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## Susceptibility of twelve soft wheat varieties (*Triticum aestivum*) to *Sitophilus granarius* (L.) (Coleoptera: Curculionidae)

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### ABSTRACT

The aim of study is the effect of trophic medium of twelve soft wheat varieties on the biotic potential of *S.granarius* L. After 3 months of storage under laboratory conditions at 27 ± 2 ° C and 70 ± 5% rh, have reveals that the preferred varieties for development of this species are Hidhab, Mahon Demias, Arfort and Siete Ceros. This latest was found to be the most susceptible. Growth index and loss were highest with 2.08 and 3.27% respectively. Laboratory analysis of the main grain components of the different varieties suggested that the susceptibility of these varieties to *S. granarius* infestation may be attributed to the high content of protein and low content of carbohydrate compared to resistance varieties.

**Keywords:** Soft wheat, Varietals susceptibility, *Sitophilus granarius* L., Storage losses.

### INTRODUCTION

Cereals are a major source of dietary protein for humans. The mean annual production in the world (2001-2005) of all cereals exceeded 2100 million tones (Shewry, 2007). Cereal grains, wheat in particular, are among the most important crops globally. Cereal grain losses during storage can reach 50% of total harvest in some countries, a worldwide loss quality of grain is caused by insects (Fornal *et al.*, 2007), because they have become cosmopolitan since humans began harvesting and storing (Padin *et al.*, 2002). Many variables affect grain storability (Maier *et al.*, 1997), noted that, the primary post-harvest pests of concern are insects and fungi, both of which develop as a function of temperature, moisture content and time Stored grains are an ideal food source for stored product insect pests, providing the essential elements required for continued growth and development. The levels of, carbohydrates, proteins, lipids and vitamins required varies with the species concerned (Mason *et al.*, 1997). *Sitophilus granarius* (L.) and *Rhyzopertha dominica* (F.) are well known pests of stored grains in Algeria along with some other pests

(Anonymous, 1993). Managing insect populations that infest stored commodities is a greater challenge today than previously because pesticide usage becomes more restricted. The search for environmentally safe alternatives is the focus of research in many laboratories around the world (Silhacek and Murphy, 2006). In our laboratory, we are seeking new approaches based upon the insect's behaviour. We looking at the growth of grain weevil on different processed soft wheat varieties products the insect's growth rate largely depend upon the variety providing the nutriment. Studies have shown that these methods play important role in the reduction of pest populations. Investigations by Baloch and Irshad (1986); Sarin and Sharma (1983), have revealed that all the stored grain pests exhibit the phenomenon of preference / non-preference for the grains of different varieties. Khattak *et al.* (1988), have conducted studies on progeny production and loss by *Sitophilus granarius* (L.) in different local maize varieties flour. Also, several authors Khattak and Shafique (1986), Rodrigues *et al* (1990), have tested different wheat varieties to *Sitophilus granarius* (L.). Weight loss in stored wheat due to *Rhyzopertha dominica* (F.) has been evaluated by Malagon and

Trochaz (1985), to *Sitophilus granarius* (L.) by Bekon and Fleurat-Lessard (1992). Susceptibility of wheat cultivars to *Rhyzopertha dominica* (F.), has been investigated by Batta *et al.* (2007).

Keeping in view the importance of the problem, various varieties of soft wheat were tested for their susceptibility to *Sitophilus granarius* L. The objective of this research was to evaluate susceptibility of soft wheat grain to weevil in the storage laboratory condition.

#### MATERIALS AND METHODS

The present study was conducted on the following wheat varieties; Ain Abid, Arz, Siete Ceros, Arfort, Anza, Orion, Mahon Demias, Marchouche, Sleab, Hidhab, Porengo and Binova.. These were obtained from the wheat program between Agricultural Experimental Station of the Field Crop Institute (ITGC) of Sétif (Algeria) and International Center for Agriculture Research in the Dry Areas (ICARDA) of Aleppo (Syria).

Adults of *Sitophilus granarius* L., were collected from a mass rearing under experimental conditions of temperature  $27 \pm 2$  ° C and  $70 \pm 5\%$  relative humidity. In each box, 5 couple of *Sitophilus granarius* L were placed in 100 grams of wheat grains of each variety to study on the one hand, the biological fertility and growth index of the insect and on the other hand, the physical parameter of thousand grain weight and moisture content of grain, chemical parameters of protein and carbohydrate content of grain. These boxes are covered with nets to aerate the insects under the same culture conditions. The number of repetitions is three.

