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AN APPRAISAL OF RESISTANCE OF OLD AND NEW WHEAT GENOTYPES TO RED FLOUR BEETLE (*TRIBOLIUM CASTANEUM* HERBST)

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Abstract

In the present investigation, 30 varieties of wheat were used to study their resistance against Red flour beetle, *Tribolium castaneum* (Herbst).The grains of all these varieties were obtained from Plant Breeding and Genetics Division, Nuclear Institute of Agriculture, Tandojam. Experiment was conducted in the laboratory at 29±2ºC and 65±5% R.H. The standard of the samples of each variety used in the experiment was 1000 grains, kept in plastic jars (15 x 6 cm). Ten pairs of newly emerged adult flour beetles (both sexes in equivalent numbers) of uniform age from laboratory stocked culture were released in each jar. The results were evaluated on the bases of adult population development, percent grain damage and frass production, revealed that none of the genotype was completely resistant to the infestation of *T. castaneum.* All the varieties suffered losses, but their degree of resistance varied significantly. On the bases of pest population development, percent damage and frass production, the least damage was noted in variety Barani-70 and Bhittai and the highest damage was recorded in T_{21} and T_{16}; hence these varieties were designated the most tolerant and the most susceptible varieties, respectively. The comparative resistance displayed by the wheat varieties, could be placed in the following order :< Barani-70 < Bhittai < T_{19} < T_{14} < T_{24} < T_{13} < T_{20} < T_9 < T_{11} < T_{15} < T_{25} < T_1 < T_{12} < T_8 < T.J.-83 < T_{22} < T_3 < T_{18} < T_{10} < T_{23} < T_5 < Marvi-2000 < T_{17} < Mehran-89 < T_6 < T_7 < T_{16} < T_{21}.

Introduction

Wheat (*Triticum aestivum* L.) is the important cereal crop and staple food of the people of Pakistan. It occupies the first position in area amongst the cereal crops and covers about 65% of food crop area of the country (Khattak *et al.*, 2000). Wheat was grown on an area of 8.6 million hectares in the year 2008-09 with production target of 25 million tons (Minfal, 2009). 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% (Ramzan *et al.,* 1991; Khan *et al.,* 2010). Live adult insects were present in about 75% of the samples taken; the most common species were *Sitotroga cerealella*, *Tribolium castaneum, Rhizopertha dominica* and *Sitophilus* spp. (Khan *et al.,* 2010). Irshad & Talpur (1993) studied the interaction between *R. dominica, S. cereallella* and *T. castaneum* and found maximum (2.5%) loss recorded in combined infestation of wheat by the three pests. *T. castaneum* has been found one of major insect species in surveys (Mahmood *et al.,* 1996; Hyden & Soren, 1987; Ghizdavu & Deac, 1994; Khalil & Irsahd, 1994; Desimpelaere, 1996; Bandyopadhyay & Gosh, 1999).

Redflour beetle, *Tribolium castaneum* (Herbst) is one of the major insect pests of stored grains with cosmopolitan distribution (Ghizdaru & Deac, 1994; Hyden & Soren, 1987; Desimpelaere, 1996; Abro, 1996; Wong *et al.,* 1996; Suresh *et al.,* 2001; Hulasare *et al.,* 2003). Although, *T. castaneum* is considered a pest of flour and other milled cereal products and a secondary pest in stored wheat (LeCato, 1975; Hamed & Khattak, 1985, Irshad & Talpur, 1993; Suresh *et al.,* 2001), a single larva can attack 88 grains during its life which leads to a considerable loss of quality and viability of grain (Atanasov, 1978). Apart from loss of weight and quality of food grains, insects of genus *Tribolium* secrete a variety of toxic quinones which are said to be carcinogenic. Presence of *Tribolium* spp., in the food grains give pungent smell and infested flour becomes dirty yellow in colour (Ladish *et al.,* 1967; Smith *et al.,* 1971; El-Mofty *et al.,* 1989) and negatively affect baking quality of flour (Ghazdavu & Deac, 1994; Flogliazza & Pagani, 2003).

