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ORIGINAL ARTICLE

Seed-Specific Dynamics: Unraveling Progeny Emergence Patterns in *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) Infestations

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Abstract

Edible seeded crops are important nutrient source for both human and animals. Among the various causes of grain losses before consumption, stored-product pests claim an important place. *Tribolium castaneum* (Herbst) damages a wide array of food commodities including grains, during storage, but the information on progeny emergence on certain commodities still remains unexplored. A laboratory experiment was conducted to evaluate the progeny development of *T. castaneum* in commonly used edible seeds during storage. Twenty, one-month-old *T. castaneum* adults were introduced to 30 g samples of each seed type, with four replicates tested. Except for dhal and groundnut, all the other edible seed types were used only as whole seeds. Test samples of dhal and groundnut were used in their whole form as well as 50% broken seeds. Samples were maintained at 30±1°C and 65±1% relative humidity. After 7 days, adults were removed, and samples were kept for progeny development. Progeny adults and larvae were counted at 30 and 60 days. The adult progeny emergence was highest in oats, sesame and proso millet (*Meneri*). Larval emergence was higher in dhal (50% broken), groundnut (50% broken), barley and proso millet (*Meneri*). These findings provide important insights into the infestation of edible seeds by *T. castaneum* and opens-up avenues for adopting suitable methods to protect these during storage. As the presence of broken seed enhances the progeny development of *T. castaneum,* preventing such occurrences during grain processing and maintaining cleanliness are important practices during postharvest operations.

Keywords: *50% broken seeds, Larval emergence, Progeny Development, Red Flour Beetle, Storage*

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1. Introduction

World food production needs to be increased by 70% to feed the growing global population, which is projected to reach 9.8 billion by 2050 (UNDESA 2017; Stathers et al. 2018). In terms of food security, protecting produced food until consumption is as important as increasing food production to meet the rising demand. For thousands of years, cereal grains have been the mainstay of the human diet and continue to be a primary energy source. Since cereal production is seasonal in many geographical areas, excess production needs to be stored to meet demand during off-seasons (Proctor 1994; Deepak and Prasanta 2017; Dowell and Dowell 2017; Kumari et al. 2020a).

Numerous types of quantitative and qualitative losses occur from production to consumption of food crops (Kumar and Kalita 2017; Dissanayaka and Wijayaratne 2020a, b; Kumari et al. 2020b). Insect damage reduces the nutrient content, caloric value, edibility, and consumer acceptability of food (Hagstrum and Subramanyam 2006; Hagstrum et al. 2012). The extent of insect damage to stored food varies from 10% to 50% globally, depending on the geographical region (Kumar and Kalita 2017; Dissanayaka and Wijayaratne 2020a,b). In Sri Lanka, insects are responsible for approximately 80% of grain loss during storage (Palipane 2001; Dissanayaka and Wijayaratne 2020a,b; Kumari et al. 2020b).

Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae), commonly known as the red flour beetle, damages a range of food during storage, including grains and grain-based products (Arthur et al. 2019, 2020b; Hettiarachchi et al. 2020). Both larvae and adults of *T. castaneum* feed on grains (Wijayaratne and Egodawatta 2021; Ratnasekera et al. 2022). Despite the broad host range of *T. castaneum* already documented (Hill 1990; Zettler 1991; Mullen 1992; Arbogast et al. 2000; Rees 2004; Hagstrum and Subramanyam 2006; Arthur et al. 2019; Gerken and Campbell 2020; Wijerathne et al. 2020), there are still knowledge gaps regarding the types of food consumed by this species. Certain grains abundantly consumed in Sri Lanka have not yet been studied for damage by *T. castaneum*. This lack of knowledge poses challenges for assessing the potential damage by this insect species during the storage of these grains.

Therefore, the objective of this study was to determine whether the progeny development of *T. castaneum* varies among different types of grains found in Sri Lanka during storage. The study also aimed to examine whether infestation varies based on the fractions (brokens) of selected food types.

