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Biochemical Composition Effect of the Some Cereal Species' on the Behaviour of *Sitophilus granarius* L. and *Rhyzopertha dominica* F. Species in Semi-Arid Zone of Setif, Algeria

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Abstract: The aim of this study is the effect of the trophic medium on the biotic potential of the two species, *Sitophilus granarius* L. and *Rhyzopertha dominica* F. and the relationship between biological observations and the quantitative loss induced by the development of insects. The quality and sensibility of cereals influential the behaviour of the 2 pests. The average descent was influenced by the cereal type. Therefore, in specific mono-population, the average emergence per day, for the corn, varies from 0.61 for *S. granarius* L. to 0.12 for *R. dominica* F.; on the other hand for the soft wheat, it varies from 4.35 to 5.81, respectively. Whereas, in hetero-specific population, sensibility of the various cereals types to the attacks by *R. dominica* F. increases in the presence of *S. granarius* L., for an initial rate of infestation of 2 couples. The reverse was observed if the rate of infestation was doubled. The longest duration of development was observed for the corn with 40 and 55 days for *S. granarius* L. and *R. dominica* F., respectively. Shortest was recorded for the rice with 28 and 42 days for both. The highest loss of dry matter, in soft wheat with 4.74 and 6.09% for *R. dominica* F. and *S. granarius* L., respectively, while in corn was less than 1%.

Key words: Cereals, biochemical compositions, sensibility of grain, dry matter losses, behaviour, *Rhyzopertha dominica*, *Sitophilus granarius*

INTRODUCTION

Cereals are the 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 grain losses during the storage can reach 50% of total harvest in some countries, a worldwide loss equivalent to thousands of millions of Euros per year (Fornal *et al*., 2007). The major part of this quantity and quality loss of grain, is caused by insects (Madrid *et al*., 1990; White, 1995; Lee *et al*., 2003; Fornal *et al*., 2007), because they have become cosmopolitan since humans began harvesting and storing (Padin *et al*., 2002).

The very serious primary pest of stored grain product are the granary weevil, *Sitophilus granarius* L. (Rees, 1996) and the lesser grain borer, *Rhyzopertha dominica* F. (Menon *et al*., 2002). The granary weevil larvae feed and develop into the kernels (Niewiada *et al*., 2005); while the lesser grain borer inside the kernels (Arthur, 2004). Also, during the grain storage, the infestation by pest follow a theoretical schema accepted by most of the storage entomologists: attacks by primary results in important alterations in the external coat seeds, which predispose seeds to damage by less dangerous secondary pests. Investigation have revealed that all the stored grain pest exhibit the phenomena of preference/non preference for the grains of different varieties (Irshad *et al*., 1991). Moreover, several research tasks were the subject of the study of the alimentation modulation of the activity of the purified enzymes starting from the insects by the natural inhibitors existing in cereals; in order to find preferred and responsible alimentation for the development of these pests (Baker *et al*., 1991; Baker, 1992; Feng *et al*., 1996). Also, the wheat represents a particular technological importance, because it was the only cereal which contains the gluten with the plastic characteristics, allowing the manufacture of several foodstuffs (Thoumy, 1995). Thus, the physico-chemical characters of medium and alimentation have a great importance for the development of the insects of stored grains. Keeping in view, the importance of the problem, we are seeking new

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approaches based upon the effect of the trophic medium on the biotic potential of the two species, *S. granarius* L. and *R. dominica* F. placed separately or in competition. We also report, the relationship between biological observations and the quantitative loss induced by the development of the insects during only one generation. Aim of this study is to understand the phenomenon of preference/non preference for the grain of different cereals and to evaluate their susceptibility/resistance to *S. granarius* L. and *R. dominica* F. for the development of durable resistance against pests.