The amount of damage in quality and quantity and health hazards due to insect infestation when converted into monetary concerns may run into millions of rupees to national exchequer annually. These losses could be prevented either by use of pesticides or by non-chemical methods. Chemical methods pose many environmental hazards. Therefore, non-chemical methods, which are safe for the environment, are encouraged. Use of resistant varieties is one of the environmentally safe methods of pest control in stored product pest management. Varietal resistance in wheat against *T. castaneum* has been studied by different workers in Pakistan (Hamed & Khattak, 1985; Khattak & Shafique, 1986; Ali *et al.*, 1989, Syed *et al*., 2001; Sartaj *et al*., 2001; Ali *et al*., 2009, Irshad *et al.,* 1991).Varietal resistance may be governed by a few or a complex of mechanisms involving interactions of various physical, physiological and biochemical factors. Present study was carried out to determine the varietal resistance of wheat varieties/genotypes against red flour beetle in 25 old and 5 recently developed commercial varieties. The purpose of this research was to evaluate and identify the insect resistance genotypes to be utilized in breeding programmes for the development of high yielding insect resistant varieties to be utilized in pest management programme for the benefit of farming community of Pakistan.

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Materials and Methods

The research on the relative resistance of old and modern varieties / genotypes of wheat to red flour beetle, *Tribolium castaneum* (Herbst) was conducted in the laboratory, Department of Entomology, Sindh Agriculture University, Tandojam from August 11, 2005 to February 11, 2006. Seeds of wheat varieties were obtained from the Plant Genetics Division, Nuclear Institute of Agriculture, Tandojam. The origin of first 25 varieties /types was from a collection of wheat varieties by a survey conducted in combined Punjab in 1907 by the Punjab Board of Agriculture from across the whole area (Aziz, 1960; Khan, 1987).The 25 varieties /types belonged to three species: T_1 to T_3 *Triticum durum* Desf. which was cultivated in the districts of Sialkot and Gujranwala; T_4 to T_7 *Triticum sphaerococum*, a dwarf drought tolerant species which was cultivated in the districts of Multan, Muzaffergarh and Dera Ghazi Khan and T_8 to T_{25} bread wheat, *Triticum aestivum* L. was grown all over the province (Khan, 1987). The remaining 5 varieties were the recently developed modern wheat varieties (Table 1). Grains of genotypes were made dust and straw free, and then the sound and healthy grains were selected. The experiment was conducted in the laboratory at 29±2ºC and 65±5% R.H., (Irshad & Talpur, 1993; Syed *et al*., 2001) replicated three times in randomized block design.

Table 1. Seed characteristics of different genotypes of wheat.

