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Evaluation of different wheat byproducts and varieties for relative population growth and weight loss by *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae) and *Trogoderma granarium* Everts (Coleoptera: Dermestidae)

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Abstract
This study investigated during summer 2015 the comparative population growth and weight loss by *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae) and *Trogoderma granarium* Everts (Coleoptera: Dermestidae) in different wheat byproducts and varieties. Maximum weight loss by *T. castenum* (1.96±0.008) was in Semolina and minimum (1.00±0.13) in wheat bran. Maximum larvae were in wheat flour (457.25±3.74) and minimum in Semolina (38.75±0.93). Numbers of adults were maximum in wheat bran (41.0±0.41) and minimum in Semolina (33.0±0.41). In wheat varieties minimum weight loss by *T. castaneum* was in Meraj (0.22±0.028) and maximum in Sehar (3.15±0.20). Maximum larvae were in Sehar (26.50±0.010) and minimum in Merja (21.25±0.09). For *T. granarium* these parameters were studied only in wheat varieties. Weight loss was more in Fareed (5.87±0.263) and minimum in Meraj (3.22±0.09). Maximum larvae were in Fareed (26.75±0.27) and minimum in Meraj (21.00±0.25). These results are important for the management of these serious storage insect pests.

Keywords: *Triticum aestivum*, khapra beetle, varietal screening, stored grain insect pests, integrated pest management

1. Introduction
In Pakistan Gross Domestic Product (GDP) it shares 2.2% while it contributes 10.3% to value added in agriculture of the country. In 2013-14, the wheat was cultivated at 9039 thousand hectares and the average yield was 2797 kg/ha [1]. Wheat is suffered by both pre-harvest and post-harvest loses. Wheat's different products are stored and consumed as suji, maida, flour etc. The crop contributes about 20 % of the total dietary calories and proteins worldwide [2]. In food industry wheat is broadly used due to its nutritional importance and easy accessibility. Wheat grains are processed to get semolina and flour which are used in making bread, potato bread, snack foods and a number of bakery products.

It is estimated that insect pests cause up to 9 percent losses of stored products in developed countries while more than 20% in developing countries [3]. Insects are the major pest of stored grains when they are in storage condition [4]. Global Post-harvest losses caused by insect pests range from 10-40% [5]. During storage wheat and its products are attacked by various insect pests. It is reported that 5-10% grain production lost globally due to damage of insects. In Pakistan these losses are 5-7% due to insect infestation [6]. During summer season when temperature and humidity is high in tropical countries these losses reach up to 50% [7 8 9]. Apart from quantity and quality losses, insect infestation also causes diseases in humans like intestinal disorders or produce toxins [10]. It has been stated that red flour beetles release certain type of liquid in flour which is disease causing sometimes carcinogenic and cause the growth of cancer [11].

Red flour beetle is economically important pest of stored grains [12]. It is an indoor pest found in storage food [13]. Infestation causes losses and also causes the development of toxic species and in certain environmental conditions there is the growth of mould [14]. Control of this pest is usually concerned with synthetic insecticides and fumigants which is uneconomical because of persistence in environment, pest resurgence and costly application [15].

Both larva and adult of *T. castaneum* are destructive in nature and cause severe damage [16]. It feeds on the human food stuff, not on the furniture but also on the biscuits, pasta beans nuts etc. The life cycle of insect is about 30-40 days; the adults live about 3 years it develops rapidly in storage condition [17].

T. granarium is also insect pest of wheat and is most notorious pest of the world [18]. *T. granarium* and other insects of the family Dermestidae are known to be the most destructive stored product pests [19 20]. Adults of khapra beetle are harmless while the larval stage is most destructive one. It has ability to cause significant economic losses by heating the grains, feeding voraciously and its larvae has ability to live even after starvation of three years and withstand at very low moisture content percentage. It not only causes quantitative losses but also decrease the germination percentage, dirty appearance, disagreeable odor, detestable taste due to contamination with insect minute and fragments [21].

It has been reported that [22] storage insect pests like red flour beetle have the resistance against synthetic pesticides *i.e.*, cypermethrin and deltamethrin. It has been reported that from the resistant wheat varieties the more resistant variety to Red flour beetle was Barani-70 while Wafaq was more sensitive to attack [23]. Therefore use of resistant varieties in breeding programs or in general cultivation can have promising role in integrated control of storage pests.

