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Appraisal of quantitative losses caused by *Trogoderma granarium* (Everts) and *Tribolium castaneum* (Herbst) in different genotypes of wheat, rice and maize during storage

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Abstract

The storage of agricultural commodities is carried out for numerous reasons and there are many factors affecting safe storage, the most important of them are the insect pests. In the present investigation genotypes of wheat (ARRI-11, Millat-11, Punjab-11), maize (Kobras, Kermess, 702) and rice (Super Basmati, Basmati 86 and Basmati 515) were evaluated for their resistance or susceptibility level against *Trogoderma granarium* (Everts) and *Tribolium castaneum* (Herbst). The results were evaluated on the bases of weight loss percentage and their progeny on larval numbers. The overall results revealed that none of the genotype was completely resistance to the infestation caused by *T. granarium* and *T. castaneum.* All these tested genotypes varied significantly in their degree of resistance in term of infestation percentage and development of progeny. On the basis of percent damage, the least damage 2.43% (*T. castaneum*) and 4.02% (*T. granarium*) was observed in maize, followed by rice 3.99% (*T. castaneum*) and 5.69% (*T. granarium*), and highest damage was noted in wheat 5.43% (*T. castaneum*) and 7.96% (*T. granarium*) genotypes. The weight loss was highest after 90 days of exposure in all the genotypes. While the results regarding the pest population progeny development was in such order; wheat > rice > maize, hence these genotypes were designated as the most tolerant and most susceptible genotypes.

Keywords: Genotypes, weight loss, progeny development, *trogoderma granarium*, *tribolium castaneum*

INTRODUCTION

Reliable studies indicate that post-harvest losses of major food commodities are enormous. Global, annual post-harvest losses to stored cereals range from 10-20% due to different factors [23], of which about 5-10% is attributed to insect damage [1]. In Pakistan, food grain losses vary, i.e. 15.3% in wheat, 17.1% in paddy and 12.6% in maize during various post-harvest operations [5]. Another research reported that 10-20% losses in wheat occurred due to the infestation of insect pests [12]. In another study, average losses of about 3.4-6.5% within a 5 months storage period have been observed [15].

One of the major causes of low maize production is insect herbivory in both the field and in storage. The infestation by post-harvest pests begins in the field, but most damage occurs during storage [7]. Worldwide seed losses were about 20% for untreated maize [6, 8].

In rice about 15% losses are reported during storage [13]. The attraction and susceptibility of rice genotypes to insect pests depends on the physico-chemcial aspects of the particular pest. Similarly a loss of about observed 4.09-12.61% storage losses of rice [27].

As in field crops, the stored foodstuffs are attacked by a wide range of insect pests, the most common being moths and beetles [34]. Stored grain insect pests like *Trogoderma granarium*, *Rhyzopertha dominica*, *Tribolium castaneum*, *Sitotroga cerealella* and *Sitophilus* spp. are of economic importance because they feed on a wide range of stored cereals and their products [13]. *Trogoderma granarium* (Everts) is a serious pest of stored foodstuff [4, 20]. Losses caused by *T. granarium* have been reported to range from 0.2-2.9% over a period of 1-10.5 months in Pakistan [11]. Similarly, *Tribolium castaneum* (Herbst) is secondary pest having an extensive association with stored food [35]. Economic loss caused by this pest, estimated to be of 34-40% [3]. When the quality, quantity and health hazards of insect grain infestation are taken in summation, the monetary impact on an economy can run into millions of rupees to national exchequer annually. Current study therefore will be designed to examine the quantitative losses caused by *T. granarium* and *T. castaneum* to different genotypes of wheat, rice and maize during storage.

MATERIALS AND METHODS

Rearing of Insects

Mixed age cultures of *T. granarium* and *T. castaneum* were collected from farm houses as well as wheat stores at Punjab Food Departments located at various districts in Punjab province, Pakistan. Culture of *T. granarium* was reared on healthy sterilized wheat grains, while the culture of *T. castaneum* was reared on wheat flour, apparently free from insects infestation. The insects were reared in glass jars, each containing one kg of sterilized wheat grain/flour. The jars were covered with muslin cloth and placed in the laboratory at 30±2°C and 65±5% relative humidity with a photoperiod of 16:8 L:D. Khapra beetle and red flour beetle pupae were separated from the heterogeneous cultures obtained from the aforementioned locations and kept in an incubator (Model MIR-254, SANYO) at optimum conditions until adult emergence. After 24 to 48 hours, one hundred adult beetles were released into the jars containing rearing medium. After three days, beetles were sieved out from the rearing medium and discarded. The resulting rearing medium, along with eggs of these insects, were placed into jars and incubated at optimum growth conditions to get a homogenous population. Finally, the uniform sized progeny of these test insects were used for further bioassay studies.