S. No.	Name of Genotypes	Weight of 1000 Grains in (g)	
1.	T_1 *Triticum durum*	28.33 ± 0.33	pqr
2.	T_2 *Triticum durum*	28.00 ± 0.57	qr
3.	T_3 *Triticum durum*	30.00 ± 0.57	lmnopq
4.	T_4 *Triticum sphaerococcum*	31.67 ± 1.33	jklmn
5.	T_5 *Triticum sphaerococcum*	28.67 ± 0.33	opqrr
6.	T_6 *Triticum sphaerococcum*	30.33± 0.88	klmnopq
7.	T_7 *Triticum sphaerococcum*	31.00 ± 0.57	klmnop
8.	T_8 *Triticum sphaerococcum*	35.67 ± 0.33	ghi
9.	T_9 *Triticum aestivum*	31.33± s1.202	jklmno
10.	T_{10} *Triticum aestivum*	34.00 ± 1.00	hij
11.	T_{11} *Triticum aestivum*	41.33 ± 1.20	cd
12.	T_{12} *Triticum aestivum*	36.33± 0.66	gh
13.	T_{13} *Triticum aestivum*	33.00 ± .57	ijk
14.	T_{14} *Triticum aestivum*	26.00 ± 1.15	r
15.	T_{15} *Triticum aestivum*	37.67 ±1.76	fg
16.	T_{16} *Triticum aestivum*	39.67 ± 0.88	def
17.	T_{17} *Triticum aestivum*	38.33 ± 0.88	efg
18.	T_{18} *Triticum aestivum*	29.00 ± 0.57	nopq
19.	T_{19} *Triticum aestivum*	29.67± 0.33	mnopq
20.	T_{20} *Triticum aestivum*	37.67± 1.333	fg
21.	T_{21} *Triticum aestivum*	29.33 ± 0.33	mnopq
22.	T_{22} *Triticum aestivum*	32.33 ± 1.20	jkl
23.	T_{23} *Triticum aestivum*	44.67 ± 0.33	b
24.	T_{24} *Triticum aestivum*	32.00 ± 0.57	jklm
25.	T_{25} *Triticum aestivum*	33.00 ± 1.15	ijk
26.	Barani-70	40.33± 0.33	def
27.	Bhattai	40.67± 0.66	de
28.	Marvi-2000	51.67± 1.20	a
29.	Mehran-89	43.67 ± 2.33	bc
30.	T.J-83	45.33± 1.45	b
	LSD	2.76	

The standard samples of each variety used in the experiment were 1000 grains, kept in plastic jars (15x 6 cm). Ten pairs of newly emerged adult red flour beetle, *T. castaneum*, (both sexes in equivalent numbers) of uniform age structure from laboratory-stock culture were released in each jar. The mouth of each jar was covered with muslin cloth, tightened with rubber band. 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) Adult population
b) Percentage grain damage.
c) Frass weight and d) Percent germination

Each 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 a*l., (1987*)*. The effect of *T. castaneum* infestation on germination of grains was determined after completion of resistance studies. The grains of all varieties / genotypes were divided into three categories i.e., control grains, healthy grains and infested grains from different treatments. Germination of 25 grains per treatment was tested in Petri dishes lined with moist (Whatman No1) filter paper. Three replications were kept for every category of grains of each genotype. The germination data were taken after 7 to 10 days.

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

Results

Adult population: Depending upon the genotype behaviors, the genotypes differed significantly ($F= 6.06$; $DF= 29, 58$; $p<0.01$) in their ability to harbor the total number of adult red flour beetle, *T. castaneum* (Table 2). The highest population build up was recorded in variety T_{21} that harbored 132.30 adults, followed by T_{16} and T_7 harboring 95.00 and 41.67 adult insects, respectively. The lowest population was recorded in Barani-70 harboring 1.33 adults, followed by Bhittai, T_{19}, T_{14} and T_2 varieties where 2.33, 4.67, 4.67 and 6.00 adults were counted, respectively. The remaining génotypes T_6, Mehran-89, T_{17}, Marvi-2000, T_5, T_{23}, T_{10}, T_{18}, T_3, T_{22}, T.J-83, T_4, T_8, T_{12}, T_1, T_{25}, T_{15}, T_{11}, T_9, T_{20}, T_{13} and T_{24} harbored 30.00, 28.00, 27.33, 26.67, 25.67,25.33, 24.33, 18.67, 16.33, 15.67, 15.00, 14.67, 14.13, 13.33, 13.00, 13.00, 12.33, 11.33, 10.67, 10.67, 8.33 and 7.00 *T. castaneum*, respectively. From the results obtained, it could be assumed that Barani-70 was the most resistant, whereas T_{21} was found the most susceptible genotypes with the lowest and the highest adult population, (1.33 and 132.33 adults), respectively. A correlation study carried out between *T. castaneum* adult population and different damage parameters, indicated that there was highly significant ($p<0.01$), positive correlation between adult population growth and damaged grains, % infestation and frass production (Figs. 1-3).

