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Comparative population growth and losses cause by beetle *Trogoderama granarium* (Everts) to selected past and present wheat genotypes

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Abstract

Studies were carried out to investigate the population growth and grain weight loss caused by Khapra beetle, *Trogoderama granarium* (Everts) to thirty recently evolved and old wheat genotypes for their resistance under laboratory conditions. For this twenty newly emerged (<10h old) larvae of Khapra beetle from laboratory culture were released in each jar containing a standard sample of 1000 wheat grains. The experiment was replicated 3 times. The evaluation was based on pest population development, percent infestation and % weight loss. The highest population build up was recorded in T_{13} *Triticum aestivum* that harbored 370.67 adults, followed by T_{18} *Triticum aestivum* harboring 277.00. The lowest population was recorded in T_1 *Triticum aestivum* cv. Barani-70 holding 38.00 adults followed by T_5 *Triticum aestivum* cv. TJ – 83 having 54.67 adult Khapra beetles per treatment. The pest population in most susceptible genotype was almost 10 times higher than the least susceptible genotype. The highest infestation (97.23 %) was recorded in variety T_{13} with 44.26% weight loss. The least percent infestation (18.46%) was recorded in T1 *Triticum aestivum* cv. Barani -70 showing 6.99% weight loss. The difference of weight loss between the most and the least susceptible genotype was also approximately six times higher. These varieties were designated as the most tolerant and susceptible varieties, respectively. The remaining genotypes/ varieties were intermediate in their response to pest infestation and weight loss and could be termed as moderately susceptible.

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Introduction

Cereals constitute a major part of food throughout the world and agro-based industries depend upon their production. Cereals as stored grains are subjected to insect infestation and deterioration by fungal and bacterial attacks. Considerable amount of damage is caused by insect pests to stored wheat in Pakistan. The damage caused by insect pests to wheat grain has been estimated at 10 to 20% (Khan *et al.,* 2010). Many grain insects are good fliers and move to stored grains from fields to infest grain bins. The insect pests move within the grain mass at a rate that is determined by season and grain temperature. During summer and fall, infestations are common on the upper surface of grains. In winter the pests congregate at the center and lower portion may escape detection until high pest populations (Shemais, 2000). Khapra beetle, *Trogoderma granarium* (Everts) (Dermestidae) is a native of India, where from it spread to other countries in Asia, Africa, Europe and North America (Atwal, 1994). The beetle thrives best in warm climate however, there is evidence that the beetle can survive in cold winter months in heated warehouses and grain storage tanks. It is poor flier and its spread is entirely by shipping. It is often found in old bags, wrappers, automobiles, steel wires, books, corrugated boxes (glue), boxes of bolts and oil paintings. It is also found in food products such as rice, peanut and dried animal skin.

Infestation results from storage of the products in infested warehouses, by transportation in infested carriers or from re-use of sacks that previously contained products infested by Khapra beetle (Poplawska *et al.,* 2001; Sunita and Mahla, 2002). Infestation of Khapra beetle, *T. granarium* causes quantitative as well as qualitative losses in stored wheat grain. The amount of loss varies; depending on many factors such as physico-chemical properties of grain of different wheat varieties vary significantly (Khattak *et al.,* 2000) which have important bearing on the degree of resistance and loss against storage insect pests. Storage insect pests also respond differently to different varieties of wheat, depending upon their biology and feeding behaviors. (Bains *et al., 1*971) reported that susceptibility of wheat varieties was associated with softness of germplasm of grain and high carbohydrates content, while (Mamedov & Shapiro 1978) observed that wheat varieties possessing high lysine content were the most susceptible. (Sharma *et al.*, 1988) screened wheat varieties *T. granarium* and found cholesterol level of insects higher on resistant varieties. (Khattak *et al.,* 2000) determined the progeny of *T. granarium* in different lines of wheat and found significant differences in number of insects, developed in different wheat lines. Insect progeny, damage and losses have been considered important parameters for varietal resistance of stored grains (Khattak *et al.,* 2000).

