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Screening of various irrigated wheat varieties against Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae)

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Abstract
A study was conducted for screening of ten different irrigated wheat varieties against Angoumois grain moth, *Sitotroga cerealella* (Olivier) under laboratory conditions (28±2C°, 60±5% RH, 12:12 L:D hours) during 2009 at The University of Agriculture, Peshawar-Pakistan. The varieties were evaluated on the basis of developmental period, total progeny of *S. cerealella* and percent grain damage, percent weight loss, grain size and chemical composition of the grains. The results revealed that none of the varieties was completely immune to the attack of *S. cerealella.* However, their response varied significantly (P< 0.05). Weight loss being main index of resistance, variety Fakhre Sarhad (3.87% weight loss) was found significantly tolerant followed by Uqab (7.610%), Sehar (7.78%), Shafaq (9.19%) and Dera-98 (9.24%) while Pirsabak-2004 (13.39%), Pirsabak-2005 (13.82%), Raj (14.10%), Saleem-2000 (14.44%) and Pirsabak-2008 (27.75%) were significantly susceptible. The coefficient of correlation between percent weight loss and fat was negative and non-significant (r = - 0.215). The correlation of percent weight loss with protein content was negative and highly significant(r = - 0.632), while it was positive and highly significant with moisture (r = 0.690) and crude fibre (r = 0.649).

Keywords: Angoumois grain moth, Irrigated wheat varieties, Screening, *Sitotroga cerealella*

1. Introduction
Wheat (*Triticum aesitvum* L.) is one of the most important and widely cultivated crops in the world. It is the major cereal used worldwide for making bread [1]. In Pakistan, the total area occupied by wheat in 2008-09 was 9046.0 thousand ha, which produced 24032.9 thousand tones food grain, while in Khyber Pakhtunkhwa the total area occupied by wheat was 769.5 thousand ha, which produced 1204.5 thousand tones [2]. Punjab is the leading producer of wheat. In Khyber Pakhtunkhwa more wheat is grown in rainfed than irrigated areas. Besides grain, wheat straw (bhoosa) is used as roughage for livestock [3].

The nature of damage and losses caused by *Sitotroga cerealella* (Olivier) in stored grains especially wheat involves the egg laying on the grains. The larvae after hatching enter the grains and feed inside the endosperm. Larvae pupate inside the grains and make a hole before pupation. The adults emerge through this hole indicating the damaged grains. Fross present in the commodity is also sign of damage and losses [4, 5].

Khan *et al.* [6] reported that in twelve wheat genotypes the damage and losses caused by *S. cerealella* varied from 19.28 – 58.29% and 12.19 – 40.93% respectively. This shows that *S. cerealella* is a serious pest of wheat cultivars during storage. Moreover, they concluded that efforts should continue to evolve high yielding varieties with higher protein content to cope up with the protein deficiency in human diet as well as to render insect resistance and reduce storage damage and losses.

So for resistance of wheat grains to *S. cerealella* is concerned, it has been reported that it depends upon multiple factors including physical and biochemical traits. Small grain size with high protein, low moisture content and low carbohydrates contributed towards insect resistance varietal traits [7, 8, 9].

Control of different stored grain insects, including *S. cerealella* which is one of the most serious insect pests of wheat, maize, rice, barley and other cereals throughout the world has been practiced using fumigants since the discovery of these chemicals. However, keeping in view the multipronged hazards and environmental pollution, there is a dire need to explore the alternate and environment friendly technologies like varietals screening which is an important component of integrated pest management programme [10, 11, 12, 13, 14, 15].

In Pakistan, screening of various wheat varieties against *S. cerealella* has been attempted as a continued process with the evolution of new cultivars. Different researchers have evaluated more than 50 cultivars of rainfed as well as irrigated lines on the basis of moth emergence, percent damage and weight loss and reported that some of these genotypes were quite tolerant to the attack of this pest [16, 17, 18, 19, 20, 21].

The present study was conducted to determine the response of various newly evolved local irrigated wheat varieties against *S. cerealella*, to screen out ten newly evolved wheat varieties against *S. cerealella* and to determine the correlation between different variable i.e. developmental period, total progeny, percent damage, percent weight loss, grain size and chemical composition e.g. ash, crude fiber, protein, fat, moisture and total carbohydrates.