To better assess fertility, we counted the number of eggs laid after 15 days. To reveal the presence of egg plugs, the method was adapted from that of Holloway (1985) in Danho *et al.*, (2000). This method involves soaking grains in warm water (25-30°C), followed by their immersion in an acid fuchsine solution at 0,5 g/l during 1-2 minutes. The grains are finally rinsed with water. The egg plugs are observed through a binocular microscope and they appear cherry red.

The observation period of larval development / total and adult emergence are followed regularly. The growth index was calculated to assess the level of sensitivity of these varieties by studying the method of antibiosis wheat varieties (Sarin and Sharma, 1983):

$$\text{Growth index} = N / D$$

Where

N: Larvae that become adult (%). D: The total development time.

Weight loss (%) was determined since the introduction of insects with the grain of wheat for each variety until adult emergence of the F1 generation. It is calculated by the method of Pointel (1980):

$$\text{WL (\%)} = \text{Wh} - \text{Wd}$$

Where

Wh = Weight healthy grains before infestation.

Wd = Weight damaged grains after infestation.

Data processing statistics are made by the software XLSTAT V7 for the analysis of the correlation matrix, the principal component analysis and the dendrogram.

#### RESULTS AND DISCUSSION

Results showed significant differences between the various of growth index of *Sitophilus granarius* L. the twelve varieties of wheat. It was comparatively higher in the variety Siete Ceros, followed by Mahon Demi, Hidhab, Arfor, Marchouch, Anza, Orion, Sleab, Ain Abid Porengo, Binova and Arz (Table 1). According Silhacek and Murphy (2006), the growth rate of *Plodia interpunctella* on different cereal products varies due to differences in availability of nutrients for insects.

An almost similar behavior was exhibited by these varieties on the basis of the number of eggs laid. These results correlate with the work of Faroni and Maria Garcia (1992), who noted that the duration of embryogenesis, larval, pupal and number of eggs laid varies according to temperature conditions, the relative humidity and the nature of the grain.

Thus, we can conclude that the varieties with the period of larval development are shorter, were more sensitive. According Trematerra *et al.*, (1999), cereal grains affects the behavior of *Sitophilus oryzae* L. and explained that they are attractive in different ways by releasing volatile substances naturally once shelled or broken.

Recently, Giacinto *et al.* (2008) showed that the antennae of adults of *Sitophilus granarius* L., detecting a wide variety of compounds such as aliphatic alcohols, aldehydes, ketones and aromas mixed with the smell of various cereal grains.

Table 1. The biological parameters of *S. granarius* L and technology varieties of soft wheat.

Parameters	Fertility	Growth index	Weight loss (%)	Weight 1000 grains	Components of grain (%)		
					Grain moisture	Protein	Carbohydrate
<b>Varieties</b>							
Ain Abid	66.82	1.14	2.1	38.32	12.33	10.15	70.98
Arz	23.35	0.69	1.39	41.50	12.35	9.27	73.70
Siete Ceros	196.12	2.08	3.27	43.43	12.02	16.63	68.06
Arfort	135.77	1.71	2.67	46.21	12.13	15.65	68.12
Anza	89.37	1.51	2.43	43.04	12.05	11.60	71.60
Orion	63.37	1.06	1.67	45.99	11.88	10.35	72.25
M.Demias	166.80	2.04	2.97	42.92	12.06	15.83	68.17
Marchouche	102.60	1.70	2.50	44.80	12.05	10.12	73.46
Sleab	77.27	1.44	2.27	45.15	12.13	11.53	70.75
Hidhab	141.0	1.94	2.67	34.97	11.89	15.62	68.25
Porenco	45.50	0.73	1.40	35.76	11.81	10.30	73.25
Binova	40.97	0.70	1.42	35.42	11.80	9.82	73.53

Other outcomes to assess the sensitivity of wheat varieties to *Rhizopertha dominica* F. Batta *et al.* (2007), suggests that resistance of these varieties can be attributed to the low protein and high in carbohydrates compared to susceptible varieties; Also, Matthew *et al.* (2006) showed that it is genetic between different varieties of wheat.

