

Bio-thermal seed treatment device– an innovative technology of heat treatment for the management of bruchids, *Callosobruchus maculatus* Fab on black gram

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ABSTRACT

An investigation was carried out to study the effect of different heat treatments on management of bruchids, a stored product pest of black gram. Seed of 10 kg of black gram was artificially infested with bruchids, *Callosobruchus maculatus* Fab and the heat treatment was given with a novel bio-thermal device developed with technical guidance of the scientists of Department of Entomology and Department of Bio-energy, TNAU, Coimbatore. Of the various ranges of temperature from 55 to 65°C for 30 min tested, black gram seeds exposed to 65°C for 30 min were free from bruchid infestation with lesser number of eggs (3 eggs/week/seed) as compared to 55 and 60°C with higher number of 4.9 and 3.6 eggs/week/seed respectively besides possessing desirable level of germination (91 per cent) without any depletion of protein content.

Keyword: Bruchids; device; heat treatment; adult emergence; mortality; germination

INTRODUCTION

Callosobruchus maculatus Fab (Bruchidae: Coleoptera) is the most serious pest and attacks invariably all the pulses under storage conditions with the mild infestation in the field as well. It is therefore imperative to save the stored pulses from this serious pest. A single beetle could cause 3.5 per cent weight loss in cowpea seeds (Booker 1967). Gujar and Yadav (1978) recorded 55-60 per cent loss in seed weight and 45.50 to 66.30 per cent loss in protein

content due to damage by the pulse beetle. Infestations can cause up to 60 per cent loss in seed weight and up to 66 per cent loss in protein content of pulses. The plant materials are potentially suitable for use in integrated pest management (IPM) effectively. Yesteryear chemicals/ insecticides were used to control stored insects which resulted in leaving objectionable residues in treated commodity and generally were hazardous to handle and apply. Some of the stored product insects have also developed

resistance to these insecticides (Srivastava et al 2000).

In order to manage the storage pests attacking grains and seeds a novel bio-thermal device has to be developed. Mohamed and Ismail (1996) recorded that pest mortality was highest at 60°C and increased with increasing duration. Solarization of seeds of pulse bruchid *Callosobruchus maculatus* reduced the oviposition as time of exposure to the sun increased especially in bruchids that were exposed for 3 h but adult mortality increased with increased exposure time. Adult emergence was also significantly lower from eggs that were exposed to the sun for 3 h than from those that were exposed for only 1 h (Lale 1998). By exposing cowpea weevil to increased temperature and time, early stage eggs (3 h old) and late stage eggs (48 h old) experienced higher mortality (values for LT99 of 42.331 and 46.652 h respectively) compared to intermediate aged eggs (24 h old, LT99 of 74.735 h) under the same conditions of low pressure and temperature (Mbata et al 2005).

Exposure of cow pea seeds infested with different stages of *C. maculatus* viz, egg, early larva, late larva and pupa at 50°C for different durations viz 2, 4 and 6 h and normal temperature 28.5°C revealed significant reduction in bruchid infestation in the heat-treated cowpea as compared to control while adult survival was also decreased with increase in exposure period

to dry heat for 4 to 10 min leading to total mortality with 12 min exposure however with slight pinch on seed germination (Bhalla et al 2008).

Under the present study a bio-thermal seed heating device was developed and a laboratory investigation was carried out to assess the effect of heat treatment against bruchids, *Callosobruchus maculatus* (Linnaeus) on black gram.

MATERIALS and METHODS

Mass culturing of bruchids

Mass culturing of bruchids was done in the insectary at TNAU, Coimbatore. The bruchid adults collected from black gram seed samples of the Department of Seed Science and Technology, confirmed as *Callosobruchus maculatus* by morphological characters, were utilized for mass culturing. The bruchids were reared on fresh black gram seeds disinfested by sun-drying to kill any existing insect stages. One hundred adult insects were released on 400 g black gram seeds in a 500 g plastic container capped with muslin cloth to ensure ventilation. The jar was kept under controlled room temperature of 25 + 5°C and 70 ± 5 per cent RH throughout the period of investigation. Adults numbering 10 pairs were released and the jar was left for 25 days to obtain uniform aged adult beetles for the experiment. Sub-culturing of this beetle was done at weekly interval so as to

have a continuous supply of insects for experiments proposed in this investigation.

