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Varietal Resistance to the Angoumois Grain Moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) in Wheat Seeds During Storage

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ABSTRACT Studies on the varietal resistance in wheat seeds to infestation by the Angoumois grain moth, *Sitotroga cerealella* (Olivier) were carried out in storage. Results showed that PBW 373 was the most resistant (least susceptible) variety showing longest developmental time (37.3 days), least F_1 adult emergence (6.0), least Susceptibility Index (4.9) and lowest weight loss (1.9%). The most susceptible (least resistant) variety was DL 788-2 (highest adult emergence of 23.0, highest SI of 9.3 and highest weight loss of 7.6%). The size of the seeds did not have any effect on susceptibility since there was no significant difference ($P > 0.05$) in the seed size of the most resistant and most susceptible varieties. There was no significant correlation between susceptibility and seed hardness. Therefore the resistance base in this study was more likely biochemical in nature. Larval to adult developmental time of females (35.2 days) was higher than that of males (33.8 days) while adult males lived longer (8.5 days) than females (7.9 days). The sex ratio showed slightly higher number of females than males.

Key words: Varietal resistance, susceptibility index, *Sitotroga cerealella*, developmental time

Wheat [*Triticum aestivum* (L.) em. Thell.], is the most widely cultivated and consumed of all cereals occupying the largest area of 229 million hectares with production of about 545 million tonnes [1]. India is the second largest producer of wheat in the world [2]. On a global basis, wheat provides more nourishment for people than any other food source and is the most important source of carbohydrates in the majority of countries in the temperate zone. Wheat is an excellent food, even though the grain is deficient in some essential amino acids (it is particularly low in lysine). The seed contains minerals, vitamins and fats (lipids) [1].

Wheat in storage is infested by a large number of insect pests. One of the most important pests of stored wheat seeds is *Sitotroga cerealella* (Olivier). One possible and desirable approach to reducing infestation by stored-product insects is the development of varieties that are resistant to attack. Pedigo and Rice [3] categorized the mechanism of resistance as non-preference, antibiosis and tolerance. In host plant resistance, the factors responsible for resistance should be determined and the characteristics causing resistance should be isolated and incorporated into a crop-breeding programme. With the advances in biotechnology it is now easier to transfer characters between different species.

In this study, some wheat seed varieties were tested for their resistance/susceptibility to infestation by *S. cerealella* during storage.

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MATERIALS AND METHODS

Culture of Sitotroga cerealella (Olivier)

Sitotroga cerealella used for this study was obtained from the already existing laboratory culture maintained for several years on paddy at the Storage laboratory of the Division of Entomology, IARI, New Delhi. The moth was subsequently reared on disinfested local wheat variety in 1 litre glass jars for three more generations before experimental work started. Conditioning on wheat was deemed necessary to avoid any short-term changes in insect behaviour or biology associated with the change of host grain. The openings of the glass jars were covered with muslin cloth held in place by rubber bands. The moth culture was maintained by continuously replacing the devoured and infested wheat with fresh, disinfested grains. The culture and the experiments were maintained at a temperature of 28±1°C and relative humidity of 65+5% in BOD incubators.

Wheat varieties

The seed of ten high yielding wheat varieties obtained from the Division of Genetics, IARI, New Delhi were used for this experiment. They include DL 153-2 (Kundan), DL 784-3 (Vaishali), DL 788-2 (Vidisha), DL 803-3 (Kanchan), HD 2329, HD 2864 (Urja), Raj 3765, PBW 373, GW 173 and Sonalika. All the grains were disinfested by keeping in the oven at 60°C for 5 hours and then equilibriated to moisture content of 12.5-13.0%.

Physical characteristics of wheat seeds

At the beginning of the experiment, ten seeds were taken randomly from each of the varieties and the mean length and width determined. The 100-seed weight was also taken. A Texture Analyzer connected to a computer measured the seed hardness. The amount of force (Newton, N) required to break the seed was taken as seed hardness.

Susceptibility of wheat varieties to S. cerealella

One hundred grammes of wheat seeds of different varieties were weighed into 250ml glass jar and replicated three times. Two pairs of 0-24hr old adult male and female *S. cerealella* were introduced into the jars and allowed to mate and oviposit for six days. The sex was identified mainly by size, the male is smaller than the female and has a narrower and darker abdomen than the female. It also bends the tip of the abdomen towards the female for mating. The jars were covered with muslin cloth held in place by rubber bands. Moths were handled using an aspirator. Twenty days after infestation with moths, the glass jars were checked daily for emerged adults. The emerged F_1 adults were counted and returned to the jars to allow for the F_2 and F_3 generations to be produced. At the end of three months the weights were taken again. The parameters measured include F_1-F_3 adult emergence, susceptibility index (SI), duration of development (days) and the percentage weight loss (g) at the end of three months (i.e. after F_3 emergence). The Susceptibility Index was calculated on the lines of Dobie [4] as under.

$$\text{Susceptibility Index (SI)} = \frac{1_nF_1}{D} \times 100$$

where F_1 is the total number of first generation emerging adults and D is the median developmental period (estimated as the time from the middle of oviposition to the emergence of 50% of the F_1 generation) in days [4].

