Relative Biochemical Basis of Susceptibility in Commercial Wheat Varieties against Angoumois Grain Moth, *Sitotroga cerealella* (Olivier) and Construction of its Life Table

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Abstract

A study was conducted to evaluate the relative biochemical basis of susceptibility of six commercial wheat varieties grown in Khyber Pakhtunkhwa, Pakistan, against angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) and construction of its life table at 28 ± 1°C, 65 ± 5 R.H.% and L:D 16:8 hours under laboratory environment. The results were evaluated on the basis of mean pest *S. cerealella* emergence, percent damage, and percent weight loss, male and female emerged along susceptibility index, 1000 grains weight, hardness and chemical composition of test wheat materials. Life table parameters of *S. cerealella* on highly susceptible and least susceptible wheat varieties were compared. On the basis of susceptibility index, variety Sirin (5.002) was recorded least susceptible and variety Pirsbak-2005 (7.832) recorded as highly susceptible. The chemical composition based on protein and carbohydrate contents (11.15%, 72.54%) revealed that the variety Sirin was recorded least susceptible, while variety Pirsabak-2005 (12.68%, 75.00%) was noted as highly susceptible. On the basis of life table, the net reproductive rate (10.9) on variety Pirsabak-2005 was higher than variety Sirin (9.4), and the intrinsic rate of increase was also higher on Pirsabak-2005 (30.7) than Sirin (15.9). With respect to doubling time being index of resistance, this time in Pirsabak-2005 was almost half (0.01 days) of the Sirin (0.02 days), which means that *S. cerealella* can develop more quickly on Pirsabak-2005 germplasm. In summation, relatively least susceptible wheat variety Sirin can be used to increase the level and diversify the basis of resistance to *S. cerealella* in the resistance breeding programs.

Keywords: Wheat germplasm; Sitotroga cerealella; Susceptibility; Resistance; Life table

Introduction

Wheat (*Triticumaestivum*L.), is the most widely grown crop in the world. Wheat is the staple food, about 40% of the world's population. This is the main cereal used around the world for making bread [1-5]. Worldwide wheat production is about 90% and most this is used for human consumption. Wheat is the largest grain crop and staple food for most of peoples in Pakistan. It occupies a central position in agriculture and economy, and thus confirms the importance of the development of agriculture policy. Wheat is cultivated on several million hectares area of the country to help in the huge income generation of the agriculture community.

It is estimated that 5-10% of world's wheat production is lost due to insect pests during storage. These losses have been reached up to 50% in tropical countries, where humidity and temperature run high in summers [6]. In Pakistan, 10-15% post-harvest losses of wheat occur every year. Live adult and immature insects are present in about 75% of the samples collected from different regions of Pakistan [7,8]. The procurement and storage of wheat is handled by public and private agencies to meet the food needs of the peoples. Most of the wheat is retained by the farmers for their own consumption and for seed purpose for sowing the next year crop. The storage capacity in the public sector is inadequate (3.34 million tons). In addition, the high moisture content of grain (>12%), high temperature (25-30°C) and relative humidity (>60%) during storage period make the environment favorable to the spread of insect pests.

Only 25% of the annual production is maintained at the appropriate pest control measure in the government warehouses, while the rest is stored under original storage conditions at farm level or temporary made stock store. Since the majority of stockiest and farmers are illiterate and poor, they cannot afford to buy chemicals to protect their produce, as a result quite a large quantity of their wheat is overwhelmed by stored grain insects. In addition, chemical pesticides used in storage are highly toxic causing many health problems.

