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Research Article

Estimation of Feeding Preference of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) and Associated Post-Harvest Losses on Different Components of Rice Cultivars

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Authors' Contributions
BA and AMS conceptualized the study and recorded the data. BA, AMS, SSA and MDG statistical analysed the data. BA, AMS, MR, MDG, MUS, THA and MAR wrote the manuscript. BA, AMS, MDG, THA and TL wrote results and discussion section of the manuscript. MUS, MA and NR edited the format of the graphs. SSA, MR, MAR, MA and NR reviewed the manuscript and gave suggestions and comments for its improvement.

Keywords
Tribolium castaneum, rice cultivars, Rice components, Feeding preference, Post-harvest losses

Abstract | *Tribolium castaneum* is one of the major stored grain pests causing infestation in both rice and wheat mills. Present study was designed to estimate the feeding preference and associated post-harvest losses (growth rate, grain damage and grain losses) of *T. castaneum* on four rice cultivars (Super Basmati, Basmati 515, Super Basmati 2019 and Super Gold) and their components (Paddy, Brown rice and Polished rice) under controlled conditions. Results indicated that maximum growth rate (64.00), grain damage (76.67%), and grain weight loss (5.15%) were recorded on polished rice of Basmati 515 as compared to other cultivars and their components. *Tribolium castaneum* preferably feeds on all the components of Basmati 515 as compared to the others. This study might be helpful for the rice millers and researchers for the timely appropriate management, development of new management tactics, and rice cultivars resistant to *T. castaneum*.

Novelty Statement | This is the first study in Pakistan to test these four varieties (which are being grown on a large area in the Punjab) for feeding preference of *T. castaneum* and associated post-harvest losses.

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Introduction

The major problem faced in the safe grains and food storage is preventing or reducing insect damage. Insects and mites are responsible to reduce all stored grain production by up to 9% under favourable climate and storage conditions (Atta et al., 2020). *Tribolium castaneum* is gained the importance of a major insect pest in stored grains, responsible to damage several commodities, including grains, flour, beans, peas, nuts, spices, and dried fruits (Shafique et al., 2006; Tripathi et al., 2009; Sarwar, 2015; Pires et al., 2017; Atta et al., 2020). Both immature and adults of *T. castaneum* feed on the already insect pests damaged commodities such as grains (Mamun et al., 2009). The larvae consume the entire grain which starts by feeding from one end and causing more excrement and alarming damage (Parashar, 2006).

In Pakistani agriculture, the most neglected aspect is grain storage management. The main focus of the farming community is only the production by ignoring the ways to minimize post-harvest losses. Most of the farmers in Pakistan have no experience in the implementation of long-term grain storage systems. Mostly storage systems for their use (either short or long term) are fundamental and poorly managed (Atta et al., 2020).

Keeping in view the above facts, there is a dire need to evaluate the rice cultivars after harvesting to develop appropriate management strategies to reduce the infestation of *T. castaneum*. This study was designed to estimate the feeding preference of *T. castaneum* and its associated post-harvest losses, including growth rate, grain damage, and grain losses, on four rice cultivars (Super Basmati, Basmati 515, Super Basmati 2019, and Super Gold) and their components (Paddy, Brown rice and Polished rice) under controlled conditions.

Materials and Methods

Study site

The present study was performed at the Entomology Laboratory, Rice Research Institute, Kala Shah Kaku (31° 43′ 17" N and 74° 16′ 14" E), Punjab, Pakistan during the year 2021-22.

Collection and rearing of Tribolium castaneum

Adult *T. castaneum* were collected from the Grain Market Sheikhupura Pakistan (31.7152° N, 73.9823° E) for the culture and were reared on artificial food made of wholemeal flour and brewer's yeast (19:1)] under laboratory conditions at 28 ± 2°C temperature, 60 ± 5% relative humidity and 12:12 Day: Light photoperiod (Atta et al., 2020). Adult *T. castaneum* were picked from culture and allowed to lay eggs for two weeks in separate plastic jars filled with sterilized whole wheat flour. The adults are then sieved and the flour containing the eggs is left in the laboratory for egg development. The jars were kept for about a month in case the adults emerged. Emerging adults are approximately one week older after one month from the date of parental adult evaluation, as it takes 25 days from egg to adult at 30°C according to Rees (2001). Before starting research trial, the adults of 2-3 weeks old after hatching were used which were not fed for 24 hours (Yang et al., 2010).