MATERIALS AND METHODS

This study was carried out at the Plant Protection Laboratory of Setif University during 2004 to 2006. The durum wheat (*Triticum durum*) grains (Vitron), soft wheat (*Triticum aestivum*) (Hidhab), barley (*Hordeum vulgare*) (Pleasant), corn (*Zea maïs*) and rice (*Oryza sativa*) ordinary are taken from the Agricultural Experimental Station of the Field Crop Institute (ITGC), Algeria. Two insect species (*S. granarius* L. and *R.dominica* F.) were used. Of each cereal, 80 g were put in plastic box (5×10 cm), infested by *S. granarius* L. and *R. dominica* F. in the following way (Farjan, 1983). In mono-specific population (4 couples of each species) and in hetero-specific population (4 couples and 2 couples of each species separately). Four replications were carried out for each treatment. The breeding enclosures were placed in a room at a constant temperature of 30±5°C and 70±2% of relative humidity (Golebiowska, 1969). So, the adult insects which were used for the infestation were isolated after 12 days from egg-laying and the grains left again under the same conditions until the adults of the second generation start to emerge (Delobel and Tran, 1993). The enumeration of the adults was made twice per week until the stop of emergences. The criteria observed initially are the average number of descendant, according to the Adams and Schulten (1978) method's the average duration of development and the dry matter loss. Then, we sought the effect of certain nutritional substances in the cereal grains by biochemical analysis such as protein, cellulose, carbone and lipids (Godon and Loisel, 1984). Obtained data were subjected by using GenStat software version 11.1.0.1557-2008.

RESULTS AND DISCUSSION

Viable average descent by female

Influence vegetable species on the descent of the 2 species: We used this criterion to estimate the susceptibility of various cereals to the attack by the 2 studied species. According to Table 1, it is clear, that the average descent of the two species is significantly influenced by the type of cereal. In specific mono-population, average emergence per day, for the corn, varies from 0.61 for *S. granarius* L. to 0.12 for *R. dominica* F., on the other hand, for soft wheat, it varies from 4.35 to 5.81, respectively.

In this knowledge, we note that the barley grain covered of its cellulose envelopes unfavourable at the weevil. Whereas, it does not seem to be a disadvantage for *R. dominica* F. It is the reverse, which occurs for the rice but it is also the cereal lowest in nitrogen matter. This results are in correlation with workings of Faroni and Garcia-Maria (1992), that noted as duration of embryogenesis, larval stages, nymphals and the number of eggs laid varies in depending on the conditions of temperature, relative humidity and the nature of cereal. The Friedman test of discrimination and classification makes it possible to highlight significant differences the threshold in 5% of error between cereals for the two species of insects (χ^2 = 14.61 for *R. dominica* F. and χ^2 = 12.33 for *S. granarius* L.).

For *R. dominica* F., the average descent by female per day varies with the various cereals, which can be classified by the Kramer test in 2 groups with the threshold of error of 5% (GenStat Eleventh Edition):

- The group with corn whose average descent by female and day varies from 0.08 at 0.16
- The group consisted with durum wheat, soft wheat, barley and the rice of which the average descent by female and day lies between 1.3 and 5.8

For *S. granarius* L., the same test enables us to form three groups of cereals according to the number of emerged insects (GenStat Eleventh Edition):

- The corn with which the viable average descent varies from 0.37 to 0.61
- The group formed by durum wheat, the barley and rice where the viable average descent varies from 2.3 to 3.9
- The soft wheat where the viable average descent is higher than 3.9

Thresholds of significance differences (at p = 0.05) between cereals proposed in comparison with the corn reference cereal, show that *S. granarius* L. and *R. dominica* F. are no significance differences for durum wheat, corn and rice; but for soft wheat we note highly significance differences for grain weevil and significance differences for lesser grain borer.