Development of Sitotroga cerealella in different wheat varieties

Several newly emerged male and female *S. cerealella* were placed in a 10x4cm glass vial. The vial was covered with muslin cloth held in place by rubber bands. A slit was made in the middle of the muslin cloth to allow the insertion of the oviposition paper. A piece of black crepe paper, on which the milky-white eggs of the moth could be seen easily, was folded accordion-like with 6 folds into a 9x2cm strip and placed in the vial. No grain was provided. Each day the paper was removed and replaced with another one. The paper strip with the eggs was carefully unfolded and the eggs (usually deposited in rows and clusters) were counted under a binocular microscope. One hundred 0-24hr old eggs were carefully removed with a fine camel hair brush and transferred to Petri dish lined with black paper. The number of eggs hatched and the incubation period were noted. The number of hatched eggs were recorded

by counting the empty egg shells (which were transparent, white and shiny) and verified by counting the unhatched, fertilized eggs (which were red) and the sterile eggs (which were wrinkled and milky white). One 0-24hr old larva was transferred to seeds of the different varieties of wheat contained in a 6.5x1.5cm glass vials (to increase the chance of locating seeds and penetration quickly, 4-5 seeds of wheat were kept in each vial). This is replicated ten times. A plastic cork perforated to allow for ventilation was used to cover the glass vials. Twenty days after introduction of the larvae, and each day thereafter, the vials were examined for adult emergence. After adult emergence, the moths were retained in the vial until death. The developmental time (days) from larva to adult, per cent survival to adult, sex ratio and longevity of emerged adults were recorded.

RESULTS AND DISCUSSION

Physical characteristics of wheat seeds

Table 1 shows the physical characteristics of wheat seeds tested. Sonalika and DL 153-2 had the same length and width (0.72 and 0.32 cm), which was significantly higher than others. The 100-seed weight of DL 153-2 was significantly higher ($P > 0.05$) than others while there was no significant difference ($P > 0.05$) in the hardness of seeds for all the varieties although the value was higher in DL 784-3 with 118.9N.

Susceptibility of wheat seeds to S. cerealella

Differences exist in the susceptibility of wheat seed varieties due to infestation by *S. cerealella*. The mean developmental time of *S. cerealella* (F_1) ranged from 33.0 to 37.3 days in the different wheat varieties (Table 2). This developmental time was shorter than similar work on wheat varieties, 38.3 to 43.5 days [5] but was within the same range to those obtained in paddy, 31.8 to 38.7 days [6] and sorghum, 35.3 to 37.8 days [7]. From this study, PBW 373, with the longest developmental time (37.3 days), least adult emergence (6.0), lowest Susceptibility Index SI (4.9) and lowest weight loss (1.9%), was the most resistant (least susceptible). DL 788-2 with the highest adult emergence (23.0), highest SI (9.3) and highest weight loss (7.6%), was the most susceptible (least resistant). The size of the seeds did not have any effect on susceptibility since there was no significant difference ($P < 0.05$) in the sizes of the most resistant and most susceptible varieties (Table 2).

Table 1. Physical characteristics of wheat seeds

Variety	Length (cm)	Width (cm)	L:W ratio	100-seed weight (g)	Seed hardness (N)+
DL 153-2	0.72±0.05a*	0.32±0.03a	2.3	5.0±0.3a	106.3±2.1a
DL 784-3	0.65±0.03cd	0.29±0.03abc	2.2	4.1±0.2d	118.9±4.2a
DL 788-2	0.67±0.04bc	0.29±0.04abc	2.3	3.8±0.1e	96.4±8.1a
DL 803-3	0.64±0.04d	0.30±0.03abc	2.1	3.8±0.2e	95.6±7.6a
HD 2864	0.67±0.04bc	0.27±0.05c	2.5	3.6±0.2e	102.9±3.3a
HD 2329	0.69±0.03b	0.30±0.06abc	2.3	4.8±0.1b	113.3±4.7a
Raj 3765	0.69±0.02b	0.31±0.02ab	2.2	4.5±0.1c	107.4±7.6a
PBW 373	0.69±0.02b	0.28±0.03c	2.5	3.7±0.1e	89.8±2.3a
GW 173	0.69±0.03b	0.31±0.02ab	2.2	4.5±0.2c	93.0±1.2a
Sonalika	0.72±0.04a	0.32±0.02a	2.3	4.5±0.1c	117.4±7.0a

*Means followed by the same letter along the column are not significantly different (P>0.05) from each other by New Duncan's Multiple Range Test. + N = Newton.

