

Full Length Research paper

Population growth of *Cathartus quadricollis* (Guerin-Meneville) (Coleoptera: Silvanidae) in products stored at different temperatures

Adalberto Hipólito Sousa^{1*}, Lêda Rita D'Antonino Faroni², Fernanda Rezende¹, Marco Aurélio Guerra Pimentel¹ and Gutierrez Nelson Silva²

¹Departamento de Biologia Animal, Universidade Federal de Viçosa, Viçosa, MG 36570-000, Brazil.

²Departamento de Engenharia Agrícola, Universidade Federal de Viçosa, Viçosa, MG 36570-000, Brazil.

Accepted 19 October, 2009

This study aims to assess the influence of temperature and food type on the instantaneous population growth rate of *Cathartus quadricollis* (Guerin-Meneville). r_i was evaluated at 20, 25, 30 and 35°C in association with broken maize, wheat, sorghum and rice, maize flour and wheat bran. The optimum development temperature was also estimated for each food. The instantaneous growth rate of *C. quadricollis* was influenced by temperature and food type. r_i values were low at the 20°C in all food types and increased at 25°C. There was a slight reduction at 30°C, but there was no insect development at 35°C, except for maize flour, with low r_i (instantaneous population growth rate) values. Optimum temperature for *C. quadricollis* growth ranged from 26.26 to 27.14°C for the most suitable foods (broken maize, wheat and sorghum and maize flour). Under favorable conditions of food and temperature, *C. quadricollis* showed high population growth values in relation to other stored-product pests, indicating that this species has reproductive potential to become an important stored-product pest.

Key words: Reproductive parameters, environmental conditions, food type.

INTRODUCTION

Square-necked grain beetle, *Cathartus quadricollis* (Guerin-Meneville) is considered a secondary pest when coexisting with primary pests such as *Sitophilus oryzae* (Linnaeus), *Callosobruchus maculatus* (Fabricius), *Rhyzopertha dominica* (Fabricius) and *Sitotroga cerealella* (Olivier) (Allotey and Morris, 1993). However, its importance has been disclosed in recent years by situations where its infestation was second to *Prostephanus truncatus* (Horn) and outnumbered species like *Sitophilus zeamais* (Motschulsky), *Tribolium castaneum* (Herbst), *Carpophilus dimidiatus* (Fabricius) and *Cryptolestes ferrugineus* (Stephens) (Pacheco and Paula, 1995; Rees, 1996; Loeck, 2002).

In warm temperature and tropical areas, such as the Southern United States, Central and South America, and West Africa, *C. quadricollis* infests maize in the field and

is very common in the tropics as a pest of farm-stored maize in subsistence farming (Faroni and Sousa, 2006). In Brazil, *C. quadricollis* infestation is also more common in the field. Picanço et al. (1994) recorded varying intensity of *C. quadricollis* infestation in field conditions in 49 Brazilian open-pollinated maize collected in the states of Espírito Santo, Minas Gerais, Paraná, Rio Grande do Sul and Santa Catarina. Recently, we have observed in our laboratory Brazilian *C. quadricollis* populations infested grains collected from food commodities from the municipalities of Aguanil and São Miguel do Anta (State of Minas Gerais, Brazil) and Nova Xavantina (State of Mato Grosso, Brazil). However, there are no reports confirming the establishment of Brazilian populations of *C. quadricollis* adapted to storage environments.

Identifying the species and having knowledge of the biology of stored-product pest insects are crucial to design integrated management strategies (Hagstrum et al., 1996). Under optimum environmental and feeding conditions, these insects usually have high biotic potential and may even cause total loss of the infested products (Faroni

*Corresponding author. E-mail: adalbertohipolito@hotmail.com, adalberto.sousa@ufv.br. Tel: (+55) (31) 3899-1919. Fax: (+55) (31) 3899-2735.

et al., 2004). Hence, the suitable use of pest management techniques requires a knowledge of the biology of the species. Such information is important to determine the pest status of a given insect species and decide the moment a control method should be used (Gracioli et al., 1998; Caldas et al., 1999). Moreover, knowledge of pest biology can also be useful to keep a given pest under laboratory conditions (Prattisoli et al., 2007). This kind of information is virtually non-existent for *C. quadricollis*.

