

Influence of grain fractions on the progeny adult emergence of the lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae) in stored rice varieties and pulses

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Abstract

Infestation of stored grains by the lesser grain borer *Rhyzopertha dominica* cause serious quantitative and qualitative losses. Grains get fractioned during milling and availability of brokens with the whole grains may alter the rate of insect infestation and progeny adult emergence. Traditional rice varieties are being reconsidered in addition to the new improved varieties in the diet of Sri Lankans due to the accompanied health benefits. In this study, the progeny development of *R. dominica* in locally-available traditional and new improved rice varieties and pulses containing different percentage of grain fractions was determined at 2-week intervals following initial infestation. More progeny adults emerged in rice than on pulses. In rice, Red Kekulu and Kuruluthuda varieties had higher adults emerged than in other varieties. Blackgram and greengram had the lowest adult emergence. Increased percentage of grain fragments in the sample decreased the progeny adult emergence. More *R. dominica* adults emerged later than early stages following initial infestation. Minimization of initial infestation reduces damage caused by *R. dominica*. The future studies need to test how the infestation by other insect species is affected by grain type and availability of broken grain in the medium to ensure better protection of stored grains from insect damage.

Keywords: Insect infestation, progeny emergence, traditional/new improved rice varieties, storage

1. Introduction

Rice stands as the status as the staple food of Sri Lankans [1] as well as more than 50% of world population [2,3]. Despite the new improved rice varieties grown abundantly in Sri Lanka, there is a renewed interest in the consumption of traditional local rice varieties due to the accompanying nutritional characteristics [4]. Rice yield is stored following harvest to meet the consumer demand in the off seasons. However, the stored paddy is subjected to serious insect infestations during storage [5,6,7,8].

The lesser grain borer *Rhyzopertha dominica* (F.) is a destructive insect species of stored grains, pulses [9,10,11,12,13,14,15] and commonly found in granaries, mills and processing plants [6,7,8,12]. Infestation by *R. dominica* reduces quality characteristics of milled grains (eg. sorghum) such as hardness, milling yield, pasting properties [16]. The penetration of the *R. dominica* larva into wheat is linked with the kernel characteristics including size and hardness [17]. However, there have been contradictions on the relationship between the grain/kernal hardness and the susceptibility to insects. The broken grains are commonly available during grain milling, and is a

practical situation where the infestations of above nature may occur. The possibility of insect infestation on these broken grains is a concern in terms of stored grain protection. Furthermore, the variety of grains affects the infestation level and the population growth of *R. dominica* [18,19,20].

In analyzing the previous studies, there has been no uniformity or defined pattern in the damage caused by different insect species in grain with varying hardness [21, 22, 23, 24, 25]. This knowledge gap imposes a great limitation in determining the damage that *R. dominica* may cause in the locally-available rice and other grains during storage. Despite the great challenge caused by this species on the protection of stored grains, no previous study has been conducted on the susceptibility of local rice varieties and other grains found in Sri Lanka to this devastating insect species. This leaves great uncertainty for the protection of paddy/rice and other grains stored to meet the consumer demand during off seasons. Therefore, the objective of the present study was to determine the level of infestation by *R. dominica* adults in traditional and new improved rice varieties, and other grains in storage having different degrees of grain fractions.

2. Materials and methods

2.1 Insects

The adults of *R. dominica* used in the experiments were reared in red raw rice (variety *Red Kekulu*) at $30\pm 1^\circ\text{C}$ and $65\pm 1\%$ relative humidity in an incubator (FH-1200, Hipoint Corporation, Kaohsiung City, Taiwan). The adults were collected by using an aspirator connected to a vacuum pump (Rocker 300, Rocker Scientific Co. Ltd, New Taipei City). From the *R. dominica* cultures maintained in the laboratory, 200 adults were introduced to 400 g of rice in a plastic container (1 Litre) and covered with a piece of cloth (material 'Poplin'). The parent adults were removed in 2 weeks. The progeny adults emerged from these cultures were used in the experiments one month following emergence.

2.2 Sample preparation

Two new improved rice varieties (*Red Kekulu*, *Red Samba*), three traditional rice varieties (*Red Heeneti*, *Kuruluthuda*, *Suwandel*) and the pulses cowpea, greengram and blackgram were used. These grains were first milled (Mixee-N, Singer India Ltd., New Delhi) and sieved using first No. 20 and then No. 30 sieves (ASTM E11, W.S. Tyler Industrial Group, U.S.A). This step was followed to ensure the uniformity of particles mixed with the whole grains. The sample remained on sieve No.30 sieve was used as the fragments and mixed with the whole grains to have a different percentage of fragments in the final samples as 0%, 10%, 20%, 40%, 60%, or 100% by weight of the whole sample (Table 1). Cowpea, greengram and blackgram were ground in the similar manner and sifted using No. 10 and No. 20 sieves. The particles held on No. 20 sieve were mixed as broken to have different broken proportions in the final mixture as mentioned above. From each grain type, a composite sample of 20 g was placed in a plastic vial (60 mL) covered with perforated plastic lid to serve as one replicate.