In Pakistan, wheat is attacked by a number of insect pest species during storage. Besides many coleopteran beetles, lepidopteron Angoumois grain moth *Sitotroga cerealella* (Olivier) has become a serious problem for stored wheat, maize, sorghum and rice. The infestation of wheat with *S. cerealella* starts in the field as females lay their eggs singly or in groups on grains [9]. The larvae start feeding inside the grains while still in the milk stage, these spend their entire life inside one grain and infestation is difficult to detect at this stage. The adults leave a conspicuous emergence hole at one end of the kernel, infested grains are characterized by this circular window created by the larvae and grains may be completely destroyed. The adults are active fliers, thus, they are able to infest neighboring granaries, consequently stimulating seed deterioration and further fungal activity leading to a reduction in seed germination.

Life table is a characteristic which describes survival of a certain

age stages, reproduction and development of insect species. The life table contains the basic information needed to study the increase or decrease rate and the rate of change of population. These describe the possibility of an individual and the number of progeny produced by a female of a given age. In ecological research, life table is the one of the most significant analytical tool, which provides detailed information of population, dynamically generated [10-15]. it also provide a complete description of the mean generation time, survival, mortality, total eggs or young one produced per female at age time, doubling time and net reproductive rate. Since there are problems created with chemical control of *S. cerealella* pest, it is significant to recognize the characteristics linked with susceptibility or resistance of wheat and their influence on pest proliferation.

Materials and Methods

The present experiments were conducted to investigate the relative susceptibility or resistance of commercial wheat varieties grown in Khyber Pakhtunkhwa against stored grain insect pest *S. cerealella* and construction of its life table at Insect Pest Management Program, Institute of Plant and Environmental Protection, National Agriculture Research Center Islamabad under laboratory condition of 28 ± 1°C, 65 ± 5% R.H.% and 16:8 (L: D), during 2012.

Collection of wheat varieties

The subsequent six commercial wheat varieties of Khyber Putkhtunkhwa i.e., Attahabib, Khyber 87, Pirsabak 2004, Pirsabak 2005, Pirsabak 2008 and Sirin were obtained from Cereal Crop Research Institute, Pirsabak, District Nowshera, and tested for their susceptibility against *S. cerealella.*

Disinfestation of wheat grains

Healthy, fully matured and sound grains of wheat were used for conducting of present experiment. The wheat varieties were disinfested before using in the experiment by keeping at 5°C in a cold incubator for a period of one week to kill any individual invading grains.

Sitotroga cerealella culture maintenance

The *S. cerealella* culture was maintained on wheat grains under the same laboratory condition (28 ± 1°C, 65 ± 5% R.H.% and 16:8 L:D) throughout the experimental duration [16,17]. The adults were collected from the rearing chamber in glass jars attached to the chamber and placed in a plate containing starch. On the next day the starch was sieved through 80 mesh sieve. After sieving the starch, the eggs were collected and confined in a Petri dish or vial. Some quantity of these eggs was placed in the glass jars containing wheat for maintaining the culture and the remaining eggs were used in the experiment.

Experimental procedure

The wheat varieties were weighed to each 50 gram sample through Mettler PE 3600 digital weight meter. There were six treatments; each treatment was replicated ten times in Completely Randomized design [18-20]. A control replicate was allotted to each treatment as well. Initially, grain from each genotype was placed in 10 × 5 cm glass jars having muslin cloth at the top tighten with rubber band. One hundred nearly to hatching eggs (red colored) were confined in respective treatments jars i.e., replicate wise and the whole stuff was kept in the laboratory under control humidity and temperature [21-23].

Date of seeding was put on label pasted on each jar. The jars were checked daily for adult's emergence, starting after 20 days of seeding

daily. Date of first adult emergence was recorded in order to know the developmental period. On emergence, the number of adults was counted. 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 [24,25]. The experiment was continued up to two generations of *S. cerealella*. Second generation adults' emergence was recorded and added to first one. This gave total progeny. At the termination of the experiment, each sample was passed through a 60-mesh sieve for separation of frass and grains. The dust passed was discarded while weight of remaining grains was taken [26,27].