Acquisition of rice cultivars and preparation of their components

Four rice cultivars (Basmati 515, Super Basmati, Super Gold, and Super Basmati 2019) were acquired from the Breeding Section. Three components of each cultivar (Paddy, Brown rice, and Polished rice) were prepared separately. Paddy samples of each cultivar were cleaned with Paddy Seed Cleaner and packed in polythene storage bag, while paddy samples were further processed milling to obtain brown rice. Brown rice was passed through Paddy Polisher to obtain Polished rice.

Assessment of feeding preference of Tribolium castaneum *and associated post-harvest losses on different components of rice cultivars*

Insect-damaged components of rice cultivars were weighed (50 g), counted, and placed in plastic jars, separately. Thirty *T. castaneum* adults picked with the help of an aspirator from the rearing jars and released them into each jar (Figure 1). The whole experiment was repeated thrice in a dark chamber for the improvement in activity of *T. castaneum*.

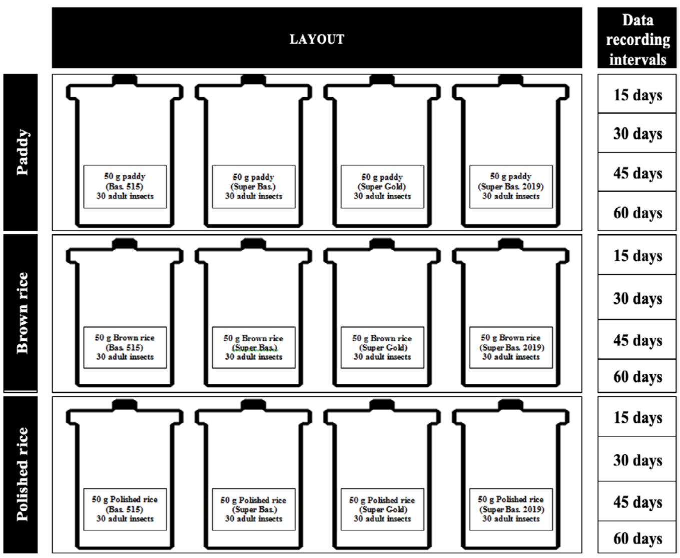

Figure 1: Layout of experiment.

After 15, 30, 45 and 60 days, these jars were properly shacked off on a sheet of paper (white in color) and left in the sun for half an hour so that if there were any live insects, they could move to seek shade. The growth rate of *T. castaneum* was counted from each jar and data was recorded. Visual inspection was done to observe the sign

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of damage on all components. Those components were believed to be damaged, with holes and visual defects due to feeding of *T. castaneum*. The components were divided into damaged and undamaged grains accordingly. All parts were clearly calculated and weighed properly (Abdullahi et al., 2018; Atta et al., 2020).

After 60 days, the damaged components of all tested rice varieties were counted and weighed with analytical balance to record the weight loss and the data was recorded with the help of the formula used by Atta et al. (2020).

Statistical analysis

Excel spreadsheets were used for data entry, and statistical analyses were executed by using Statistical Software (Statistix® version 8.1). Three-way analysis of variance (ANOVA) for the estimation of growth rate of *T. castaneum*, while two-way ANOVA for grain damage and grain losses was applied to factorial experiments in CRD. Bonferroni test, $P < 0.05$ was used to separate the means.

Results and Discussion

The growth rate of Tribolium castaneum on different components of rice cultivars

The maximum growth rate of *T. castaneum* was found on paddy, brown rice, and polished rice of Basmati 515 (43.17, 62.08, and 64.00, respectively), while the minimum growth rate of *T. castaneum* was found on paddy, brown rice, and polished rice of Super Basmati 2019 (33.42, 42.00, and 48.58, respectively). Among these components, polished rice was found more suitable for the maximum growth of *T. castaneum* as compared with paddy and brown rice (Figure 2). The maximum growth rate of *T. castaneum* was found after 60 days of exposure to paddy, brown rice, and polished rice cultivars (43.75, 63.58, and 67.42, respectively), while the minimum growth rate of *T. castaneum* was found after 15 days of exposure to paddy, brown rice, and polished rice cultivars (33.50, 39.17, and 44.17, respectively). Among these components, polished rice was found more suitable for the maximum growth of *T. castaneum* after 60 days of exposure as compared with paddy and brown rice (Figure 3).

