

Adult Emergence of *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) in Stored Rice Varieties and Pulses with Broken Grains

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ABSTRACT

The rice weevil, *Sitophilus oryzae*, is a serious pest of stored paddy and rice. Much information on its development during the storage of traditional and new improved rice varieties is not found in Sri Lanka. During milling, some percentage of rice is broken, and broken rice generally enhances the development of insects. However, the ability of progeny development of *S. oryzae* in the presence of broken rice particles is unknown. Hence, this study was conducted to assess the progeny development of *S. oryzae* in different rice and pulse media with a variable percentage of broken grains. Locally-available rice varieties, Red Kekulu, Red Samba, Red Heeneti, Kuruluthuda, Suwandel and the pulses, cowpea, greengram and blackgram having different broken percentages were tested for progeny adult emergence at

2, 4 and 6 weeks following initial infestation. The number of adults emerged varied with the grain type, broken percentage and the duration following initial infestation. Greengram (0-1.5) and blackgram (0-0.75) had very low adult emergence while Red Heeneti (0-191.75) and Red Kekulu (0.25-194.67) had the maximum adult emergence. The increase of the broken percentage initially increased the adult emergence and then decreased. The study concluded that *S. oryzae* adult emergence followed a trend of initial increasing and decreasing trend at the latter part in the samples with increasing percentages of broken rice. The adult emergence was higher at intermediate duration following infestation than the first and last durations. Future studies are needed to determine the reasons underlying the variation in the adult emergence across different grain types and broken percentages.

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Keywords: Broken grains, Duration of infestation, Progeny development, Pulses, *Sitophilus oryzae*, Traditional rice varieties

INTRODUCTION

Agricultural produce is stored mainly for future consumption and trade purposes. Insects infest almost all types of food commodities during

storage. The quantitative and qualitative losses due to insect infestations have significant impacts on consumers as well as traders, and affect their nutritional requirements and good health. It is estimated that the losses of crop yield in storage can vary as 10% in temperate areas and as 50% in tropical areas (Wijayaratne *et al.*, 2018). Of these total post-harvest losses of grains, the damage due to insects can be quite high (Kumar and Kalita, 2017). In Sri Lanka, loss of stored paddy/rice and pulses due to insect attack is frequently reported (Kumari *et al.*, 2020a) and the damage caused by insects in stored paddy/rice may reach nearly 80% of total storage losses (Wijayaratne *et al.*, 2009; Kumari *et al.*, 2020b). Stored-product insects cause significant economic impacts through nutrient loss; reduced seed viability; contamination of raw or processed food by the presence of living or dead insects, insect fragments, webbing or feces of insects, larval and pupal exuviae; development of hot spots; and health risks such as pathogenic microbial infections (Hill, 1990) and allergic reactions (Campbell *et al.*, 2004). Insect infestations in stored grains can also lead to undesirable taste and odors, and thus make the product inedible (Arthur *et al.*, 2012).

The rice weevil *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) is a major pest of stored rice and other cereals in many tropical and sub-tropical countries (Hill, 1990; Arbogast, 1991; Rees, 2004; Mason and McDonough, 2012). This species has been reported from Sri Lanka in stored paddy (Kumari *et al.*, 2020b). In addition to the feeding by insects during storage of food, the infestation by rice weevil accelerates growth of secondary pests and creates favorable conditions for pathogenic invasion of food (Okram, 2019). Therefore, studies on the protection of stored food from infestation by *S. oryzae* are important.

The various operations occurred during the processing of paddy/rice can create cracked grains and different-sized particles including flour and dust. These conditions are known to alter the degree of insect infestation. Similarly, the pulses may also be physically damaged during processing, and thus subjected to a different degree of insect infestation (Wijesooriya and Priyadarshana, 2013). However, details on how insect infestation occurs in different rice varieties and pulses consumed in Sri Lanka are not yet available. Unawareness of these facts is a great

impedance for the adoption of appropriate management methods. Therefore, the objective of this research was to determine the degree of infestation by *S. oryzae* in whole grains and particles of different rice cultivars and pulses.

MATERIALS AND METHODS

Insects

The adults of *S. oryzae* reared at $30\pm 1^{\circ}\text{C}$ and $65\pm 1\%$ relative humidity in an incubator (FH-1200, Taiwan Hipoint Corporation, Kaohsiung City) were used in the experiments. Two hundred *S. oryzae* adults were introduced to 400 g of red raw rice variety Red Kekulu in a plastic container and covered with a perforated lid. The parent adults were sifted out after 2 weeks. The progeny adults were used in the experiments one month following emergence.

