



Efficacy of thermal treatments against rice weevil, *Sitophilus oryzae*

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Rice weevil, *Sitophilus oryzae* (L.) is one of the most important insect-pest of stored grain/seeds which mainly infests cereals. Germination, viability and vigour index of seed material is drastically affected by this insect pest. The conventional method to control this insect is treating the stored grain with chemical insecticides, which cause the bigger problem of insect resistance (Metcalf 1994). Other drawbacks of synthetic insecticides are resurgence and outbreak of secondary pests and harmful effects on non-target organisms (Charles *et al.* 2003). Undesirable residue of chemical insecticides in food items is a major limiting factor in international trade. Besides, there are increasing public concerns over the use of agricultural chemicals that are harmful to the environment and human health (Bulathsinghala and Shaw 2014). In India, only methyl bromide, aluminium phosphide and ethylene dichloride-carbon tetrachloride (EDCT) are registered fumigants to mitigate the insect-pests problem in stored grain commodities, plants and planting material including true seed meant for import and export under the Insecticides Act, 1968. But methyl bromide is designated as ozone depleting substance in the Montreal Protocol (1987) hence it was to be eventually phased out globally by 2015. However, methyl bromide has critical use exemption for quarantine and pre-shipment applications. The country is also committed to reduce the ozone depleting substances under the signed international treaties hence, an effective, user and eco-friendly alternative to methyl bromide needs to be identified. The purpose of this study was to investigate and determine the efficiency of heat treatments as an alternative to conventional chemical fumigation and to find out the lethal parameters of heat treatment in eradicating *S. oryzae* in wheat. In the past, several researchers have

demonstrated the effectiveness of heat treatments against a number of storage insect-pests in food processing facilities, wood structures and equipment (Field 1992, Fields *et al.* 1997, Dowdy 1999 and 2000, Dowdy and Fields 2002, Mueller 2002, Yan *et al.* 2014).

The experiment was conducted at ICAR-National Bureau of Plant Genetic Resources, New Delhi during 2016-17. Ten adults of *S. oryzae* were used per replication and transferred to a plastic vial carrying 50 g seeds of wheat (*Triticum aestivum*) variety Raj-3765. The adults were exposed at 35, 40, 45, 50, 55 and 60±1°C for a period of 1, 2 and 3 h. After the exposure, the adults were placed at 27 ±1°C temperature and 65 ± 5% relative humidity for recovery. The mortality of test insect was recorded immediately after the treatment and after 24 h. To ascertain the effect of heat on germination viability of wheat seed, the seed germination test was conducted in a seed germinator to observe per cent seed germination. Seed vigour index was also calculated by the formula developed by Abdul-Baki and Anderson (1973). The data was statistically analyzed using completely randomized design.

Data revealed that no adult mortality was observed at 35±1°C and untreated control after 1, 2 and 3 h of exposure while 63.33, 73.33 and 83.33% mortality of adult insect was recorded at 40±1°C after 1, 2 and 3 h of exposure respectively (Table 1). However, 100% mortality of *S. oryzae* adult was observed at 45, 50, 55 and 60±1°C after 1, 2 and 3 h of exposure. No significant difference in germination viability was recorded among the heat treated and untreated wheat seed. Full 100% germination of wheat seed was observed at 35, 40, 45, 50 and 55±1°C after 1, 2 and 3 h of exposure including untreated control. However, the per cent germination of wheat seed at 60±1°C after 1, 2 and 3 h of exposure was recorded 99.67, 100.00 and 99.67, respectively (Table 2). No significant difference in vigour index of wheat seed was recorded at 35, 40, 45, 50, 55 and 60±1°C after 1, 2 and 3 h of exposure and untreated control (Table 3). Hence it is evident from the results that heat treatments, i.e. 45, 50, 55 and 60±1°C after 1, 2 and 3 h of exposure gave 100% mortality of test insect without affecting germination viability and vigour index of wheat seed. Seed safety and lethal effect of heat on adult weevil,

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Table 1 Adult mortality (%) of *Sitophilus oryzae* at different temperatures