Grain damage (%) due to Tribolium castaneum *on different components of rice cultivars*

The maximum percent grain damage due to *T. castaneum* was found on paddy, brown rice, and polished rice of Basmati 515 (10.00%, 64.00%, and 76.67%, respectively), while the minimum percent grain damage was found on paddy, brown rice, and polished rice of Super Basmati 2019 (6.00%, 32.67%, and 49.33%, respectively). Among these components, grain damage was higher in polished rice as compared with paddy and brown rice (Figure 4).

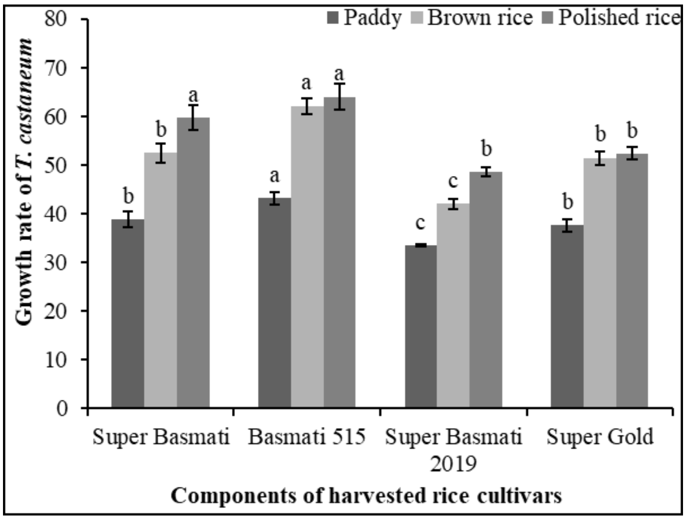

Figure 2: Insect growth rate of *Tribolium castaneum* exposed to different components of harvested rice cultivars.

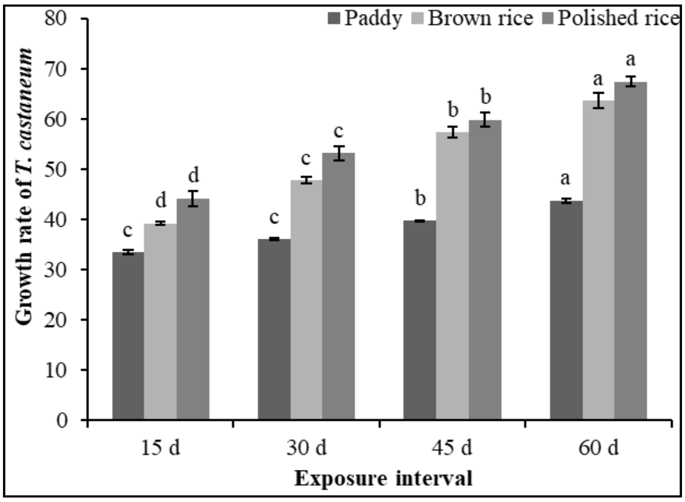

Figure 3: Insect growth rate of *Tribolium castaneum* exposed to different components of harvested rice cultivars at various time intervals.

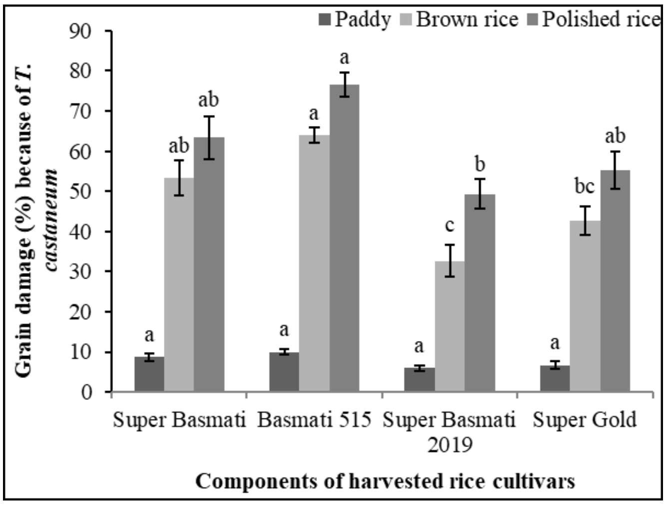

Figure 4: Grain damage (%) due to *Tribolium castaneum* exposed to different components of harvested rice cultivars.

