



Contents lists available: [Bio-Research](#)
Journal of Biological Research and Biotechnology

journal homepage: <https://www.bio-research.com.ng> and
<https://www.ajol.info/index.php/br/about>



Suitable Heat Treatment to Control *Sitophilus zeamais* in Stored Maize and Sustain Farming



Ogaugwu Christian^{1*}, Nwana Aaron¹, Ogedengbe Joseph¹, Ayodele Olusegun¹ and Adebayo Raphael²

¹Department of Animal and Environmental Biology, Federal University Oye-Ekiti, Ekiti State, Nigeria

²Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Ondo State, Nigeria

Received: 10th November 2025 / Accepted: 10th December 2025 / **Published Online: 15th February, 2026**

© The Author(s), under exclusive license to Bio-Research-Journal-of-Biological-Research-and-Biotechnology, 2025

DOI: <https://dx.doi.org/10.4314/br.v23i3.6>

*Corresponding author: Ogaugwu Christian: christian.ogaugwu@fuoye.edu.ng

Abstract

Heat treatment is an environment-friendly alternative to chemical insecticides for management of the maize weevil, *Sitophilus zeamais*, in stored maize. But heat may damage seeds and consequently prevent seed germination or fruiting of plants. In this study, standard procedures were followed utilising the SAMMAZ-52 maize cultivar to determine the suitable heat treatment for effective control of weevils in stored maize without limiting subsequent use in maize farming. Adult male and female weevils were added to 30g of maize grains with moisture content of 14.3% and exposed to temperatures of 50°C, 60°C, 70°C or 80°C for 30 minutes or 1 hour. 50°C for 30 minutes or 1 hour was ineffective for killing the weevils. However, 60°C, 70°C and 80°C for 30 minutes or 1 hour completely killed adult weevils present. Viability test showed that maize seeds exposed to 50°C, 60°C or 70°C for 1 hour were viable and germinated after planting, whereas those exposed to 80°C for 1 hour failed to germinate. All germinated maize plants performed well and yielded cobs with numerous seeds. Temperatures between 60°C and 70°C are therefore suitable for controlling *S. zeamais* in maize stored for both consumption and farming, while 80°C is suitable for controlling *S. zeamais* in maize stored only for consumption.

KEYWORDS: *Sitophilus zeamais*, Pest management, Seed viability, Sustained maize farming

Introduction

Maize (*Zea mays*) is a cereal staple that is grown worldwide and has an important position in the fight against food insecurity. Maize storage is severely threatened by the maize weevil, *Sitophilus zeamais* (curculionidae: coleoptera), which is the major insect pest of stored maize (Markham *et al.* 1994; Ojo and Omoloye 2012). Control of the maize weevil and other stored products insect pests heavily rely on the use of chemical insecticides such as phosphine, organophosphates, pyrethroids and carbamates. (White and Leesch, 1996; Golić *et al.*, 2011). Continued use of chemical insecticides to store maize and other grains are currently being discouraged due to the dangers they

posed such as health problems from insecticide residues in food, environmental contaminations, insecticide resistance among stored product pests, and so on (Rajendra and Narasimhan, 1994; Akinneye *et al.* 2018). Heat treatment is an environment-friendly alternative to chemical insecticides for post-harvest management of insect pests of stored products such as maize, rice, cowpea, adzuki beans, and others (Mohammed-Dawd and Morallo-Rejesus, 2000; Mekasha *et al.*, 2006; Golić *et al.*, 2011; Loganathan *et al.*, 2011; Opit *et al.*, 2011; Li *et al.*, 2015). However, reports from several studies on the effect of heat on viability suggest that there are varying responses from different seeds to heat treatment (Murdock and