Thermal treatment	Per cent mortality of <i>Sitophilus oryzae</i> adult h after exposure		
	1 h	2 h	3 h
35±1°C	0.00	0.00	0.00
40±1°C	63.33	73.33	83.33
45±1°C	100.00	100.00	100.00
50±1°C	100.00	100.00	100.00
55±1°C	100.00	100.00	100.00
60±1°C	100.00	100.00	100.00
Untreated control (27±1°C)	0.00	0.00	0.00
CD at 5%	3.86	3.86	3.86

Table 2 Germination (%) of wheat seed (Raj-3765) at different temperatures

Thermal treatment	Per cent germination of wheat seeds h after exposure		
	1 h	2 h	3 h
35±1°C	100.00	100.00	100.00
40±1°C	100.00	100.00	100.00
45±1°C	100.00	100.00	100.00
50±1°C	100.00	100.00	100.00
55±1°C	100.00	100.00	100.00
60±1°C	99.67	100.00	99.33
Untreated control (27±1°C)	100.00	100.00	100.00
CD at 5%	NS	NS	NS

S. oryzae in wheat grain was the main objective of this study. The present study describes the killing efficacy of heat treatment against *S. oryzae* along with safety to germination viability and vigour index of wheat seed.

Temperature-related mortality is often linked to duration of insect heat exposure (Dowdy 1999, Dowdy and Fields 2002, Mahro *et al.* 2003b). Arthur (2006) reported that complete mortality of all life stages of *Tribolium castaneum* and *T. confusum* occurs within 2 and 1 h of exposure at 51 and 54°C temperatures, respectively. Therefore, even the most heat-tolerant insect stages *i. e.* adult, may be killed during a normal heat treatment. However, complete mortality of all life stages in the grain bin would likely occur in a matter of h when temperatures exceed 50°C. Beckett *et al.* (1998) observed 99% mortality of *S. oryzae* adults at 48°C in wheat grain within 38 min of exposure. Several other researchers observed that 50°C is effective temperature for direct use in protection of stored products (Fields 1992, Beckett and Morton 2003). Jian *et al.* (2002) showed that adult of *Cryptolestes ferrugineus* (Laemophloeidae) were unable to move away from the heat source in wheat at 50°C, with 100% mortality after 3 h. Yan *et al.* (2014) observed minimum holding time for

Table 3 Vigour index of wheat seed (Raj-3765) at different temperatures

Thermal treatment	Vigour index of wheat seeds h after exposure		
	1 h	2 h	3 h
35±1°C	2820.00	2816.66	2813.00
40±1°C	2813.33	2810.00	2813.33
45±1°C	2810.00	2813.00	2810.00
50±1°C	2813.33	2803.33	2810.00
55±1°C	2816.66	2806.66	2806.66
60±1°C	2810.00	2803.33	2806.66
Untreated control (27±1°C)	2816.66	2810.00	2813.13
CD at 5%	NS	NS	NS

100% mortality of *S. oryzae* adults at 44, 46, 48 and 50°C about 130, 50, 12 and 4 min. respectively. Fields (1992) and Dosland *et al.* (2006) reported 3 different responsive stages in storage insect-pests as the temperature increases above the optimum temperature (32°C). In the first stage (40-45°C), developments halts and population starts to die out. In second stage (45-55°C), severe water loss occurs and individual die within h. In third stage (more than 55°C), entire population die in minutes to seconds. Tilley *et al.* (2007) observed 100% mortality of *Tribolium castaneum* at 50°C within 2 h. Zimba (2017) observed 100% mortality of maize weevil, *S. zeamais* at 48°C within 30 min of exposure without affecting germination ability of maize seeds. These results are consistent with insect groups in general and many studies indicate that temperature about 45 and 50°C resulted in 100% mortality of storage insects within h.

SUMMARY

Thermal treatments at 35, 40, 45, 50, 55 and 60±1°C for a period of 1, 2 and 3 h were evaluated against *Sitophilus oryzae* adult along with germination test and vigour index of wheat seeds. No mortality of insect was observed at 35±1°C after 1, 2 and 3 h of exposure while 63.33, 73.33 and 83.33% mortality of adult insect was recorded at 40±1°C after 1, 2 and 3 h of exposure respectively. However, 100% mortality of *S. oryzae* adult was observed at 45, 50, 55 and 60±1°C for all time periods. Almost 100% germination of wheat seed was observed under all the temperature treatments and durations as above. No significant difference in vigour index of wheat seed was recorded at different temperatures for all the three duration of exposure.