Table 2. Mean developmental time, adult emergence, weight loss and index of susceptibility of wheat seeds due to *Sitotroga cerealella* infestation

Variety	Developmental time F_1 (days)	Adult emergence F_1	Index of susceptibility	Developmental time F_2 (days)	Adult emergence F_2	Weight loss (%)
DL 153-2	33.0±0.0cd*	14.3±6.1bc	7.9±1.0bc	32.0±0.8cd	22.7±5.7ab	3.9±1.3de
DL 784-3	33.0±0.0cd	17.0±6.5b	8.5±0.8'b	32.3±1.3bcd	13.3±3.4cd	4.9±2.2cd
DL 788-2	33.3±0.5bcd	23.0±5.9a	9.3±1.0a	31.7±3.1d	24.3±5.5a	7.6±1.0a
DL 803-3	32.7±0.9d	13.7±1.3bc	7.3±0.4cd	34.7±4.5abc	25.7±15.7a	6.7±2.6ab
HD 2864	33.7±0.9bcd	9.3±3.3cde	6.9±1.2d	31.7±1.3d	20.3±1.7abc	3.0±0.3ef
HD 2329	34.7±1.3b	7.0±0.8de	5.9±0.4e	36.0±2.9a	13.0±5.0cd	2.0±0.7f
Raj 3765	36.7±3.1a	14.3±5.6bc	7.4±1.2cd	35.0±2.2ab	22.3±4.8ab	2.8±0.8ef
PBW 373	37.3±0.9a	6.0±1.6e	4.9±1.0f	30.3±0.5d	15.7±7.6bcd	1.9±0.5f
GW 173	33.3±0.5bcd	11.3±3.7cd	7.0±0.6cd	31.3±1.3d	22.0±8.6ab	4.9±0.7cd
Sonalika	34.3±2.1bc	13.0±8.2bc	7.6±0.4bcd	33.0±0.8bcd	8.7±4.9d	5.5±0.1bc

*Means followed by the same letter along the vertical column are not significantly different (P>0.05) from each other by the New Duncan's Multiple Range Test.

Bhatia [8] and Cogburn *et al.* [6] observed that small sorghum seeds and *Oryza* spp seeds respectively, suffered less damage than larger ones. Anand Prakash *et al.* [9] observed a weight loss of 2.22% and 1.34% in PBW 343 and WH 147, respectively when two pairs of adults were used for seed infestation. Infestation by *S. cerealella* in this study was confined to the upper layers of wheat seeds where almost all the seeds were damaged. Fig. 1 shows that there was no significant correlation between susceptibility and seed hardness. The differences in physical characteristics (length, width, weight of seeds and seed hardness) did not correlate with differences in susceptibility observed in this study. Therefore susceptibility/resistance to *S. cerealella* was perhaps due mainly to differences in their biochemical characteristics. Pedigo and Rice [3] have described the mechanisms involved in the expression of resistance as antibiosis, nonpreference and tolerance.

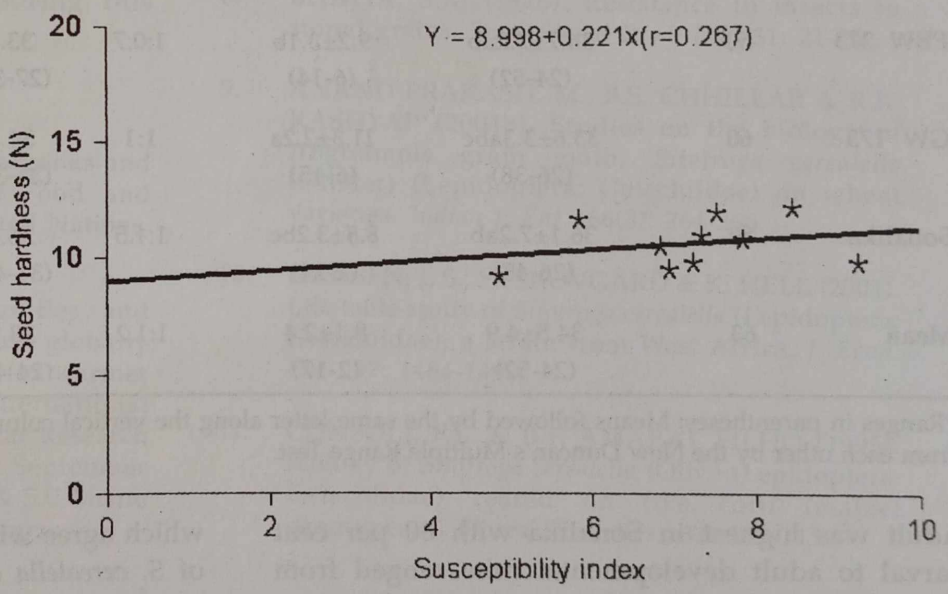

Fig. 1. Relationship between index of susceptibility and seed hardness

Survival, larval to adult developmental time, longevity and sex ratio of S. cerealella

