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Effectiveness of insect egg removal device in controlling insect progeny development in stored grains

Athanase Hategekimana [1*], **Sarma Mohan** [2]

[1]Rwanda Agriculture and Animal Resources Development Board RAB, PO Box 5016 Kigali, Rwanda
[2]Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore 641 003, India

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Anisur Rahman
anis_fpm@bau.edu.bd

*Corresponding Author
Athanase Hategekimana
ahategekimanaa@gmail.com

ABSTRACT

The side effects of pesticides and fumigants have led to the development of ecofriendly stored grains in insect management methods. Insect egg remover is one of the recent inventions to be used in the management of stored grain insects. The inner brushing arrangement in the device facilitates the crushing of the eggs, if any, in the grains. Investigations were made to determine the effectiveness of the insect egg remover for the management of stored grain insects. The number of times the grains passed in the device (one, two and three times) and the density of insects (10, 20 and 30) were the two factors of the experiment. After rotating the grains with eggs in the machine, they were incubated for 60 days for assessing progeny production and grains damage. The device proved effective in reducing the emergence of *Rhyzopertha dominica* (F) and *Tribolium castaneum* (Herbst) adults without the influence of the densities of insects artificially introduced in paddy and sorghum grains, respectively. The pattern of emerged adults was significantly less in three passes. In addition, the density of insects did not influence significantly the emergence of adults and grain damage. However, grains damage at 40 and 60 days of incubation was significantly affected by the number of passes in the device. The lowest damage was recorded in three passes and the highest damage was in untreated grains. Most farmers could benefit by using this mechanical device. The design of the device is such that it can facilitate in crushing eggs beside the rapid removal of adult insects from mild and severely infested grains and consequently prevent grains damage and eliminates the possibility of the pests developing resistance over time. However, the machine has the limitations of controlling only external feeding stored insects and this study recommends a cost-benefit analysis.

Keywords: Insect egg remover, progeny development, stored grain

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1 Introduction

Stored insect pests are among the major problems associated to stored products (Buckland, 1981; Levinson and Levinson, 1994). Post-harvest losses in India amount to 12 to 16 million metric tons of food grains each year, an amount that the World Bank estimates could feed one-third of India's poor (Singh, 2010). For longtime, the control measures against stored grain insect pests relied on some traditional methods, synthetic insecticides and fumigants or plant extracts (Levinson and Levinson, 1989). The side effects caused by contact insecticides and fumigants has led to the development of ecofriendly stored grain insect management methods. Physical control, especially by mechanical devices assumed greater importance. Physical control methods are safe, simple and with low costs in controlling stored insect pests in warehouses or storehouses (Facknath, 1993; White et al., 2005; Suleiman et al., 2016). Physical exclusion of air, insects removal, and impact or physical disturbance of insects are the most known (Banks, 1987). They are preferable to synthetic pesticides because of their free-chemical residues, safety to applicators and minimal likelihood of the development of insect resistance (Hollingsworth and Armstrong, 2005).

Different authors documented the use of mechanical devices in the management of stored grain insects. The effectiveness of mechanical impact depends on targeted species and life stages of the insects (Ungsunantwiwat and Mills, 1979; Suleiman et al., 2016). Plarre and Reichmuth (2000) reported that impact machines are very effective in destroying insect eggs. In addition, the insects are highly susceptible to the combination of acceleration and deceleration of the machines. Joffe and Clarke (1963) suggested that different developmental stages of insects vary in their susceptibility to the mechanical impact. Loschiav (1978) studied and revealed the effect of disturbance of wheat grains on four insect species such as *C. ferrugineus*, *T. castaneum*. *S. granarius*, and *S. oryzae*. He concluded that mechanical handling of grains may be a more practical means of controlling stored grain pests than using insecticides.

In India, the commercial model of insect egg remover is one of the recent inventions. The prototype models of insect egg remover were extensively tested, and their effectiveness were well established in removing adult stored product insects (Divya et al., 2009; Jayaprakash et al., 2010). The recent development of the commercial models of the above-mentioned device (Mohan, 2011) made it necessary to thoroughly investigate their effect on stored grain insect eggs management (crushing) and consequently prevent grains damage so that they can directly be transferred to the end-users. Hence, the objective of this investigation was to assess the effectiveness of insect egg remover at various passes of the grains through the device and starting with different levels (density) of insect infestation of the grains in the management of stored insects.