The quantitative Loss of weight ranged from 6.01 to 22.8% in stored wheat due to infestation of *T. granarium* (Badawy & Hassan, 1965). Variable wheat grain weight loss due to infestation of *T. granarium* and *R. dominica* in different varieties was recorded by (Shah, 1969). (Azeem *et al.,* 1976) investigated the relative susceptibility of some wheat varieties to *T. granarium* and *R. dominica* and reported the loss of 7.33 to 18.66% in different varieties. Irshad and Bloch (1985) reported that 3.6 to 22.5% loss of wheat occurred during storage at different places. (Irshad *et al.*, 1988) studied losses in public storage in Rawalpindi region and observed that insect which caused most damage were *T. granarium* and *R. dominica*, *S. oryzae* and *T. castanenum. (*Khattak *et al.,* 2000). Determined damage and weight loss in wheat lines and reported a maximum of 92.91% damage and 54.83% weight loss in BWL-91033 line of wheat. Infestation of Khapra beetle, *T. granarium* apart from weight loss also causes grain quality loss due to depletion of nutrients. Infestation of *T. granarium* in food grains causes significant decrease in crude fat, total carbohydrates, sugars and true protein contents and increases moisture, crude fiber and total protein contents (Jood & Kapoor, 1993; Jood *et al.*, 1993, 1996a). Besides, substantial loss of vitamins e.g. thiamin, riboflavin and niacin occurs due to infestation (Jood & Kapoor, 1994). Significant increase in hazardous non-protein nitrogen and unacceptable levels of uric acid has been recorded in infested grains (Jood & Kapoor, 1993). *T. granarium* infestation also causes significant increase in antinutrient polyphenol and phytic acid (Jood *et al.*, 1995). The barbed hairs of *T. granarium* larvae that rub off and remain in the grain may present a serious health hazard if swallowed (Morison, 1925). Cast skins may also cause dermatitis in people handling heavily infested grains (Pruthi & Singh, 1950).

Very little work is reported from Sindh province of Pakistan on the relative resistance of different varieties of wheat to khapra beetle. Keeping the damage by this notorious pest in view an experiment was carried out under laboratory conditions at Entomology Department, Sindh Agriculture University Tandojam to evaluate population growth and damage caused by Khapra beetle *Trogoderma granarium* to some recently evolved genotypes of wheat and compared with old genotypes.

The aim of the current study was to determine the screening was to get information on genetic makeup of these genotypes to be utilized in breeding program for evolving insect resistant high yielding wheat varieties. This basic information on the damage may also be utilized for safe storage of different varieties according to their resistance status under local environmental conditions.

Materials and methods

Experimental Place

The experiment on the relative resistance of modern and old varieties of wheat to Khapra beetle *Trogoderma granarium* (Everts), was carried out at Department of Entomology, Sindh Agriculture University, Tandojam, 70050 Sindh province of Pakistan from August 11, 2005 to February 11, 2006.

Source of wheat varieties

Seeds of wheat genotypes/ varieties were obtained from the Plant Genetics Division, Nuclear Institute of Agriculture (NIA), Tandojam Pakistan. The first 5 varieties T_1 *Triticumaestivum*cv. Barani-70, T_2 *T. aestivum* cv. Bhattai, T_3 *T. aestivum* cv. Marvi – 2000, T_4 *T. aestivum* cv. Mehran – 89 and T_5 *T. aestivum* cv. TJ – 83 were the recently developed modern wheat varieties (also see Table-1). The origin of remaining 25 genotypes was from a collection of wheat varieties by a survey conducted in combined Punjab, British era Punjab in 1907 by the Punjab Board of Agriculture from across the whole area (Aziz, 1960; Khan, 1987). The 25 genotypes belonged to three species: T_1 to T_{22} bread wheat, *Triticum aestivum* were grown all over the province; T_{23} to T_{27}, *Triticum sphaerococum* a dwarf drought tolerant species which was cultivated in the districts of Multan, Muzaffergarh and Dera Ghazi Khan; and T_{28} to T_{30}, *Triticum durum* Desf. which was cultivated in the districts of Sialkot and Gujranwala (Khan, 1987).

Table 1. Seed weight of different genotypes/ varieties of wheat.

S. No.	Name of genotypes/ varieties	Weight of 1000 grains in (g)	*No. of damaged grains*
1	T_1 *Triticum aestivum* cv. Barani-70	39.33±0.36cde	286.33±3.18m
2	T_2 *T. aestivum* cv. Bhattai	38.67±0.33cde	367.33±7.54m
3	T_3 *T. aestivum* cv. Marvi – 2000	49.33±1.20a	785.00±18.56ef
4	T_4 *T. aestivum* cv. Mehran – 89	40.00±2.58cd	474.33±3.38k
5	T_5 *T. aestivum* cv. TJ – 83	42.33±2.33bc	184.67±2.25n
6	T_6 *T. aestivum*	28.33±1.33hijkl	588.67±5.61h
7	T_7 *T. aestivum*	25.67±0.33klmn	830.00±11.50b
8	T_8 *T. aestivum*	34.33±1.20hi	542.67±8.17j
9	T_9 *T. aestivum*	31.67±0.67gh	267.00±14.62 m
10	T_{10} *T. aestivum*	28.33±2.03hijkl	552.67±25.03ij
11	T_{11} *T. aestivum*	27.67±1.20ijkl	267.67±_10.73m
12	T_{12}*T. aestivum*	23.00±1.73n	453.33±17.05l