2. Materials and Methods

Ten wheat varieties *viz.* Pirsabak-04, Pirsabak-05, Pirsabak-08, Shafaq, Raj, Sehar, Saleem-2000, Dera-98, Fakhr-e-Sarhad and Uqab were obtained from Wheat Breeding Department of Cereal Crop Research Institute Pirsabak, Nowshera-Pakistan during 2009.

The samples of the respective varieties were sterilized in Speedy Autoclave at 121 ºC for 30 minutes. This relates conditioning of the test sample to disinfest them against any insect pest already present [22]. After sterilization, the samples were taken out and five lots, each of 35 g, were made and placed in 10X5 cm glass jar, covered with perforated lid. Before putting the samples, all samples were checked to ensure that the wheat material is insect free and suitable for further experimentation.

These five lots were designated as 4 replicates and a control (without insects). Grain size of all the irrigated wheat varieties was determined by counting the total number of grains per 35 gm of sample. Chemical analysis including ash, fat, protein, moisture, crude fiber and carbohydrates % of all samples were carried out according to standards set by Williams [23].

There were ten treatments and each treatment was replicated four times in Complete Randomized design. A control was allotted to each treatment. Initially grain from each variety was placed in 10x5cm glass jars covered with lid having perforated holes. Culture of *S. cerealella* was maintained at 28±2 ºC and 60±5% RH with 12:12 h (L: D) cycle. Thirty nearly hatching eggs (red coloured) were placed in respective treatment jars, i.e., replicate wise and the whole stuff was kept in laboratory under controlled temperature and humidity (28±2 ºC and 60±5% RH) with a photoperiod of 12:12 h L:D cycle.

Date of seeding (eggs placed in respective jar) was put on each jar. The jars were checked daily for adult emergence, after 20 days of seeding. Date of first adult emergence was recorded in order to know the developmental period. On emergence, the number of adults was counted by using chloroform cotton plugs, to immobilize them. Developmental period of first generation was calculated by subtracting the initial seeding date from emergence date. The total number of insects in first generation was counted and then dead adults were removed. The experiment was continued up to two generations. Second generation adult emergence was recorded and added to the first one to record total progeny. At the termination of the experiment, each sample was passed through a 60- mesh sieve for separation of fross and grains. The dust passed was discarded while weight of remaining grains was taken.

The grains containing adult emerging hole were separated from the sound grains and weighted. These grains were termed as damaged grains and their percent damage was calculated according to following formula of Khattak *et al.* [24].

$$\text{Percent Damage} = \frac{\text{WCS - WS}}{\text{Weight of control sample}} \times 100$$

Percent weight loss was also recorded according to following formula reported by Khattak *et al.* [24].

$$\text{Percent Weight loss} = \frac{\text{WCS - (WS + DGS)}}{\text{Weight of control sample}} \times 100$$

Where
WCS = Weight of Control Sample
WSDGS = Weight of Sound + Damage grains of test Sample
WS = Weight of Sample

Data recorded for developmental period, total progeny, percent damage, percent weight loss, grain size and chemical composition were subjected to statistical analysis by analysis of variance and means were compared by using least significant difference (LSD) and Dunkun's Multiple Range (DMR) test [25]. (Steel and Torrie, 1980). Coefficient of correlation between percent weight loss and other parameters including chemical composition was also determined [9].

3. Results

The parameters studied were developmental period, total progeny, percent damage, percent weight loss, grain size (No. of grains per 35 gm sample) and chemical composition.

The results of developmental period and total progeny of *S. cerealella* in ten irrigated wheat varieties are presented in Table I. The longer developmental period of 23.50 days was recorded in Sehar followed by Shafaq (23.25 days), Saleem-2000 (22.25 days), Fakhre Sarhad (22.25 days) and Uqab (22.25 days), while it was shorter in Pirsabak-2008 (19.5 days) followed by Raj, (20.50 days), Pirsabak-2005 (21.50 days), Pirsabak-2004 (22.00 days) and Dera-98 (22.00 days). The statistical analysis showed that the developmental period of Sehar was significantly higher than Pirsabak-2008, Pirsabak-2005, Pirsabak-2004 and Dera-98, while it was non significant with Shafaq.