The grains containing adult emerging holes were separated from the sound grain and % damage was calculated according to following formula.

$$\% \text{ Damage} = \frac{\left(\text{Wt. of control sample } - \text{ Wt. of sound grains in test sample}\right)}{\text{Wt. of control sample}} \times 100$$

Percent weight loss was also recorded and calculated according to the following formula reported [28].

$$\% \text{ Weight loss } = \frac{[\text{Wt. of control sample} - (\text{wt. of sound grains} + \text{Wt. of damaged grains})]}{\text{Wt. of control sample}} \times 100$$

Susceptibility index of *S. cerealella* was determined on all the varieties for the confirmation of highly susceptible and least susceptible [29]. For the susceptibility of wheat varieties developmental period of *S. cerealella* was determined on all the varieties. The susceptibility index was calculated by the following formula $\text{Susceptibility index} = \frac{\log_e \cdot F \times 100}{D}$.

Where F: is the total number of adult emerged and D: is mean developmental period.

Proximate analysis of wheat varieties

Proximate Analysis comprised a partitioning of compounds in a feed into six categories based on the chemical properties of the compounds [30,31]. The whole analysis was carried out at the Grain Quality Testing Lab at National Agriculture Research Council. Proximate composition of the grains (i.e., determination of moisture, crude protein, crude fat, crude fiber, ash and carbohydrates) was performed in accordance with the standard method of Association of Official Analytical Chemists Washington.

Life table studies

Life table comprised a most important analytical tool, which provided detailed information of population dynamics to generate simple but more informative statistics. To calculate life table of *S. cerealella* on two wheat varieties i.e., highly susceptible variety and least were selected susceptible out of tested varieties [32]. The highly susceptible wheat variety was Pirsabak 2005, while least susceptible appeared to be Sirin. For the construction of life table 10 pairs of male and females of known age were collected, confined in small vials (3 × 1″) and covered with lid of 75 mesh size sieve and placed upside down on the dish containing starch of both varieties. After 24 hours the data collection were started and the starch was sieved with 85 mesh size sieve. The eggs were collected daily and the process was continued till the death of all females in the experiments [33].

The collected eggs were kept in other plastic vials on paper strip to check the hatching. Upon hatching the larvae were fed on the above mentioned varieties up to adult's emergence in the next generation. Ten total adults emergence and numbers of female progeny per day per female were calculated. The following parameters were calculated:-

T=mean generation time, DT=doubling time, Lx=survivorship of female from birth to adult living, Dx=mortality rate, Mx=mean fecundity rate, GRR=mean total number of eggs produced by a female over its life time, Ro=net reproductive rate, R_m=intrinsic rate of increase. For mean generation time T the mean data from egg to adult were taken, mean fecundity rate i.e., mean number of eggs laid by female.

Doubling time was calculated by formulas: DT=Log $2/r_m$

Survival rate was calculated by: $Lx = \dfrac{\text{Number of eggs survived}}{\text{Total number of eggs}}$

Net reproductive rate was calculated by formulas: Ro=Σ Lx. Mx

Intrinsic rate of increase was calculated by: $R_m = \dfrac{\text{Total numbers of female}}{\text{Total number of replications}}$.

Results

Relative susceptibility study

The present research conducted determined the relative susceptibility of different commercial wheat varieties grown in Khyber Pakhtunkhwa against stored grain insect pest *S, cerealella* damage, percent weight loss, number of male and female emerged, susceptibility index, 1000 grain weight, hardness, chemical composition and life table parameters.

Adults emergence, percent damage, percent weight loss and numbers of male and female emerged are presented in Table 1. The highest number of adult emergence (86.4) was in Pirsabak-2005 followed by Khyber-87 (69.4), Pirsabak-2008 (66.4) and Pirsabak-2004 (64.2), while it was lowest in Sirin (28.4) followed by Attahabib (43.1). The statistical analysis showed that the emergence in Pirsabak-2005 was significantly different from Sirin and Attahabib, however, no significantly difference was recorded in Khyber-87, Pisabak-2008 and Pirsabak-2004.