There were variations in larval survival to adult in the different wheat seeds (Table 3). Survival to

Table 3. Survival, larval developmental time, sex ratio and longevity of adult *Sitotroga cerealella* in wheat seeds

Variety	Survival (%)	Larval-adult developmental time (days)	Longevity (days)	Sex ratio M:F	Larval-adult developmental		Longevity (days)	
					Male	Female	Male	Female
DL 153-2	60	35.0±2.3abc (31-40)	7.3±2.6c (4-10)	1:1	32.0 (31-33)	38.0 (36-40)	7.0 (4-10)	7.5 (6-9)
DL 784-3	70	31.1±4.1c (24-36)	11.3±3.1a (4-17)	1:1.3	34.7 (34-35)	28.0 (24-36)	12.3 (12-13)	10.5 (4-17)
DL 788-2	70	35.9±4.9abc (30-46)	5.0±1.2d (2-8)	1:1.5	37.5 (34-41)	34.4 (30-46)	2.5 (2-5)	7.3 (4-8)
DL 803-3	60	35.5±3.3abc (27-41)	7.0±1.2c (4-10)	1:1	31.5 (27-36)	39.5 (38-41)	8.5 (7-10)	5.5 (4-7)
HD 2864	60	37.3±7.7a (28-51)	7.0±2.1c (2-11)	1:1	36.0 (28-48)	38.6 (31-51)	9.3 (8-11)	4.7 (2-9)
HD 2329	70	31.1±3.5c (25-37)	8.0±2.0bc (2-13)	1:1.3	31.0 (29-34)	31.2 (25-37)	10.0 (7-13)	6.5 (2-10)
Raj 3765	50	32.3±5.1bc (24-40)	6.3±2.6cd (2-10)	1:1	31.0 (24-40)	33.6 (27-36)	7.0 (7-7)	6.0 (2-10)
PBW 373	50	36.7±7.2ab (24-52)	9.2±3.1b (6-14)	1:0.7	33.3 (27-39)	39.9 (24-52)	8.7 (8-9)	10.0 (6-14)
GW 173	60	33.6±3.3abc (26-38)	11.3±2.2a (6-15)	1:1	34.3 (31-38)	32.7 (26-38)	11.0 (8-15)	11.7 (6-15)
Sonalika	80	36.1±7.2ab (26-48)	8.8±3.2bc (2-14)	1:1.5	36.8 (31-48)	35.7 (26-48)	8.8 (7-12)	8.8 (7-14)
Mean	63	34.5±4.9 (24-52)	8.1±2.4 (2-17)	1:1.2	33.8 (24-48)	35.2 (24-52)	8.5 (2-15)	7.9 (2-17)

*Ranges in parentheses; Means followed by the same letter along the vertical column are not significantly different (P>0.05) from each other by the New Duncan's Multiple Range Test.

adult was highest in Sonalika with 80 per cent larval to adult developmental time ranged from 24-52 days while longevity ranged from 2-17 days. The sex ratio showed slightly higher number of females than males except in PBW 373. In summary, the overall mean developmental time of females (35.2 days) was higher than males (33.8 days) while males lived longer (8.5 days) than females (7.9 days). Anand Prakash *et al.* [5] reported male: female sex ratio of 1: 0.97, which differs slightly from the present study. In a similar study, the males of *S. cerealella* lived longer than females [9], which agree with our findings. In life table studies of *S. cerealella* on corn, the sex ratio was close to 1 : 1 at all temperatures and humidity and developmental time of females was significantly shorter than that of males [10].

In conclusion, with recent advances in biotechnology it is possible to transfer desirable characters from resistant varieties to other varieties to improve their resistance to *S. cerealella* and other stored product insects. However the manipulation of specific genes can modify the nutritional

composition of seeds affecting physical structure such as texture, shape and amount of endosperm. These alterations can change the seeds susceptibility to some pests affecting pest-host relationship. In addition, these modifications can affect the pest's performance such as growth rate, adult weight, dispersion, survivorship, female fecundity and fertility and probably will affect the future progeny [11]. Further research should be carried out on the role of biochemical characteristics of wheat seeds in development of resistance to *S. cerealella* and other stored product pests.

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