Influence of the co-existence of *S. granarius* L. and *R. dominica* F.: The sensitivity of the various types of cereals to the attacks by *R. dominica* F. increases in the presence of *S. granarius* L., for an initial rate of infestation of two couples of *S. granarius* L. and two couples of *R. dominica* F. by 80 g; but the inverse phenomenon is observed, *R. dominica* F. decreases in the presence of *S. granarius* L. if the rate of infestation is doubled (Table 1). Hence, the average descent of *S. granarius* L. is not significantly affected by the presence of *R. dominica* F. Weston and Rattingourd (2000), showed that the effects on infestation of maize by *Sitotroga cerealella* O. on progeny production by two common secondary colonizers of grain, *Tribolium castaneum* H. and *Oryzaephilus surinamensis* L. reached highest numbers. The statistical analysis by the Friedman test support this observation ($\chi^2 = 9.33$). It involves the fact that the interaction between these two species is favourable for *R. dominica* F. to a density of an insect by 10 g. Under these conditions, it seems that the holes of alimentation of the adults of *S. granarius* L. facilitate the penetration of the larva of the first and possibly of the second stage of *R. dominica* F. inside the grain. Thresholds of significance difference (at $p = 0.05$) of the interaction between the monospecific and heterospecific populations of *S. granarius* L. and *R. dominica* F. show that for lesser grain borer, no significance differences for one population of 4 couples and 2 couples; for grain weevil, highly significance differences for one population of 4 couples.

Therefore, larval mortality could be considerably reduced. The reduction in the number of adults emerged with a double rate of infestation can be explained by a competition between the females of the 2 species for the research of the site of egg-laying and an increase in consecutive larval mortality. In the same sense, Giga and Canhao (1993) showed the effects of intraspecific and interspecific competition between *Prostephanus truncatus* H. and *Sitophilus zeamais* M. in maize at 25 and 30°C and the reproduction curves were different in form. Both species were adversely affected by competition interactions. Moreover, Danho *et al.* (2000) confirmed that there was a real competition between the lesser grain borer and the maize weevil. These results showed that the larger grain borer damaged indiscriminately both infested and uninfested grains. Therefore, the deterrent effect of *S. zeamais* M. against *P. truncatus* H. was also associated with the existence of substances deposited on the grain surface by adult weevils.

Average duration of development: Analysis of results in Table 2 shows that the average duration of development varies according to the type of cereal. The longest duration of development is observed for the corn with 40 and 55 days for *S. granarius* L. and *R. dominica* F., respectively. The shortest duration is recorded for the rice with 28 and 42 days for the 2 species. According to Trematerra *et al.* (1999), the kernels of cereals affects the behaviour of *S. oryzae* L. and explained that the

Table 1: Average progeny by female and per day according to the type of cereal (30°C and 14% of water content)

	Populations					
	Monospecific		Heterospecific			
	S. granarius (4 couples)	*R. dominica* (4 couples)	*S. granarius* + *R. dominica* (2 couples + 2 couples)		*S. granarius* + *R. dominica* (4 couples + 4 couples)	
Cereals						
Durum wheat	3.71	3.02	2.40	4.08	2.25	2.20
Soft wheat	4.35	5.81	4.47	5.24	3.89	4.02
Barley	2.36	5.29	3.09	8.06	2.35	4.81
Corn	0.61	0.12	0.43	0.16	0.37	0.08
Rice	3.86	1.89	2.45	1.86	3.06	1.30

Table 2: Average duration of development in days of *S. granarius* L. and *R. dominica* F. according to the type of cereal

	Populations					
	Monospecific		Heterospecific			
	S. granarius (4 couples)	*R. dominica* (4 couples)	*S. granarius* + *R. dominica* (2 couples + 2 couples)		*S. granarius* + *R. dominica* (4 couples + 4 couples)	
Cereals						
Durum wheat	30.1	44.3	30.80	44.5	29.30	45.6
Soft wheat	35.3	49.2	35.00	49.5	36.25	49.7
Barley	31.2	47.0	34.30	48.6	31.70	46.4
Corn	40.4	55.1	40.50	57.5	40.50	55.6
Rice	27.9	42.2	28.63	43.6	28.10	42.7

