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Effect of paddy variety, milling status and aeration on the progeny emergence of *Sitophilus oryzae* L. (Coleoptera: Curculionidae)

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A B S T R A C T

In Sri Lanka, insects cause enormous losses in stored paddy; the rice weevil *Sitophilus oryzae* is a devastating insect. The magnitude of losses in stored paddy caused by insects varies with characteristics of paddy but has not yet been fully investigated. Due to the increased concerns on the use of synthetic chemicals, safer alternative pest management strategies for stored paddy are needed. Objectives of this study were to determine the effect of paddy variety, milling status and nature of aeration on the progeny emergence of *S. oryzae*. The experimental design was a three-factor factorial, completely randomized design (CRD).

Freshly emerged *S. oryzae* adults were introduced to un-milled paddy or milled/polished rice belonging to traditional and improved varieties. The samples were maintained either open or airtight, and the progeny adults emerged was determined at monthly intervals. Progeny emergence was lower in the traditional varieties, un-milled paddy and under air-tight condition compared to improved varieties, milled/polished rice and aerated samples, respectively. Overall, the improved variety Bg 300 exhibited the maximum resistance to infestation by *S. oryzae*. Furthermore, white-colour and long-grain varieties produced lower progeny of *S. oryzae* than red-colour and short-grain varieties, respectively. It is concluded that the maximum protection in paddy/rice from insect infestation during storage can be achieved by using traditional varieties, stored as un-milled paddy (without dehusked) under airtight condition.

1. Introduction

The losses due to insects during storage of grains are a great challenge for grain handling personnel across the world (African Post Harvest Losses Information System, 2011). In Sri Lanka, paddy is grown in two seasons and the surplus production is stored to meet the demand for consumption year around. Various losses occur during the storage of paddy; insects cause 80% of losses (Palipane, 2001). The grain handlers are concerned on the presence of insects in grains (Khare, 2015). Adults and larvae of *S. oryzae* feed on paddy/rice seeds, rice flour or processed products. Its feeding causes quantitative (Subramanyam and Hagstrum, 1996) and qualitative alterations (Vassanacharoen et al., 2008), and heavily-infested paddy/rice or other food commodities would have to be discarded (Koehler, 2012).

Synthetic chemicals have successfully been used in different ways such as structural sprays, grain protectants or fumigants against stored-product insects (Arthur and Subramanyam, 2012; Wijayaratne and Rajapakse, 2018), but concerns on the possible toxicity on the non-target organisms (Arthur, 1996), and negative impact on the environment emphasize the importance of alternative control methods for stored-product insects (Hagstrum and Subramanyam, 2006; Wijayaratne et al., 2018).

Air-tight storage has long been a promising way of grain protection (Donahaye et al., 1967; Smith and Boon-Long, 1970; Hyde et al., 1973). Change in the gaseous concentrations inside the enclosed storage structures has been extensively studied (Navarro et al., 1991). This method has evolved over the years, and tested

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for the ability to suppress insect population (Navarro et al., 1999; Adhikarinayake et al., 2006; De Groote et al., 2013). Thus, air-tight storage is a viable alternative for the use of neurotoxic insecticides (Navarro et al., 2002). In Sri Lanka, paddy in bulk storage has been tested under airtight conditions (Donahaye et al., 1991) but few studies have been conducted on the effect of hermetic storage on insect progeny emergence in different paddy varieties.

There is a renewed interest on exploiting the outstanding characteristics of traditional paddy varieties and using them for the benefit of human. The traditional rice varieties may fulfill certain needs of consumers such as nutritional value (Bhat and Riar, 2015) but still need to be tested for their susceptibility to insect infestation during storage. In maize, the hardness affects infestation and progeny production by insects including *S. oryzae* (Russell and Rink, 1965). Different rice varieties have shown varying levels of susceptibility to *S. oryzae* (Russell, 1968) but the difference in the susceptibility between traditional and improved varieties has not yet been substantially investigated. Therefore the objectives of this study were to determine if the paddy variety, milling type (paddy or rice) and aeration (airtight condition or open condition) affect the progeny emergence in *S. oryzae*.

2. Materials and methods

2.1. Insect cultures

Unsexed, one hundred *S. oryzae* adults aged four weeks were introduced into a plastic bottle (1500 mL) containing 500 g of rice medium (variety Bg 358). These bottles were maintained under ambient environmental conditions (30±2°C and 60 ± 5% relative humidity) for 3 days, and the parent adults were removed using a sieve (850 μm) (ASTM E11, W.S. Tyler Industrial Group, Mentor OH, U.S.A.). Two-week-old progeny adults were used in the experiments.