Shade, 1991; Chuaham and Ghaffar, 2002; Mekasha *et al.*, 2006). In addition, there are speculations that some heat-treated seeds that remain viable or germinate may be unable to yield fruits or seeds upon maturity. For sustainability, it would be ideal that stored grains or seeds remain pest-free and still viable for farming after heat treatment has been applied as local farmers in rural communities in many developing countries usually rely on their stored grains for the next planting season. This study therefore aimed to investigate the effects of different heat temperature range, as well as durations of exposure, on adults of the maize weevil, the viability of the heat-treated maize grains and their ability to yield cobs upon maturity. These investigations will enable the determination of suitable heat treatment range to control the maize weevil in stored maize and at the same time sustain maize farming. The findings of this study will be of importance to farmers in rural communities particularly in Nigeria and other developing countries where insect pests and poor storage facilities are both among the leading causes of post-harvest losses in maize (Agada and Ijih, 2019).

Materials and Methods

Study location

This study was conducted at the Department of Animal and Environmental Biology, Federal University, Oye-Ekiti, Nigeria (coordinates: N 07° 46.69' and E 005° 18.93', 527m above sea level). The ambient laboratory conditions during the period of the study were average temperature of $25.34 \pm 1^\circ\text{C}$, relative humidity of $78.35 \pm 6\%$ and daylight to darkness period of 12:12 hours.

Collection of materials

Maize grains (SAMMAZ-52 cultivar) were purchased from a commercial vendor. This yellow provitamin A cultivar is popular in Nigeria as it is also early maturing and streak resistant. The moisture content of the maize was determined in the laboratory by heating the maize in an oven at 75°C and weighing after every 20 minutes until there was no more reduction in weight. The percentage moisture content was calculated using the formula: $\text{Moisture Content} = \left[\frac{\text{initial weight} - \text{oven dry weight}}{\text{oven dry weight}} \right] \times 100\%$ (Reeb and Milota, 1999). Adults of *S. zeamais* were retrieved from infested stored maize grains obtained from a maize farmer at Ado-Ekiti. Male and female adults were differentiated under a stereo microscope based on the appearance of their rostrum and subsequently maintained on uninfested maize grains separately. The male has a shorter, wide and rough rostrum, while the female has a longer, slender and smooth shiny rostrum (Ojo and Omoloye, 2012).

Experimental groups and heat treatment

Maize grains weighing 30g were put into a round plastic container of diameter 8.5cm and height 4.2cm (Figure 1). Ten (10) males and 10 females of *S. zeamais* were used to infest the

grains in the container and then covered with a piece of muslin cloth before capping with a plastic lid having three holes in it for aeration and prevention of any invading insects (Figure 1).



Figure 1: A section of the experimental set-up used for assessment of the effect of heat treatment on both maize seeds and adults of *Sitophilus zeamais*.

The experimental groups were as follows: Group 1 (Negative control: no exposure to heat, without weevils) has 3 replicate containers of 30g of maize grains without *S. zeamais*. Group 2 (Positive control: no exposure to heat, with weevils) has 3 replicate containers of 30g of maize grains with *S. zeamais*. Group 3 (exposure to heat of 50°C for 30 minutes) has 3 replicate containers of 30g of maize grains with *S. zeamais*. Group 4 (exposure to heat of 60°C for 30 minutes) has 3 replicate containers of 30g of maize grains with *S. zeamais*. Group 5 (exposure to heat of 70°C for 30 minutes) has 3 replicate containers of 30g of maize grains with *S. zeamais*. Group 6 (exposure to heat of 80°C for 30 minutes) has 3 replicate containers of 30g of maize grains with *S. zeamais*. Group 7 (exposure to heat of 50°C for 1 hour) has 3 replicate containers of 30g of maize grains with *S. zeamais*. Group 8 (exposure to heat of 60°C for 1 hour) has 3 replicate containers of 30g of maize grains with *S. zeamais*. Group 9 (exposure to heat of 70°C for 1 hour) has 3 replicate containers of 30g of maize grains with *S. zeamais*. Group 10 (exposure to heat of 80°C for 1 hour) has 3 replicate containers of 30g of maize grains with *S. zeamais*. Treatments at 50°C to 70°C were performed in a DHP-9032 incubator, while that at 80°C was performed in a Genlab oven. After exposure to heat, all treatment groups were kept at ambient laboratory conditions with average temperature of $25.34 \pm 1^\circ\text{C}$, relative humidity of $78.35 \pm 6\%$ and daylight to darkness period of 12:12 hours. The adult maize weevils were evaluated after one week. Each container was opened, the maize weevils were recounted and examined under a stereo microscope to ascertain their sexes and by prodding or picking up with a pair of entomological forceps to determine those that were dead or alive respectively.