Table 2. *Tribolium castaneum* population and damage characteristics on different genotypes of wheat.

S. No.	Name of genotypes	No. of damaged grains	Adult population	(%) Infestation	Frass weight *(mg)*
1.	T_1 *Triticum durum*	43.67 ± 3.18 mno	13.00 ± 0.57 cd	4.37 ± 0.31 no	36.67 ± 0.88 ghijklmn
2.	T_2 *Triticum durum*	38.67 ± 0.88 opq	6.00 ± 1.52 d	3.87 ± 0.08 op	29.00 ± 4.72 jklmn
3.	T_3 *Triticum durum*	40.33 ± 4.70 nop	16.33 ± 4.09 cd	4.03 ± 0.47 o	49.33 ± 7.62 defghijkl
4.	T_4*Triticumsphaerococcum*	66.00 ± 1.15 hij	14.67 ± 2.66 cd	6.60 ± 0.11 ij	41.67 ± 7.26 efghijklmn
5.	T_5 *Triticum sphaerococcum*	93.33 ± 5.66 f	25.67 ± 4.37 cd	9.33 ± 0.56 f	71.67 ± 2.72 de
6.	T_6 *Triticum sphaerococcum*	77.67 ± 5.36 gh	30.00 ± 6.24 cd	7.76 ± 0.53 gh	59.33 ± 9.35 defghijk
7.	T_7 *Triticum sphaerococcum*	87.33 ± 1.20 fg	41.67 ± 12..03 c	8.73 ± 0.13 fg	104.33 ± 3.38 bc
8.	T_8 *Triticum sphaerococcum*	58.33 ± 8.41 jkl	14.13 ± 3.18 cd	5.83 ± 0.84 jkl	61.33 ± 35.83 defghi
9.	T_9 *Triticum aestivum*	47.33 ± 0.66 1mno	10.67 ± 2.90 cd	4.73 ± 0.06 mno	32.00 ± 3.46 hijklmn
10.	T_{10} *Triticum aestivum*	124.00 ± 8.54 d	24.33 ± 4.41 cd	12.40 ± 0.49 d	60.67 ± 5.60 defghij
11.	T_{11} *Triticum aestivum*	42.33 ± 0.66 mno	11.33 ± 1.45 cd	4.23 ± 0.06 no	30.00 ± 13.29 jklm
12.	T_{12} *Triticum aestivum*	49.00 ± 2.08 klmno	13.33 ± 4.91 cd	4.90 ± 0.20 lmno	30.67 ± 2.72 ijklmn
13.	T_{13} *Triticum aestivum*	20.00 ± 3.05 rs	8.33 ± 5.36 d	2.00 ± 0.30 qrs	18.00 ± 7.00 mn
14.	T_{14} *Triticum aestivum*	29.00 ± 5.03 pqr	4.67 ± 1.76 d	2.90 ± 0.50 pq	19.67 ± 2.96 lmn
15.	T_{15} *Triticum aestivum*	41.00 ± 3.21 nop	12.33 ± 2.72 cd	4.10 ± 0.32 o	35.33 ± 8.87 ghijklmn
16.	T_{16} *Triticum aestivum*	138.67 ± 3.33 c	95.00 ± 30.07 b	13.87 ± 0.33 c	132.67 ± 14.51 b
17.	T_{17} *Triticum aestivum*	164.67 ± 2.60 b	27.33 ± 7.35 cd	16.47 ± 0.26 b	130.67 ± 21.82 b
18.	T_{18} *Triticum aestivum*	116.00 ± 2.30 de	18.67 ± 2.72 cd	11.60 ± 0.23 de	63.67 ± 4.91 defg
19.	T_{19} *Triticum aestivum*	40.67 ± 1.33 nop	4.67 ± 1.33 d	4.07 ± 0.13 o	34.33 ± 18.52 hijklm
20.	T_{20} *Triticum aestivum*	52.00 ± 9.16 klmn	10.67 ± 0.33 cd	5.20 ± 0.52 klmn	38.33 ± 6.33 fghijklm
21.	T_{21} *Triticum aestivum*	284.00 ± 27.31 a	132.33 ± 48.21 a	28.40 ± 0.45 a	228.00 ± 22.053 a
22.	T_{22} *Triticum aestivum*	61.67 ± 1.33 ijk	15.67 ± 3.66 cd	6.17 ± 0.13 ijk	47.33 ± 8.87 efghijklm
23.	T_{23} *Triticum aestivum*	109.33 ± 1.45 e	25.33 ± 4.84 cd	10.93 ± 0.14 e	116.33 ± 4.84 b
24.	T_{24} *Triticum aestivum*	26.33 ± 2.66 qrs	7.00 ± 1.00 d	2.63 ± 0.26 qr	25.00 ± 4.04 klmn
25.	T_{25} *Triticum aestivum*	44.33 ± 3.71 mno	13.00 ± 6.08 cd	4.43 ± 0.37 mno	47.67 ± 6.48 efghijklm
26.	Barani-70	16.33 ± 1.45 rs	1.33 ± 0.33 c	1.63 ± 0.14 rs	14.00 ± 2.08 m
27.	Bhattai	15.00 ± 1.00s	2.33 ± 0.66 d	1.50 ± 0.10s	10.67 ± 2.88 n
28.	Marvi-2000	72.00 ± 4.16 hi	26.67 ± 0.88 cd	7.20 ± 0.41 hi	67.33 ± 2.33 def
29.	Mehran-89	175.67 ± 3.84 b	28.00 ± 5.85 cd	16.57 ± 0.84 b	80.33 ± 6.33 cd
30.	T.J-83	54.67 ± 3.33 jklm	15.00 ± 2.51 cd	5.47 ± 0.33 klm	37.33 ± 5.03 fghijklmn
	LSD	13.01	31.01	1.08	31.67