The results of total progeny of *S. cerealella* were higher in Pirsabak-2008 (129.0) followed by Raj (87.5), Pirsabak-2005 (76.5), Pirsabak-2004 (71.5) and Saleem-2000 (61.8), while it was lower in Fakhre Sarhad (44.5) , followed by Dera-98 (47.5), Sehar (48.5), Shafaq (51.5) and Uqab (54.0). The statistical analysis of the data showed significant differences among various wheat varieties. The total progeny in Fakhre Sarhad, Dera-98, Sehar and Uqab was non significant (Table 1).

Table 1: Mean developmental period and total progeny of *Sitotroga cerealella* in wheat varieties at The University of Agriculture, Peshawar-Pakistan during 2009.

Wheat Varieties	Developmental period (Days)	Total progeny (Number)
Pirsabak-2004	22.00 abc	71.5 cd
Pirsabak-2005	21.50 abc	76.5 bc
Pirsabak-2008	19.75 c	129.0 a
Shafaq	23.25 a	51.5 ef
Raj	20.50 bc	87.5 b
Sehar	23.50 a	48.5 f
Saleem-2000	22.25 ab	61.8 de
Dera-98	22.00 ab	47.5 f
F. Sarhad	22.25 ab	44.5 f
Uqab	22.25 ab	54.0 ef
LSD(0.05)=	2.340	12.76

Mean values in the same column followed by similar letters are not significantly different at 5% level of probability.

The results for multiple comparisons of percent damage and percent weight loss are presented in Table II. Percent damage was significantly higher in Pirsabak-2008 (56.5%) followed by Saleem-2000 (42.6%), Pirsabak-2005 (28.40%), Raj (27.8%) and Pirsabak-2004 (23.95%), while it was recorded lower in Fakhre Sarhad (7.1%) followed by Sehar (14.9%), Uqab (15.2), Shafaq (17.5%) and Dera- 98 (18.8%). The statistical analysis of the data showed that the percent damage was significantly higher in Pirsabak-2008 than the rest of the varieties followed by percent damage caused in Saleem-2000, which is significantly higher than Fakhre Sarhad, Sehar, Uqab, Shafaq, Dera-98, Pirsabak-2004 and Pirsabak-2005.

The percent weight loss by *S. cerealella* was observed higher in Pirsabak- 2008 (27.75%) followed by Saleem-2000 (14.44%), Raj (14.10%), Pirsabak-2005 (13.82%), Pirsabak-2004 (13.39%). While the lowest percent weight loss was observed in Fakhre Sarhad (3.87%), followed by Uqab (7.61%), Sehar (7.78%), Shafaq (9.19%) and Dera-98 (9.24%). The statistical analysis of the data indicates that the percent weight loss in Pirsabak-2008 was significantly higher than the rest of the wheat varieties (Table II).

Table 2: Percent damage and percent weight loss of wheat varieties infested by *Sitotroga cerealella* at The University of Agriculture, Peshawar-Pakistan during 2009.

Wheat Varieties	Percent Damage	Percent Weight loss
Pirsabak -2004	23.95 c	13.39 b
Pirsabak-2005	28.40 c	13.82 b
Pirsabak-2008	56.50 a	27.75 a
Shafaq	17.50 cd	9.19 c
Raj	2 7.80 c	14.10 b
Sehar	14.90 cd	7.78 c
Saleem-2000	42.60 b	14.44 b
Dera -98	18.80 cd	9.24 c
F. Sarhad	7.10 d	3.87 d
Uqab	15.20 cd	7.61 c
LSD (0.05)	13.50	2.95

Mean values in the same column followed by similar letters are not significantly different at 5% level of probability.