Individuals that showed no sign of movement of body parts were considered to be dead. The recount and re-examination of the maize weevils in each container was repeated 7 weeks after treatment to determine the influence of the heat treatment on the next generation.

Seed viability assessment

One week after heat exposure, ten maize seeds that have no visible signs of damage were taken at random from each replicate container within the positive control group with weevils (Group 2) and the treatment groups exposed to heat for 1 hour (Groups 7-10). The chosen seeds were planted in 100g of loam soil put in a small transparent plastic bag (diameter of 8.5cm and height of 6-7cm), watered with 25ml of water and kept under same ambient laboratory conditions described earlier. The bags were checked 10 days later and the germinated maize were counted.

Yield performance assessment

Germinated maize was transplanted from the plastic bags onto ridges in the field and allowed to grow under natural outdoor conditions. There were three ridges in a column and four ridges in a row. Maize plants from each replicate were put on one ridge and all the three replicates from each experimental group were located in the same column. There were 12 ridges in total. The maize plants were allowed to grow to maturity and to yield cobs. Cobs on the maize plants were harvested at 13 weeks after planting. The number of plants having inflorescence, the number of cobs and measurements of the length and circumference of the cobs were also taken. Surface area for each cob harvested was obtained by multiplying the length and circumference for cobs that had maize seeds, and the value was used to assess cob yield for the different treatment groups.

Statistical analysis

GraphPad Prism 5 software was used for statistical analysis. One-way Analysis of Variance (ANOVA) with Dunnett's Multiple Comparison Test was used to compare various treatment groups and the negative control with the positive control. Two-way ANOVA with Bonferroni's posttests was used to determine if both heat treatment and sex had significant influence on the response of the weevils. One-way ANOVA with Tukey's Multiple Comparison Test was used to compare the cob yields from various treatment groups with those from the positive control and among themselves. Differences between means for all tests were determined to be statistically significant at $p < 0.05$.

Results

Effect of different temperatures on maize weevils

An average of $86.7\% \pm 14.4\%$ of maize weevils in the positive control were alive after 1 week of the experiment. In the treatment group exposed to 50°C for 30 minutes, an average of $73.3\% \pm 7.6\%$ of the weevils were alive 1 week after treatment,