cereals are attractive in different ways; naturally dehulled and hulled cereals release volatile substances once artificially dehulled or split. Thus, in order of decreasing attraction are: the germ part, the kernel endosperm without the germ, the kernel pericarp layers, etc. Recently, Giacinto *et al.* (2008) showed that the antennae of *S. granarius* L. adults detect the odor blend such as, aliphatic alcohols, aldehydes, ketones and aromatics of various cereal grains. The statistical analysis by the Friedman test using GenStat eleventh edition, gave significant results between the durations of development observed for the five cereals tested ($\chi^2 = 14.61$; $\chi^2_{0.05} = 12.59$ for *S. granarius* L. and $\chi^2 = 13.09$; $\chi^2_{0.05} = 12.59$ for *R. dominica* F. The analysis of the significant differences by the Kramer test, enable us to distinguish with the threshold from error from 5%, three groups from cereals for the weevil and only two groups for the lesser grain borer from the grains:

- **For *S. granarius* L.:** First group (rice); second group (soft wheat, barley and durum wheat); third group (corn)
- **For *R. dominica* F.:** First group (rice, soft wheat, barley and durum wheat); second group (corn)

Also, thresholds of significance differences at (p = 0.05) recorded on the average duration of the development when *S. granarius* L. and *R. dominica* F. are nourished from various cereals in comparison with rice as reference cereal, show that for lesser grain borer and grain weevil, no significance differences for durum wheat, soft wheat and barley; very highly significance differences for the corn. These results show that the classification of the development duration according to vegetable species was appreciably same whatever the species. So, we sought the effect of certain nutritional substances on the development and the average descent by female. According to Silhacek and Murphy (2006), the growth rates of Indian meal moth, *Plodia unterpunctella* H., on different cereal products varies widely indicating product related differences in nutrient availability for the insects. For that, the biochemical analysis in the cereal grains were carried out (Table 3). Possible combinations two by two of the content of some nutrients were analyzed by the method of the multiple correlations. Consequently, it proved that 2 substances act significantly on the biotic performances of the two species to knowing the lipid content and cellulose. The influence of the two factors over the development duration results in the 2 significant curves of equations:

$$Z_1 = 3.71x + 1.02y + 34.72$$
$$Z_2 = 3.53x + 0.68y + 21.57$$

For which Z_1 and Z_2 are the development duration of *R. dominica* F. and *S. granarius* L., respectively expressed in day; x and y being lipid contents and of cellulose, respectively (coefficient of correlation $r^2 = 0.75$ for *R. dominica* F. and $r^2 = 0.66$ for *S. granarius* L. to the threshold of error of 1%). It is clear according to the two equations that more the cellulose and lipid contents, was high more the cycle duration of development was long. It seems that the effect of the lipid content is appreciably the same one for the two species of insects (coefficients are 3.71 and 3.53). It should be announced that if the content cellulose acts in the same direction for the 2 species by increasing their development duration, its action on the viable descent by female was the same one in absolute value (the same coefficient) but with a contrary sign. The two equations, which translate this phenomenon are determined by GenStat Eleventh Edition:

$$Z_1 = 5.30 - 1.30x + 0.42y, \text{ for } R.\ dominica \text{ F.}$$
$$Z_2 = 7.41 - 1.18x - 0.46y, \text{ for } S.\ granarius \text{ L.}$$

For which Z_1 and Z_2 represent the development durations of *R. dominica* F. and *S. granarius* L., expressed in day respectively; x and y being lipid content and of cellulose, respectively (coefficient of correlation $r^2_1 = 0.59$ for *R. dominica* F. and $r^2_2 = 0.92$ for *S. granarius* L. to the threshold of error of 1%).