Keeping in view of importance of host screening against different storage pests for the integrated control of storage product pests, the present study was designed for *T. castaneum* (Coleoptera: Tenebrionidae) and *T. granarium* (Coleoptera: Dermestidae) with following objectives.

1. Study of weight loss and population growth by *T. castaneum* in wheat byproducts *viz*., Maida, Semolina, Whole wheat flour and Wheat bran and four wheat varieties namely Aas, Galaxy, Meraj, Sehar and Shafaq within 45 days interval
2. Study of weight loss percentage and population growth of *T. granarium* in five wheat varieties *viz*., Aas, Freed, Meraj, 2809 and 0766346 in 45 days interval

2. Materials and Methods

2.1 Collection and rearing of *T. castaneum*

The study was conducted during summer (May-June) of 2015 in laboratory of Entomology, University College of Agriculture and Environmental sciences, The Islamia University of Bahawalpur, Pakistan. Randomly selected area population of *Tribolium castaneum (*Herbst) was collected from different godowns of Bahawalpur. The collected population was released in plastic jars (1 kg volume capacity) for rearing on a diet consisting of whole wheat flour and yeast (95:5% by weight) weighed by electrical weighing balance at the optimum conditions of temperature (30±2 ºC) and R.H. 65±5%.

2.2 Uniform population

Uniform age population of *T. castaneum* adults for experiments was obtained and for this purpose mixed population (male: female) of red flour beetle adults was released in plastic jars of 1 liter volume capacity containing whole wheat flour. Fecundity was checked at different time intervals and after two weeks adults were sieved out. Wheat flour with eggs was left for egg development for about one month period in laboratory conditions to get uniform age adults. After one month the homogeneous age adults were separated from rearing culture for releasing into the experimental setup.

2.3 Experimental setup for wheat byproducts

Byproducts of wheat *i.e.*, Maida, Semolina, Wheat Bran and Wheat flour were purchased from the market and checked for any previous infestation. 100 gm (weighed by electrical weighing balance) of the byproducts free from any previous insect infestation were kept into 16 jars of 250ml capacity and having the weight almost 22.5 gm (without culture media) making a total of 122.5 gm per jar in all 4 replications. 50 homogeneous age adults of red flour beetle that were reared in culture were released in each jar in for 4 replications. The initial weight of the jars and products was counted together to obtain the weight loss in this products. Jars containing byproducts and insects were left for recording weight loss percentage after 15, 30 and 45 days following this experimental set up. Population growth of insects was determined as well after 45 days of this experimental set up. The design for experiment followed was completely randomized design (CRD).

2.4 Weight loss of wheat byproducts by adult *T. castenum*

The weight loss was checked after 15, 30, 45 days following experimental set up. The byproduct weighed by electrical balance and weight that was consumed by population was obtained. Weight loss was obtained by using [24] formula below

$$\text{Weight loss} = \frac{\text{Initial weight} - \text{Finalweight}}{\text{Initial weight}} \times 100$$

Initial weight was obtained by adding product weight and jar weight (100 +23). Final weight was measured and loss occurred in weight of byproducts was calculated. Data was collected by weighing byproducts by electrical balance.

2.5 Experimental setup for wheat varieties for *T. castenum*

After rearing F1 progeny was obtain which are homogenous age adults. 20 plastic jars of 250ml volume was taken containing wheat varieties *viz.*, Aas, Galaxay, Sehar, Shafaq and Meraj 20g weight of grains and number of grains counted in each replication. Thirty (30) homogenous adults collected and weight loss was calculated according to below equation [25].

$$\text{Weight loss} = \frac{(\text{Wu} \times \text{Nd}) - (\text{Wd} \times \text{Nu})}{\text{Wu} \times (\text{Nd} + \text{nu})} \times 100$$

Wu = Weight of undamaged grain
Nd= No. of damaged grain
Wd= Weight of damaged grain
Nu= No. of undamaged grain

2.6 Collection and rearing of *T. granarium*

T. granarium adults were collected from grain market of Bahawalpur, Pakistan. Adults were reared in wheat grains for a period of one month. When sufficient larvae were generated the uniform age larvae usually of 3rd to 5th instars were used in experiments.

2.7 Experimental setup for wheat varieties for *T. granarium*

The experimental setup and procedures for weight loss determination were same for *T. granarium* as were for *T. castaneum* except that wheat varieties used were *i.e.*, Aas, Fareed, Meraj, 2809 and 0766346.