2 Materials and Methods

2.1 Study area and device description

The study was conducted in the Insectary, Department of Agricultural Entomology, Tamil Nadu Agricultural University (TNAU), India. The metallic device used has a grain feeding hopper, a cleaning unit with an outlet to collect insects separately and an outlet for the treated grains (Fig. 1). The device can easily be hand-operated and within a period of around five minutes, most of the insects present in the grains can be removed and collected in the insect collection outlet (Hategekimana and Mohan 2013).

2.2 Grain and insect tests

Paddy rice (IR 36) (Oryza sativa L: Poaceae) and sorghum (CO 26) (Sorghum bicolor L: Poaceae) commonly produced in India, with moisture content of 15% were used in the experiment. The two stored grains are mainly damaged by R. dominica for paddy and T. castaneum for sorghum. Grains were obtained from Seed Technology department at Tamil Nadu Agricultural University.

2.3 Mass culturing insects

Paddy grains infested with R. dominica were collected from the Paddy Breeding Station, TNAU while the T. castaneum adults were collected from broken cumbu grains of Biological control laboratory, Department of Agricultural Entomology, TNAU. Insects were reared following the method of Tefera et al. (2010).

2.4 Experiment procedures

The experiment was composed of two factors viz., the number of insects released (0, 10, 20 and 30 adult insects per 500 g of grains) and the number of passes or times the grains passed in insect egg remover (0, 1, 2 and 3 times) in three minutes for each pass. Half kilogram each of paddy and sorghum grains insect-infested samples were passed through the insect egg remover following the number of passes already predetermined. After grains treatment in the insect egg remover, the grains were placed in plastic containers and covered with a muslin cloth. They were kept in room temperature (26-27 °C) and humidity of 65% for six days for oviposition. After the oviposition, the grains with adult insects and eggs were put on paper to remove adult insects by the free movement of insects. In view of early findings that the insect eggs were sensitive to regular small disturbances, sieving was avoided during the preparation and handling of cultural material.

After separation, grains were placed in the insect egg remover to destroy the eggs of each insect species on the grains. The treated grains were kept in containers for a period of 40 and 60 days to allow adult development. The efficiency of the insect egg remover in eggs crushing was assessed by adult development and the number of damaged grains by insects. The new hatchlings were daily counted, recorded and then discarded. The total number of newly adults at the 60th day was the sum of adults observed on 40th day and 60th day. This gave the total number of newly emerged adults removed.

Grain damage was determined by taking randomly 100 grains in each treatment and the number of damaged grains counted on the 40th and 60th days. The grains were examined for weevil and beetle

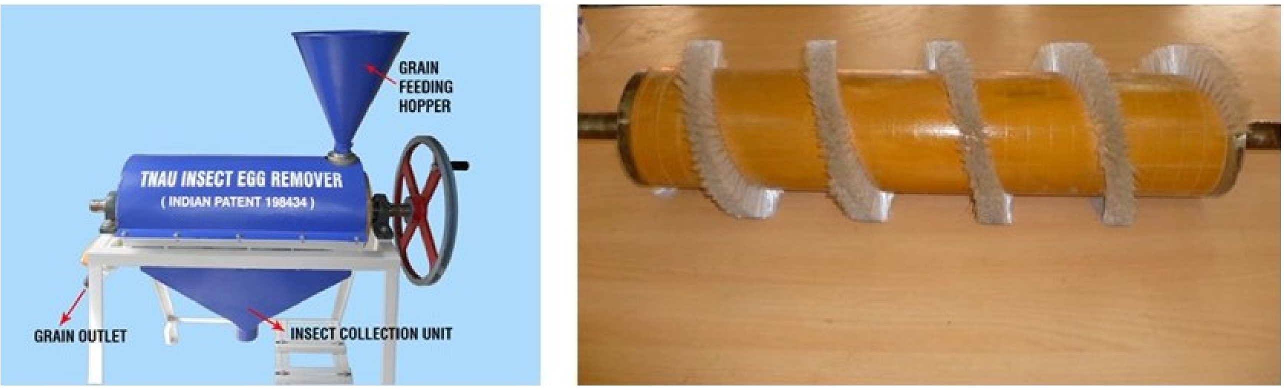

Figure 1. Outer view (left) and inner view (brush) of an insect egg remover (right)

damage using a magnifying glass and separated into damaged and undamaged kernels and the percentage of damaged grains was worked out. The efficiency of the device was based on the capacity of the inner brush to destroy, crush and clean the eggs on the grain samples was premised on the fact that in nature, these insects do not actually reside inside the grains during the infestation cycle. They simply lay eggs on the surface of the grain, and it is the larvae that bore into the grains after hatching.