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REFERENCES

Abdul-Baki A and Anderson J D. 1973. Vigor Determination in

- Soybean by Multiple Criteria. *Crop Science* **13**: 630–3.
- Arthor F H. 2006. Initial and delayed mortality of late instar-larvae, pupae, and adults of *Triboliuncastaneum* and *Tribolium confusum* (Coleoptera: Tenebrionidae) exposed at variable temperatures and time intervals. *Journal of Stored Products Research* **42**(1): 1–7.
- Beckett S J and Morton R. 2003. The mortality of three species of Psocoptera, *Liposcelisbostrychophila* Badone II. *Journal of Stored Products Research* **23**: 73–7.
- Beckett S J, Morton R and Darby J A. 1998. The mortality of *Rhyzoperthadominica* (F.) (Coleoptera: Bostrychidae) and *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) at moderate temperatures. *Journal of Stored Products Research* **34**: 363–76.
- Bulathsinghala A T and Shaw I C. 2014. The toxic chemistry of methyl bromide. *Human and Experimental Toxicology* **33** (1): 81–91.
- Charles V, Guy H, Bernard P and Francis F L. 2003. Management of agricultural insects with physical control methods. *Annual Review of Entomology* **48**: 261–81.
- Dosland O, Subramanyan B H, Sheppard K and Mehroo R. 2006. Temperature modification for insect control. (ed.) Heaps J. *Insect Management for Food Storage and Processing*, 2nd edn. American Association for Clinical Chemistry, St Paul, Minnesota, pp 89–103.
- Dowdy A K. 1999. Mortality of red flour beetle, *Tribolium castaneum*, exposed to high temperature and diatomaceous earth combinations. *Journal of Stored Products Research* **35**: 175–82.
- Dowdy A K. 2000. Heat treatment as an alternative to methyl bromide fumigation in cereal processing plants. *Proceeding of the 7th international working conference on street product protection*, Beijing, China **7**: 1089–95.
- Dowdy A K and Fields P G. 2002. Heat combined with diatomaceous earth to control the confused four beetle (Coleoptera: Tenebrionidae) in a flour mill. *Journal of Stored Products Research* **38**: 11–22.
- Fields P G. 1992. The control of stored-product insects and mites with extreme temperatures. *Journal of Stored Products Research* **28**: 89–118.
- Fields P, Dowdy A and Marcotte M. 1997. Structural pest control: the use of an enhanced diatomaceous earth product combined with heat treatment for the control of insect pests in food processing facilities. *Canada-United States Working Group on Methyl Bromide Alternatives*. 25 p.
- Jian F, Jayas D S, White N D and Muir W E. 2002. Temperature and geotaxis preference by *Cryptolestes ferrugineus* adult in response to 5°C/m temperature gradients at optimum and hot temperatures in stored wheat and their mortality at higher temperature. *Environmental Entomology* **31**(5): 816–26.
- Mahroof R, Subramanyam B, Throne J and Menon A. 2003b. Timemortality relationships for *Tribolium castaneum* (Coleoptera: Tenebrionidae) life stages exposed to elevated temperatures. *Journal of Economic Entomology* **96**: 1345–51.
- Metcalf R L. 1994. Insecticides in pest management. In: Metcalf R L and Luckmann W H, eds. *Introduction to Insect Pests Management* pp 245–314.
- Mueller D. 2002. Alternatives to methyl bromide for disinfestation of structures and food facilities. *Proceedings of the International Conference on Alternatives to Methyl Bromide* **74**: 3 p.
- Tilly DR, Casada ME and Arthur FH. 2007. Heat treatment for disinfestation of empty grain storage bin. *Journal of Stored Products Research* **43**: 221–8.
- Yan R, Huang Z, Zhu H, Johnson J A and Wang S. 2014. Thermal death kinetics of adult *Sitophilus oryzae* and effects of heating rate on thermotolerance. *Journal of Stored Product Research* **59**: 231–6.
- Zimba M. 2017. Preliminary observations on a hot water equipment for disinfesting maize grain from larger grain borer, *Proste phanustruncatus* (Horn) and greater rice weevil, *Sitophilus zeamais* (Motschulsky) (Coleoptera: Bostrychidae): A tool for rural farmers. *Journal of Stored Product and Post-Harvest Research* **8**(4): 54–64.