2.8 Data Analysis

Data was analyzed statistically by analysis of variance

(ANOVA) and means were separated by LSD test at 5 % level of probability by using software Statistix 8.1. [26]

3. Results

3.1 Comparative population growth and weight loss by *T. castaneum* in different wheat byproducts

Results showed that after 15 days significantly more weight loss occurred in semolina (0.89±0.18) and least in wheat bran (0.11±0.002) ($F_{3, 12:}$ 10.9; P: 0.0010) (Table 1). After 30 days significantly more weight loss occurred in semolina (1.29±0.005) and significantly less in wheat bran (0.45±0.005) ($F_{3, 12:}$ 6.90; P: 0.0059). After 45 days time interval more weight loss occurred in semolina (1.96±0.008) and least in wheat bran (1.00±0.13) with significant difference between means (($F_{3, 12:}$ 13; P: 0.0005).

Population growth of *T. castaneum* in wheat byproducts varied significantly (P < 0.05; Table 2). Larvae of *T. castaneum* were found maximum in wheat flour (457.25±3.74) and minimum in semolina (38.75±0.0.93) ($F_{3, 9:}$ 362.36; P: 0.0000). Adults were found maximum in wheat bran (41.0±0.41) and minimum in semolina (33.0±0.41) ($F_{3, 9:}$ 4.12; P: 0.0428). While more dead insects were recorded (20.0±0.57) in Maida and minimum in wheat flour (12.5±0.30) ($F_{3, 9:}$ 1.77; P: 0.2218).

3.2 Comparative population growth and weight loss by *T. castaneum* in different wheat varieties

Results showed that after ten days of incubation more weight loss occurred in Sehar (2.60±0.43) and minimum occurred in Meraj (0.25±0.030) ($F_{4, 19}$: 2.29; P:.1078) (Table 3). After 25 days significantly more weight loss occurred in Sehar (3.15±0.20) and less in in Meraj (0.22±0.028) ($F_{4, 19}$: 5.85898; P:.0005).

Population growth of *T. castaneum* in wheat varieties varied significantly (P < 0.05; Table 4). Adults were greatest in Meraj (7.75±0.09) and minimum in Shafaq (1.75±0.18) ($F_{4, 19:}$ 7.49; P:.0016). Larval population was greatest in Sehar (26.50±0.010) and minimum in Meraj (21.25±0.09) ($F_{4, 19}$: 6.25; P:.0036). Dead insects were more in Shafaq (2.50±0.10) and least were in variety Meraj (1.00±0.14b) ($F_{4, 19}$: 1.85; P:.1726).

3.3 Comparative population growth and weight loss by *T. granarium* in different wheat varieties

Results showed that after 15 days more weight loss due to *T. granarium* occurred in Fareed (4.21±0.27) and minimum in Meraj (1.48±0.089) ($F_{4, 19}$: 4.89; P: 0.0100) (Table 5). After 30 days significantly more weight loss occurred in Fareed (1.48±0.24) and least in in Meraj (0.41±0.06) ($F_{4, 19}$: 2.69; P:.0713). After 45 days significantly more weight loss occurred in Fareed (5.87±0.263a) and least in Meraj (3.22±0.09) ($F_{4, 19}$: 4.35; P: 0.015).

Population growth of *T. granarium* in wheat varieties varied significantly (P < 0.05; Table 6). Adults were greatest in 2809 (4.25±0.31a) and minimum in Fareed (2.25±0.17b) ($F_{4, 19:}$ 12.56; P: 0.0001). Larval population was greatest in Fareed (26.75±0.27a) and minimum in Meraj (21.00±0.25) ($F_{4, 19}$: 1.57; P:.2329). Dead insects were more in Meraj (6.25±0.27) and least was in variety Fareed (1.00±0.14) ($F_{4, 19}$: 2.67; P:.0713).