S. No.	Name of genotypes/ varieties	Weight of 1000 grains in (g)	***No. of damaged grains***
13	T_{13} *T. aestivum*	37.33±1.20def	972.33±3.76 a
14	T_{14} *T. aestivum*	36.00±1.00fg	428.67±10.17 l
15	T_{15} *T. aestivum*	26.33±3.40ijklm	787.00±5.63 c
16	T_{16} *T. aestivum*	23.67±1.76mn	766.67±2.33 cd
17	T_{17} *T. aestivum*	34.00±2.52fg	553.67±18.59 ij
18	T_{18} *T. aestivum*	27.00±0.58ijklm	761.00±7.64fg
19	T_{19} *T. aestivum*	29.33±1.45hijk	585.67±5.61i
20	T_{20} *T. aestivum*	44.00±0.58a	771.67±5.63 c
21	T_{21} *T. aestivum*	29.00±0.58hijk	718.33±14.75 de
22	T_{22} *T. aestivum*	28.33±1.58hijkl	429.33±8.21 l
23	T_{23} *T. sphaerococcum*	26.00±0.00jklmn	566.00±5.29ij
24	T_{24} *T. sphaerococcum*	25.00±1.00klmn	741.00±10.15 cde
25	T_{25} *T. sphaerococcum*	27.67±0.67ijkl	643.33±34.52gh
26	T_{26} *T. sphaerococcum*	27.67±0.33ijkl	582.00±14.56ij
27	T_{27} *T. sphaerococcum*	27.33±2.19ijklm	559.33±11.05ij
28	T_{28} *T. durum*	27.33±0.33ijklm	275.27± 10.73 m
29	T_{29} *T. durum*	27.33±0.88ijklm	437.67±18.68l
30	T_{30} *T. durum*	29.68±0.33nij	791.33±18.67c
	LSD	3.90	38.65

Mean ± S.E followed by same letter in a column are not significantly ($P<0.05$) different from each by LSD.

Cleaning of Wheat Varieties

Grains of all these genotypes were mechanically made dust and straw free, and then the sound and healthy grains were selected.

Experimental Design

The experiment was conducted in the laboratory at 29±2 °C and 65±5% R.H and replicated three times in a completely randomized design.

Moisture Content Measurement

To overcome the effect of difference in moisture content of each variety, the test varieties grain moisture content will be recorded with the help of Digital Grain Moisture Meter of 1000 grain of each variety replicated three (3) times. Dars *et al.*, (2001), Syed *et al.*, (2001) Hulasare *et al.*, (2003), and Khanzada *et al.*, (2011).

Laboratory Temperature and Relative Humidity

Experiment was conducted in the laboratory at 29±2 °C and 65±5% R.H. Irshad and Talpur (1993), Syed *et al.*, (2001), Khanzada *et al.*, (2011).

Source of Insect (Khapra Beetle)

Two Thousand (2000) of newly emerged larvae *Trogoderma granarium* of uniform age from laboratory stocked culture collected from the Nuclear Institute of Agriculture Center (NIA), Tandojam, Pakistan.

Preparation of Experimental Jars

The standard samples of each variety used in the experiment were 1000 grains, kept in plastic jars (15x 6 cm). Twenty newly emerged (<10h) larvae of Khapra beetle *T. granarium* of uniform age structure taken from homogenous laboratory culture were released in each jar. The mouth of each jar was covered with muslin cloth, tightened with rubber band.

Germination

The germinations period was started on 04-03-2006 and checked on 08-3-2006. For the purpose to check the germination, 25 seeds/grains of both Treated (Healthy and damage) and control samples were placed in a patria dish which contains moist bloating paper. After the compellation of germination, the germination will be checked and germination result was presented in %.