Commodities

Different genotypes of wheat (ARRI-11, Millat-11, Punjab-11), maize (Kobras, Kermess, 702) and rice (Super Basmati, Basmati 86 and Basmati 515) were used. The seeds of these cereal genotypes were obtained from Punjab Seed Corporation and were cleaned of straw and dust, prior to use. Prior to the experiments, the moisture contents of the grains were adjusted to 13.5%, as it considered optimum for insect feeding.

Weight Loss

Grains of test commodities (wheat, maize and rice) weighing 200 grams from each variety of the test cereals were put in 250 ml glass jars after sterilization. Thirty uniform size roughly one week old larvae of Khapra and Red flour beetles were taken from the culture and introduced in each jar. The grain medium used for red flour beetle larvae infestation consisted of 80% whole grains and 20% cracked grains. The jars were covered tightly with fine mesh cloth to prevent the insects from escaping. There were four replications for each genotype of cereal. Insects were allowed to feed on these cereal grains for a period of 3 month in controlled conditions. After this incubation, progeny development and % age weight loss data was recorded at 4, 8, and 12 week intervals. The weight loss %age was assessed by following Gravimetric method [9].

Where,

U = Weight of undamaged grain
D = Weight of damaged grain
Nu = Number of undamaged grains
Nd = Number of damaged grains

Statistical Analysis

All the treatments were replicated four times using Completely Randomized Design (CRD). Data was collected for weight loss and progeny production. The collected data was analyzed statistically by using the statistical software (Stat Soft, 8.0) [31] and the means of the treatments were compared by using a Tukey HSD test ($p \leq 0.05$).

RESULTS

The results were evaluated on the bases of weight loss percentage and their progeny on larval numbers. The overall results revealed that none of the genotype was completely resistance to the infestation caused by *T. granarium* and *T. castaneum.* All these tested genotypes varied significantly in their degree of resistance in term of infestation percentage and development of progeny. On the basis of pest population progeny development and percent damage, the least damage was observed in maize genotypes and highest damage was noted in wheat genotypes (Fig. 1), hence these genotypes were designated as the most tolerant and most susceptible genotypes.

Percent Infestation

The results regarding the percentage infestation (Fig. 2) showed that in wheat genotypes the highest damage was noted in AARI-11 with value 7.65% followed by Millet-11 and Punjab-11 with infestation values 6.91 and 5.54%, respectively. In term of percentage infestation, AARI-11 was the most susceptible and Punjab-11 was the least susceptible one in wheat genotypes. Among rice genotypes, highest weight loss (5.74%) was recorded in Basmati-515 and weight loss was minimum (3.90%) in Super Basmati. While in Basmati-86 weight loss of 4.89% was recorded. In rice genotypes, Super Basmati was least susceptible while Basmati-515 was most susceptible. Similarly in maize genotypes, minimum damage (2.43%) was noted in Kobra followed by Kermess (3.37%) and highest infestation (3.88%) was observed in genotype 702. So in maize genotype 702 was the most susceptible one.

The overall percentage infestation data in term of exposure periods (Fig. 3) shows that the highest damage (9.04%) was recorded after 90 days of exposure to the test insects followed by a weight loss value of 6.35% and 4.68% after 60 and 30 days of exposure period, respectively. In rice highest damage was also recorded after 90 days of infestation with value 6.83% followed by 4.63% after 60 days of infestation, while weight loss was minimum 3.05% after 30 days of exposure to the both test insects. Similarly, in maize weight loss was 5.57% after 90 days of exposure that was highest and least weight loss was observed after 30 days of exposure period to the test insects. It is also obvious from these results that there is direct relationship among exposure period and weight loss percentage.

The result in Table 1 shows the interaction effect of time period and test insects against different genotypes of wheat. The results revealed that highest damage (11.89%) was caused by *T. granarium* in AARI-11 genotype followed by Millat-11 after 90 days of exposure period. Minimum weight loss was noted in case of *T. castaneum* infestation that was 3.18% in Punjab-11 genotype after 30 days of infestation. The minimum weight loss in case of *T. granarium* was 5.31% observed in Punjab-11 genotype after 30 days of exposure period. The highest weight loss in *T. castaneum* infestation was 8.73% in AARI-11 genotype followed by Millat-11 with weight loss 8.48% after 90 days of infestation.