Table 1: Comparative weight loss of wheat byproducts by *T. castaneum*

Byproducts	15 days treatment (Mean ± S.E)	30 days treatment (Mean ± S.E)	45 days treatment (Mean ± S.E)
Semolina	0.89±0.18a	1.29±0.005a	1.96±0.008a
Maida	0.54±0.05b	1.01±0.04ab	1.50±0.02b
Wheat flour	0.30±0.00bc	0.73±0.06bc	1.09±0.06c
Wheat bran	0.11±0.002c	0.45±0.005c	1.00±0.13c
F	10.9	6.90	13
Df	3, 12	3, 12	3, 12
P	0.0010	0.0059	0.0005

Values sharing the same alphabets in a column are not significantly different from each other at P=0.05

Table 2: Comparative population growth of *T. castaneum* in wheat byproducts after 45 days interval

Byproducts	Number of larvae (Mean ± S.E)	Byproducts	Number adults (Mean ± S.E)	Byproducts	Number of dead Insects (Mean ± S.E)
Wheat flour	457.25±3.74a	Wheat bran	41.0±0.41a	Maida	20.0±0.57a
Maida	162.75±2.37b	Wheat flour	40.5±0.30a	Semolina	15.5±0.93a
Wheat bran	154.25±0.91b	Maida	37.5±0.11ab	Wheat bran	16.0±0.60a
Semolina	38.75±0.0.93c	Semolina	33.0±0.41b	Wheat flour	12.5±0.30a
F	362.36	F	4.12	F	1.77
Df	3, 9	Df	3, 9	Df	3, 9
P	0.0000	P	0.0428	P	.2218

Values sharing the same alphabets in a column are not significantly different from each other at P=0.05

Table 3: Comparative weight loss of wheat varieties by *T. castaneum*

Variety	10 days treatment (Mean ± S.E)	25 days treatment (Mean ± S.E)
Sehar	2.60±0.43ns	3.15±0.20a
Shafaq	1.15±0.14	2.41±0.211ab
Aas	1.06±0.11	1.41±0.06bc
Galaxy	0.59 ±0.098	0.69±0.10cd
Meraj	0.25±0.030	0.22±0.028d
F	2.29	5.85898
Df	4, 19	4, 19
P	.1078	.0005

Values sharing the same alphabets in a column are not significantly different from each other at P=0.05; ns: non-significant

Table 4: Comparative population growth of *T. castaneum* in wheat varieties after 25 days

Varieties	Number of adults (Mean ± S.E)	Varieties	Number of larvae (Mean ± S.E)	Varieties	Dead Insects (Mean ± S.E)
Meraj	7.75±0.09a	Sehar	26.50±0.010a	Shafaq	2.50±0.10a
Aas	5.25±0.58a	Shafaq	25.50±0.18ab	Sehar	1.75±0.09ab
Galaxy	5.00±0.39a	Galaxy	23.50±0.48bc	Galaxy	1.50±0.010ab
Sehar	2.00 ±0.17b	Aas	23.25±0.40bc	Aas	1.50±0.23ab
Shafaq	1.75±0.18b	Meraj	21.25±0.09c	Meraj	1.00±0.14b
F	7.49	F	6.25	F	1.85
Df	4, 19	Df	4, 19	Df	4, 19
P	.0016	P	0.0036	P	.1726

Values sharing the same alphabets in a column are not significantly different from each other at P=0.05

Table 5: Comparative weight loss of wheat varieties by *T. granarium*

Varieties	15 days treatment (Mean ± S.E)	30 days treatment (Mean ± S.E)	45 days treatment (Mean ± S.E)
Fareed	4.21±0.27a	1.48±0.24ab	5.87±0.263a
Aas	3.89±0.18ab	1.56±0.11ab	4.46±0.183ab
2809	3.07±0.17ab	0.88±0.09b	4.16±0.29ab
0766346	2.68±0.99bc	2.43±0.24a	3.96±0.23bc
Meraj	1.48±0.089c	0.41±0.06b	3.22±0.09c
F	4.89	2.69	4.35
Df	4, 19	4, 19	4, 19
P	0.0100	.0713	0.015

Values sharing the same alphabets in a column are not significantly different from each other at P=0.05

Table 6: Comparative population growth of *T. granarium* in wheat varieties after 45 days

Varieties	Number of adults (Mean ± S.E)	Varieties	Number of larvae (Mean ± S.E)	Varieties	Dead Insects (Mean ± S.E)
2809	4.25±0.31a	Fareed	26.75±0.27a	Meraj	6.25±0.27a
Aas	3.25±0.23ab	0766346	25.75±0.17a	2809	3.50±0.43b
0766346	3.00±0.15ab	Aas	23.50±0.27b	Aas	3.25±0.27bc
Meraj	2.75±0.17ab	2809	22.25±0.27bc	0766346	1.25±0.09cd
Fareed	2.25±0.17b	Meraj	21.00±0.25c	Fareed	1.00±0.14d
F	12.56	F	1.57	F	2.67
Df	4, 19	Df	4, 19	Df	4, 19
P	0.0001	P	.2329	P	.0713