Laboratory Analysis and Data Recording

The observations were taken at 15 days intervals and adult beetle population fluctuations were recorded at each interval by counting the number of adults. Increase/ decrease in adult numbers was considered criterion for the relative resistance of a genotype to insect attack. After the expiry of the experimental period, the following parameters were studied to judge the relative susceptibility of wheat genotypes:

a) Percent infestation, b) Percent weight losses and c) Percent seed germination. After completion of experiment, each treatment sample was passed through a 60-mesh sieve for separation of frass and grains. The grains containing holes were separated from the sound grains as damaged grains. The percent damage was calculated according to the method of Khattak *et al.* (1987). The effect of *T. granarium* infestation on germination of seeds was determined after completion of resistance studies. The seeds of all varieties were divided into three categories i.e., control seeds, healthy seeds and infested seeds from different treatments. Germination of seeds was tested in Petri dishes lined with moist (Whatman® No 1) filter paper. Three replications were kept for every category of seed of each genotype and there were 25 seeds per treatment. The germination data were taken 7 to 10 days after the test.

The data obtained were statistically analyzed by analysis of variance and means were compared using DMR test by computer programme Statistix 8.1. The coefficient of correlation between various parameters was also determined (Steel *et al.,* 1997).

Results and discussion

Adult population

Grain size of different wheat genotypes varied significantly (F= 22.94; df= 2, 29; P, 0.001). The number of seeds damaged by *T. granarium* also differed significantly (F= 217.28; df= 2, 29; P, 0.001) (Table 1). Depending upon the varietal behavior all the varieties differed significantly (F=22.18; df =29, 58, P<0.001) in their ability to harbor the total number of adult Khapra beetle *T. granarium* (Table-2). The peak population build up was recorded in T_{13} *T. aestivum* that harbored 370.67 adults, while T_{18} *T. aestivum* and T_{30} *T. durum* were graded as second and third harboring 277.00 and 246.33 adults insects, respectively.(Table-2). The lowest population was counted in variety T_1 *T. aestivum* cv. Barani-70 holding 38.00 adults, which was followed by T_5 *T. aestivum* cv. TJ – 83, T_3 *T. aestivum* cv. Marvi – 2000, T_4 *T. aestivum* cv. Mehran – 89, and T_2 *T. aestivum*cv. Bhattai, with *T. granarium* population of 54.67, 61.67, 69.67, and 87.67, respectively. The remaining genotypes/ varieties were intermediate harboring insects population between those varieties which were on both extremes. From the results obtained, it could be assumed that variety T_1 *T. astivum* cv. Barani-70 was the most resistant, whereas the old genotype T_{13} *T. astivum* was found the most susceptible variety with the lowest and the highest adult population, respectively. A correlation carried out between grain size and *T. granarium* adult population was negative and significant (F=4.29; df= 1,28; P= 0.0476) (Fig. 1).

Table 2. Population, % infestation and % weight loss of trogoderma *granarium* on different varieties/ genotypes of wheat.

S. No	Name of genotypes/varieties	Adult population	(%) Infestation	(%) Weight loss (mg)
1	T_1 *Triticum aestivum* cv. Barani-70	38.00±1.00 o	18.47±2.25 o	6.99±0.04jk
2	T_2 *T. aestivum* cv. Bhattai	87.67±3.76 mm	26.73±7.54 m	8.15±0.33ijk
3	T_3 *T. aestivum* cv. Marvi – 2000	61.67±6.67 no	68.50±18.56 def	9.28±0.04 degh
4	T_4 *T. aestivum* cv. Mehran – 89	69.67±2.91 no	47.43±3.84jk	7.63±0.05ijk