These tests showed that the variety Siete Ceros was most sensitive to *Sitophilus granarius* L. based on the weight loss of about 3, 27%. These observations are consistent with results observed with the progeny average on different cereals and confirm the good correlation between the multiplication rate and the loss recorded (Bekon and Fleurat-Lessard, 1992).

Also, the results of Barney *et al.* (1991) showed that when abiotic conditions are favorable for oviposition, larval development and emergence of the progeny of *Sitophilus zeamais* M. Therefore, ash, fat and protein

content of grain will increase relative to the weight loss of grain.

Therefore, these results are consistent with previous studies. We can conclude that each variety behaves differently to pests of stored grain. However, this aspect should be taken into account in program improvement. Thus, Khattak and Shafique (1986) evaluated wheat varieties, respectively, against *Tribolium castaneum* H. and *Sitophilus granarius* L. Sharma (2000), Saljoqi *et al.* (2002), Laskar and Ghost (2004) and Sharma *et al.* (2005) against *Sitophilus oryzae* L. But the varieties used were different from those tested in the context of the present study.

To better assess the results obtained, an analysis of the correlation matrix between the physical and technological parameters of wheat varieties and biological parameters of *Sitophilus granarius* L was performed (Table 2).

Table 2. The correlation matrix

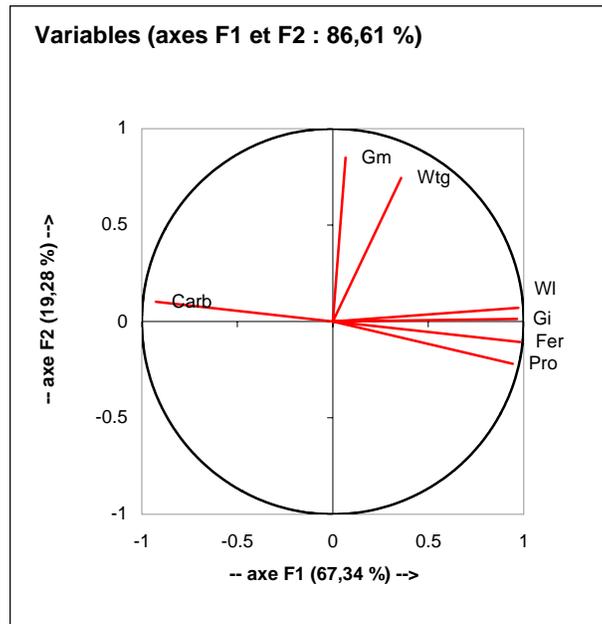
Variables	Fer	Gi	Wl	Wtg	Gm	Pro	Carb
Fer	1						
Gi	<b>0,949</b>	1					
Wl	<b>0,957</b>	<b>0,981</b>	1				
Wtg	0,282	0,364	0,374	1			
Gm	-0,038	0,042	0,127	0,367	1		
Pro	<b>0,935</b>	<b>0,851</b>	<b>0,852</b>	0,158	-0,081	1	
Carb	<b>-0,877</b>	<b>-0,827</b>	<b>-0,840</b>	-0,180	-0,073	<b>-0,953</b>	1

Fer: Fertility; Gi: Growth index; Wl: Weight loss; Wtg: Weight thousand grain; Gm: Grain moisture; Pro: Protein; Carb: Carbohydrate.

According to the correlation matrix, we retain the most significant variables in the error threshold of 5%. The correlation matrix has shown a strong correlation between different parameters. Fertility, growth index, weight loss and protein are strongly correlated, and negatively with starch content. But

the weight of thousand grains and grain moisture are independent of changes in other parameters.

The principal component analysis of the distribution of variable data on the biology of the insect and the quality of the twelve varieties of soft wheat has identified two main factors explaining 86.61% of the Total variability (figure 1).



**Fer:** Fertility; **Gi:** Growth index; **WI:** Weight loss; **Wtg:** Weight thousand grain; **Gm:** Grain moisture; **Pro:** Protein; **Carb:** Carbohydrate.