Percent damage was highest in Pirsabak-2005 (59.5%) followed by Khyber-87 (48.6%), Pirsabak-2008 (46.6%) and Pirsabak-2004 (41.8%), while it was lowest in Sirin (25.1%) followed by Attahabib(35.2%). The statistical analysis revealed that all the varieties were significantly different from each other. Percent weight loss by *S. cerealella* was observed higher in Pirsabak-2005 (34.3%), followed by Pirsabak-2008 (28.6%), Khyber-87 (27.3%) and Pirsabak-2004 (24.3%), while the lowest percent weight loss was observed in Sirin (7.7%) followed by Attahabib (10.1%). The statistical analysis showed that all the varieties were significantly different from each other.

Highest number of males of *S. cerealella* emerged in Pirsabak-2005 (40.6%), Khyber-87 (30.8%), Pirsabak-2008 (30.4%) and Pirsabak-2004 (29.7%), while the lowest numbersemergence (7.2%) was inSirin and in Attahabib (19.1%). The multiple comparisons showed that male

emergence in Pirsabak-2005 was significantly different from Sirin and Attahabib, while no significant differences were observed in Pirsabak-2008, Khyber-87 and Pirsabak-2004.

On the other hand, highest female emergence was recorded in Pirsabak-2005 (45.8%) followed by Khyber-87 (37.6%), Pisabak-2008 (36.0%) and Pirsabk-2004 (34.5%). The lowest female emergence was observed in Sirin (11.0%) and Attahabib (24.0%). Statistical analysis revealed that female emergence in Pirsabak-2005 was significantly differentthan Sirin and Attahabib, however, no significant difference was found in Khyber-87, Pirsabak-2004 and Pirsabak- 2008, respectively.

The results for multiple comparison of susceptibility index are presented in Table 2. The susceptibility index was highest (7.832) in Pirsabk-2005 followed by Khyber-87 (7.220), Pirsabk-2008 (6.980) and Pirsabak-2004 (6.890), while the lowest susceptibility index was found in Sirin(5.002) and Attahabib 5.875). The statistical analysis for susceptibility index showed that Pirsabak-2005 was significantly different from Sirin. Sirin and Attahabib are significantly different from the other varieties such as Khyber-87, Pirsabak-2004 and Pirsabak-2008. But Khyber-87, Pirsabk-2004 and Pirsabak-2008 are not significantly different from one another.

The results for 1000 grains weight and hardness are presented in Table 2. The highest grains weight (43.7 gm) was recorded in Pirsabak-2005 followed by Khyber-87 (40.2 gm), Attahabib (39.1 gm), Pirsabak-2004 (38.2 gm), while lowest (35.1 gm) was noted in Sirin and Pirsabak-2008 (37.3 gm). Statistical analysis for 1000 gains weight showed that all the varieties were significantly different from each other.

It is revealed from the results that highest hardness was (31.5%) in Sirin, Attahabib (30.3%), Pirsabak-2004 (30.1%), while lowest was (24.3%) in Pirsabak-2005 (24.3%), Khyber-87 (27.4%) and Pirsabak-2008 (29.4%). The statistical analysis for hardness showed that the Sirin was significantly different from all of the other varieties [34,35]. The varities Attahabib and Pirsabak-2004 are non-significant. Pirsabak-2008 was significantly different from Attahabib, Khyber-87 and Pirsabak-2004. Khyber-87 was significantly different from Attahabib, Pirsabak-2008 and Pirsabak-2005. Pirsabak-2005 was significant different from rest of the varieties.

Proximate analysis of wheat varieties

The results for chemical composition are presented in Table 3. Higher moisture content was recorded in Pirsabak-2005 (9.18%) followed by Pirsabak-2004 (9.16%) and Khyber-87 (9.06%), while it was lower in Sirin (8.93%), Attahabib (8.93%) and Pirsabak-2008 (8.97%). The statistical analysis revealed that the varieties Pirsabk-2004, Pirsabak-2005 and Khyber-87 did not differ in moisture content. Khyber-87, Pirsabak-2004 and Pirsabak-2005 are significantly different from rest of the varieties.