Values sharing the same alphabets in a column are not significantly different from each other at P=0.05

4. Discussion

Results on weight loss in byproducts by adult *T. castaneum* varied significantly in four different wheat byproducts. It was revealed that all products suffered losses but with difference to each other. More weight loss occurred in semolina followed by maida, wheat flour and wheat bran in descending order. Population counts showed more population of larvae was in wheat flour significantly greater than in other byproducts. It was followed by maida, wheat bran and semolina in descending order. These results may be compared with findings [27] which reported that significantly higher numbers of red flour beetle were attracted towards wheat flour and have rapid population, all larvae changed into adults in flour rather than suji and less damage occurred in fine wheat while in our experiment more weight loss occurred in suji following by maida, wheat bran and wheat flour. Population growth was more in wheat flour followed by wheat bran, maida and semolina. Current study findings are similar and supported by other scientists reports which showed that the population development of *T. castaneum* was higher in wheat flour and flour with yeast rather than other starches (potato starch, corn starch, wheat starch, waxy corn starch). Larvae of red flour beetles failed to developed normally in starches because these starches have no essential nutrients for normal development of red flour beetles while flour and flour with yeast have nutrients for normal feeding of beetles therefore larva complete its development stages beyond third instars, in starches larvae failed to develop beyond first or second instars. In our results number of adults and dead insects did not vary with greater margin among tested arenas and greatest variation occurred in number of larvae.

In another experiment on weight loss and population growth by *T. castaneum* in different wheat varieties showed more weight loss occurred in variety Saher (3.15±0.20) and least in Meraj (.22±0.028). While study of population growth showed more larval population in Saher and least in Meraj. However more adults were recorded in Meraj and least in Shafaq. Dead insects were more in Shafaq and least in Meraj. These results may be compared with other scientists [29] who showed that the varieties selected for attack of red flour beetle from which the highly tolerant variety was Marvi-2000 and G.A-2002 was more susceptible towards the attack. In another study it has been reported that from the resistant wheat varieties the more resistant variety to red flour beetle was Barani-70 while Wafaq was more sensitive to attack [23]. Therefore it is not surprising that different wheat germplasms in current research behaved differently and to a different response by *T. castneum* for population growth and weight loss percentage.

Our results in experiment for population growth and weight loss in wheat varieties by *T. granarium* showed that more loss occurred in Fareed variety followed by Aas, 2809, 0766346 and Meraj in descending order. A study [30] reported that the more resistant variety was Mehran while less resistant as TJ-0787 against *T. granarium*. A study conducted on screening of rice varieties and its products against different storage

insect pests including *T. granarium*. They found that there was significant difference in weight loss, development period of immature stages and in development success of hatchlings from egg to adult stage in different culture media [31].

In our experiments weight loss by *T. castaneum* ranged from.11 to 1.96 in byproducts and from.25 to 3.15 in varietal trial. In case of *T. granarium* weight loss ranged from 1.48 to 5.87. More weight loss by *T. granarium* compared with *T. castaneum* is not with surprise as it shows the feeding host which is essentially wheat grains for *T. granarium*. Population growth of *T. castaneum* larvae ranged from 38.75 in semolina to 475.25 in wheat flour showing the relative suitability of these byproducts for this pest species. Adult population of *T. castaneum* varied as well but with smaller difference between substrates and same was the case with dead insect percentage. Population of adult *T. granarium* varied from 1.75 on Shafaq to 7.75 on Meraj. Larval population varied from 21.00 on Meraj to 26.75 on Fareed. Number of dead insects varied from 1.00 on Fareed to 6.25 on Meraj. These results showed the relatively suitability of different wheat varieties against *T. granarium.*

5. Conclusion

These results conclude that among the tested varieties, variety Meraj proved relatively resistant against both pest species as it sowed least population growth and least weight loss percentage as well both species. It is further recommended investigate further the physico-chemical and physico-morphic traits of such varieties as well to elucidate the underlying mechanisms of their resistance against storage insect pests' management. Such varieties as are resistant as this level experiment should be included in breeding programs for the development of resistant varieties against storage insect pests' management.

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