2.5 Data analysis

Data on adults emerged and grains damage by insects were subjected to analysis of variance using GenStat 14.1. Least Significant Difference (LSD) was employed to compare mean treatments.

3 Results

3.1 Insect egg removal efficiency

The mean adult emergence of *R. dominica* after 40 and 60 days of incubation on paddy grains are presented in Table 1. The results showed that insect density did not influence significantly the efficiency of insect egg remover device. On the other hand, the number of passes in insect egg remover significantly reduced the number of R. dominica adults emerged. The efficiency of the device with reference to emerging adults was in the order of three passes (11.2 insects) < two passes (19.7 insects) < one pass (24.7 insects). In the untreated control, the number of emerged adults was 33.3 insects. In the case of *T. castaneum*, the data on the mean number of emerging adults (Table 1) showed no significant difference between the densities of insects introduced in sorghum grains. The number of passes influenced significantly the number of adults emerged. The mean number of emerged adults of T. castaneum were found to be 11.4, 7.6, 3.7 and 15.1 in one, two, three passes and in untreated control, respectively. The pattern of adult emergence of T. castaneum revealed that the number of emerged adults was significantly less in grains treated with three passes.

3.2 Grain damage by insects

The results of Table 2 indicated that *R. dominica* and *T. castaneum* insect's density did not influence significantly the grain damage by insects. However, the numbers of passes reduced significantly the grain damage at 40 and 60 days after incubation. For *R. dominica* at 40 days of incubation, the lowest damage was recorded in three passes followed by two passes and one pass with grain damage percentages of 1.1 %, 1.7 % and 2.8 %, respectively. In the control (untreated grains) the damage was 4.5 % after 40 days of incubation. After 60 days, the lowest damage was found in three passes followed by two passes with grains damage of 1.1 % and 1.6 %, respectively. The highest grains damage was 5.8 % and 7.6 % for one pass and untreated grains, respectively. The mean number of emerged adults of *T. castaneum* were found to be 11.41, 7.66, 3.77 and 15.11 in 1, 2, 3 passes of grains and in untreated grains, respectively. The pattern of adult emergence of *T. castaneum* revealed that the number of emerged adults were significantly less in three passes grains.

4 Discussion

The data showed that the eggs were effectively destroyed by insect egg removal device from the paddy and sorghum grains. Any number of eggs was destroyed by the device "brush". Grains rotated in three passes showed significantly a smaller number of adults emerged. This could be due to the increased number of impacts or physical disturbance on the insect eggs which would remove or damage the eggs. This resulted in fewer number of emerged larvae which would feed on paddy grains and cause damage. The present results are in conformity with those of Jayaprakash et al. (2010) who carried out an essay

Table 1. Impact of insect egg remover on the egg stage by way of assessing the emerged adults (mean number) of *R. dominica* and *T. castaneum* adults from artificial infested paddy and sorghum grains respectively

Treatments	No. of *R. dominica*	No. of *T. castaneum*
Factor A: Insects density (D)		
D1 (10 insects)	22.41±3.34	10.16±1.14
D2 (20 insects)	21.91±2.67	10.16±0.60
D3 (30 insects)	22.50±1.97	10.00±0.77
LSD (P = 0.05)	0.65 NS	0.24 NS
Factor B: Number of rotations/passes (R)		
R0 (Control)	33.33±3.37 a	15.11±2.24 a
R1 (One rotation)	24.77±1.42 b	11.41±2.30 b
R2 (Two rotations)	19.77±0.89 c	7.66±0.94 c
R3 (Three rotations)	11.22±0.94 d	3.77±1.45 d
LSD (P = 0.05)	0.3	0.102
Interaction (D x R)		
LSD (P = 0.05)	NS	NS

NS = Not significant; Means followed by the same letters within column are not significantly different at P=0.05 (LSD)