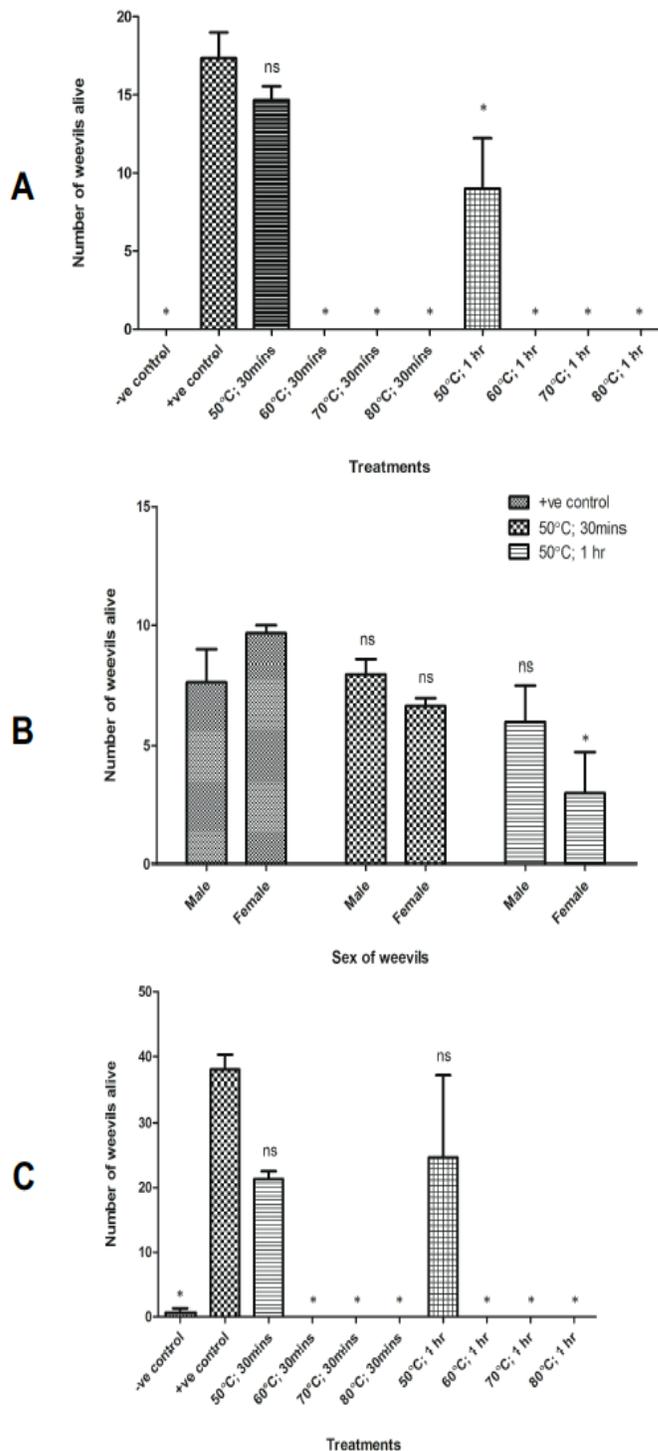


Figure 2: Effects of heat treatment on *Sitophilus zeamais* adults in stored maize. (A) weevil population one week after heat treatment (B) heat effect on different sexes (C) weevil population 7 weeks after heat treatment. Bars with asterisk (*) are significantly different from the positive (+ve) control, while those with ns are not significantly different.

DOI: <https://dx.doi.org/10.4314/br.v23i3.6>

while an average of $45.0\% \pm 22.7\%$ of the weevils exposed to 50°C for 1 hour remained alive. The temperature ranges of 60, 70 and 80°C for either 30 minutes or 1 hour completely killed off the weevils that were exposed (Figure 2A). When means of the different treatment groups were compared with that of the positive control, there was no significant difference between the positive control and the group treated at 50°C for 30 minutes. However, there were significant differences between the positive control group and the group treated at 50°C for 1 hour ($p < 0.05$), as well as between the positive control group and all other treatments groups ($p < 0.05$). Two-way analysis of both the treatment groups and sex of weevils shows that heat treatment generally had a significant effect on the weevils ($p < 0.05$), while sex had no significant effect on the general response of the weevils. The difference between the means of females treated at 50°C for 30 minutes and females from the positive control was not significant, but there was a significant difference ($p < 0.05$) between the females treated at 50°C for 1 hour and the positive control (Figure 2B). After 7 weeks of the heat treatment (to allow enough time for the reproduction of up to one generation), the containers having the different groups of control or heat-treated maize weevils were checked again. The negative control which had no weevil at the start of the experiment had 2 weevils present. The positive control had an average increase of $121.3\% \pm 21.5\%$ from the previous population at 1 week. The group treated at 50°C for 30 minutes had an average increase of $40.6\% \pm 7.7\%$ from the previous population alive at 1 week, while those treated at 50°C for 1 hour had an average increase of $141.7\% \pm 102.7\%$ from the previous population alive at 1 week. The groups treated at 60°C , 70°C and 80°C for either 30 minutes or 1 hour still had no weevils present in them (Figure 2C). Comparison of the means of the different groups with the positive control showed that there was no significant difference between treatments at 50°C for 30 minutes or 50°C for 1 hour and the positive control, while the negative control and other treatment groups (60°C , 70°C and 80°C for 30 minutes or 1 hour) were significantly different from the positive control ($p < 0.05$).