The result in Table 2 shows the interaction effect of time period and test insects against different genotypes of rice. Overall results revealed that all the genotypes of rice were statistically significant from each other in term of percentage infestation. The least damage (2.11%) was observed in case of Super Basmati due to the attack of *T. castaneum* followed by Basmati 86 (2.51%) after 30 days of exposure period. The highest weight loss (9.62%) was observed after 90 days of exposure period in Basmati 515 due to the attack of *T. granarium.* After 60 days of exposure period the weight loss due to the attack of *T. granarium* was 3.96, 5.23 and 6.90% in Super Basmati, Basmati 86 and Basmati 515, respectively while in case of *T. castaneum* weight loss was in such order

Super Basmati (3.43%) < Bastami 86 (3.86%) < Basmati 515 (4.47%).

Results regarding the percentage infestation (Table 3) caused by *T. granarium* and *T. castaneum* on maize genotypes (Kobra, Kermess and 702) were showing varying degree of susceptibility and statistically different from each other. The highest level of infestation (7.51%) was noted in case of *T. granarium* in 702 genotype followed by Kermess (6.69%) after a period of 90 days exposure. The minimum weight loss (0.34%) was observed in Kobra genotype due to the attack of *T. castaneum* after 30 days of infestation. In case of *T. castaneum* the highest weight loss was 5.01% in 702 genotype followed by 4.60 and 4.20% in Kermess and Kobra genotypes, respectively. So, it is obvious from these results that 702 genotype was most susceptible and Kobra was least susceptible among maize genotype in term of infestation caused by *T. granarium* and *T. castaneum.*

Progeny Development

The parameter to assess the degree of susceptibility and resistance in the test genotypes of wheat, rice and maize was the development of progeny (larval no.). Overall results revealed that all the genotypes were significantly different in their ability to harbor the total number of both test insects. In wheat genotypes (Table 4) the highest population buildup of *T. granarium* was noted in AARI-11 that was 1014.75 after 90 days of exposure period followed by millet with 951.00 mean numbers of larvae and the minimum number (297.75) of larvae were noted in Punjab-11 genotype after 30 days of exposure period. The least number (191.75) of progeny was observed in Punjab-11 that was of *T. castaneum* after 30 days of exposure. The highest progeny of *T. castaneum* was noted in AARI-11 and that was 929.75 followed by Millat-11 (908.50).

In case of rice (Table 5) the highest (977.75) progeny was observed in Basmati 515 that was of *T. granarium* after 90 days of exposure period. The minimum progeny of *T. granarium* was noted in Super Basmati and that was 260.75 after 30 days of release of insects. In case of *T. castaneum* the lease number (147.75) of larvae was noted in Super Basmati followed by Basmati 86 (177.75) and Basmati 515 (200.25) after 30 days of infestation. While the highest number (885.25) of larvae were observed in Basmati 515, followed by 864.50 and 836.50 in Basmati 86 and Basmati 515, respectively in *T. castaneum*.

Progeny development in maize genotypes (Table 6) showed that the highest population of *T. granarium* was recorded after 90 days of infestation in 702 genotype that harboring 921.75 larvae, followed by Kermess and Kobra genotypes where 858.00 and 815.00 larvae were counted. After 60 days of exposure the larval progeny in the test genotypes of maize was in such order, 702 (636.25) > Kermess (599.00) > Kobra (561.50). The lowest larval count was made after 30 days of infestation, which were 250.25 in 702 genotype, followed by Kermess and Kobra with 229.00 and 204.75 number of larvae, respectively. In case of *T. castaneum* the lowest progeny (204.75) was noted after 30 days of exposure in Kobra, followed by Kermess (149.75) and 702 (172.25) genotypes. The progeny was highest (857.75) in 702 genotype, followed by Kermess and Kobra with 836.50 and 808.50 numbers of larvae, respectively. From these results, it could be assumed that Kobra was the most resistant, whereas 702 genotypes was found most susceptible genotype with the lowest and highest larval population, respectively among maize genotypes.