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Grain weight loss (%) due to Tribolium castaneum *on different components of rice cultivars*

The maximum percent grain weight loss due to *T. castaneum* was found on paddy, brown rice, and polished rice of Basmati 515 (0.67%, 4.30%, and 5.15%, respectively), while the minimum percent grain weight loss was found on paddy, brown rice, and polished rice of Super Basmati 2019 (0.40%, 2.19%, and 3.31%, respectively). Among these components, grain damage was higher in polished rice as compared with paddy and brown rice (Figure 5).

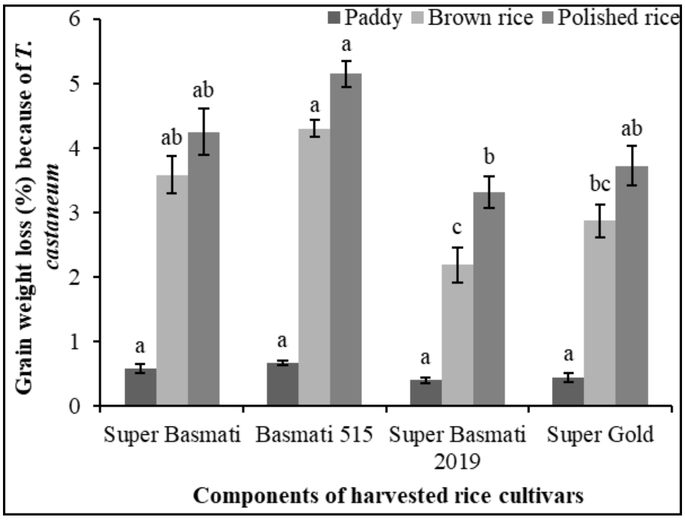

Figure 5: Grain weight loss (%) due to *Tribolium castaneum* exposed to different components of harvested rice cultivars.

Results of a previous study by Atta et al. (2020) explained that the growth rate of *T. castaneum* is increased with the passage of storage interval in polypropylene storage bags (mostly used in by rural farmers) without any management strategy. They also summarized their findings that *T. castaneum* is responsible to cause more grain damage to agricultural produce when stored in polypropylene bags without any chemical management. Meanwhile, an infestation of stored grain by insect pests is attacked by moisture, moderate heat, and damaged kernels. Furthermore, the high moisture content in grains not only offers an encouraging physical environment for the development of many insect pest species but also promotes fungal growth, which serves as their food source (Lord, 2008).

The difference in feeding preference and adult development of *T. castaneum* observed in this study is by the results of Nadeem et al. (2011), that brown rice was much preferred by *T. castaneum* and *T. granarium* for the development of the adult and have reasoned out that brown rice during storage were prone to insect infestation and quality deterioration (Pomeranz, 1987). This explanation could be extended to this study. Shafique et al. (2006) have reported that in the case of *T. castaneum*, the development and survival, and increase in the population depends on the nature of contents in food, environmental temperature, and moisture. High chalkiness in raw rice can attract more insect pests and broken grains along with sound grains are always conducive to the development of secondary storage insects during rice grain storage. This may be because of the selective preference of *T. castaneum* toward raw rice (Mariadoss and Umamaheswari, 2020).

Conclusions and Recommendations

This study concluded that *T. castaneum* preferably feeds on all the components of Basmati 515, more on polished rice, which ultimately results in more grain damage and weight loss. This study might be helpful for the rice millers and researchers for the timely appropriate management, development of new management tactics, and rice cultivars resistant to *T. castaneum*.

Conflict of interest

The authors have declared no conflict of interest.

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