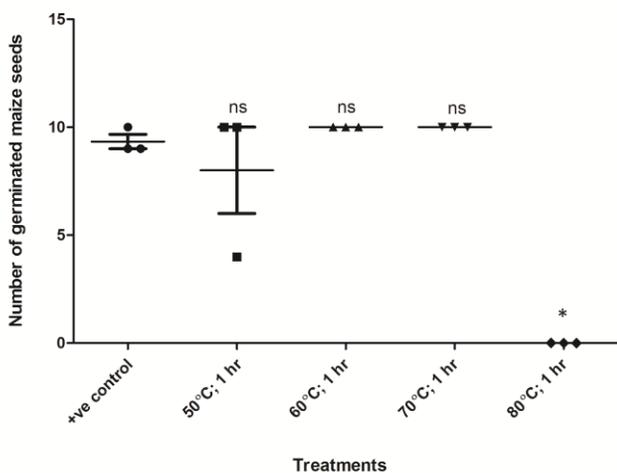


Figure 3: Effect of heat treatment on germination of maize seeds



Figure 4: Effect of heat treatment on germination of maize seeds

Viability and yield performance of maize exposed to different temperatures

It was observed that an average of $93.3\% \pm 5.8\%$ of planted maize seeds germinated from the positive control, $80\% \pm 34.6\%$ from 50°C for 1 hour, $100\% \pm 0.0\%$ for 60°C for 1 hour and $100\% \pm 0.0\%$ for 70°C for 1 hour. No maize seed (0.0%) germinated among all seeds chosen from the 3 replicates of the group treated at 80°C for 1 hour. The means of germinated seeds from the positive control was significantly different from that of 80°C for 1 hour ($p < 0.05$), but not significantly different for other treatments (Figure 3 and Figure 4). The germinated maize plants were transplanted to the field and allowed to grow to maturity (11 to 13 weeks after planting) to determine if they would produce cobs and the respective yield performances. Maize plants from positive control and the 50°C , 60°C and 70°C for 1 hour groups all produced cobs with lots of maize seeds (Table 1). Comparison of the mean surface area of the cobs from the different groups showed that the 70°C for 1-hour group was significantly bigger than the positive control ($p < 0.05$), but all the other different groups were not significantly different from one another in terms of their surface area (yield) (Figure 5)

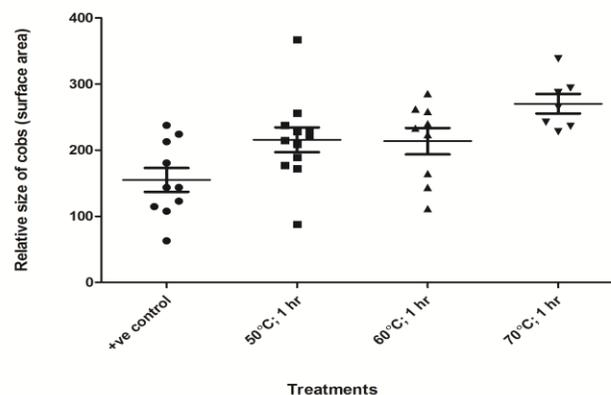


Figure 5: Cob yield of heat-treated maize.