Some of the primary factors governing insect abundance are temperature, moisture, and food availability and quality. Environmental factors and food, influence insect abundance through their effects on insect developmental times, survival and egg production. According to Ileleji et al. (2007), stored-product pests are primarily thermophilic in nature, that is, their growth and survivability are greatly influenced by temperature. The optimum developmental range of many stored-grain insects is approximately 25 -35°C (77 - 95°F) (Fields, 1992). But in rural storages, which are not usually airtight, insects as well as storage grains are continuously subject to variations in temperature because storage temperature fluctuates with the outside environment (Prakash and Rao, 1986).

Because stored-product pest insects are polyphagous, that is, they feed on several types of products; there are few studies on the influence of diet on such insects. This may be a misconception because some species have preferences or dietary restrictions for specific food products. According to Ileleji et al. (2004), the type of food used by insects considerably affects their reproductive performance, and for this reason, extensive data are available on the effect of these factors on reproductive parameters, predicting phenological events in the insect life cycle and population trends of insect species. The preference for certain foods can be associated with their physical or nutritional attributes, which modify behavioral responses or negatively affect the development or survival of insect pest species (Throne et al., 2000). For instance, Osuji (1982) observed that *R. dominica* larvae developed more rapidly when fed on germ than on the endosperm of maize because of the higher nutritional value of the former.

Given that knowledge of the factors affecting the biology of stored-product pest insects is important to design control strategies, this study aims to assess the influence of temperature and food type on the instantaneous population growth rate of *C. quadricollis*.

MATERIALS AND METHODS

The reproductive potential of *C. quadricollis* was assessed in different food types and temperature ranges by determining the instantaneous population growth rate (r_i) in each diet and temperature. Such rate is a direct measure of population growth during a given period of time. It varies similarly to the intrinsic population growth rate (r_m) and can be used to predict the population growth of arthropods (Walthall and Stark, 1997). The main advantage

of calculating r_i rather than r_m is that there is no need to design a fertility life table (Stark and Banks, 2003).

The insects were collected from maize grains at a warehouse in the city of Aguanil, State of Minas Gerais, Brazil, in 2008. Insect species were analyzed and identified as *C. quadricollis* (Guerin-Meneville) (Coleoptera: Silvanidae) according to Pereira and Almeida (2001). These insects were reared in glass jars (1.5 L) at 30 ± 2°C, 70 ± 5% relative humidity (Rh), and in continuous darkness. Broken maize grains (13% moisture content) were used as the food source. Grains were disinfested by storage at -18°C for at least 1 month prior to use to avoid initial infestation.

The r_i value was evaluated at 20, 25, 30 and 35°C in association with broken maize, wheat, sorghum, and rice, maize flour and wheat bran. These food products were used because they were the main source of infestation foci of *C. quadricollis* in the stored-product samples received by our laboratory between 2004 and 2008. The bioassays were performed on Petri dishes with 140 mm diameter x 10 mm width containing 50 g of each food type. The Petri dishes were individually infested with 20 non-sexed adults of *C. quadricollis* (2 - 4 weeks old) and incubated in BOD chambers at the pre-established temperatures for 60 days. After this period, adult progeny was counted.

The experiment was set up in a complete randomized design, in a 4 × 6 factorial arrangement (4 temperatures × 6 food media), with six replications. The instantaneous population growth rate (r_i) was calculated from the equation proposed by Walthall and Stark (1997) (Equation 1), using the initial and final insect numbers (progeny). The data were examined through analysis of variance (ANOVA) and followed by the Tukey test ($p < 0.05$) to compare r_i among the different foods at each temperature, using SAS software (SAS Institute, 2002). Regression analyses were used to evaluate the effect of temperature on the r_i value for each food, using Sigma Plot software, version 7.0 (SPSS, 2001), and the models were chosen according to the significance of the regression coefficients (t , $p < 0.05$) and the coefficient of determination.

$$r_i = \ln(N_f/N_0/\Delta T) \quad (1)$$

Where: N_f = final number of insects/plate; N_0 = initial number of insects / plate; ΔT = time variation (bioassay duration, in days).