Preparation of Grains

The rice varieties Red Kekulu, Red Samba, Red Heeneti, Kuruluthuda, Suwandel and the pulses cowpea, greengram and blackgram were used in the study. All the grain types were ground (Mixee-N, Singer India Ltd, New Delhi) and passed

through No. 20 (850 μm) and No. 30 (600 μm) sieves. The particles retained on sieve No. 30 were mixed as broken-grains with the whole grains to have a final broken-grains as 0%, 10%, 20%, 40%, 60% or 100% of the total weight. Cowpea, greengram and blackgram were ground and sifted using No. 10 (2 mm) and No. 20 (850 μm) sieves. The particles that remained on No. 20 sieve were mixed as broken-grains to have different broken proportions as 0%, 10%, 20%, 40%, 60% or 100% of the total weight. From a given grain type, 20 g was weighed and placed inside a plastic vial (60 mL) and covered with a perforated lid.

Introduction of Adults into Grains

Twenty *S. oryzae* adults were introduced into one plastic vial which previously received 20 g of a particular grain type. These parent adults were removed from the grain sample 2 weeks following introduction. All the grains were maintained at $30\pm 1^{\circ}\text{C}$ and $65\pm 1\%$ relative humidity inside the incubator. Four replicates were tested from each treatment. The progeny adults emerged in each replicate grain sample were counted and removed at.

every 2-week intervals for 6 consecutive weeks

Experimental Design and Data Analysis.

Experiments were set up as Completely Randomized Design with four replicates. The *S. oryzae* adults emerged in one replicate of a particular grain type and broken percentage were analyzed using GLM procedure of ANOVA using Statistical Analysis System (SAS Institute, 2002-2008). The means were separated by Student-Newman-Keuls (SNK) test at $p = 0.05$.

RESULTS AND DISCUSSION

Variation in Adult Emergence with Respect to the Percentage Broken Grain

The adult emergence of *S. oryzae* differed with the grain type ($p < 0.0001$), broken grain percentage in the sample ($p < 0.0001$) and duration following infestation ($p < 0.0001$). Furthermore, the three interactions (grain type x broken percentage), (grain type x duration) and (broken percentage x duration) were significant ($p < 0.0001$). On the whole, the rice varieties had higher adult emergence

than pulses (Tables 1 and 2; Figure 1). With regards to the broken percentage, *S. oryzae* adult emergence increased with the lower percentage of grain fractions in the sample. In general, higher *S. oryzae* adult emergence occurred in 10% than in other broken percentages. The lowest adult emergence was in 100% broken grains. In general when the broken percentage increased from 0-100% the adult emergence followed a trend of initial increasing and subsequent decreasing pattern. This was demonstrated in Red Kekulu and Red Heeneti to a greater extent and in Red Samba and Kuruluthuda varieties with some fluctuations. In contrast, in Suwandel, cowpea, greengram and blackgram, the adult emergence mostly did not differ with the varying percentage of broken grains.

Variation in Adult Emergence with Respect to the Duration

With regard to the duration, the adult emergence in the middle duration (15-28 days) was higher than first (1-14 days) and last (29-42 days) durations. The higher number of adults emerged in Kuruluthuda (mean 46.4), Red Heeneti (44.8) and Red

Kekulu (44.1) than other grain types whereas the lowest adults emerged in blackgram (0.153), greengram (0.347), cowpea (1.70) and Suwandel (1.958). The moderate level adult emergence was observed in Red Samba (32.7) (Tables 1 and 2).

In general, all the pulses (cowpea, greengram and blackgram) had very low adult emergence. There was virtually no adult emergence in rice variety Suwandel at 1-14 days, greengram at 29-42 days and blackgram at 15-28 and 29-42 days following removal of parent adults. Furthermore, greengram and blackgram had no significant differences in adult emergence across the different broken percentages throughout all the time durations tested.

The current findings agree with the previous record that *S. oryzae* progeny emergence is higher in larger grain particles. This is believed to be a consequence of the preference of females to oviposit in larger particles (Campbell, 2002). The progeny development of another internal feeder of stored rice *Rhyzopertha dominica* (F.) on sorghum depends on kernel hardness (Arthur *et al.*, 2020).

Hardness of wheat kernels changes the progeny production in *S. oryzae* as well (McGaughey *et al.*, 1990). The current study revealed that *S. oryzae* progeny development was greater on samples with fewer percentages of broken grains (higher percentage of intact grains). A possible explanation is that *S. oryzae* adults prefer larger grain particles for feeding and oviposition. Therefore, future research needs to be designed to test the hypothesis, if there is a relationship between grain particle size, its hardness and the progeny development in *S. oryzae*. In contrast, progeny adult emergence in the related species *Sitophilus zeamais* Motschulsky was higher in fractions of maize than whole maize. Furthermore, the duration from egg laying to the inception of progeny emergence was lower in small particle sizes (Schoonhoven *et al.*, 1974). However, in *Oryzaephilus surinamensis* (L.), the development was minimum in whole wheat kernels (Fleming, 1988). Contrary to the alteration of progeny with the particle size, the survival of immature rusty grain beetles *Cryptolestes ferrugineus* (Stephens) is not varied among different particle sizes of cracked corn (Thorne, 1992). The deviations from the previous studies as found in the current findings

Table 1. Number (mean±SE) of *Sitophilus oryzae* adults emerged at 14, 28 and 42 days following infestation in different fractions of rice varieties *Red Kekulu*, *Red Samba*, *Red Heeneti*, *Kuruluthuda* and *Suwandel* (n=4).