Table 1. Different milling factions tested for progeny adult emergence in *Rhyzopertha dominica*.

% Milling fraction	Composition of grains (g)
0	Whole grain 20g
10	Whole grain 18g+ grain fragments 2g
20	Whole grain 16g+ grain fragments 4g
40	Whole grain 12g+ grain fragments 8g
60	Whole grain 8g+ grain fragments 12g
100	Grain fragments 20g

2.3 Introduction of *Rhyzopertha dominica* adults into grains

The experiments were conducted using grain samples placed inside plastic bottles. The one-month-old *R. dominica* adults were introduced at the rate of 20 adults per one culture bottle (60 mL) which contained 20 g sample of a particular grain type (having a given percentage of broken). Four replicates from each grain type were tested. The parent adults introduced were sifted out following 2 weeks. The grain samples were kept inside the incubator maintained at $30\pm 1^\circ\text{C}$, $65\pm 1\%$ r.h. The progeny *R. dominica* adults emerged in each replicate grain sample were counted every 2 weeks interval following the removal of parent adults for 6 weeks.

2.4 Experiment design and data analysis

The experiment was set up as Complete Randomized Design with four replicates. The number of *R. dominica* progeny adults emerged in a particular replicate (a particular grain type and broken percentage) were analyzed using GLM procedure of Statistical Analysis System [26]. The means were separated by Tukey's test at $P=0.05$.

3. Results

The *R. dominica* progeny adults emerged differed with the grain type ($F_{7,561}=58.06$, $P<0.0001$), broken grain percentage present in the sample ($F_{5,561}=5.43$, $P<0.0001$) and the duration following initial infestation by parent adults ($F_{2,561}=108.30$, $P<0.0001$). Considering all the grain types tested, *R. dominica* adult emergence was higher at 42 days than 14 or 28 days following initial infestation.

With regard to adult emergence throughout the entire storage period, the grains belonged to three categories. The highest adult emergence was in Red Kekulu (maximum 80) and Kuruluthuda (maximum 104). The middle level adult emergence was observed in Red Samba (maximum 31.5) and Red Heeneti (maximum 30.75). The lowest adult emergence was in blackgram (maximum 9.75) and greengram (maximum 4). Cowpea had adult emergence higher (maximum 10.25) than blackgram (maximum 9.75) and greengram (maximum 4) but lower than Suwandel (maximum 33.25), Red Heeneti (maximum 30.75) and Red Samba (maximum 31.5). Consequently, the adult emergence from highest to the lowest was Red Kekulu=Kuruluthuda> Suwandel=Red Samba=Red Heeneti >Cowpea > blackgram= greengram (Tables 2 and 3).

Table 2. Number (mean±SE) of *Rhyzopertha dominica* adults emerged 14, 28 and 42 days following infestation in Red Kekulu, Red Samba, Red Heeneti, Kuruluthuda and Samba rice varieties having different percentages of grain fragments (n=4).

Grain	% grain fragments	Adults emerged (mean±SE) ^a		
		Duration following infestation (days)		
		14	28	42
Red Kekulu	0	0.25±0.25b	65.25±6.16b	80.0±6.25a
	10	1.25±1.25a	92.0±7.01a	67.0±14.29b
	20	0.75±0.75b	80.0±4.42ab	48.25±7.69c
	40	0.25±0.25b	56.75±4.59c	30.75±7.87c
	60	0b	40.75±4.21c	35.25±17.61c
	100	0.75±0.48b	17.75±1.7c	20.5±7.89c
Red Samba	0	0a	1.0±0.41c	2.25±1.11c
	10	0a	15.75±5.02b	31.5±1.44a
	20	0a	14.5±1.32c	28.5±4.05a
	40	0.25±0.25a	17.0±2.74b	21.25±2.02ab
	60	0a	17.0±1.96b	13.0±2.42b
	100	0a	25.5±2.33a	11.75±1.75b
Red Heeneti	0	0a	24.25±8.69a	15.25±2.78b
	10	0.25±0.25a	9.25±1.65c	25.25±4.21ab
	20	0a	16.5±2.10b	30.75±5.63a
	40	0.5±0.29a	10.75±0.85c	10.5±0.65c
	60	0a	8.25±0.63c	13.5±4.35b
	100	0.5±0.5a	10.25±0.85c	2.0±1.08c
Kuruluthuda	0	0.25±0.25a	47.5±5.66a	102.0±7.34a
	10	0a	46.5±2.32ab	104.5±5.85a
	20	0.5±0.5a	24.75±2.32c	67.75±2.72c
	40	0a	31.0±2.12b	86.25±2.32b
	60	0a	28±3.58b	58.25±3.73c
	100	0.5±0.5a	21.25±1.89c	16.5±1.85c
Suwandel	0	0a	1.25±0.48b	7±1.47c
	10	0a	4.25±0.85b	13.5±3.28bc
	20	0a	6±0.91b	33.25±7.56a
	40	0a	7.5±2.10b	23±4.95b
	60	0a	9.25±1.11b	9.75±1.11c

100 0a 20.25±4.25a 6.25±0.63c

^aFor a given duration, means followed by the same letter are not significantly different according to Tukey’s test following ANOVA at P=0.05.

