSION

The study concluded that *S. zeamais* is a major pest of maize in The Gambia and in the absence of timely and proper control measures, any number of infestations greater than 5 weevils could result to severe damage to stored seeds. This implies that for long storage durations, control measures are needed for the protection of stored maize grains to maintain quality and germination viability.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Department of planning. Ministry of Agriculture, The Gambia; 2013.
2. Knoema; 2019. Available:https://knoema.com/atlas/Gambia/topics/Agriculture/Crops-Production-Quantity-tonnes/Maize-production Accessed 13/03/19.
3. Harashima A. Maize and Grace: Africa's encounter with a new world crop, 1500–2000 – By James C. McCann. The Developing Economies. 2007;45:242-245.
4. Okweche SI, Ogunwolu EO, Adeyemo MO. Parameters, interrelationships with yield and use of carbofuran to control stem borers in maize (*Zea Mays* l.) at Makurdi in the Nigerian Southern Guinea Savanna. Greener Journal of Agricultural Sciences. 2013;3:702-706.
5. Midega CAO, Murage AW, Pittchar JO, Khan ZR. Managing storage pests of maize: Farmers' knowledge, perceptions and practices in western Kenya. Crop Protection. 2016;90:142-149.
6. Throne JE. Life history of immature *S. zeamais* (Coleoptera: Curculionidae) on corn stored at constant temperatures and relative humidity in the laboratory. Environmental Entomology 1994;23:1459-1471.
7. Giles PH, Ashman F. A study of pre-harvest infestation of maize varieties by *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) in the Kenya highlands. Journal of Stored Product Research. 1971;7(2):69-72. Elsevier Science Ltd., London, England.
8. Bosque-Perez NA. Major insect pest of maize in Africa: Biology and control. IITA Research Guide 30, IITA Training Programme, International Institute of Tropical Agriculture (IITA), Ibadan. Nigeria. 1992;28p.
9. Meija D. Food and Agriculture Organization Corporate Document Repository; 2007. Accessed on 17th July 2019. Available:www.fao.org/docrep
10. Adedire CO, Lajide L. Efficacy of powders of some tropical plants in the control of the pulse beetle, *Callosobruchus maculatus* (F.) (Coleoptera: Bostrichidae). Applied Tropical Agriculture. 1999;6:11-15.
11. Dobie P, Haines CP, Hodges RJ, Prevett PF, Rees DP. Insects and Arachnids of tropical stored products: Their biology and identification (training manual). (Natural Resources Institute, Chatham Maritime, UK,). 1991;232.

12. Sharifi S, Mills RB. Radiographic studies of Sitophilus zeamais Mots. In wheat kernels. Journal of Stored Product Research 1971;7:185-206.
13. Giga DP, Canhao SR. Competition between Prostephanus truncates (Horn) and Sitophilus zeamais (Motsch.) in maize at two temperatures. Journal of Stored Product Research. 1993;29(1):63-70.
14. Gotelli Nicholas J. A primer of ecology. 4th ed. Sunderland, MA: Sinauer; 2008.
15. Adda C, Borgemeister C, Biliwa A, Meikle WG, Markham RH. Poehling HM. Integrated pest management in postharvest maize: a case study from Republic of Togo. Agricultural Ecosystem and Environment. 2002;93: 305- 321.
16. Tefera T, Mugo S, Likhayo P. Effect of insect population density and storage time on grain damage and weight loss in maize due to the maize weevil *Sitophilus zeamais* and the larger grain borer Prostephanus truncatus. African Journal of Agricultural Research. 2011;6(10):2249-2254
17. Arbogast RT. Beetles: Coleopteran, in Ecology and Management of Food Industry Pests, J. R. B. Gorham, Ed., Association of Official Analytical Chemists, Arlinghton, Va, USA. 1991;133–150.

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