**Fig 1. Principal component analysis of the distribution of parameters on the main factor**

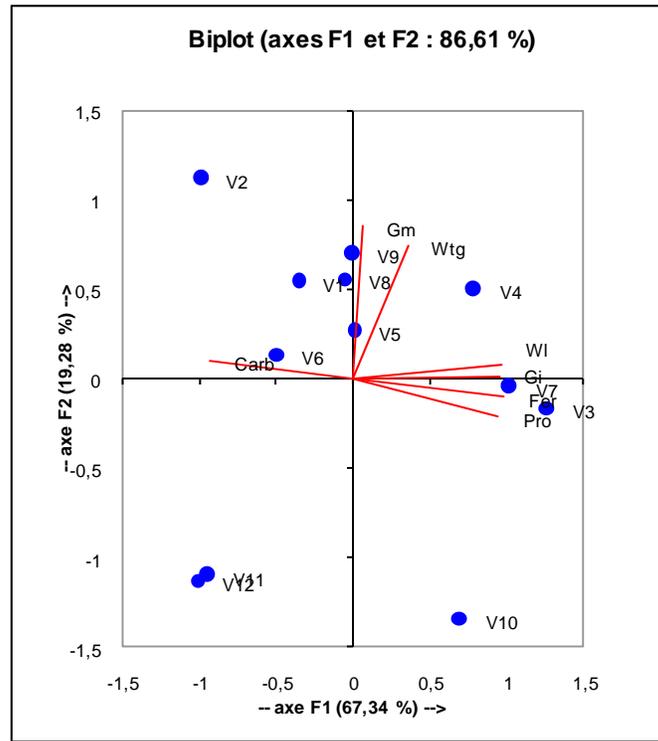
Axis 1: It represents the axis of fertility, loss of weight, growth index content of protein and carbohydrate alone explains 69.34% of the total variability.

Axis 2: It represents the axis of the grain moisture and weight of thousand grains and alone explains 19.28% of the total variability.

Moreover, the figure 2, shows clearly that the axis of fertility is positively related to weight loss, the growth

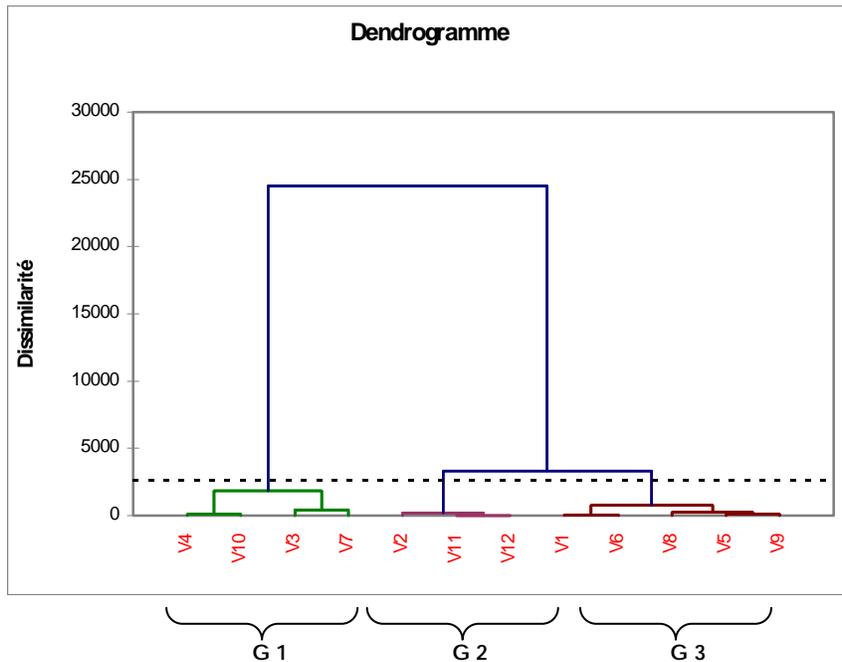
index, protein and varieties Siete Cerros and Mahon Demias and negatively with the content carbohydrate and Orion. But the axis of the grain moisture is positively related to the weight of thousand grains and varieties Sleab, Anza and Marchouche.

In addition, the hierarchical clustering of the description of the dendrogram (Figure 3) has identified 03 groups of varieties.