Grain type	Days following initial infestation	Number of adults emerged (mean±SE) ^a					
		% broken grains					
		0	10	20	40	60	100
<i>Red Kekulu</i>	1-14	2.5±1.19b	26.67±7.31a*	20.75±6.05a	4±1.73b	1±0.71b	0.5±0.28b
	15-28	112.5±23.5b	162.5±8.76a	194.67±28.24a*	63.25±14.67c	53.5±9.46c	0.25±0.25c
	29-42	36.5±2.33b	66.25±3.33a	34.25±2.21b	23.75±1.38c	23.75±5.15c	0.75±0.48d
<i>Red Samba</i>	1-14	5.75±2.81ab	5.25±1.70ab	18.75±6.84a	4±1.58ab	10.5±3.48ab	0.75±0.48b
	15-28	125±1.68ab	77.5±13.17bc	142±36.12a*	46±0.91c	86.33±6.69bc*	0d
	29-42	14.5±2.75a	30.75±0.63a	23±4.18a	18.5±3.92a	20.25±8.64a	0.5±0.5b
<i>Red Heeneti</i>	1-14	6.25±3.04b	5.75±1.75b	18.5±3.77a	1.25±0.63b	1.5±0.86b	0.25±0.25b
	15-28	135.75±36.66ab	134.25±2.21ab	191.75±16.54a	69.25±11.41b	72.5±3.28b	0c
	29-42	34.75±2.75a	38±1.08a	40.5±2.9a	34±1.47a	21±1.58b	0.75±0.48c
<i>Kuruluthuda</i>	1-14	33.67±11.84a*	56.0±4.62a*	29.75±6.73a	29.67±2.73a*	41.33±7.84a*	0.75±0.25b
	15-28	105±27.19ab	142±28.54a	45.75±5.98bc	106.75±18.4ab	58.±3.61bc*	0.25±0.25c
	29-42	12±1.08b	136±17.22a	16±3.63b	18.5±1.55b	0.25±0.25b	0.5±0.28b
<i>Suwandel</i>	1-14	0a	0a	1±0.71a	0a	0a	0a
	15-28	3.5±1.85a	0a	0a	0.75±0.48a	1.75±1.75a	0a
	29-42	7±1.22a	0.75±0.48b	3.25±0.85b	9±0.91a	6.5±1.32a	1.75±0.48b

^aFor a given variety and duration, means followed by the same letter are not significantly different according to Student-Newman-Keuls (SNK) test following ANOVA at $p = 0.05$.

*Only 3 replicates were considered due to the presence of extreme outliers.

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Table 2. Number (mean±SE) of *Sitophilus oryzae* adults emerged at 14, 28 and 42 days following infestation in different fractions of pulses cowpea, greengram and blackgram (n=4).

Grain type	Days following initial infestation	Number of adults emerged (mean±SE) ^a					
		% broken grains					
		0	10	20	40	60	100
Cowpea	1-14	1.23±0.95a	0a	0.25±0.25a	0a	1±0.41a	0.25±0.25a
	15-28	3.5±1.76a	4.25±2.17a	0a	1.25±0.48a	1.5±0.96a	0a
	29-42	8.75±0.63a	1±0.41d	2.25±0.25c	0.25±0.25d	5±0.41b	0.25±0.25d
Greengram	1-14	0a	0.25±0.25a	0.25±0.25a	0a	0.5±0.29a	1.25±0.75a
	15-28	1.5±0.65a	0.75±0.48a	0.25±0.25a	0.25±0.25a	0.5±0.29a	0a
	29-42	0	0	0	0	0	0
Blackgram	1-14	0.25±0.25a	0.25±0.25a	0.25±0.25a	0.75±0.75a	0.75±0.48a	0.5±0.29a
	15-28	0	0	0	0	0	0
	29-42	0	0	0	0	0	0

^aFor a given variety and duration, means followed by the same letter are not significantly different according to Student-Newman-Keuls (SNK) test following ANOVA at $p = 0.05$.



Figure 1. Red raw (*Red Kekulu*) rice infested with *Sitophilus oryzae*

would have been caused by the difference in either the grain type (rice vs. maize), insect species (*S. oryzae* vs. *S. zeamais*) or both factors, and need to be confirmed in a separate study.

CONCLUSION

Sitophilus oryzae adult emergence was highest in the rice varieties, Kuruluthuda, Red Heeneti and Red Kekulu. The lowest adult emergence occurred in blackgram, greengram, cowpea and Suwandel. The adult

emergence in Red Samba was at moderate level. In general, when the broken percentage increases from 0-100%, *S. oryzae* adult emergence follows an initial increasing and later decreasing pattern. The progeny development of *S. oryzae* was higher at the middle duration following initial infestation compared to the initial and later durations. Future studies are required to test the infestation and progeny emergence of other insect species in grain samples having different broken percentages

maintained at different durations of storage.

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