Bio-thermal seed heating device comprised the following major components (Fig 1)

Cylindrical drum: The airtight cylindrical drum of 10 kg volume made with aluminium sheet was fitted with baffles. Baffles were vertically made with MS pipe and provided inside the cylinder to distribute hot air equally throughout the cylindrical drum. Perforations of 3 mm diameter were made on the baffles at 1 inch gap to flow hot air into the cylindrical drum (Fig 2). Top of the seed container was covered with lid to prevent the hot air loss and escape of bruchids.

Gear box: A gear box was fitted below the airtight cylindrical drum to facilitate the drum to rotate at 60 rpm. The gear box was provided with handle to operate manually.

Hot air unit: Hot air unit of cylindrical chamber was made of aluminium sheet (Fig 3). A copper coil of 10 feet length and 1 inch diameter was fixed inside the cylindrical chamber (Fig 4). The copper coil carried the ambient air that was sent through blower and converted it into hot air by conducting heat through it. Hot air unit and handle for rotation were attached in 'L' shape to facilitate easy operation of the device. The cylindrical chamber was filled with water

to arrest the heat losses and was provided with inlet and outlet tubes to supply water inside the chamber. The outlet pipe from the hot air unit was connected with the cylindrical drum inlet pipe with coupling pipe to transfer the hot air to the baffles in the cylindrical drum.

Biogas stove and blower: Biogas stove was fixed at the bottom of the hot air unit which received gas from the biogas plant and supplied heat at constant rate to the hot air unit. Manual blower was fixed by side to supply the air into hot air unit.

Temperature control meter: Temperature control meter was connected with the device to control the high temperature of 55, 60 and 65°C in the duration of 30 minutes. Temperature varied from outer to inner surface of the container.

Working procedure of the bio-thermal seed treatment device

The treatment samples of 10 kg each were subjected to hot air treatment in cylindrical drum for 30 minutes. In order to have the desired level of temperature in the treating cylinder, the temperature level of hot air (usually higher level) to be passed from the hot air unit was standardised by preliminary tests. Temperature was created in the hot air device after at least 30 minutes initial heating with complete release of gas and heating unit was brought down to simmering condition and temperature indicated correspondingly in the treating