Percent infestation: The percent infestation caused by *T. castaneum* to grains of different genotypes varied significantly ($F= 223.07$; $DF= 29, 58$; $p< 0.01$). The least percent damage was recorded in Bhittai showing 1.50% infestation and the highest was recorded in genotype T_{21} showing 28.40% infestation, hence both these genotypes were designated as the most tolerant and the most susceptible genotypes, respectively. Genotypes Mehran-89, T_{17}, T_{16}, T_{10}, T_{18}, T_{23} and T_5 gave relatively susceptible responses as 16.57, 16.47, 13.87, 12.40, 11.60, 10.93 and 9.33% damage was recorded, respectively on these genotypes. Most of the remaining genotypes, T_7, T_6, Marvi-2000, T_4, T_{22}, T_8, T.J-83, T_{20}, T_{12}, T_9, T_{25}, T_1, T_{11}, T_{15}, T_{19}, T_3, T_2 and T_{14}, exhibited moderately susceptible responses with percent infestation of 8.63, 7.77, 7.20, 6.60, 6.17, 5.83, 5.47, 5.20, 4.90, 4.73, 4.43, 4.37, 4.23, 4.10, 4.07, 4.03 and 3.87. Rest of genotypes T_{14}, T_{24}, T_{13} and Barani-70 were categorized as relatively resistant that displayed 2.90, 2.63, 2.00 & 1.63% of infestation.