RESULTS

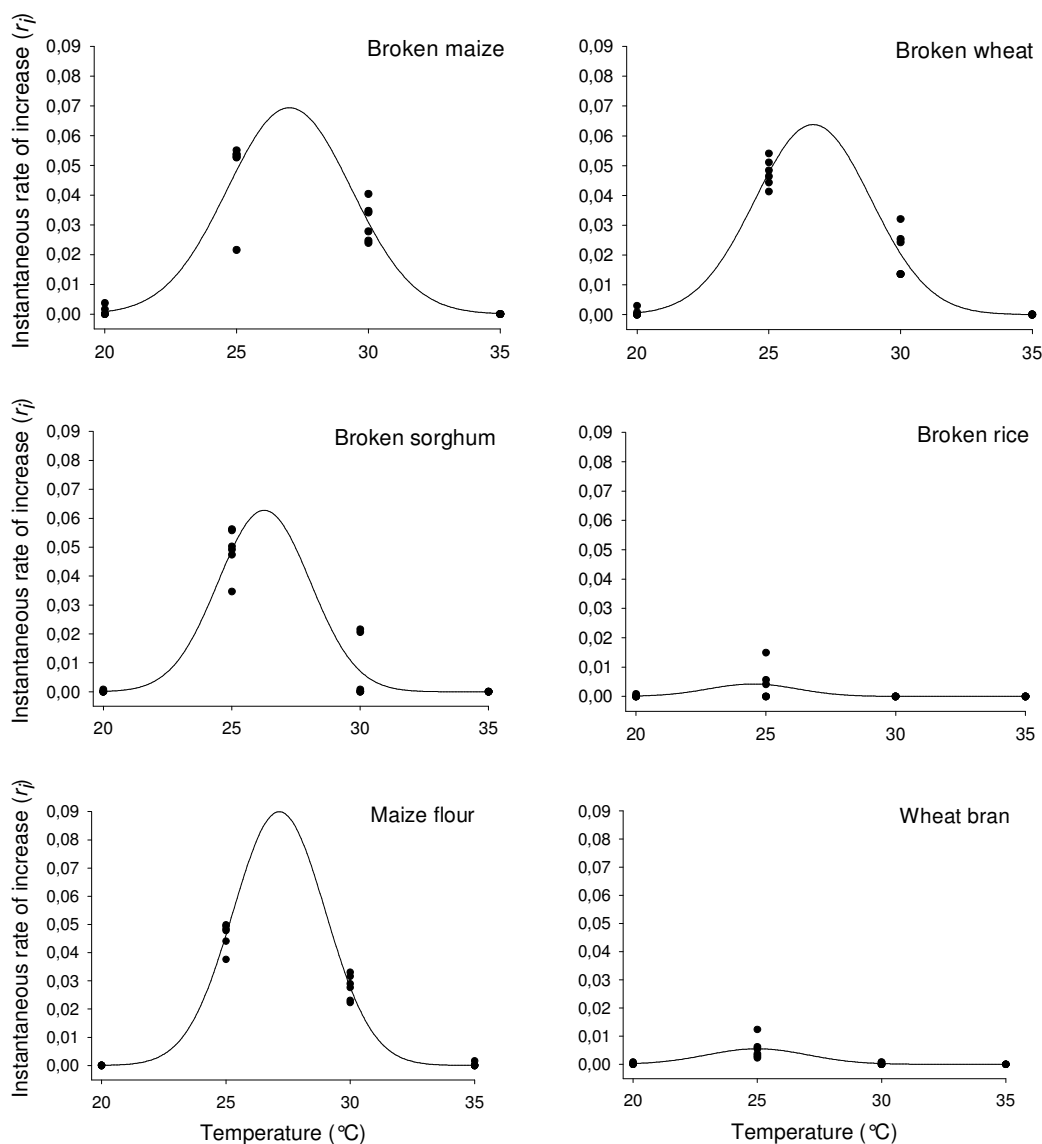
The r_i value for *C. quadricollis* was significantly influenced by temperature ($F_{3,120} = 376.60$, $p < 0.01$) and food type ($F_{5,120} = 74.49$, $p < 0.01$). The three-parameter Gaussian distribution model $y = a \exp(-0.5((x-b)/c)^2)$ provided the best adjustment for the regression analyses as a function of temperature in all the investigated foods (Table 1 and Figure 1). The r_i values were substantially low at 20°C in all food types and increased at 25°C (Figure 1). There was a slight reduction at 30°C, but there was no insect development at 35°C, except for maize flour, with low r_i values.

The equations showed that the optimum temperatures for *C. quadricollis* development for broken maize, wheat and sorghum and maize flour were 27.01, 26.68, 26.26 and 27.14°C, respectively, with a variation of 3.24% among them (Table 1). Lower optimum temperatures were found for broken rice and wheat bran (24.50 and 25.00°C) (Table 1) because of the low reproductive per-

Table 1. Summary of non-linear regression analyses of the instantaneous population growth rate for *C. quadricollis* as a function of temperature in six food media.