Table 2. Storage paddy and sorghum grains damage by *R. dominica* and *T. castaneum* respectively at 40th and 60th days after treating grains by different passes of insect egg remover device

Treatments	Grain damage by *R. dominica* (%)		Grain damage by *T. castaneum* (%)	
	After 40 days	After 60 days	After 40 days	After 60 days
Factor A: Insects density (D)				
D1 (10 insects)	2.66±1.30	4.00±1.90	1.50±0.32	3.58±0.43
D2 (20 insects)	2.50±1.24	4.08±0.87	1.41±0.03	3.41±0.51
D3 (30 insects)	2.58±0.56	4.16±1.45	1.75± 0.21	3.08±0.25
LSD (P = 0.05)	0.45 NS	1.16 NS	0.89 NS	0.78 NS
Factor B: Number of rotations/passes (R)				
R0 (Control)	4.55±0.73a	7.66±1.67a	3.44±0.40a	7.44±1.54a
R1 (One Rotation)	2.89±0.05b	5.88±1.83a	1.77±0.41b	3.77±0.93b
R2 (Two Rotations)	1.77±0.12c	1.66±0.43b	0.77±0.12c	1.77±1.02c
R3 (Three Rotations)	1.11±0.23d	1.11±0.60b	0.22±0.12d	0.44±0.08d
LSD (P = 0.05)	0.52	1.34	0.03	0.9
Interaction (D x R)				
LSD (P = 0.05)	NS	NS	NS	NS

NS = Not significant; Means followed by the same letters within column are not significantly different at P=0.05 (LSD) on the removal of eggs of *R. dominica* and *T. castaneum* from infested paddy grains, and reported that a significant number of eggs were removed and that among, 1, 2 and 3 days rotated grains the higher percentage of reduction in emergence of offspring adults was observed in 3 days rotated grains. Quentin et al. (1991) showed that regular bean tumbling drastically lowered the bean weevil Acanthoscelides obtectus (Say) populations by approximately 97% in kidney bean, *Phaseolus vulgaris* (L.). Richards. (2009) noted that frequent disturbing of weevils by shaking produced a depressing effect on the oviposition which was similar to overcrowding. Bailey (1969) stated that physically disturbing wheat containing immature stages of *S. granarius* (L.) might prevent many or all of them from developing successfully, especially if the grains were disturbed more than twice a week.

There was a negatively relationship between the disturbance frequency and progeny production reduction. There was no much variation in eggs crushing of *R. dominica* and *T. castaneum* in different grains *viz.*, paddy and sorghum respectively. Among different grains, efficiency was high in sorghum. The smooth grain structure of sorghum compared to paddy grains facilitated the efficiency of the device in destroying the eggs and consequently low adult emergence. Joffe and Clarke (1963) demonstrated that mechanical disturbance of maize grains was harmful to the pre-emergent stages of the *S. oryzae*. The egg stage is more sensitive against physical disturbance; even the eggs of *S. oryzae* which are normally covered with gelatinous secretions were even removed or damaged due to the agitation caused by rotation. They attributed the effect of turning to the lethal effect of disturbance on the insects. Joffe and Clarke (1963) considered that insects in maize grains could be controlled by exposure to a low-level physical disturbance applied at time intervals. On the other hand, no significant grain damage could be observed due to the density of insects with reference to *R. dominica* and *T. castaneum* in either grain species under study. But observations of the grain damage showed that rotating the grains for 3 passes resulted in the most effectiveness control of *R. dominica* and *T. castaneum*. Increasing the frequency of passes would make the grains exposed to the physical disturbance for a long time resulting in the eggs removal and consequently fewer number of emerged adults which would feed on paddy grains. Suleiman et al. (2016) reported that the physical disturbance was effective in protecting maize grains *S. zeamais* and increased the storage duration of stored grains for consumption, animal feeding or seeds. Comparing the damage at 40th and 60th days, the damage was much higher at 60 days. This could be to the increased feeding exposure period of paddy grains to R. dominica and the increasing number of emerged adults of *R. dominica* to feed on paddy grains.

The overall results suggest that the insect egg remover machine can be used by farmers to prevent stored grains damage especially for carry over insects. It is free of any residues and non-harmful to the environment and friendlier to the health of users. The machine has the limitations of controlling only external feeding stored insects. The study recommends conducting a cost-benefit analysis due to the cost of the machine and the returns obtained after the control of insects.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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