2. Materials and Methods

Rearing of insects

A population of *Tribolium castaneum* obtained from a rice mill located in Ragala, Nuwara Eliya, Sri Lanka, was reared in 1 L plastic bottles containing wheat flour (7-Star whole meal flour, Serendib Flour Mills Pvt. Ltd., Orugodawatte, Sri Lanka). For this, 200 unsexed adults were introduced to 250 g of wheat flour (Wijayaratne 2011; Dissanayaka et al. 2018;

Bandara et al. 2021). The openings of these bottles were covered with Poplin cloth. The insect cultures were maintained under ambient environmental conditions (30±1°C, 65±1% relative humidity) for 7 days, after which the parent adults were removed from the mother cultures. The progeny adults were used in the experiment 30 days following emergence (Wijayaratne et al. 2019).

Conducting experiment

This experiment was conducted in the Entomology laboratory at the Department of Plant Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka, following a Completely Randomized Design. Blackgram, sesame, oats, Proso millet (*Meneri*), sago seeds, basil seeds, and barley were used only as whole grains. In contrast, chana dhal (split chickpea lentil) and groundnut were used in two forms: whole grains and 50% broken grains (Hettiarachchi et al. 2020). The seeds were purchased from a retailer shop (Table 1), and 30 g of a particular seed type was placed inside a transparent, small plastic vial (60 mL) to serve as one replicate. Four replicates were tested from each seed type.

Tribolium castaneum adults were separated from flour medium used to rear them by using a No. 30 (850 µm mesh) sieve (ASTM E11, W.S. Tyler Industrial Group, USA). Twenty unsexed adult insects were introduced to each plastic vial containing a particular seed medium. After 14 days, the adult insects were removed from each vial (Wijerathne et al. 2020). All cultures were maintained under ambient conditions (30±1°C and 65±1% relative humidity). The progeny emerged in each replicate was counted at 30 days and 60 days following the removal of the parent adults.

Statistical analysis

The data set was tested for normality using the Shapiro-Wilk test which confirmed normal distribution. The homogeneity of variances was verified with Bartlett's test. The progeny emerged was analyzed using ANOVA procedures in the Statistical Analysis System (SAS) (SAS Institute 2002-2008) (Zar 1999; Wijayaratne et al. 2019; Karunarathne et al. 2020; Sajeewani et al. 2020; Sammani et al. 2020). The grain type served as the treatment, and the number of individuals emerged as progeny (adults or larvae) was the response variable. Mean separation was conducted using Tukey's test, with significance tested at $p=0.05$.

3. Results and Discussion

Progeny emergence in different grains one month following initial infestation

There were significant differences in the emergence of progeny as adults ($F=128.85$, $P<0.0001$) as well as larvae ($F=6.49$, $P<0.0001$) in different seed types at 30 days following initial infestation. Concerning the adult emergence, the highest progeny was obtained in oats (Figure 1). Besides that, only sesame and Proso millet (*Meneri*) recorded progeny adults one-month following initial infestation. In all other seeds, no progeny adults emerged.

Table 1. Details of seeds used to test the progeny emergence in *Tribolium castaneum*.

	Seed type	Scientific name	Brand	Company and Origin
i	Blackgram	*Vigna mungo* (L.) Hepper	Sethum	Sethum Products, 479/A, Deniyayawaththa Road, Baththramulla, Sri Lanka.
ii	Sesame	*Sesamum indicum* L.	Orient	15/202, Sri Gunananda Mawatha, Colombo 13, Sri Lanka.
iii	Oats	*Avena sativa* L.	Kellogg's	Aussee Oats Milling Pvt Ltd, 28 BOI EPZ, Mirigama Sri Lanka.
iv	Proso millet (*Meneri*)	*Panicum miliaceum* L.	Dahami	No 176, Main Road, Aththidiya Dehiwala, Sri Lanka.
v	Sago seeds	*Metroxylon sagu* Rottb.	Dil foods	Dil foods, Templeberg Industrial Zone, Stage 11, Panagoda, Homagama, Sri Lanka.
vi	Basil seeds	*Ocimum basilicum* L.	Thulshi	Omega Traders 62A, Old Moor Street, Colombo 12, Sri Lanka.