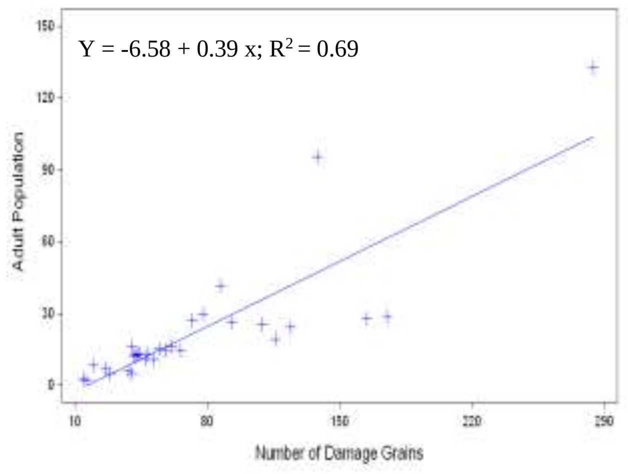

Fig. 1. Relationship between adult populaiton and number of damage grains.

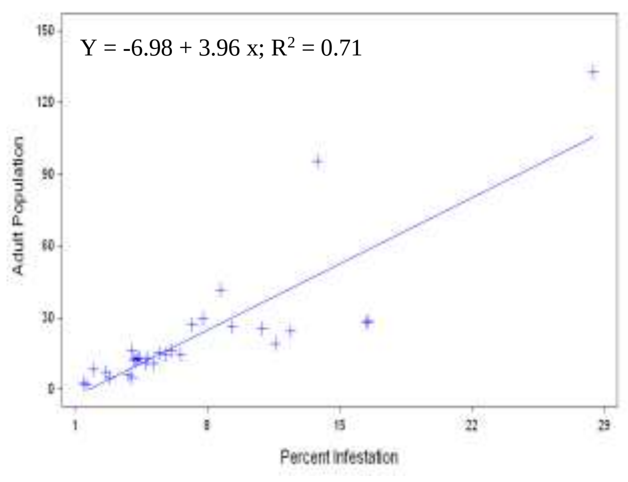

Fig. 2. Relationship between adult population and percentage infestation.

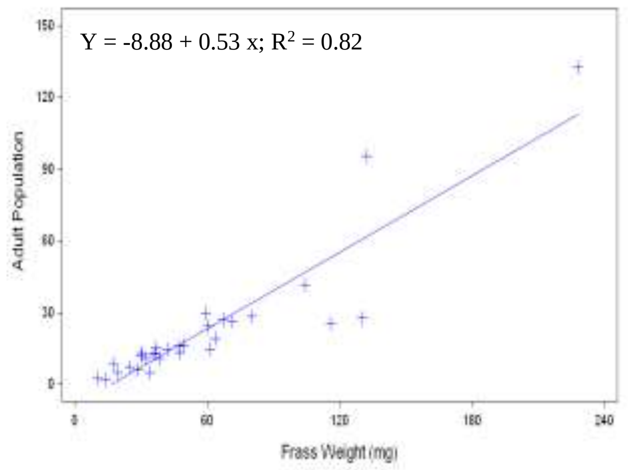

Fig. 3. Relationship between adult population and frass weight (mg).

Frass weight: Frass produced as a result of feeding by *T. castaneum* on seeds of different genotypes varied significantly (F= 17.28; DF= 29, 58; p< 0.01). Frass weight followed almost similar pattern in all the genotypes as was observed in case of percent infestation. Maximum frass material was recorded in genotype T_{21} (228.00) milligrams followed by T_{16} (132.67) milligrams and T_{17} (130.67) milligrams. The minimum frass material was found in genotype Bhittai having (10.67) milligrams followed by Barani-70 with (14.00) milligram and T_{13} (18.00) milligrams. These observations clearly proved that genotype Bhittai was most resistant and T_{21} the most susceptible amongst all the genotypes tested. All the remaining genotypes T_{23}, T_7, Mehran-89, T5, Marvi-2000, T_{18}, T_8, T_{10}, T_6, T_3, T_{25}, T_{22}, T_4, T_{20}, T.J-83, T_1, T_{15}, T_{19}, T_9, T_{12}, T_{11}, T_2, T_{24}, T_{14} and T_{13} showed frass weight in the order of 116.33, 104.33, 80.33, 71.67, 67.33, 63.67, 61.33, 60.67, 59.33, 49.33, 47.67, 47.33, 41.67, 38.33, 37.33, 36.67, 35.33, 34.33, 32.00, 30.67, 30.00, 29.00, 25.00, 19.67, 18.00 and 14.00 milligram, respectively. A highly significant correlation was recorded between percent grain infestation and frass production (Fig. 4). The grain size of different varieties in present study varied significantly (F= 40.79; DF= 29, 58 p<0.001). The highest weight of 1000 grains was recorded in variety Marvi-2000 followed by TJ-83 and T_{23} (Table 1).