Variety	Number of male emerged ± S.E	% Weight loss ± S.E	% Damage ± S.E	% Male emergence ± S.E	%Female emergence ± S.E
Attahabib	43.1 ± 0.99 c	10.1 ± 0.01 e	35.2 ± 0.08 e	19.1 ± 0.67 c	24.0 ± 0.55 c
Khyber-87	69.4 ± 3.57 b	27.3 ± 0.09 c	48.6 ± 0.09 b	30.8 ± 2.17 b	37.6 ± 1.88 b
Pirsabak-2004	64.2 ± 3.85 b	24.3 ± 1.10 d	41.8 ± 0.08 d	29.7 ± 2.16 b	34.5 ± 1.71 b
Pirsabak-2005	86.4 ± 1.29 a	34.3 ± 0.10 a	59.5 ± 0.13 a	40.6 ± 0.71 a	45.8 ± 1.08 a
Pirsabak-2008	66.4 ± 2.31 b	28.6 ± 0.11 b	46.6 ± 0.12 c	30.4 ± 1.33 b	36.0 ± 1.21 b
Sirin	28.4 ± 1.85 d	7.7 ± 0.06 f	25.1 ± 0.01 f	7.2 ± 0.44 d	11.0 ± 0.53 d
LSD(α=0.05)	7.2	0.2	0.2	4.0	3.6

Note: Mean values in the same column followed by similar letters are not significantly different at P ≤ 0.05, ANOVA followed by LSD test.

Table 1: Mean emergence, weight loss, damage and males and females emergence% of *S. cerealella* on wheat varieties.

Varieties	Susceptibility index	1000 Grain weight	Hardness
Attahabib	5.875 d	39.1 c	30.3 b
Khyber-87	7.220 b	40.2 b	27.4 d
Pirsabak-2004	6.890 c	38.2 d	30.1 b
Pirsabak-2005	7.832 a	43.7 a	24.3 e
Pirsabak-2008	6.980 bc	37.3 e	29.4
Sirin	5.002 e	35.1 f	31.5 a
LSD (0.05)	0.24	0.3	0.2

Note: Mean values in the same column followed by similar letters are not significantly different at 0.05 level of significance, ANOVA followed by LSD test.

Table 2: Mean susceptibility index, thousand grain weight and hardness for wheat varieties.

Varieties	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	Fiber (%)	Carbohydrate (%)
Attahabib	8.93 b	11.51 c	1.86 b	1.56 ab	2.06 c	73.16 d
Khyber-87	9.06 ab	12.29 b	1.44 f	1.65 a	2.27 a	73.38 c
Pirsabak-2004	9.16 a	11.45 c	1.70 e	1.62 a	2.01 d	74.41 b
Pirsabak-2005	9.18 a	12.68 a	1.75 c	1.56 ab	1.68 e	75.00 a
Pirsabak-2008	8.97 b	12.28 b	1.72 d	1.50 b	2.26 a	73.01 e
Sirin	8.93 b	11.15 d	1.96 a	1.60 b	2.14 b	72.54 f
LSD (0.05)	0.14	0.10	0.10	0.01	0.01	0.01

Note: Mean values in the same column followed by similar letters are not significantly different at 0.05 level of significance, ANOVA followed by LSD test.

Table 3: Mean chemical composition of wheat varieties.

Life Table Parameters	Wheat Varieties	
	Pirsabak-2005	Sirin
Adult survival rate (Lx)%	50	50
Gross Reproduction rate (GRR) Female/female/day	21.9	18.9
Net Reproductive rate (r_m) Female/female/day	10.9	9.4
Intrinsic rate of increase (R_o) days	30.7	15.9
Generation Time (T) days	33.9	41.7
Death Rate (Dx)%	50	50

Table 4: Life table parameters of *S. cerealella* on highly susceptible (Pirsabak-2005) and least susceptible variety (Sirin).