vii	Barley	*Hordeum vulgare* L.	Kothmale Food Products	Kothmale Food Products (Pvt Ltd), P.O. Box 01, New Town Kothmale, Sri Lanka.
viii	Chana dhal/Split Chickpea Lentil	*Cicer arietinum* L.	Orient	15/202, Sri Gunananda Mawatha, Colombo 13, Sri Lanka.
ix	Groundnut	*Arachis hypogaea* L.	David Gram stores	David Gram Stores, 214, Gasworks Street, Pettah, Colombo 11, Sri Lanka.

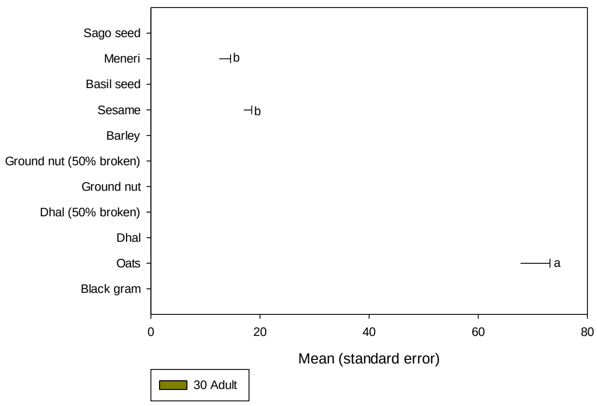

Figure 1. *Tribolium castaneum* progeny adults emerged (mean±SE) in different seeds one-month following initial infestation. Mean progeny followed by the same letter are not significantly different at P=0.05 according to Tukey's test following ANOVA.

Following one month, in terms of larval emergence, the seed types could broadly be categorized into two groups (Figure 2). A higher number of larvae was recorded in dhal with brokens, barley, groundnut with brokens, and Proso millet (*Meneri*), with no significant differences among them. Basil seeds recorded the lowest progeny larvae. The progeny larvae emerged in blackgram, dhal (whole seeds), sago seeds, oats and sesame were higher than those in basil seeds but not significantly different from those in ground nut with brokens or Proso millet (*Meneri*). The emergence of larvae in whole groundnut showed an intermediate response compared to the other groups of seeds.

Progeny emergence in different grains two months following initial infestation

At 60 days following infestation, there was a significant difference in the emergence of progeny adults (*F=166.70, P<0.0001*) and larvae (F=2.45, P<0.0001). The oats medium showed the highest progeny adults followed by sesame (Figure 3). The lowest progeny emerged were in whole dhal, whole or broken groundnut, and barley. Sago, basil seeds and blackgram had no progeny adults emerged even after two months of initial infestation. When dhal was present as a mixture with brokens, more adults developed compared to whole dhal but fewer than in sesame. Compared to the infestation at one month, an enhancement of progeny adult development was observed at two months in all the commodities tested except in blackgram, basil seeds and sago seeds.

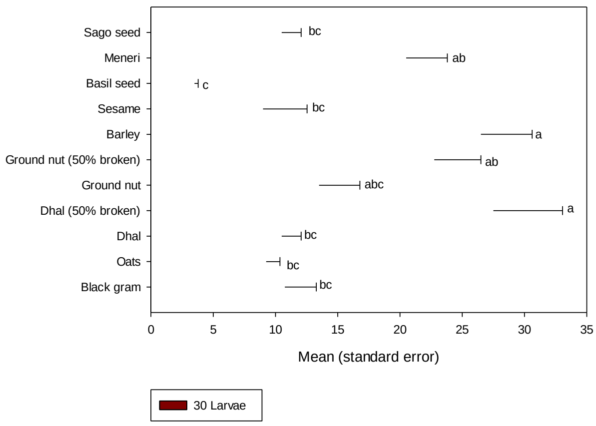

Figure 2. *Tribolium castaneum* progeny larvae emerged (mean±SE) in different seeds one-month following initial infestation (n=4). Mean progeny followed by the same letter are not significantly different at P=0.05 according to Tukey's test following ANOVA.