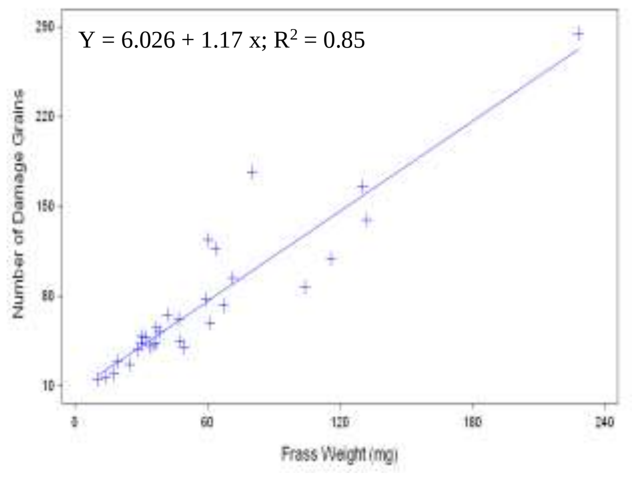

Fig. 4. Relationship between number of damage grains and frass weight (mg).

There was 100% germination in control and healthy seeds from infested treatments, whereas the germination was nil of damaged grains.

Discussion

The rate of increase in population densities and the resultant loss to stored wheat due to insect development and feeding were the two parameters used to assess the relative resistance or susceptibility of various wheat genotypes. The results of present study are in accordance with the finding of previous workers where it is concluded that each wheat variety or genetic line behaved differently to stored grain insect pests. The idea was to categorize these varieties according to their potential to resist the attack of stored grain insects under laboratory conditions. Similar studies have been conducted by different workers against red flour beetle such as Singh *et al.,* (1968), Sarin & Sharma (1977, 1982), Singh *et al.,* (1977), Bhatia (1978), Nehra *et al.,* (1985), Levchenko (1986), Bergerson & Wool (1987), Ramzan & Chahal, (1987), Tiwari *et al.,* (1989). Varietal resistance studies have also been undertaken against red flour beetle in Pakistan by various scientists such as Hamed & Khattak (1985), Ali *et al.*, (1989), Irshad *et al.*, (1991), Abro (1996), Lohar *et al.*,

(1997) and Sartaj *et al.*, (2001). These researchers evaluated different wheat cultivars, which were different from the genotypes tested during the present research.

In present study minimum *T. castaneum* population was recorded in variety Barani-70 followed by Bhattai. These varieties also showed minimum percent infestation and frass production by pest indicating that these varieties were comparatively the most resistant genotypes in present study. There was a highly significant positive correlation between adult population, percent infestation and frass production. Highly significant correlation has been reported between pest population increase and grain weight loss and grain moisture (Syed *et al*., 2001; Khan *et al*., 2005). Sinha *et al.,* (1988) examined the susceptibility of 7 wheat cultivars to 9 stored grain pest species and concluded that the susceptibility was related to kernel hardness. Irshad *et al.,* (1991) tested ten wheat varieties against red flour beetle and the total development period and larval development in red flour beetle was inversely proportional with susceptibility. Warchalewski & Nawrot (1993a) studied the population parameters of various stored grain insects including *Tribolium,* feeding on nine wheat varieties, whose physicochemical properties were analyzed. Some properties such as kernel hardness, falling number, non-protein nitrogen content and protein quality (rather than quantity) appeared to contribute towards increased wheat grain resistance. Further it was inferred that, grain hardness had close relationship with the insect resistance and protein content possibly acted through hardness changes in gluten strength. The degree of resistance and susceptibility of different wheat genotypes seemed to be dependent upon number of factors like hardness, texture, colour, and size, percent moisture content and different chemical constituents of the grain. Possibly, a combination of more than one or all the factors, play their part in making a variety resistant or susceptible to insect attack. Warchalewski & Nawrot (1993b) recorded that increased levels of non protein nitrogen had a negative effect on growth of *T. castaneum* and other insects.