The results of grain size and chemical composition are given in Table III. It was observed that the larger grain size (No. of grains /35gm sample) was observed in Sehar (682.8), Uqab (737.2), and Raj (767.5), while smaller grain size was recorded in Saleem-2000 (1023), Pirsabak-2008 (990.0), Shafaq (852.5) Pirsabak- 2004 (827.5), Dera-98 (800.2) and Fakhre Sarhad (785.8). The statistical analysis revealed that the grain size was significantly larger in Sehar than rest of the varieties.

Table 3: Grain size and chemical composition of irrigated wheat varieties carried out at Nuclear Institute for Food and Agriculture Peshawar-Pakistan during 2009.

Varieties	Grain size (No. of grains/35 g)	Ash (%)	Fat (%)	Protein (%)	Moisture (%)	Crude Fiber (%)	Carbohydrates (%)
Pirsabak-2004	827.5 bc	1.8 abc	2.8 bc	8.3 cd	10.5 ab	1.9 ab	74.7 ab
Pirsabak-2005	767.5 de	1.9 ab	3.0 ab	8.7 c	10.7 ab	2.1 ab	73.6 b
Pirsabak-2008	990.0 a	1.9 ab	2.2 d	8.1 d	11.7 a	2.2 a	73.8 b
Shafaq	852.5 b	2.0 a	3.0 ab	9.4 ab	10.4 ab	1.6 c	73.6 b
Raj	767.0 de	1.300 e	2.300 d	8.475 cd	11.57 a	2.025 ab	74.32 ab
Sehar	682.8 f	1.6 cd	2.1 d	9.5 ab	10.1 ab	1.4 c	75.3 ab
Saleem-2000	1023.0 a	1.8 abc	2.6 c	9.8 a	9.1 b	1.9 b	74.8 ab
Dera-98	800.2 cd	1.4 de	2.1 d	9.9 a	9.3 b	1.4 c	75.9 a
F. Sarhad	785.8 cd	1.8 bc	3.1 a	9.7 ab	9.5 b	1.4 c	74.5 ab
Uqab	737.2 e	1.4 de	2.1 d	9.2 b	9. b	2.0 ab	75.8 a
LSD(0.05)	43.9	0.3	0.3	0.5	1.7	0.3	2.0

Mean values in the same column followed by similar letters are not significantly different at 5% level of probability.

The ash content was found higher in Pirsabak-2008 (2.25%) followed by Shafaq (1.950%), Pirsabak-2005 (1.900%), Saleem-2000 (1.800%), and Pirsabak-2004 (1.775%), while it was lower in Raj (1.300%), Dera-98 (1.425%), Uqab (1.450%), Sehar (1.600%) and Fakhre Sarhad (1.750%). The statistical analysis showed that varieties Pirsabak-2008 was significantly different from Fakhre Sarhad, Pirsabak-2004, Saleem-2000 and non significant with from Shafaq and Pirsabak-2005 varieties.

The Fat content was found higher in Fakhre Sarhad (3.125%), while it was lower in Dera-98 (2.100%), Sehar (2.127%), Uqab (2.150%), Pirsabak-2008 (2.200%) and Raj (2.300%). The statistical analysis showed that varieties Fakhre Sarhad was significantly different from Dera-98, Sehar, Uqab, Pirsabak-2008, Raj and Saleem-2000, while non significant to the rest of varieties.

The crude protein content was found higher in Dera-98 (9.875%) followed by Saleem-2000, (9.800%), Fakhre Sarhad (9.675%), Sehar (9.450%), Shafaq 99.400%), and Uqab (9.250%), while it was lower in Pirsabak-2008 (8.125%) followed by Pirsabak-2004 (8.25%), Raj (8.475%) and Pirsabak-2005 (8.725%). The statistical analysis showed that variety Dera-98 was significantly different from Pirsabak-2008, Pirsabak-2004, Raj and Pirsabak-2005, while non significant to the rest of varieties.

The moisture content was found higher in Pirsabak-2008 (11.70%) followed by Raj (11.57%), Pirsabak-2005 (10.73%), Pirsabak-2004 (10.45%), Shafaq (10.45%) and Sehar (10.12%), while it was lower in Fakhre Sarhad (9.00%), Saleem-2000 (9.150%), Dera-98 (9.350%) and Uqab

(10.00%). The Pirsabak-2008 was significantly different from Fakhre Sarhad, Saleem200, Dera-98 and Uqab.