S. No	Name of genotypes/varieties	Adult population	(%) Infestation	(%) Weight loss (mg)
5	T_5 *T. aestivum* cv. TJ – 83	54.67±0.74 no	28.66±3.18 n	8.98±0.66ghij
6	T_6 *T. aestivum*	161.00±19.29 hijkl	58.86±5.61 gh	21.53±0.12fghij
7	T_7 *T. aestivum*	199.67±3.18 defgh	83.00±1.15b	40.51±0.23bcd
8	T_8 *T. aestivum*	166.33±1.20 ghijk	54.26±8.17ij	24.26±0.17efghi
9	T_9 *T. aestivum*	167.67±28.42 ghijk	26.70±14.62n	12.85±0.35 ijk
10	T_{10} *T. aestivum*	179.33±8.99 fghij	55.26±8.17ij	23.93±0.025efghi
11	T_{11} *T. aestivum*	123.33±11.89 m	27.66±10.73n	10.84±0.06k
12	T_{12} *T. aestivum*	171.33±15.30ghijk	45.33±17.05kl	43.65±0.27 b
13	T_{13} *T. aestivum*	370.67±12.33a	97.23±0.38a	44.28±0.27a
14	T_{14} *T. aestivum*	237.67±11.14bcd	42.86±10.17lm	11.89±0.14h ijk
15	T_{15} *T. aestivum*	207.00±8.57 cdefg	78.70±0.23bc	36.95±0.15 defg
16	T_{16} *T. aestivum*	215.67±14.71 cdef	76.67±2.33bcd	43.55±0.35b
17	T_{17} *T. aestivum*	190.67±15.38 efghi	55.36±18.59ij	17.29±0.45defgh
18	T_{18} *T. aestivum*	277.00±3.51 b	67.10±7.64efg	29.48±0.58 defg
19	T_{19} *T. aestivum*	132.00±0.21 kl	58.56±5.61 hi	21.17±0.01efghi
20	T_{20} *T. aestivum*	228.00±29.26 cde	77.17±1.02 bcd	16.32±0.12 fghij
21	T_{21} *T. aestivum*	191.00±29.82 efghi	71.83±14.75 cde	24.38±0.13defgh
22	T_{22} *T. aestivum*	170.33±19.15 ghijk	42.93±8.21 klm	13.34±0.06jk
23	T_{23} *T. sphaerococcum*	156.67±16.59 ajkl	56.60±5.30 hi	27.38±0.29efghi
24	T_{24} *T. sphaerococcum*	219.00±11.02 cdef	74.10±10.15 cd	37.76±0.24 cdef
25	T_{25} *T. sphaerococcum*	163.00±10.54 hijkl	64.33±34.52 fg	30.94±0.31 bc
26	T_{26} *T. sphaerococcum*	172.33±15.30 ghijk	58.20±14.56 hi	25.73±0.35 efghi
27	T_{27} *T. sphaerococcum*	148.67±20.96 jkl	55.93±11.05l	34.54±0.32 bcde
28	T_{28} *T. durum*	185.33±11.46 fghij	27.56±10.99 n	16.61±0.07ijk
29	T_{29} *T. durum*	184.00±17.69 fghij	43.76±18.68 klm	24.37±0.09efghi
30	T_{30} *T. durum*	246.33±10.59 bc	79.13±1.70 bc	28.81±0.07efghi
	LSD	41.34	6.54	0.72

Mean ± S.E followed by same letter in a column are not significantly (P<0.05) different from each by LSD.

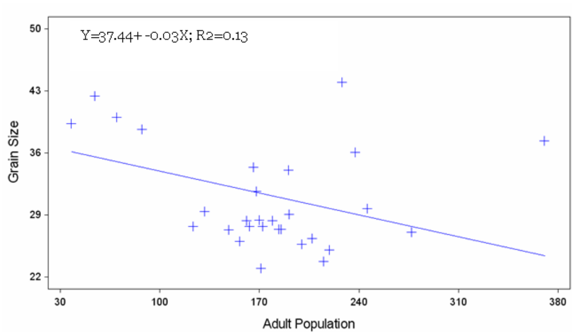

Fig. 1. Relationship between Grain Size and Adult Population.

Percent infestation

The result on percent infestation caused by *T. granarium* to grain of different varieties varied significantly (F=73.72; df= 29, 58; P<0.01). The least percent damage was recorded in variety T_1 *T. aestivum* cv. Barani-70 showing 18.47% grain damage and the highest damage was recorded in variety *T. aestivum* T_{13} showing 97.23% grain damage, hence both these varieties were designated as the most tolerant and susceptible varieties, respectively. Genotypes T_7, T_{30}, T_{15}, T_{20}, T_{16}, T_{24} and T_{21} were comparatively susceptible showing 83.00, 79.13, 78.70, 77.17, 76.67, 74.10 and 71.83 % damage were recorded susceptible. The varieties, T_3 *T. aestivum* cv. Marvi – 2000, T_{18}, T_{25}, T_6, T_{19}, T_{26}, T_{23}, T_{27}, T_{17}, T_{10}, T_8, T_4 *T. aestivum* cv. Mehran – 89 , T_{12}, T_{29}, T_{22}, T_{14}, T_5 *T. aestivum* cv. TJ – 83and T_2 *T. aestivum* cv.

Bhattai, exhibited moderate response and their damage varied from 68.50, 67.10, 64.33, 58.86, 58.56, 58.20, 56.60, 56.60, 55.93, 55.36, 55.26, 54.26, 47.43, 45.33, 43.76, 42.93, 42.86, 28.66, to26.73 % infestations. The genotypes were regarded moderately resistant. The remaining genotypes such as T_{11}, T_{28}, T_9, and T_5 *Triticum aestivum* cv. TJ – 83 were categorized as relatively resistant that displayed 27.66, 27.56, 26.70 and 18.47 percent infestation. The correlation carried out between pest population and percent grain damage was positive and significant (*F*=20.61; *df* = 1, 28; *P*=0.0001) (Fig. 2).