Table 3. Number (mean±SE) of *Rhyzopertha dominica* adults emerged 14, 28 and 42 days following infestation in cowpea, greengram and blackgram having different percentages of grain fragments (n=4).

Grain	% grain fragments	Adults emerged (mean±SE) ^a		
		Duration following infestation (days)		
		14	28	42
Cowpea	0	0a	0.5±0.5c	5.0±1.96b
	10	0a	0.25±0.25c	9.25±0.63ab
	20	0.25±0.25a	0.5±0.5c	14±1.68a
	40	0a	2.0±1.08b	3.5±1.55b
	60	0a	10.25±1.44a	10.25±0.48ab
	100	0a	9.5±0.65a	2.5±1.04b
Greengram	0	0a	0c	0.5±0.28c
	10	0.25±0.25a	0.5±0.29c	1.5±0.65c
	20	0.25±0.25a	0.25±0.25c	4.0±1.22a
	40	0a	0.5±0.5c	2.75±0.75b
	60	0a	1.25±0.48b	3.5±0.65ab
	100	0a	4.0±1.78a	0.5±0.28c
Blackgram	0	0a	0.75±0.75b	9.75±3.57a
	10	0.25±0.25a	0b	0.25±0.25c
	20	0.25±0.25a	0b	1.0±0.41c
	40	0a	1.25±0.75a	9.75±1.31a
	60	0a	2.0±0.91a	7.75±2.42b
	100	0a	0b	0.75±0.48c

^aFor a given duration, means followed by the same letter are not significantly different according to Tukey’s test following ANOVA at P=0.05.

The adult emergence in the grain sample having different percentage of grain fractions followed a characteristic pattern. In general, all the rice varieties produced higher *R. dominica* adult emergence than other grain_types. In general, adult emergence was higher in the samples having lower

percentages of broken grain in Red Kekulu, Red Samba, Red Heeneti, Suwandel and Kuruluthuda. The exceptions observed in Red Samba at 28 days, and Red Heeneti and Suwandel at 42 days following removal of adults where lower percentage of broken grains had low adult emergence.

4. Discussion

Rhyzopertha dominica is an internal feeder. The larva emerged from eggs penetrates into the seed [22]. The current study revealed that the development of *R. dominica* progeny adults occurs more on grains having less amount of grain particles and more amount of intact grains. Also as previously shown more *R. dominica* progeny adults develop in the larger particles of the gelatinized wheat product, Bulger. Furthermore, the weight of these developed adults are also greater than those developed on small-sized particles [27]. Similarly, Arthur et al. [28] showed that *Tribolium castaneum* (Herbst) progeny adults emerged was high in large particles of sorghum milling fractions (bran of >900 µm than coarse grits 600-900 µm). The current finding is contradictory to Suleiman et al. [25] who reported that harder maize kernels are less prone to damage by *S. zeamais* than soft kernels. Furthermore Toews et al. [22] also reported that *R. dominica* penetrates more on smaller and softer wheat kernels. The harder wheat kernels are less susceptible to penetration by this species.

The progeny emergence by *Sitophilus oryzae* is negatively correlated with sorghum kernel hardness [29,30]. Furthermore, Fang et al. [24] reported that there is no relationship of the hardness of wheat kernel on susceptibility to *R. dominica*. Toews et al. [22] also reported that the kernel harness does not affect the progeny emergence by *R. dominica*. Gudrups et al. [23] reported that the kernel hardness of maize and the damage by *S. zeamais* are not linked. The current study revealed that *R. dominica* progeny development was higher on samples having less percentages of particles (higher degree of intact grains). This might be due to the fact that *R. dominica* adults and larvae prefer to choose larger grain particles for feeding and oviposition. Even though not tested in the current study, it is worth investigating if there is a relationship between grain particle size and hardness affecting progeny development in *R. dominica*.

Even though, the common practices in Sri Lanka for managing stored-product insects include the use of botanicals and chemical applications [31,32], the requirement of these attempts, however, would be minimized if the sanitation of the storage facilities is properly maintained. It can thus be suggested clearly that the removal of the grain particles produced during milling would help in minimizing the infestation of insects, resulting in minimizing the use of synthetic pesticides.

5. Conclusions

Rhyzopertha dominica progeny adult emergence varies with the grain type, grain particle size and days following initial infestation of grains. Adult emergence is higher in rice varieties than pulses. More progeny adults emerge on the presence of less percentage of grain fragments. Adult emergence is higher lately than early durations following initial infestations. Prevention of initial infestation by insects in stored grains would help to minimize the grain losses due to *R. dominica* in particular and other insect species in general.

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