DISCUSSION

In present investigation, three genotypes of wheat, rice and maize each were evaluated for their relative resistance or susceptibility level against *T. granarium* and *T. castaneum.* Two parameters, weight loss percentage to test commodities (wheat, rice and maize) and increase in population densities (their progeny on larval numbers) were used to evaluate the relative susceptibility or resistance [28, 33]. Overall results revealed that none of the genotype was completely resistance to the infestation caused by *T. granarium* and *T. castaneum.* On the basis of pest population progeny development and percent damage, the least damage was observed in maize genotypes and the highest damage was noted in wheat genotypes, hence these genotypes were designated as the most tolerant and most susceptible genotypes, respectively. Our results on this study are in accordance with the outcomes of previous scientists, who concluded that each genotype of any cereal responds in a different way to the stored product insect pests. The idea of this experiment was to categorize the genotypes of wheat, rice and maize under study into most resistant or most susceptible according to their potential and from these, most susceptible genotypes of wheat, maize and rice (one from each) were used as diet for further experimentation just to ensure that insects did not die due to hunger and must intake sufficient amount of diet to determine the effect of IGRs. Similar investigations have been carried out by various researchers against *T. castaneum* such as Khanzada et al. [16], Lohar et al. [19], Nehra et al. [21], Sarin and Sharma [25], Sartaj et al. [26], and against *T. granarium* such as Ahmedani et al. [2], Khattak et al. [18], Riaz, et al. [24] and Shafique and Chaudry [28]. These scientists have worked on different genotypes of maize, rice and wheat than the genotypes under current investigation.

In current investigation, the highest weight loss and *T. granarium* population was recorded in AARI-11 among wheat genotypes. Similar trend was found to *T. castaneum.* Among maize genotypes, the maximum population and infestation for both the test insects was found on 702 genotype. Data regarding population density and weight loss in rice genotypes showed that the highest damage was recorded on Basmati 515 and was found on Super Basmati for both *T. granarium* and *T. castaneum* on all the three exposure periods. There was a direct relationship between weight loss and progeny development with respect to exposure period among all the genotypes. Similar results have been reported by Khan et al. [14] and Syed et al. [32] which indicated that a direct positive correlation exist between increase in pest population and infestation percentage. Sinha et al. [30] evaluated the seven wheat genotypes against nine species of stored grain insect pests and concluded that degree of susceptibility was related to hardness of grain. In another study, Warchalewski and Nawrot [36] reported that grain hardness, non-protein nitrogen contents and falling number also play a major role in grain resistance. Furthermore, resistance in stored grains to insect depends on various different factors such as insect species, genotype, its chemical properties [10, 17, 29] and moisture [12, 14, 32]. Possibly, a combination of all or more than one factors play a significant role in making a genotypes susceptible or resistance to attack of insect pests.

CONCLUSION

From the finding of the current study, it is concluded that from the current experiments that the AARI-11 (wheat), 702 (maize) and Basmati 515 (rice) were the most vulnerable to the insect pests attack during storage.

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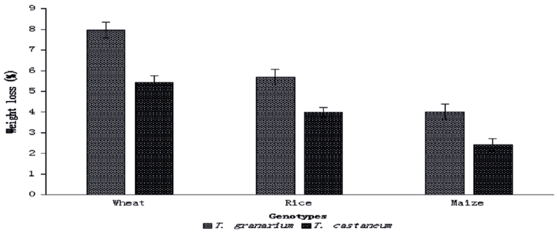

Fig. 1: Overall weight loss caused by *T. granarium* and *T. castaneum* to wheat, rice and maize

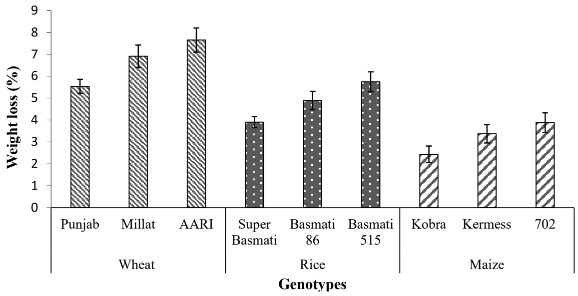

Fig. 2: Response of different genotypes of wheat, rice and maize towards infestation caused by *T. granarium* and *T. castaneum*

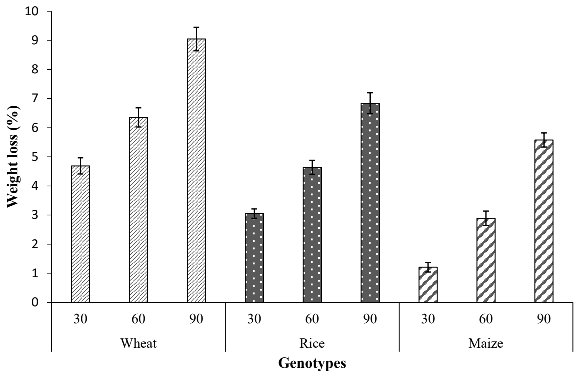

Fig. 3 Weight loss caused by *T. granarium* and *T. castaneum* to wheat, rice and maize at different exposure periods