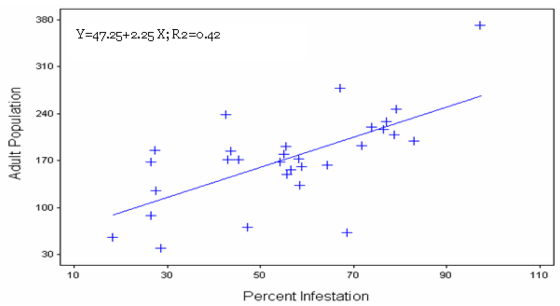

Fig. 2. Relationship between Adult Population and Percent Infestation.

Percent weight loss

Percent Weight loss of grains of different genotypes due to feeding by *T. granarium* varied significantly (*F*=14.25; *df*= 29, 58; *P*<0.01). Weight loss followed almost similar pattern in all the varieties as was observed in case of percent damage levels. Maximum weight loss was recorded in genotypes T_{13} (44.28%) followed by T_{12} with (43.65%) and T_{16} (43.55%). The minimum weight loss was found in genotypes T_1 *T. aestivum* cv. Barani-70 showing (6.99%) followed by T_4 *T. aestivum* cv. Mehran – 89 (7.63%) and T_2 *T. aestivum* cv. Bhattai (8.15%) weight loss was recorded. These results clearly showed that genotypes T_1 *T. aestivum* cv. Barani-70 was most resistance and T_{16} the most susceptible amongst all the genotypes tested. All the reaming genotypes T_7, T_{24}, T_{15}, T_{27}, T_{25}, T_{18}, T_{23}, T_{26}, T_{21}, T_{29}, T_8, T_{10}, T_6, T_{19}, T_{17}, T_{28}, T_{20}, T_{22}, T_9, T_{14}, T_{11}, T_3*T. aestivum* cv. Marvi – 2000 and, T_5 *T. aestivum* cv. TJ – 83 showed the weight loss in the order of 40.51, 37.76, 36.95, 34.54, 30.94, 29.48, 27.38, 25.73, 24.38, 24.37, 24.26, 23.93, 21.53, 21.17, 17.29, 16.61, 16.32, 13.34, 12.85, 11.89, 10.84, 9.28, and 8.98%, respectively. The correlation between carried out between adult population and percent grain weight loss was positive and significant (*F*=19.32; *df* = 1, 28; *P*=0.0001) (Fig. 3) and the correlation carried out between number of damage grains and percent grain weight loss was positive and significant (F=21.50; df= 1, 28; P=0.0001) (Fig. 4).

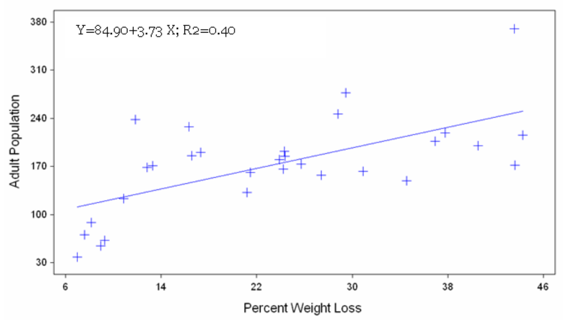

Fig. 3. Relationship between Adult Population and Percent Weight Loss.

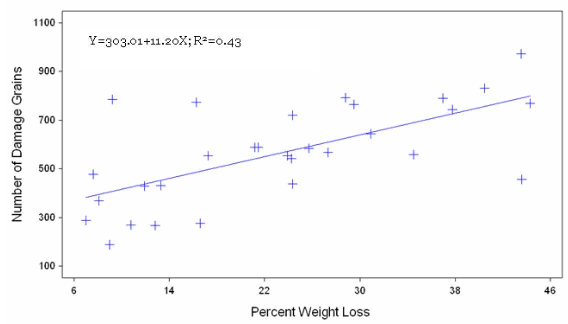

Fig. 4. Relationship between Number of Damage Grains and Percent Weight Loss.

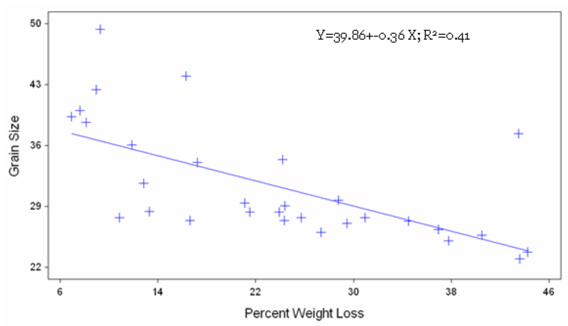

Fig. 5. Relationship between Grain Size and Percent Weight Loss.