Table 1. Field performance of maize exposed to different temperatures

Category	Replicate	Number of transplanted maize plants	Number of maize plants 11 weeks after planting	Number of maize plants with inflorescence	Number of maize plants with cobs	Cob size (cm) [length; circumference]	Cob size by surface area (cm ²)
Group 2 (2 nd control)	i	10	3	3	3	16.6;13.5, 9.7;11.1, 9.0;7.0	224.1, 107.7, 63.0
	ii	9	6‡#	5	5	13.3;10.8, 15.2;14.0, 10.5;11.7, 16;11.3	143.6, 212.8, 122.9, 180.8
	iii	9	4	4	3	13.5;8.5, 11.6;12.4, 19;12.5	114.8, 143.8, 237.5
Group 7 (50°C for 1 hour)	i	10	7#	6	6	18;13.2, 19;12, 15.0;14.3, 17.0;13.5, 16.7;12.5, §	237.6, 228.0, 214.5, 229.5, 208.8
	ii	4	4	4	4	27.0;13.6, 15.5;12.2, 17.3;14.8, §	367.2, 189.1, 256.0
	iii	10	7‡	6	5	14.1;12.2, 16.7;10.6, 16;13.8, 11.0;8.0, §	172.0, 177.0, 220.8, 88.0
Group 8 (60°C for 1 hour)	i	10	3#	3	3	16.0;15.0; 19.0;13.6, §	240.0, 258.4
	ii	10	3	3	2	15.2;14.7; 18.8;12.4	223.4, 233.1
	iii	10	6	6	5	21.0;13.6, 20.0;13.1, 14.7;11.2, 15.3;9.4, 12.0;9.3	285.6, 262.0, 164.6, 143.8, 111.6
Group 9 (70°C for 1 hour)	i	10	3	3	3	19.5;13.6, 21.0;14, 17.3;14	265.2, 294.0, 242.2
	ii	10	2‡	1	1	20.5;14	287.0
	iii	10	4	3	3	19;12, 20.5;16.5, 17.5;13.5	228.0, 338.3, 236.3

*Maize plants were between 6-8 feet in height; some plants were lost to rodents, termites, rain storms, etc., while some cobs were lost to birds

‡ case where at least one maize plant stalk got broken off due to biotic/abiotic factors

case where at least one maize plant experienced stunted growth and had height of 3ft or less

§ case where at least one maize cob had no seeds or was lost

Discussion

Heat treatment is a cleaner and convenient alternative method to chemical insecticides for the management of maize weevils. This study explored heat treatment and the effects on both the adults of the maize weevil *S. zeamais* and the maize seeds (SAMMAZ-52 cultivar). Of the temperature ranges that were investigated, 60°C, 70°C and 80°C proved lethal and effective at killing off all maize weevils in stored maize whereas 50°C was found to be ineffective. These observations on the lethal temperatures of 70 and 80°C for 1 hour were in agreement with an earlier report by Mohammed-Dawd and Morallo-Rejesus (2000) in XVH-5 and IPB-VAR-1 cultivars. Besides, this present study has found out in addition that 60°C for 30 minutes or for 1 hour, as well as 70°C or 80°C for 30 minutes are equally effective in killing all adult maize weevils present in stored maize. The results of an investigation by Lü and Zhang (2016) on the effect of acclimation on the susceptibility of *S. zeamais* adults to high temperatures further support the findings of this study by showing that temperatures of 51°C and 55°C (with or without acclimation) could not completely kill off all *S. zeamais*