Table 1. Percent infestation caused by *T. granarium* and *T. castaneum* on wheat genotypes (Punjab-11, Millat-11 and AARI-11) at different exposure times

Insects	Wheat Genotypes	Infestation (%)		
		30DAT	60DAT	90DAT
T. granarium	Punjab-11	5.31±0.010k	6.23±005i	8.04±0.008f
	Millat-11	5.69±0.010j	7.50±0.006g	11.07±0.011b
	AARI-11	6.78±0.009h	9.17±0.011c	11.89±0.006a
T. castaneum	Punjab-11	3.18 ±0.006o	4.39±0.009l	6.08±0.009i
	Millat-11	3.48±0.009n	5.23±0.009k	8.48±0.006e
	AARI-11	3.69±0.009m	5.63±0.006j	8.73±0.244d

Table 2. Percent infestation caused by *T. granarium* and *T. castaneum* on rice genotypes (Super Basmati, Basmati 86 and Basmati 515) at different exposure times

Insects	Rice Genotypes	Infestation (%)		
		30DAT	60DAT	90DAT
T. granarium	Super Basmati	3.04 ± 0.010n	3.96 ± 0.005k	5.77 ± 0.009e
	Basmati 86	3.42 ± 0.010m	5.23 ± 0.006g	8.80± 0.011b
	Basmati 515	4.51 ± 0.009i	6.90 ± 0.011c	9.62 ± 0.006a
T. castaneum	Super Basmati	2.11 ± 0.008q	3.43 ± 0.009m	5.11 ± 0.009h
	Basmati 86	2.51 ± 0.009p	3.86 ± 0.009l	5.51 ± 0.006f
	Basmati 515	2.72 ± 0.009o	4.47 ± 0.018j	6.24 ± 0.005d

Table 3. Percent infestation caused by *T. granarium* and *T. castaneum* on maize genotypes (Kobra, Kermess and 702) at different exposure times

Insects	Maize Genotypes	Infestation (%)		
		30DAT	60DAT	90DAT
T. granarium	Kobra	0.93 ± 0.010n	2.16 ± 0.005k	5.46 ± 0.007c
	Kermess	2.18 ± 0.013k	4.12 ± 0.006h	6.69 ± 0.011b
	702	2.40 ± 0.009j	4.79 ± 0.011e	7.51 ± 0.006a
T. castaneum	Kobra	0.34 ± 0.009q	1.51 ± 0.009m	4.20 ± 0.009g
	Kermess	0.60 ± 0.009p	2.02 ± 0.028l	4.60 ± 0.006f
	702	0.81 ± 0.009o	2.75 ± 0.006i	5.01 ± 0.015d

Table 4. Progeny development of *T. granarium* and *T. castaneum* exposed to infestation on wheat genotypes (Punjab-11, Millat-11 and AARI-11) at different exposure times

Insects	Wheat Genotypes	Progeny (No. of Larvae)		
		30DAT	60DAT	90DAT
T. granarium	Punjab-11	297.75j	654.50g	908.00cd
	Millat-11	322.00ij	692.00f	951.00b
	AARI-11	343.25i	729.25e	1014.75a
T. castaneum	Punjab-11	191.75l	588.25h	880.50d
	Millat-11	221.75kl	654.00g	908.50cd
	AARI-11	244.25k	691.25f	929.75bc

Table 5. Progeny development of *T. granarium* and *T. castaneum* exposed to infestation on rice genotypes (Super Basmati, Basmati 86 and Basmati 515) at different exposure times

Insects	Rice Genotypes	Progeny (No. of Larvae)		
		30DAT	60DAT	90DAT
T. granarium	Super Basmati	260.75k	617.50gh	871.00c
	Basmati 86	285.00jk	655.00f	914.00b
	Basmati 515	306.25j	692.25e	977.75a
T. castaneum	Super Basmati	147.75m	544.25i	836.50d
	Basmati 86	177.75lm	610.00h	864.50cd
	Basmati 515	200.25l	647.25fg	885.25bc

Table 6. Progeny development of *T. granarium* and *T. castaneum* exposed to infestation on maize genotypes (Kobra, Kermess and 702) at different exposure times

Insects	Maize Genotypes	Progeny (No. of Larvae)		
		30DAT	60DAT	90DAT
	Kobra	204.75jk	561.50g	815.00c
T. granarium	Kermess	229.00ij	599.00ef	858.00b
	702	250.25i	636.25d	921.75a
	Kobra	119.75m	516.25h	808.50c
T. castaneum	Kermess	149.75lm	582.00fg	836.50bc
	702	172.25kl	619.25de	857.75b