Germination

The results of germination test showed that the germination of treated (healthy) grains was 100%, damaged grains did not germinate and zero 0% germination was recorded. In control grains, there was 100% germination.

Discussion

Stored wheat grain resistance to insect pests depends upon many factors such as hardness of grain (Sinha *et al.,* 1988; Rao *et al.,* 2004; Singh *et al.,* 2008), grain moisture (Khan *et al*., 2005; Syed *et al.,* 2006, Khan *et al*., 2010), chemical composition of a variety and insect species. Protein quality and non protein nitrogen play an important role through gluten strength and seed hardness of wheat towards increased wheat grain resistance to stored grain insects pest (Warchalewski and Nawrot 1993a, b). Negative correlation has been reported between protein content of wheat grains and insect damage and grain weight loss for insect pest species. Highly significant positive correlation has been found between carbohydrate content of stored grains and insect damage and grain weight loss (Mansha, 1985; Warchalewski and Nawrot 1993b; Khan *et al.,* 2010). In the present study, all old wheat genotypes except T_{20} had grain size smaller than modern wheat varieties. The old wheat genotype T_{13} with smallest grain size had the maximum adult *T. granarium* population, maximum number of damaged grains and maximum grain weight loss. While modern wheat cultivars T_1-T_5 with large grain size had significantly less pest population, less damaged grains and less grain weight loss compared with old wheat genotypes (Tables 1 and 2). There was a highly significant negative correlation between grain size and *T. granarium* population (Fig. 2). This indicated wheat grain size was an important factor in the infestation and population build of *T. granarium* in stored wheat. (Khattak *et al.,* 2000) evaluated 12 wheat genotypes against *T. granarium,* reported negative and non-significant correlation between grain size and other parameters. (Rao *et al.,* 2004) found that wheat grain size played an important role in resistance and susceptibility of wheat grain to Khapra beetle. While the same was not important factor in infestation of *T. castaneum* in stored wheat grain (Khanzada *et al.,* 2011). In present study, we evaluated 30 wheat genotypes for their resistance to *T. granarium*, 25 genotypes were very old cultivated by farmers through generations. The purpose of evaluation was to find out any potential resistance in these genotypes against pest infestation to be utilized in breeding program for insect resistance in wheat. Our research showed that modern wheat varieties were comparatively better in their response to pest infestation. Moreovers, their grain size was also significantly larger than old genotypes. The most susceptible old genotype, T_{13} in present study was almost 10 times more susceptible than modern variety, T_1 harboring 370.67 *T. granarium* compared to 38.0. (Khattak *et al.,* 1995) screened new wheat genotypes against *T. granarium* under controlled laboratory conditions The coefficient correlation between progeny and weight loss, progeny and damage, and weight loss and damage was positive and significant between grain size and other parameters. The correlation between moisture and weight loss, and ash and weight loss was negative and significant. (Singh & Sudhakar, 1995) evaluated twenty wheat strains for grain resistance to *T. granarium* using no-choice tests and recorded strains with moderate resistance were UP 262, C 273, PV18 and Kalyansona, while NP 200, HD 2122, Janak, CC 464, C 306, Malvika and Jayraj were highly susceptible. The remaining strains showed intermediate response were: VL 421, HP 1102, NP 710, Arjun, Hira, IWP 72, WH 157 and Pusa Lerma. (Ram and Singh, 1996) evaluated grain resistances to *T. granarium* in 64 wheat varieties through no-choice progeny tests. Susceptibility exhibited significant and negative correlation with grain hardness and crude fibre content. But grain size, protein content and oil content did not show any significant correlation with susceptibility (Khattak *et al.,* 2000) appraised twelve rainfed wheat lines, including Pirsabaq-91 against Khapra beetle, *T. granarium* in the laboratory. Data were recorded for total progeny, percent damage and weight loss. The results revealed that none of the lines showed complete immunity, however, their response varied significantly ($P<0.05$). The correlation was negative and significant between moisture and weight loss, but positive between ash and weight loss. It was negative and non-significant between grain size and other parameters. These results concluded that the line BWL-91042 and Pirsabaq-91 were significantly tolerant while BWL-91033 and BWL-91037 were highly susceptible to *T. granarium*. (Malathi & Singh, 2001) studied the inheritance of resistance to khapra beetle, *T. granarium* in wheat grain in reciprocal progenies of resistant (UP262) and susceptible (Janak) cultivars. The genetic analysis of the data on mean progeny beetle emergence among various generations revealed that the