adults. However, a contrasting report by Li *et al.* (2015) showed that 50°C for 14 minutes was sufficient to completely kill adults of *S. zeamais*. In this study, 50°C even after 1 hour of exposure was not effective for complete elimination of the maize weevils. While the finding of Li *et al.* (2015) is clearly in contrast to this study, their study applied heat treatment directly to adults of *S. zeamais* alone in a bag instead of having these beetles together with stored maize. It could be that treating weevils in stored maize reduces the overall lethal effect of heat on them. When the weevils were allowed to reproduce for one generation, it was observed that the groups exposed previously to 60°C, 70°C and 80°C for 30 minutes or 1 hour had no increase in population because there were no weevils present to reproduce and re-infestation was not possible due to the small-sized mesh that was used to cover the containers in the experiment. However, the groups exposed to 50°C treatment for 30 minutes or 1 hour and the positive control had population increase after 7 weeks as they contained weevils that were alive to reproduce. Also, the negative control which had no weevil from the start of the experiment had some weevils after 7 weeks. This infestation could be from eggs or other developmental stages that may have

been present in the maize grains from the start of the experiment, suggesting that exposure to the lethal temperatures used in this study could also kill the developmental stages and might be necessary in stored maize to prevent future infestations from premature stages. Though it appeared rather interestingly that heat treatment killed more females than males at 50°C, the influence of sex on the responses of the weevils was generally not significant. No other study has reported such occurrence and it is not clear what could be responsible for this observation. Further studies may be needed to understand or substantiate this phenomenon. Some studies in pigeon peas and cowpea had reported that temperature has no effect on seed viability (Murdock and Shade, 1991; Chuaham and Ghaffar, 2002). However, Mekasha *et al.* (2006) reported that temperatures of 80°C and above significantly reduced germination of adzuki bean seeds. This study found out that maize seeds treated at 80°C for 1 hour failed to germinate, while maize seeds treated at 70°C or lower did germinate. A possible explanation for this observation could be that the temperature of 80°C for 1 hour destroys the germ cells of maize seeds thus preventing germination. For sustainable maize farming, especially in developing countries where farmers depend on stored maize seeds for the subsequent farming seasons, it is recommended from the findings of this study that temperature ranges from 60°C to 70°C should be utilised for control of maize weevils in stored maize that is intended both for future use in planting and for consumption. This is because the temperature ranges of 60°C to 70°C for 30 minutes or 1 hour can completely kill maize weevils in stored maize and yet retain seed viability to sustain farming. Nevertheless, stored maize treated at 80°C can be kept solely for consumption. There are speculations that some heat-treated seeds that germinate might not successfully yield fruits. However, the result of this study showed that the maize treated at lethal temperatures of 60 and 70°C for 1 hour gave good yield when planted. The mean relative surface area or yield of the maize cobs that had been exposed to 70°C appeared significantly bigger than those of the positive control, but they were not significantly bigger than those treated at 50°C and 60°C. While this observation shows that maize treated between the ranges of 50°C and 70°C can yield as well or better than those from the positive control group, it is important to note that the observed result does not necessarily imply that 70°C-treated maize seeds will always perform better than other groups. From Figure 5, a gradient increase in yield or mean relative surface area of cobs is observable from the positive control maize to the 70°C-treated group. It could be that varying slope and soil fertility at the locations where the maize plants were grown had some influence on crop yield.

Conclusion

In conclusion, this study has established temperature ranges for heat treatment of maize to control the maize weevil *S. zeamais* in stored maize and retain viability of the seed for subsequent

planting. Maize seeds from the SAMMAZ-52 cultivar were utilized in laboratory conditions of an average temperature of $25.34 \pm 1^\circ\text{C}$ and relative humidity of $78.35 \pm 6\%$. Heat treatment conditions should therefore be optimized for different maize cultivars since cultivar type and environmental conditions can influence treatment outcomes.

Acknowledgements

We are grateful to Mr. Bayo Ayeni of the Department of Animal and Environmental Biology, Federal University Oye-Ekiti for technical assistance.

Conflict of interest

The authors report no conflict of interest.