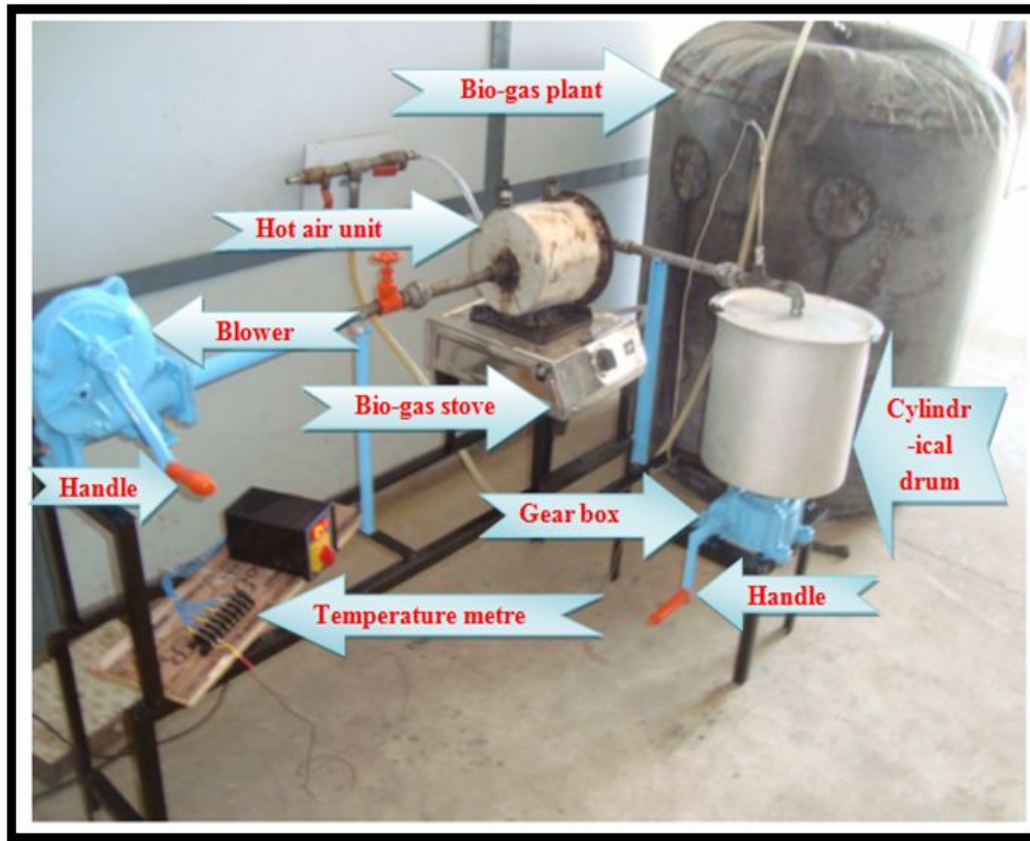


Fig 1. Bio-thermal seed treatment device



Fig 2. Arrangement of baffles inside the cylindrical drum



Fig 3. Hot air unit



Fig 4. Copper coil fixed in the aluminium container

cylinder was measured so as to standardise the level of required hot air temperature, to maintain the temperature to treat the seeds (Table 1). Infested seeds of 10 kg were transferred to cylindrical drum and subjected to the designated level of temperature for a period of 30 minutes as standardised above. The treated seeds at three different levels (55, 60 & 65°C) were then transferred to polybags (45 x 60 cm) suitably perforated for aeration. Sufficient number of replications were maintained and kept to observe adults emerged weekly (live and dead); dead adults were removed from the released adults and also counted on eggs on weekly basis. Germination of the treated seeds and protein content were assessed after eight weeks of treatment using the gel-dhal equipment available with Post Harvest Technology unit of the TNAU.

Seed germination: Seed germination was assessed by following roll-towel method as recommended by Anon (1999) in

germination room maintained at $25 \pm 5^\circ\text{C}$ temperature and 95 ± 3 per cent RH. After eight days the seedlings were evaluated and the normal seedlings were counted and expressed in percentage.

Root length: At the time of germination count all normal seedlings from each treatment were considered for the root length measuring from the collar region to the tip of primary root and the mean was expressed in centimetres.

Shoot length: The seedlings used for measuring root length were also used for measuring shoot length. The shoot length was measured from the collar region to shoot apex and the mean was expressed in centimetres.

Vigour index: Vigour index (VI) was calculated by using the formula suggested by Abdul-Baki and Anderson (1973) and expressed in whole number.

$$VI = \text{Germination percentage} \times [\text{Root length (cm)} + \text{shoot length (cm)}]$$

$$\text{Germination percentage} = \frac{\text{Total number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

Statistical analyses: The data obtained were analyzed by analysis of variance as described by Panse and Sukhatme (1985). Per cent values were subjected to arc sin transformation and insect counts

were transformed to square root transformation before subjecting to the analysis. The critical differences (CD) were calculated at 5 per cent probability level.

Table 1. Exposure period of seeds in minutes to high temperature treatment

Outer temperature (°C)	Inner temperature (°C)	Time (min)
95	55	30
105	60	30
120	65	30

RESULTS and DISCUSSION

Field infested seeds when subjected to temperature of 55, 60, and 65°C for 30 minutes resulted in desirable significant effect on adults emerged as infested seeds exposed to the temperature range of 60°C (0.13 adults/week/100 g seed) and 65°C (0.05 adults/week/100 g seed) had fewer live adults up to three weeks and thereafter no live adults could be seen until eight weeks of observation. Adults in the absolute check progressively increased from 56.0 to 112.5 /100 g seed (Table 2) as the weekly period of observation commenced from first to eighth week while in the seeds subjected to 55°C for 30 minutes had 5.8 to 42 adults per 100 g of seed with an average of 80.5 adults.