2.2. Paddy varieties

Paddy varieties were received from Rice Research and Development Institute, Bathalagoda, Sri Lanka. Five improved (Bg 300, Bg 352, Bg 358, Bg 450, Bg 94/1) and five traditional (Sudu Heenati, Kalu Heenati, Pachchaperumal, Pokkali, Suwandel) paddy/rice varieties were used in the study.

2.3. Sample preparation

From each paddy variety, half the sample was dehusked, different varieties separately, using a rubber roll sheller (SC2K, Satake, New Delhi). The bran (30%) was removed by abrasive polisher (VTA10, Satake, New Delhi). From each variety, either unmilled or milled/polished, 35 g of paddy/rice were weighed by an electric balance (sp 202, Scout Pro, China) into a transparent plastic culture bottle (60 mL). Ten unsexed *S. oryzae* adults were introduced into each vial, maintained for 14 days, and removed. The paddy/rice samples were maintained under ambient environmental conditions (30±2°C, 60 ± 5% relative humidity) for four weeks, and the progeny adults emerged in each paddy/rice sample were counted at monthly intervals. At each counting, the emerged adults were removed from the sample.

2.4. Experimental design

The experiment was arranged as a three factor-factorial Completely Randomized Design (CRD). The three main factors were paddy/rice variety (improved/traditional), milling status (polished/unpolished) and status on aeration (aerated/air tight). Improved and traditional varieties mentioned in section 2.2 were used in the study. The options on milling status were un-milled paddy or 30% milled/polished rice. The options for aeration were aerated or air-tight condition. There were 40 treatment combinations and each had four replicates; accordingly in total, 160 samples were prepared.

2.5. Data analysis

Data analysis was done by Poisson regression using Statistical Analysis Software (SAS Institute, 2002–2008) by using Proc Genmod. Significant differences in the progeny production between different paddy/rice varieties, milling status (polished/unpolished paddy) and aeration (open/air tight) were determined compared with the variety Pachchaperumal, un-milled paddy and airtight condition, respectively (in Genmod procedure, last character is taken as the reference or the 'control'). The same analysis method was used to determine differences in traditional vs. improved varieties, long-grain vs. short-grain varieties or red vs. white varieties in terms of progeny production by *S. oryzae*. The significance was tested at P = 0.05.

3. Results

3.1. Performance of paddy varieties in the first month

3.1.1. Progeny adult emergence

In the first month, in overall the progeny *S. oryzae* adults emerged was significantly low only in Bg 300 (compared with

Table 1
Poisson regression analysis of progeny *Sitophilus oryzae* adults emerged (mean ± SE) on traditional and improved paddy/rice varieties maintained under open or airtight conditions for one month.

Parameter	DF	Estimate	Standard Error	Wald 95% Confidence limits		Chi- Square	Pr>ChiSq
Intercept	1	−2.2690	1.8089	−5.8144	1.2764	1.57	0.2097
Bg 358	1	−0.0840	0.1795	−0.4358	0.2678	0.22	0.6398
Bg 300	1	−2.2916	0.4100	−3.0915	−1.4881	31.24	<0.0001
Bg 352	1	−0.1890	0.1846	−0.5508	0.1728	1.05	0.3060
Bg 450	1	0.1920	0.1920	−0.1369	0.5210	1.31	0.2526
Bg 94/1	1	−0.1617	−0.1617	−0.5208	0.1974	0.78	0.3776
Pokkali	1	0.2422	0.2422	−0.0831	0.5675	2.13	0.1444
Sudu Heenati	1	−0.0313	−0.0313	−0.3784	0.3158	0.03	0.8597
Kalu Heenati	1	−0.1598	0.1831	−0.5188	0.1991	0.76	0.3828
Suwandel	1	−0.1598	0.1831	−0.5178	0.2000	0.75	0.3855
Pachchaperumal	0	0.0000	0.0000	0.0000	0.0000	.	.
Milled/Polished Rice	1	7.5328	1.8050	3.9950	11.0706	17.42	<0.0001
Un-milled Paddy	0	0.0000	0.0000	0.0000	0.0000	.	.
Open (aerated)	1	0.1680	0.0838	0.0038	0.3322	4.02	0.0449
Air tight	0	0.0000	0.0000	0.0000	0.0000	.	.