Highest crude protein was examined (12.68%) in Pirsabak-2005, Khyber-87 (12.29%) and Pirsabak-2008 (12.28%), while lowest in Sirin (11.15%), Attahabib (11.51%) and Pirsabak-2004 (11.45%). Statistical analysis showed that Pirsabak-2005 was significantly different from Sirin, and Attahabib and Pirsabak-2004 are not significantly different from one another. Similarly, Khyber-87 and Pirsabak-2008 are also not significantly different from each other. However, these two groups are significantly different from each other [36,37].

Ash contents in all six varieties of the tested wheat are significantly different from one another. Highest content was recorded in wheat variety Sirin, while the lowest in Khyber-87. These genotypes are graded as 1.44<1.70<1.72<1.75<1.86<1.96 in Khyber-87, Pirsabak-2004, Pirsabak-2008, Pirsabak-2005, Attahabib and Sirin, respectively.

For crude fat no statistical difference was noted among Attahabib, Khyber-87, Pirsabak-2004 and Pirsabak-2005. Similarly, no statistical difference was observed in Attahabib, Pirsabak-2005, Pirsabak-2008 and Sirin. However, Khyber-87 and Pirsabak-2004 were statistical different from Pirsabak-2008 and Sirin wheat varieties.

The results for crude fiber were higher (2.27%) in Khyber-87, Pirsabak-2008 (2.26%), Sirin (2.14%), while it was found lower in Pirsabak-2005 (1.68%), Pirsabak-2004 (2.01%) and Attahabib (2.06%). The statistical analysis showed that the varieties Khyber-87 and Pirsabak-2008 are non-significantly different from one another. Khyber-87 and Pirsabak-2008 are significantly different from rest of the varieties.

The total carbohydrate contents were found higher (75.00%) in Pirsabak-2005 followed by Pirsabak-2004 (74.41%), Khyber-87 (73.38%) and Attahabib (73.16%), while it was found lower in Sirin (72.54%) followed by Pirsabak-2008 (73.01%). The statistical analysis revealed that all the varieties are significantly different from each other.

Life table study

Results for life table parameters of *S. cerealella* are presented in Table 4. It is revealed from the results that adult survival rate (Lx) and death rate (Dx) of *S. cerealella* was similar at both highly susceptible and least susceptible varieties i.e., Pirsabak-2005 and Sirin, respectively. However, Gross Reproductive Rate (GRR), Net Reproductive rate (rm), Intrinsic rate of increase (Ro) were higher in high susceptible variety Pirsabak-2005 than least susceptible varietsy Sirin. On the other hand, mean generation time (T), was lower in high susceptible variety (Pirsabak-2005) than least susceptible variety Sirin i.e., 33.9 and 41.7 days, respectively.

Similarly, longevity/survival and fecundity of *S. cerealella* were higher on high susceptiblevariety Pirsabak-2005 (Figures 1 and 2) than least susceptible variety Sirin (Figures 3 and 4).