The crude fibre was found higher in Pirsabak-2008 (2.200%), Pirsabak- 2005 (2.075%), Raj (2.025%), Uqab (2.025%), Pirsabak-2004 (1.95%) and Saleem 2000 (1.900%), while it was lower in Fakhre Sarhad (1.350%), Dera-98 (1.425%), Sehar (1.425%) and Shafaq (1.550%). The variety Pirsabak-2008 was significantly different from the rest of varieties.

The carbohydrates were recorded highest in Dera-98 (75.83%) followed by Uqab (75.82%), Sehar (75.25%), Saleem-2000 (74.78%), Pirsabak-2004 (74.75%), Raj (74.32%), Fakhre Sarhad (74.30%), while it was lower in Pirsabak-2005 (63.62%) followed by Shafaq (73.65%) and Pirsabak-2008 (73.80%). The statistical analysis revealed that all the varieties were non significantly different from one another except Pirsabak-2005, Pirsabak-2008 and Shafaq.

The results with respect to coefficient of correlation between life cycle parameters of *S. cerealella* and others variables are presented in Table IV. The results of coefficient of correlation between developmental period with total progeny was highly significant and negative, while the correlation of developmental period with percent damage was significant and negative and developmental period with percent weight loss was highly significant and negative.

Table 4: Coefficient of correlation between some life cycle parameters of *Sitotroga cerealella* with respect to damage and losses in grains and chemical composition of wheat varieties during 2009.

	Developmental period	Total progeny	Percent damage	Percent weight loss	Grain size (Number of grain/35gm)
Developmental period	–	-0.539**	-0.333*	-0.487**	-0.214
Total progeny	-0.539**	–	0.740**	0.928**	0.476**
Percent damage	-0.333*	0.740**	–	0.837**	0.680**
Percent weight loss	-0.487**	0.928**	0.837**	–	0.618**
Grain size	-0.214	0.476**	0.680**	0.618**	–
Ash	-0.072	0.357*	0.368*	0.423**	0.478**
Fat	0.071	-0.154	-0.176	-0.215	0.122
Protein	0.386*	-0.718**	-0.371*	-0.632**	-0.049
Moisture	-0.435**	0.580**	0.368*	0.690**	0.088
Crude fiber	-0.319*	0.641**	0.539**	0.649**	0.280
Carbohydrate	0.308	-0.378*	-0.293	-0.330*	-0.241

* Significant at 5% level; ** Significant at 1% level.

The correlation of developmental period with grain size was negative and non significant.

The correlation of developmental period with ash was non significant and negatives while with fat it was non significant and negative, however, with moisture content and crude fiber it was significant and negative and with protein it was positive and significant.

The correlation of total progeny with damage and loss was positive and highly significant, while the correlation between total progeny and grain size was positive and highly significant. The correlation of total progeny with moisture content and crude fiber was positive and highly significant, while with ash it was positive and significant. With protein it was highly significant and negative and with carbohydrates it was negative and significant.

The correlation of percent damage and percent weight loss was positive and highly significant, while with grain size it was highly significant and positive.

The correlation of percent damage with fat and carbohydrate was non significant and negative, while with protein it was negative and significant. The correlation of percent damage with moisture, fat, ash and crude fibre it was significant and positive.

The correlation of percent weight loss with total progeny, damage, grain size and crude fibre was highly significant and positive, while with carbohydrates it was significant and negative.

4. Discussion

It has been reported by many workers in the past that resistance of stored grains to storage insects depends upon multiple factors. These factors include type of variety, insect species, grain size and environment. In addition to this there could be variation within the variety such as texture of grains, chemical constituents, surface area and grain size etc. [16, 8, 19].

In the present studies ten different wheat varieties were evaluated against *S. cerealella* through the same parameters as already reported by the aforesaid workers and found almost similar results which are quite comparable and in agreement with them.