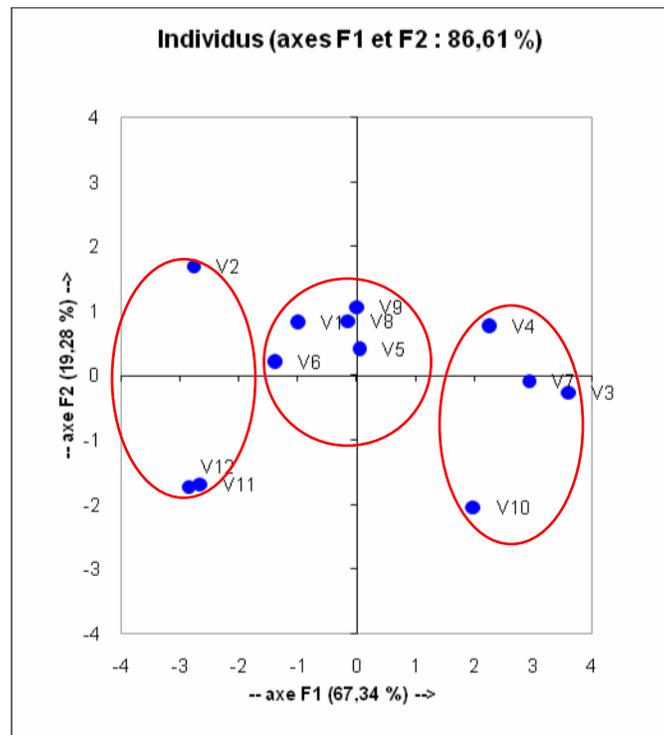


**Fer:** Fertility; **Gi:** Growth index; **WI:** Weight loss; **Wtg:** Weight thousand grain; **Gm:** Grain moisture; **Pro:** Protein; **Carb:** Carbohydrate.

**Fig 2. Principal component analysis of the distribution of parameters and varieties on the main factors.**



**Fig 3. Ascending hierarchical classification of the description of dendrogram.**



V1: Aïn Abid; V2: Arz; V3: Siete Ceros; V4: Arfort; V5: Anza; V6: Orion; V7: Mahon Demias; V8: Marchouche; V9: Sleab; V10: Hidhab; V11: Porengo; V12: Binova.

Fig 4. Principal component analysis of the distribution varieties on the factors

Table 3. Description of groups of soft wheat varieties.

Parameters Groups	Fertility (Nbres)	Growth index	Weight loss (%)	Weight of 1000 grains (g)	Grain moisture (%)	Protein (%)	Carbohydrate (%)
G1	159.92±27.68	1.94±0.16	2.89±0.29	41.85±4.80	12.02±0.1	15.93±0.47	68.15±0.08
G2	38.27±8.89	0.71±0.02	1.40±0.01	37.56±3.42	11.99±0.31	9.80±0.51	73.49±0.23
G3	79.89±16.25	1.37±0.26	2.19±0.33	43.46±3.07	12.08±0.15	10.75±0.75	71.81±1.09

Thus, three groups of varieties are distributed on the two axes F1 and F2 (Figure 4)

We notice that Group 1 is composed of varieties (Arfort, Hidhab, Siete Ceros and Mahon Demias),

group 2 varieties (Arz, Porengo and Binova) and group 3 varieties (Aïn Abid, Orion, Marchouche, Sleab and Anza). The characteristics of these groups are listed in Table 3.

Group 1 is characterized by a high fertility ( $159.92 \pm 27.68$ ) eggs, growth index ( $1.94 \pm 0.16$ ), weight loss ( $2.89 \% \pm 0.29$ ) and protein content ( $15.93 \% \pm 0.47$ ). But a low carbohydrate content ( $68.15 \% \pm 0.23$ ). We can say that this group contains varieties that are considered sensitive.

Group 2 is characterized by a low fertility ( $38.27 \pm 8.89$ ) eggs, growth index ( $0.71 \pm 0.02$ ), weight loss ( $1.40 \% \pm 0.01$ ) and protein content ( $9.80 \% \pm 0.51$ ). But a high carbohydrate content ( $73.49 \% \pm 0.23$ ). This allows us to say that this group contains varieties that are considered resistant.

Group 3 is characterized by a high thousand grain weight ( $43.46 \pm 3.07$ ), grain moisture ( $12.08 \% \pm 0.15$ ) and slightly carbohydrate content ( $71.81 \% \pm 1.09$ ). But the other parameters are low. Then, we can say that this group contains varieties that are considered moderately sensitive.