resistance to khapra beetle was under genetic control and highly heritable polygenic in nature, governed by additive and additive x additive gene effects, independent of maternal effects, and exhibiting evidence of transgressive segregation. (Rao *et al.,* 2004) screened twenty-eight wheat cultivars for their resistance to *T. granarium*. In this investigation mean number of progeny beetles per 20 grams of different cultivars ranged 10.0 to 36.9. The wheat varieties Kalyansona, HS 240, WTN 50 and UAS 2023 were found as the most resistant, while MACS 2846, Sonalika, Raj 6062, DT 46 and GW 1188 proved to be the most susceptible. (Syed *et al.,* 2006) studied resistance of twelve wheat varieties to *T. granarium* and *Rhizopertha dominica* (Febricus), separately. The population growth, percent weight loss and percent grain damage were taken as criteria for measuring relative resistance of the varieties against these insects. The grain moister content was correlated to different parameters; population growth was correlated with percent weight loss and grain damage. Population build up in both insect treatments was observed to be the lowest in variety cv. Mehran – 89, whereas the highest population was recorded in the cv.TJ-0787. The moisture content played a significant ($P<0.01$) role in population growth, percent weight loss and percent grain damage. In present study, the highest wheat grain weight loss was recorded in old wheat genotype T_{13} which was more than six times higher than modern wheat variety, T_1. The 97.23% seeds of this genotype were infested compared with only 26.73% seeds of most resistance variety, T_1 in this study. There was highly significant positive ($F=21.25$; df= 1, 28; $P=0.0001$) correlation between adult *T. granarium* population and grain weight loss (Fig. 3). (Khattak *et al.,* 2000) reported that the correlation between progeny, damage and weight loss was positive and highly significant ($P<0.01$). (Gharib, 2004) carried out studies on the susceptibility of thirteen Egyptian wheat varieties to infestation by the Khapra beetle and lesser grain borer. Their results revealed significant differences in growth index, percent weight loss, and damage. (Rao *et al.,* 2004) reported the maximum percentage loss in weight was recorded in MACS 2846 (63.6) and minimum in Kalyansona (19.6). (Syed *et al.,* 2006) recorded the percent grain weight loss in wheat varieties caused by infestation of *T. granarium* and *R. dominica* and reported that the most resistant variety to both insect species was found to be the Mehran-89, while the least resistant varieties recorded were Sarsabaz followed by TJ-0787. In present study, there was a significant negative correlation between grain size and % weight loss ($F=19.56$; df= 1, 28; $P= 0.0001$) (Fig. 5). Due to *T. granarium* feeding. (Ram & Singh, 1996) reported that grain size, protein content and oil content did not show any significant correlation with susceptibility. (Khattak *et al.,* 2000) recorded that there was a negative and non-significant between grain size and other parameters (Rao *et al.,* 2004) revealed that grain size and hardness played a role in resistance and susceptibility of wheat grain against khapra beetle. In present study, the seed grains which were damaged by *T. granarium* did not germinate. There are many reports on *T. granarium* feeding and damage to stored seeds. (Khare *et al.*, 1974) reported that insect infestation in stored wheat grain reduced germination. (Prasad *et al.*, 1977) observed 24 percent reduction in viability of wheat grains due to infestation of *T. granarium* in few months of storage. (Gharib, 2004) reported that Khapra beetle infestation in wheat significantly affected germination (%). (Parashar, 2006) reported that *T. granarium* larvae were one of the most serious stored grain pests. The larvae start feeding from embryo point and later consume the entire kernel/seed, which makes the grain hollow and only the husk remains. In case of severe infestations, infested grains are filled with frass, cast skins and excreta, which badly deteriorates quality of the grains.

Conclusions

Present study showed that amongst the accessible storage method. Use of resistant genetic stock can be the most effective measure to minimize the damage, provided that proper management practices are followed. Present studies showed that different varieties of wheat tested, T16 was found significantly susceptible to Khapra beetle. In the light of such findings, prolonged storage of such most sensitive variety should be discouraged. Whenever, such situation prevails then there is a dire necessity to adopt adequate remedy measures against the storage insects such as Khapra beetle. Through the methods of hybridization and genetic recombination, efforts are needed to enhance for evolution of insects resistance and high yielding cultivars like TJ-83. Transfer of pest resistance traits from such resistant sources to agronomic ally acceptable variety can play an important role in the IPM of storage insects.

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