Discussion

The present studies were conducted to study the resistance behavior of six commercial wheat varieties grown in Khyber Pakhtunkhwa against *S. cerealella*. The life table of *S. cerealella* on most susceptible and least susceptible varieties was constructed for comparison. Resistance of grains to stored grain insect pests depends upon multiple factors. Some of the important factors are variety, insect species, grain weight
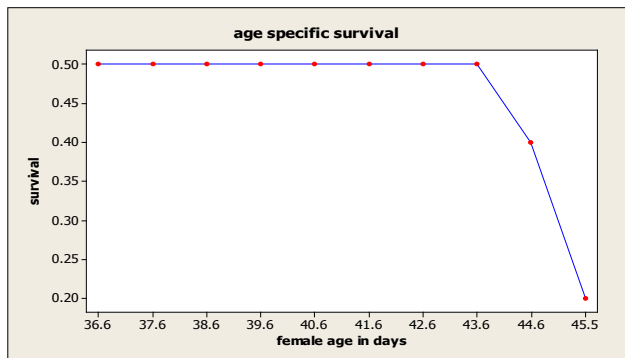
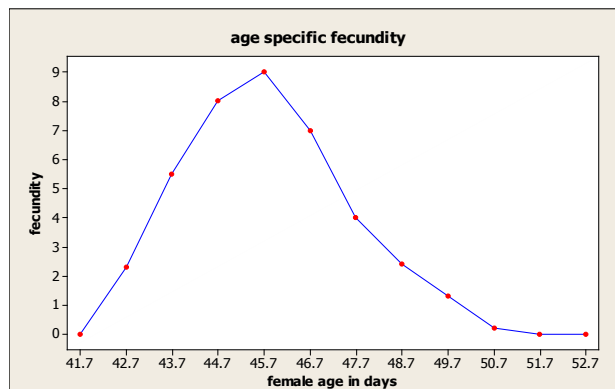**Figure 1:** Age specific survival of *S. cerealella* on variety Pirsabak-2005.
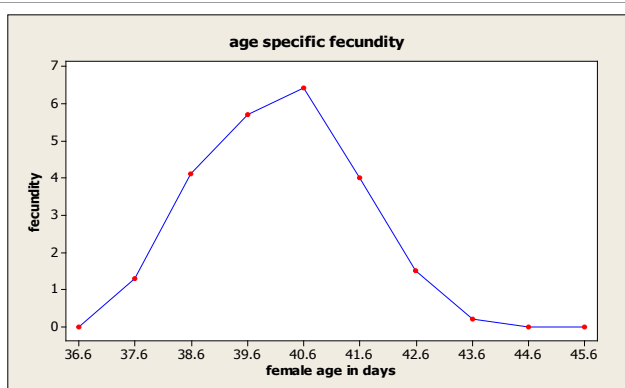

Figure 2: Age specific fecundity of *S. cerealella* on variety Pirsabak-2005.

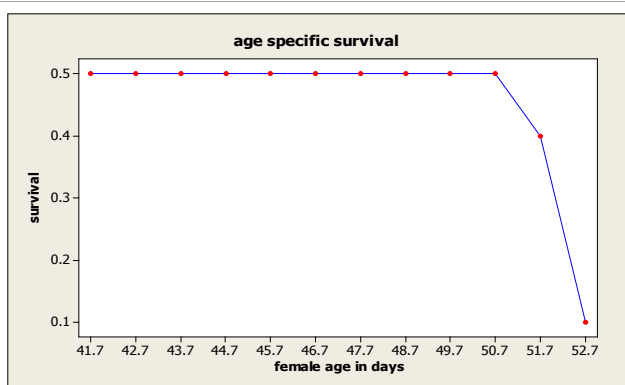**Figure 3:** Age specific survival of *S. cerealella* on variety Sirin.

Figure 4: Age Specific Fecundity of *S. cerealella* on variety Sirin.

and chemical composition. Within variety there could be variations like texture, smooth or rough surface and chemical constituents of the grains.

All the varieties differed in grain weight and chemical composition, hence their response varied significantly to the attack of this insect. The results indicated that lowest emergence of *S. cerealella* was recorded in Sirin and highest observed in Pirsabak-2005. Therefore, our current results are in close conformity, who reported that the number of emerged stored insects is a better indicator of seed resistance than the number of eggs present on the seed.

All the varieties have different index of susceptibility. The highest index of susceptibility index was found in Pirsabak-2005, while lowest in Sirin. As the adult emergence increased, the index of susceptibility also increased. Our results are similar, who reported that the increase in adult emergence also increased the susceptibility index.