Though the dead adults in the absolute check ranged from 22.6 to a maximum of 46.1/100 g of seed, the seeds exposed to 65°C had 58.2, 60°C had 38.9 and 55°C only 22.8 (Table 2) indicating the effect of killing due to exposure to high temperature ranges. As the trend observed in live adults, similar effect was reflected in the dead also.

Earlier attempts by Loganathan et al (2011) suggesting 60°C for 15 min while 55°C for 45 minutes to get complete control of *C maculatus* in chickpea and Lale and Vidal (2003) reporting that no development of the *C maculatus* on bambara groundnut, *Vigna subterranea* (L.) Verdcourt when subjected to constant temperature of 40°C are in support of the present investigation to promote the use of heat against bruchids. Mbata et al (2005) reported that mortality of cowpea weevil increased with exposure time and also with increasing temperature in all life stages of *C maculatus*. The adult was the most susceptible life stage to low pressure; 99 per cent mortality was achieved within exposure period between 28.98 and 153.20 h at temperature of 20 to 35°C.

The seeds exposed at 65°C had lower eggs (3 eggs/week/seed) as compared to 55 and 60°C that had higher number of 4.9 and 3.6 eggs/week/seed respectively (Table 3).

Exposure of the various developmental stages of *C maculatus* to heat up to 45 minutes resulting in complete

Table 2. Effect of heat on black gram bruchids in infested seeds

Treatment	# dead adults (weeks after treatment)							
	1	2	3	4	5	6	7	8
Live adults								
Absolute check	56 (7.5)	69 (8.3)	74 (8.6)	77 (8.8)	80 (8.9)	83.5 (9.1)	92 (9.6)	112.5 (10.6)
55°C + 30 min	7.8 (2.8)	5.8 (2.5)	8.2 (2.9)	29.7 (5.4)	31.9 (5.6)	39 (6.2)	40.5 (6.4)	42 (6.5)
60°C + 30 min	0.5 (0.9)	0.3 (0.8)	0.1 (0.8)	0.2 (0.8)	0.0 (0.7)	0.0 (0.7)	0.0 (0.7)	0.0 (0.7)
65°C + 30 min	0.2 (0.8)	0.1 (0.8)	0.1 (0.8)	0.0 (0.7)	0.0 (0.7)	0.0 (0.7)	0.0 (0.7)	0.0 (0.7)
Mean	16.1 (4.0)	18.8 (4.4)	20.6 (4.6)	26.7 (5.2)	27.9 (5.3)	30.6 (5.5)	33.1 (5.8)	38.6 (6.2)
Dead adults								
Absolute check	33.9 (5.8)	46.1 (6.8)	32 (5.7)	22.6 (4.8)	44.6 (6.7)	38.5 (6.2)	28.0 (5.3)	22.6 (4.8)
55°C + 30 min	20.4 (4.5)	22.8 (4.8)	21.2 (4.6)	13.5 (3.7)	14.6 (3.8)	13.1 (3.6)	14.0 (3.7)	17.8 (4.2)
60°C + 30 min	11.3 (3.4)	18.5 (4.3)	27 (5.2)	30.2 (5.5)	30.9 (5.6)	34.4 (5.9)	38.2 (6.2)	38.9 (6.2)
65°C + 30 min	41.5 (6.4)	40.9 (6.4)	43.6 (6.6)	46.3 (6.8)	49.2 (7.0)	51.8 (7.2)	53 (7.3)	58.2 (7.6)
Mean	26.7 (5.2)	32.0 (5.7)	30.9 (5.6)	28.1 (5.3)	34.8 (5.9)	34.4 (5.9)	33.3 (5.8)	34.3 (5.8)