Moreover, the increase in the content cellulose results in an increase in the viable descent of *R. dominica* F. and a reduction in the viable descent of *S. granarius* L. This observation go in the same analysis of Anan and Pant (1980), they attested that the lesser grain borer can profit from the favourable action of symbiontes of the digestive tract which have an action recognized on the assimilation of the cellulose (character of Bostrichidae). At the weevil, whose larvae can be nourished exclusively with gluten and starch complemented in vitamins and rock salt, the digestion of cellulose was not possible. The depressive effect

Table 3: Analysis of the compositions' of different cereal species (content in g/100 g)

Compositions	Soft wheat	Durum wheat	Corn	Barley	Rice
Proteins	12.80	15.53	12.22	12.87	8.97
Cellulose	2.90	2.70	3.00	6.10	1.70
Carbone	43.55	43.22	45.76	43.73	43.61
Lipids	1.70	2.10	4.50	1.90	2.20

Table 4: Dry matter loss (%) induced by the development of the average progeny of *S. granarius* L. and *R. dominica* F.

	Populations			
	Monospecific		Heterospecific	
Cereals	*S. granarius* (4 couples)	*R. dominica* (4 couples)	*S. granarius* + *R. dominica* (2 couples + 2 couples)	*S. granarius* + *R. dominica* (4 couples + 4 couples)
Soft wheat	4.74	6.09	4.45	4.01
Corn	0.96	0.26	0.34	0.40
Barley	2.63	3.97	5.34	2.95
Durum wheat	3.72	1.95	3.27	2.40
Rice	3.76	2.31	2.59	1.98

on the average number of descendants of the grains with strong content cellulose (barley and rice) was thus not due randomly. For the lipids, the depressive effect generally exists for many insects' species of the stored alimentation, products. In this case, the corn which is the seed richest in lipids and also that gives the weakest multiplication. The same result was observed on *Trogoderma granarium* E. on wheat, maize and sorghum (Jood *et al*., 1996). Several Nawrot *et al*. (1995) researchers explain that lipids in kernels become oxidized over time, thus liberating volatiles that may influence the movement of stored-product insects toward or away from the grain. Other results obtained to evaluate the susceptibility of wheat cultivars to the lesser grain borer; Batta *et al*. (2007) suggested that the resistance of these cultivars may be attributed to the low content of protein and high content of carbohydrate compared to susceptible cultivars; Matthew *et al*. (1990, 2006) showed that is genetic between different variety of wheat.

Dry matter loss: Results analysis shows in Table 4, that the dry matter loss induced by the average descent development of the two insects' species depends on infested cereal. The highest loss was observed for the soft wheat of two insects with 4.74 and 6.09% for *R. dominica* F. and *S. granarius* L., respectively. The corn was the least damaged cereal; the recorded dry matter loss was less than 1% with the two species. These observations are in agreement with the results observed with the average descent on various cereals and confirm the good correlation between the multiplication rate and the recorded loss (Bekon and Fleurat-Lessard, 1990). Also, the results of Barney *et al*. (1991) showed when abiotic conditions were favourable for *S. zeamais* M. oviposition, larval development and progeny emergence; the ash, lipid and protein content of the kernels was increased, as was kernel weight loss.

CONCLUSION

Managing insect population that infested stored commodities is a greater challenge today, than previously because pesticide usage becomes more restricted. For a better approach of control, this study revealed on the one hand, that all the stored grain exhibit the phenomenon of preference/non-preference for the grains of different cereals. This phenomenon is due in the structure and composition of cereal such as, starch, protein, carbohydrates, enzymes etc. (Evers *et al*., 1999) and on the other hand, brings new elements for their susceptibility/resistance to the two harmful species to the grains stored in semi-arid zone of Setif, Algeria. In this context, available information on the mechanisms of resistance to pests in cereals is discussed by Chandrashekar and Satyanarayana (2006). The resistance of sorghum to insects is due in the chemical and physical composition of the grain. Thus, phenolic compounds such as ferulic acid and tannins are potent inhibitors of the insects. Moreover, grain hardness is a major deterrent to infection. Prolamins, constitute a physical barrier since they are resistant to digestion by insects. Also, an understanding of the natural mechanisms of resistance in the grain is paramount for the development of durable resistance against pests.

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