Our studies revealed that developmental period was significantly shortest in Pirsabak-2008 i.e. 19.75 days while it was longest in Sehar (23.50 days). The shortest developmental period indicates that this variety is mostly preferred by the pest as life cycle is completed in shortest possible time whereas the longest developmental period shows that the life cycle will be prolonged and the variety will not be liked. This information could be freely shared with other researchers in the past by emphasizing the related phenomena which ultimately results in a susceptible or resistant variety. Therefore our results on the developmental period coincide with those of the Khattak *et al.* [5]; Hamed and Khattak [8].

Varieties were different with grain size and chemical composition hence their response varied significantly to the attack of *S. cerealella*. The results indicate that the lowest progeny was recorded in Fakhre Sarhad and the highest was observed in Pirsabak-2008. Therefore, our above results are in close conformity with Ahmad *et al.* [26] who reported that the number of emergence is a better indicator of seed resistance than the number of eggs present on the seed. Similarly Johnson *et al.* [27] tested that physical factors of the seed were not associated with resistance. In the present study none of the cultivars tested against *S. cerealella* was completely resistant to attack in no choice test.

The highest percent weight loss was observed in Pirsabak-2008 while the lowest percent weight loss was recorded in Fakhre Sarhad. The percent protein may be positive factor here for resistance. Therefore our results are in accordance with those of Mansha [7] who found that for every increase of one percent of carbohydrates contents, the percent damage and

percent loss in weight decreased respectively. He concluded that carbohydrates could be a negative factor in decreasing the percent damage and percent weight loss. He also found that with an increase of one percent crude protein, the percent damage and percent weight loss decreased respectively. The crude protein proved to be a positive factor in reducing both damage and losses in grains.

Adult emergence was more in Pirsabak-2008, while less in Fakhre Sarhad. The possible reason for this could be multiple factors. The present results agree with Manajlovic [28] who found the weight loss of larger grain of maize and wheat was reduced more by the attack of *S. cerealella* than that of small grains and more eggs were laid by females developing from larvae that developed in large grains than those from larvae in small grains.

The results of the present investigation revealed that none of the genotypes were completely resistant to the attack of *S. cerealella*, however, their response to the attack of this pest varied significantly. The present findings are comparable to the results of Khattak and Shafiq [16] and Khan *et al*. [6] who studied the susceptibility of some wheat varieties to Angoumois grain moth *S. cerealella* under controlled laboratory conditions and found that none of varieties was completely immune to the infestation of this pest. On the basis of percent weight loss by *S. cerealella* the varieties can be arranged in the following ascending order;

Fakhre - Sarhad < Uqab < Sehar < Shafq < Dera-98 < Pirsabak-2004 < Pirsabak-2005 < Raj < Saleem-2000 < Pirsabak-2008

The comparative resistance of various wheat genotypes *to S. cerealella* in the present studies has great future prospects of safe storage. This information, of course, to all concerned agencies is a valuable contribution towards stored grain research and wheat food self sufficiency programme in Pakistan which will further strengthen our economy by reducing insect losses through insect resistant cultivars.

It is concluded from the above discussion that considering percent weight loss as main parameter of resistance response in wheat varieties against *S. cerealella*, variety Fakhre-Sarhad emerged as a significantly tolerant, while Pirsabak-2008 was the most susceptible one. Also the variety Sehar showed good tolerance to the pest and have bright future prospects. Now-a-days, *Trichogramma* spp (egg parasitoid) are encouraged as biocontrol agent, for controlling many serious lepidopterous pests i.e. *Helicoverpa* spp and borers' etc. These parasitoids are reared in laboratories on *S. cerealella* eggs. Therefore it is suggested that Pirsabak-2008, the most susceptible variety is best for mass production of *S. cerealella* and *is* recommended for *Trichogramma* rearing. Further research needs to be done to screen and evaluate more genotypes against *S. cerealella* and also to find the genes of resistance in irrigated wheat against *S. cerealella*. It is also suggested that breeder should concentrate efforts on evolving varieties that have potential yield and more insect resistance.

5. Recommendations

The present studies revealed that on the basis of percent weight loss, variety Fakhre-Sarhad being significantly tolerant, followed by Uqab, Sehar and Shafaq, could be stored safely with least plant protection measures. However, efforts should continue for the evolution of new varieties having insect tolerant traits.

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