Figures in parentheses are square root transformed values

	Live adults		Dead adults	
	SE (D)	CD _{0.05}	SE (D)	CD _{0.05}
Treatment	0.07	0.15		
Period	0.10	0.21		0.24
Interaction	0.21	0.43		0.34
				0.69

control and potential of using solar energy in controlling storage insect pests through heating of grains in various types of solar heaters was proposed by Mekasha (2004). Superheating of food grains provided extra protection without treating with any insecticide. Grain temperature raised up to 55-65°C for 10 to 12 h could effectively kill all life stages of stored grain pests in warehouses (Upadhyay and Ahmad 2011). Mbata and Phillips (2001) arrived at the conclusion that the eggs were more tolerant to heat than larvae and pupae of *T. castaneum* and *R. dominica* F. Time-mortality response of red flour beetle eggs, young larvae, old larvae, pupae and adult stages increased with increase in temperature and exposure time (Boina and Subramanyam 2004). More specifically eggs and young larvae are most susceptible at high temperature than old larvae. Mahroof et al (2005) reported that most insects were inactive below 55°F. Mariam (2011) exposed cowpea seeds to high temperature range of 60, 65 and 70°C for either 30 or 60 minutes and found that 55°C for 60 minutes gave excellent result with hundred percentage mortality against adult bruchids.

The exposed seeds to varied defined temperatures were tested for germination. Though the highest desirable germination of 91 per cent (Table 4) in the seeds exposed to 65°C for 30 min was achieved, the germination at 55°C as well as 60°C for 30 min was on par. However the germination was significantly higher in

absolute check (93.0%) and low at 55°C (78.0%).

Protein content of the seeds exposed to different temperatures ranged from 22.18 to 22.81 per cent in seeds exposed to 60 and 65°C respectively while the standard check had 22.44 per cent (Table 5). The mean protein content of treated and untreated seeds was 22.41 per cent with just 0.29 and 0.15 per cent as standard deviation (SD) and standard error (SE) respectively in the treatments indicating the variation in the protein content was not vitiated due to heat treatments.

CONCLUSION

The heat treatment of black gram seeds at 65°C for 30 minutes would be the important step to be adopted in bruchid pest management as the treatment was highly favourable for preventing the bruchid infestation until four weeks without any detrimental effect on nutritional quality besides enhancing the germination. A novice attempt was made in the present investigation to develop heating device which was totally renewable energy dependent ie through biogas plant. Attempts were made to standardize the required temperature in the hopper by means of adjusting the control value of blower. The device fabricated may serve as a model for devolving pilot plants when there is necessity to go for the use of renewable energy at farm level.

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Table 3. Effect of heat on bruchid eggs on black gram infested seeds

Treatment	# eggs/seed (weeks after treatment)				Mean
	1	2	3	4	
Standard check	7.5 (2.8)	8 (2.9)	6.5 (2.6)	8 (2.9)	7.5 (2.8)
55°C + 30 min	6 (2.5)	4 (2.3)	4.5 (2.2)	5 (2.3)	4.9 (2.3)
60°C + 30 min	4.5 (2.2)	4 (2.1)	3 (1.8)	3 (1.8)	3.6 (2.0)
65°C + 30 min	4 (2.1)	1 (1.1)	4.5 (2.2)	2.5 (1.7)	3 (1.8)
Mean	5.5 (2.4)	8.5 (3.0)	4.6 (2.2)	4.3 (2.2)	5.7 (2.5)
	SE(d)	CD _{0.05}			
Treatment	0.13	0.28			
Period	0.13	0.28			
Interaction	0.26	0.56			

Table 4. Effect of heat on germination of black gram infested seeds

Treatment	Germination (%)	Vigour index (VI)
Absolute check	93 (74.66)	2736.4 (3.43)
55°C + 30 min	78 (62.02)	2223.00 (3.34)
60°C + 30 min	84 (66.42)	2282.45 (3.35)
65°C + 30 min	91 (72.54)	3068.42 (3.48)
Mean	94 (75.82)	2577.56 (3.41)
SE(d)	3.91	0.02
CD _{0.05}	9.03	0.06

Figures in parentheses are log transformed values

Table 5. Effect of heat on protein content of black gram infested seeds

Treatment	Protein content (%)
Standard check	22.44
55°C + 30 min	22.20
60°C + 30 min	22.18
65°C + 30 min	22.81
Mean	22.40
SD	0.29
SE	0.15

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