From this, we deduced that the presence of biochemical constituents within twelve varieties of wheat that will allow or prevent the development of this pest and, in the presence or not of substance acting at the both factors as repellents and biochemical inhibitors.

These results imply that stored grain managers should be aware of potential differences in susceptibility, attributable to wheat varieties, to *Sitophilus granarius* L infestation.

## CONCLUSION

For a better approach of control of this pest, this study revealed on the one hand, that all the stored grain exhibit the phenomenon of preference / non-preference for the grains of different varieties. This phenomenon is due in the structure and composition of soft wheat such as, starchs, carbohydrates, enzymes (Evers *et al.*, 1999 ); proteins (Gupta *et al.*, 2000); on the other hand, brings new elements for their susceptibility/resistance to the harmful specie to the grains stored in semi-arid zone of Setif, Algeria. It seems that susceptibility to the attacks of *Sitophilus granarius* L., is reached at the Siete Ceros, Arfort, Mahon demias and Hidhab varieties; whereas the resistant varieties are respectively Arz, Porenco and Binova. However, in addition to food proteins, there exists naturally in corn, the substance of proteinic nature inhibiting the action of the proteases of the insects (Piasecka *et al.*, 2005). It would be desirable to carry out technological analysis by studying food modulation of the activity of enzymes purified from the insect by natural inhibitors in cereals to find

favorite foods and responsible development of these granivorous, and aimed to identify and create new varieties of soft wheat resistant. Such resistant varieties could be therefore selected for using in breeding programs for developing varieties resistant to *Sitophilus granarius*.

## REFERENCES

- Anonymous, (1993). Investigation on insects stored food of cereals and dry vegetables in Algeria. Nat. Inst. Plant. Prot, Algiers, 7p.
- Baloch, U.K. and Irshad, M (1986). Post-harvest Research on Food Grains. Rev Crop Sci, Division, Pakistan Agric. Res. Coun., Islamabad, 45 p.
- Batta, Y., Saleh, A. and Salameh, S (2007). Evaluation of the susceptibility of wheat cultivars to lesser grain borer (*Rhyzopertha dominica* F.), (Coleoptera: Bostrichidae). Arab. J. Pl. Prot. 25: 159-162.
- Barney, R.J., Sedlacek, J.D., Siddiqui, M. and Price, B.D (1991). Quality of stored corn (maize) as influence by *Sitophilus zeamais* (Motch.) and several management practices. J. Stor. Prod. Res. 27: 225-237.
- Bekon, K.A. and Fleurat-Lessard, F (1992). Assessment of dry matter loss and frass production in cereal grain due to successive attack by *Sitophilus oryzae* (L.) and *Tribolium castaneum* (Herbst.). Insect. Sci. Applic. 13: 129-136.
- Danho, M., Haubruge, E., Gaspar, C. and Lognay, G (2000). Selection of grain-host by *Prostephanus truncatus* (Coleoptera: Bostrichidae) in the presence of *Sitophilus zeamais* (Coleoptera: Curculionidae) previously infested grains. Belg. J. Zool. 130: 1-9.
- Evers, A.D., Blakeney, A.B. and O'brien, L (1999). Cereal structure and composition. Aust. J. Agri. Res. 50: 629-650.
- Faroni, L.R.A. and Garcia-Maria, Y.F (1992). Influence of temperature on biological parameters of *Rhyzopertha dominica* (F.). Bol. San. Veg. Pest. Spanish. 18: 455-467.
- Fornal, J., Jelinski, T., Sadowska, J., Grunda, S., Nawrot, J., Niewiada, A., Waechalenski, J.R. and Blaszczyk, W (2007). Detection of granary weevil *Sitophilus granarius* L., eggs and internal stage analysis. J. Stor. Prod. Res. 43: 142-148.
- Giacinto, S., Cristofaro, G.A. and Rotundo, G (2008). Behavioral responses of adult *Sitophilus granarius* L. to individual cereal volatiles. J. Chem. Ecol. 34: 523-529.
- Gupta, A.K., Bahal, S.R., Awasthi, B.K and Verma, R.A (2000). Reaction of protein, starch and ash constituent of different varieties of maize on growth and development of *Sitophilus oryzae* L. Indian. J. Entomol. 62: 375-381.