Bekon & Fleurat (1992) assessed dry matter loss and frass production in 200 g wheat samples by *T. castaneum*. The average frass production varied from 27 to 44 mg per pair. Tiwari & Sharma (2002) determined the response of 60 wheat genotypes (*Triticum aestivum and T. durum*) on the growth and development of three major stored grain insect pests i.e., *Sitophilus oryzae*, *Rhizopertha dominica* and *Tribolium castaneum.* The extent of damage caused by all three insect species was significantly different and the genotypes differed significantly in their susceptibility to the same insect. The growth and development of all tested insect species was found lowest on *durum* wheat germplasm. In present study, 3 genotypes of old germplasm belonged to *T. durum* which did not show any degree of resistance against *T. castaneum*. Treatment (T2) showed moderate level of resistance against pest compared with other two genotypes. In old genotype T_9 which belonged to *T. aestivum* also showed moderate level of resistance against pest with comparatively low population growth and percent grain damage (Table 2). Ali *et al.*, (2009) screened 10 wheat varieties against *T. castaneum* and found wheat variety Marvi-2000 was the most tolerant variety with minimum pest population, percentage of infestation and frass production compared with other varieties.

The significant differences observed among the wheat varieties for different parameters in present study agree with findings of Simwat & Chahal (1982), and Ramzan & Chahal (1986), where the extent of damage in different wheat varieties has been reported to differ. Sarin & Sharma (1982) found that the resistant varieties had lower moisture and carbohydrate contents as compared with the susceptible ones.

Stored grain resistance to insects depends upon many factors such as hardness of grain (Sinha *et al.*, 1988; Singh *et al.*, 2008), moisture (Khattak *et al.*, 2000; Syed *et al.*, 2001; Khan *et al*., 2005; Syed *et al.*, 2006, Khan *et al*., 2010), chemical composition of a variety and insect species. Highly significant positive correlation has been found between carbohydrate content of store grains and insect damage and weight loss and highly significant negative correlation has been reported for protein content of stored grains and insect damage and weight loss for a number of insects (Mansha, 1985; Khan *et al.*, 2010).

In the present study, grain size was not important factor in the infestation of *T. castaneum.* The highest population of *T. castaneum* was recorded in variety (T_{21}) with medium grain size. The second highest *T. castaneum* population was recorded in T_{16}, while the lowest pest population was recorded in Barani-70. The grain size of both varieties (T_{16} and Barani-70) was almost same (Table 1). This indicated that the grain size was not important factor in the resistance of wheat grains to *T. castaneum*. Correlation studies carried out between grain size and pest population showed insignificant relationship between both parameters (r = -0.0356). Khan *et al.*, (2010) reported higher emergence of *Sitotroga cerealella* from larger grain size but the correlation between grain size and progeny was not significant (-0.053) which indicated that grain size was not an important factor.

In the present study, the seeds damaged by *T. castaneum* could not germinate. This could be due to damage caused to embryo by insect feeding. Germination of seeds becomes important consideration when the grain is stored for seed purpose. There are reports which indicate that infestation of stored grain pests adversely affect the germination of seeds (Krzymanska & Grolebiowska, 1987; Ghazdava & Deac, 1994).

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