References

- Agada, M.O. & Ijih, B.E. (2019). Analysis of post-harvest management practices among maize farmers in Oju, Benue State, Nigeria. *Journal of Agriculture and Environmental Sciences* **8**(1): 191-198.
- Akinneye, J.O., Adedolapo, O.A. & Adesina, F.P. (2018). Quantification of organophosphate and carbamate residue on stored grains in Ondo State, Nigeria. *Journal of Biology and Medicine* **2**(1): 1-6.
- Chuaham, Y.S. & Ghaffar, M.A. (2002). Solar heating of seeds – a low cost method to control bruchid (*Callosobruchus* spp.) attack during storage of pigeon pea. *Journal of Stored Products Research* **38**: 87-91.
- Golić, M.P., Andrić, G. & Kljajić, P. (2011). Effects of 50°C temperature on *Sitophilus granarius* (L.), *Sitophilus oryzae* (L.) and *Sitophilus zeamais* (Motsch.). *Journal of Pesticides and Phytomedicine (Belgrade)* **26**(3): 221-227.
- Loganathan, M., Jayas, D.S., Fields, P.G. & White, N.D.G. (2011). Low and high temperatures for the control of cowpea beetle, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) in chickpeas. *Journal of Stored Products Research* **47**: 244-248.
- Li, W., Wang, K., Chen, L., Johnson, J.A. & Wang, S. (2015). Tolerance of *Sitophilus zeamais* (Coleoptera: Curculionidae) to heated controlled atmosphere treatments. *Journal of Stored Products Research* **62**: 52-57.
- Lü, J. & Zhang, H. (2016). The effect of acclimation to sublethal temperature on subsequent susceptibility of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) to high temperatures. *PLoS ONE* **11**(7): e0159400.

DOI: <https://dx.doi.org/10.4314/br.v23i3.6>

Markham, R.H., Bosque-Perez, N.A., Borgemeister, C. &

Meikle, W. (1994). Developing pest management strategies for *Sitophilus zeamais* and *Prostephanus truncatus* in the tropics. *FAO Plant Protection Bulletin* **42**(3): 97–116.

Mekasha, C., Dzolkifli, O., Yusuf, S., Rita, M. & Noorma, O. (2006). Effect of heat treatment on developmental stages of *Callosobruchus maculatus* (Coleoptera: Bruchidae) in stored adzuki bean *Vigna angularis*. *International Journal of Tropical Insect Science* **26**: 273-279.

Mohammed-Dawd, E. & Morallo-Rejesus, B. (2000). Heat treatment for the control of corn weevil, *Sitophilus zeamais* Motsch. in stored corn. *Shashpa* **7**(1): 57-62.

Murdock, L.L. & Shade, R.E. (1991). Eradication of cowpea weevil (Coleoptera: Bruchidae) in cowpea by solar heating. *American Entomologist* **37**: 228–231.

Ojo, J.A. & Omoloye, A.A. (2012). Rearing the maize weevil, *Sitophilus zeamais*, on an artificial maize–cassava diet. *Journal of Insect Science* **12**: 69.

Opit, G.P., Arthur, F.H., Bonjour, E.L., Jones, C.L. & Phillips,

T.W. (2011). Efficacy of heat treatment for disinfestation of concrete grain silos. *Journal of Economic Entomology* **104**(4): 1415–1422.

Rajendran, S. & Narasimhan, K.S. (1994). Phosphine resistance in the cigarette beetle *Lasioderma serricornis* (Coleoptera: Anobiidae) and overcoming control failures during fumigation of stored tobacco. *International Journal of Pest Management* **40**: 207–210.

Reeb, J.E. & Milota, M.R. (1999). Moisture content by the oven-dry method for industrial testing. https://ir.library.oregonstate.edu/concern/conference_proceedings_or_journals/fq977v782. Accessed 8 February, 2025.

White, N.D.G. & Leesch, J.G. (1996). Chemical Control. In: Bubramanyam B, Hagstrum DW, editors. *Integrated Management of Insects in Stored Products*. Marcel Dekker, New York. pp. 287–330.

Publisher's Note: Bio-Research remains neutral with regard to jurisdictional claims in published maps and institutional affiliations. Bio-Research or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.