- Kattak, S.U., Zeb, A., Khatoon, R. and Khan, A (1988). Studies on the progeny production and losses by *Tribolium castaneum* (Herbst.) in different local maize varieties flour. Sarhad J. Agric. 4: 313-316.
- Kattak, S.U. and Shafique, M (1986). Varietal susceptibility studies of ten wheat cultivars flour to *Tribolium castaneum* (Herbst.) (Coleoptera: Tenebrionidae). Pakistan J. Zool. 18: 257-261.
- Laskar, N. and Ghosh, S.K (2004). Relative susceptibility of some wheat *Triticum aestivum* L. against *Sitophilus oryzae* L. Environ. Ecol. 22: 411-413.
- Maier, D.E., Rulon, R.A. and Mason, L.J (1997). Chilled versus ambient aeration and fumigation of stored popcorn; Part 1: Temperature management. J. Stor. Prod. Res. 33: 39-49.
- Malagon, M.E. and Trochaz, P.A (1985). Evaluation of weight loss in stored wheat caused by lesser grain borer, *Rhyzopertha dominica* (F.) and observations on its life cycle under laboratory conditions. Acta Agron, 35: 78-90.
- Masson, L.J., Rulon, R.A. and Maier, D.E (1997). Chilled versus ambient aeration and fumigation of stored popcorn. Part 2: Pest management. J. Stor. Prod. Res. 33: 51-58.
- Matthew, J., Broughton, N. and Dunkel, F.V (1990). Interactions of genetic traits, agronomic conditions and prior insect damage on post-harvest insect resistance in Montana hard wheat varieties. Depart. Entomol. Montan. Univ. Bozeman. 49 p.
- Rodrigues-Cobos, C., Haubruge, E. and Gaspar, C (1990). Susceptibility of grains to several varieties of wheat, *Triticum aestivum* (L.) to *Sitophilus granarius* (L.) (Coleoptera: Curculionidae). Med. Fac. Landbouw. Rijkuniv.Gent. 55: 395-404.
- Padin, S., Bello, G.D. and Fabrizio, M (2002). Grain loss caused by *Tribolium castaneum*, *Sitophilus oryzae* and *Acanthoscelides obtectus* in stored durum wheat and bean treated with *Beauveria bassiana*. J. Stor. Pro. Res. 38: 69-74.
- Piasecka, K.D., Gawlak, M., Niewiada, A., Nawrot, J., Warshalewski, J.R., Fornal, J. and Grundas, S (2005). An effect of chemical properties of three wheat grain varieties on feeding intensity and developmental parameters of the granary weevil (*Sitophilus granarius* L.).Progr. Plant. Prot. 45: 982-985.
- Saljoqi, A.U.R., Afridi, M.K., Sajjad, A. and Abdur, R (2002). Relative resistance of some wheat cultivars to *Sitophilus oryzae* L. in stored wheat grains. Sarhad. J. Agr. 18: 237-240.
- Sarin, K. and Sharma, K (1983). Study of antibiosis in wheat varieties. Part I. Correlation of diapause and growth index. Bull. Grain Tech. 21: 24-30.
- Sharma, R.K (2000). Studies on relative resistance of some maize varieties to *Sitophilus oryzae* L. Ann. Agr. Res. 21: 145-147.
- Sharma, R.P., Mohamad, M., Paul, S.K., Amitava, B. and Maity, S (2005). Susceptibility of different varieties of wheat against *Sitophilus oryzae* L. (Coleoptera: Curculionidae). Envir. Ecol. 23: 90-91.
- Shewry, P.R (2007). Improving the protein content and composition of cereal grain. J. Cereal. Sci. 46: 239-250.
- Silhacek, D. and Murphy, C (2006). A simple wheat germ diet for studying the nutrient requirements of the Indian meal moth, *Plodia interpunctella* (H.). J. Stor. Prod. Res. 42: 427-437.
- Trematerra, P., Fontana, F., Mancini, M. and Sciarretta, A (1999). Influence of intact and damaged cereal kernels on the behaviour of rice weevil, *Sitophilus oryzae* L. (Coleoptera: Curculionidae). J. Stor. Prod. Res. 35: 265-276.