All the varieties were different in percent damage and percent weight loss. The highest percent damage was recorded in Pirsabak-2005, while the lowest percent damage noted in Sirin. Similarly, the highest percent weight loss was recorded in Pirsabak-2005, while the lowest found in Sirin. The protein is also an important factor in determining the susceptibility level. The highest protein content was recorded in Pirsabak-2005, while the lower recorded in Sirin. The carbohydrate content could also be a positive factor in increasing the percent damage and percent weight loss. Therefore, our results are in close conformity with the work, who found that the variety with more protein was more susceptible, while that variety which has low protein was least susceptible. Similarly, every increase of one percent in carbohydrates contents, the percent damage and percent weight loss increased by 7.12 and 0.34, respectively.

The grain weight of Pirsabak-2005 was higher than Sirin. The possible reason for susceptibility in that might of larger grain weight of the former varieties as compared to later. This could also be owing to lowest hardness that was recorded in Pirsabak-2005, while highest found in Sirin. Our results are in close conformity, who found that weight of large grains of maize and wheat was reduced more by the attack of *S. cerealella* than that of small grains, and more eggs were laid by female developed from larvae that developed in large grain than by those from larvae in small grains. A relative hard variety undoubtedly reduces the successful entry of newly hatched *S. cerealella* larvae into kernels. The same was observed in our study that the hardness of variety Sirin was more than Pirsabak-2005. Similarly, our results are also in conformity with the results, who reported that bean beetle infestation decreases with kernel hardness.

No oviposition was observed within 24 hours after female emergence during a preliminary study. So, the females used for the life study were up to 24 hours old. In this study the life table parameters including gross reproductive rate (GRR), net reproductive rate (Ro), intrinsic rate of increase (Rm), and mean generation time (T) showed that all the parameters observed was higher in variety Pirsabak-2005, except the adult survival rate (Lx) and death rate (Dx) which was similar in both the varieties.

The highest net reproductive rate observed in variety Pirsabak-2005 at 28°C and 65 ± 5% R.H., while the lowest recorded on Sirin. The gross reproductive rate was higher on variety Pirsabak-2005, as compared to

Sirin. The results are in close conformity to the results, who studied the biology of *S. cerealella* on a commercial maize variety and four mutant varieties at 30°C and 65% R.H., and they found significant differences between the performances of the test insect on some of the different maize genotypes. Thus, our present results are similar to their previous results.

The intrinsic rate of natural increase (r_m) is probably the best parameter to compare pest species and varieties. The highest intrinsic rate of increase was observed on Pirsabak-2005, while lowest on Sirin. Our results are in conformity, who found two important parameters in calculation of intrinsic rate of natural increase i.e., longevity and fecundity of *S. cerealella* were higher on one variety than others. Accordingly, the life table parameters confirm that the variety Sirin is least susceptible to *S. cerealella* as compared to Pirsabak-2005.

Conclusions

The comparative susceptibility of various wheat varieties 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 programs in Pakistan, which will further strengthen our economy by reducing insect losses through evolving insect resistance varieties.

It is concluded from the above discussion that considering emergence, percent damage and percent weight loss as parameter factors of susceptibility response in the six varieties, and life table parameters of *S. cerealella* on most susceptible and least susceptible germplasm. Variety Sirin emerged as a significantly least susceptible variety, while Pirsabak-2005 found the most susceptible one. Also the variety Khyber-87 showed less susceptibility to the pest and has bright future prospects in breeding program.

Now a day's *Trichogramma spp*, (egg parasite) are encouraged as biocontrol agent for controlling of many serious Lepidopterous pests i.e., *Helicoverpa spp*., and borers etc. These parasites are reared in laboratories on *S. cerealella* eggs. Therefore, it is suggested that Pirsabak-2005 the most susceptible variety and best for mass production of *S. cerealella* can be recommended for *Trichogramma* rearing, further research needs to be done to screen and evaluate more varieties against *S. cerealella* and also find the genes of resistance in wheat against *S. cerealella*. It is also suggested that breeders should concentrate efforts on evolving varieties that have potential yield and more insect resistance level.

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