The emergence of larvae at two months following initial infestation varied with the seed type (Figure 4). The maximum number recorded in oats did not significantly differ from dhal with brokens, barley, sesame, basil seeds, Proso millet (*Meneri*), or sago seeds. In contrast, the number of progeny larvae emerged on oats was significantly higher than those on dhal (without brokens) and blackgram.

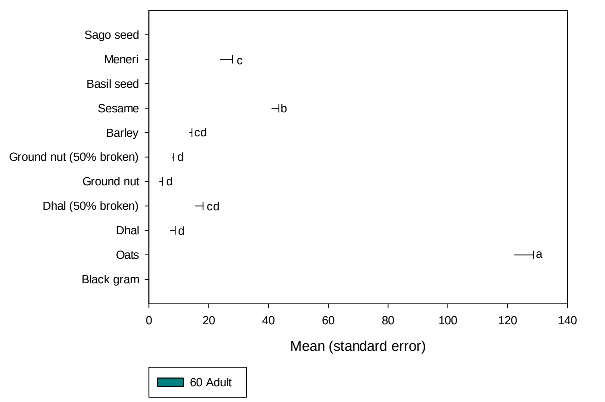

Figure 3. Progeny adults emerged (mean±SE) in different seeds two months following initial infestation (n=4). Mean progeny followed by the same letter are not significantly different at P=0.05 according to Tukey's test following ANOVA.

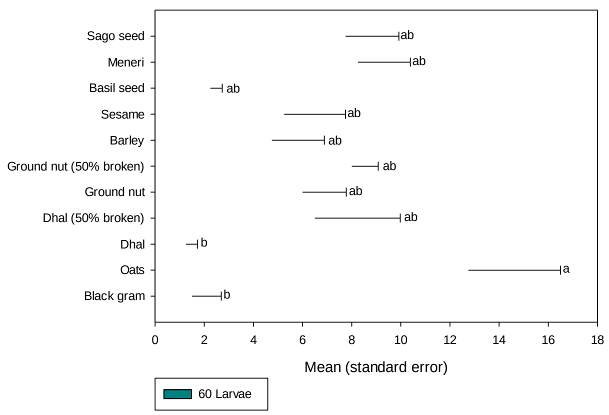

Figure 4. Progeny larvae emerged (mean±SE) in different seeds two months following initial infestation. Mean progeny followed by the same letter are not significantly different at P=0.05 according to Tukey's test following ANOVA.

A previous study has reported that grain type, percentage of broken grains and the duration following initial infestation alter progeny development by *T. castaneum.* The same study has proven that the presence of broken grains increases the infestation by *T. castaneum* (Hettiarachchi et al. 2020). Similarly, increased infestation of *T. castaneum* in sorghum has been associated with a higher degree of broken grains (Arthur et al. 2020a). The current findings align with these previous results.

As found in early studies, the degree of oviposition and emergence of progeny adults depend heavily on the substrate type and its nature (Ziegler 1976). The nutritional content of different grains varies significantly. Differences in kernel hardness as well as nutritional content, with an emphasis on protein and starch, also determine the level of insect infestation (Arthur et al. 2020a). While these factors may explain the differences observed in progeny development in different seed types during the current study, future experiments are needed to uncover the exact reasons underlying.

4. Conclusions

The infestation by *T. castaneum* varies significantly with the seed types tested in this study. In general, adult emergence is higher in oats, sesame and Proso millet (*Meneri*). The presence of broken seeds exacerbates infestation by *T. castaneum*. This information is crucial not only for understanding the potential damage to the seed types tested in this study but also for identifying optimal substrates for rearing insects for experiments. Recognizing how these factors influence infestation helps in developing effective strategies for managing and mitigating the impact of *T. castaneum* on stored grains.

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