Food media	Model	ODT*	df _{error}	F	P	R ²
Broken maize	$r=0.0694\exp(-0.5([x-27.01]/2.35)^2)$	27.01	21	98.21	< 0.001	0.90
Broken wheat	$r=0.0638\exp(-0.5([x-26.68]/2.20)^2)$	26.68	21	221.08	< 0.001	0.95
Broken sorghum	$r=0.0628\exp(-0.5([x-26.27]/1.79)^2)$	26.26	21	116.99	< 0.001	0.92
Broken rice	$r=0.0042\exp(-0.5([x-24.50]/1.71)^2)$	24.50	21	4.58	0.022	0.30
Wheat bran	$r=0.0055\exp(-0.5([x-25.00]/2.03)^2)$	25.00	21	19.44	< 0.001	0.65
Maize flour	$r=0.0899\exp(-0.5([x-27.15]/1.86)^2)$	27.14	21	465.14	< 0.001	0.97

*ODT = optimum development temperature.

**Figure 1.** Instantaneous population growth rate (r_i) of *C. quadricollis* at different temperatures in six food media.

performance occurring in these foods at 20, 30 and 35°C (Figure 1).

Table 2. Means of the instantaneous population growth rate (r_i) of *C. quadricollis* in broken maize, wheat, sorghum, and rice, maize flour and wheat bran at different temperatures.

Temperature (°C)	Food type ± SEM					
	Broken maize	Broken wheat	Broken sorghum	Maize flour	Broken rice	Wheat bran
20	0.00088 ± 0.00062 a	0.00063 ± 0.00049 a	0.00013 ± 0.00013 a	0.00000 ± 0.00000 a	0.00013 ± 0.00013 a	0.00027 ± 0.00017 a
25	0.04823 ± 0.00534 a	0.04760 ± 0.00189 a	0.04892 ± 0.00320 a	0.04618 ± 0.00191 a	0.00410 ± 0.00237 b	0.00552 ± 0.00150 b
30	0.03093 ± 0.00266 a	0.02045 ± 0.00323 a	0.00717 ± 0.00441 b	0.02777 ± 0.00178 a	0.00000 ± 0.00000 b	0.00027 ± 0.00017 b
35	0.00000 ± 0.00000 a	0.00000 ± 0.00000 a	0.00000 ± 0.00000 a	0.00027 ± 0.00027 a	0.00000 ± 0.00000 a	0.00000 ± 0.00000 a

Means followed by same letter in the rows are not significantly different by the Tukey's test, at $p < 0.05$.

It was observed that at 25°C, the r_i value for *C. quadricollis* was significantly higher in broken maize, wheat, and sorghum and maize flour than in broken rice and wheat bran (Table 2). At 30°C, r_i was significantly higher in broken maize and wheat and maize flour than in broken sorghum, wheat bran and broken rice. However, there was no significant variation in r_i among the food types at 20 and 35°C because r_i values were substantially low at these temperatures.

DISCUSSION

The results of this study indicate that *C. quadricollis* reaches reproductive status as a pest under optimum temperature and suitable feeding, as is the case with the main stored-product pest insects (Pimentel et al., 2007; Sousa et al., 2008). The best reproductive performance for *C. quadricollis* was observed at 25 and 30°C. Optimum development temperature was estimated between 26.26 and 27.14°C for insects fed on broken sorghum, wheat, and maize and maize flour. In contrast, the insects showed low reproductive performance at 20 and 35°C and when fed on broken rice and maize flour. This suggests that the population growth of *C. quadricollis* occurs at a short interval around the optimum temperature for the development of the species under suitable

feeding conditions. Nevertheless, the optimum temperature for *C. quadricollis* was lower than that of other species from the family Silvanidae, such as *Oryzaephilus surinamensis* (Linnaeus), 32.5 to 35°C; *Oryzaephilus mercator* (Fauvel), 30 to 32.5°C and; *Ahasverus advena* (Walt), 30°C (Pacheco and Paula, 1995; Rees, 1996; Faroni and Sousa, 2006).

The low reproductive performance of *C. quadricollis* at extreme temperatures (20 and 35°C), and feeding on broken rice and wheat bran can be associated with a few factors such as increase in development time, reduction in survival and egg production, since this has been frequently observed in other stored-product insects (Faroni and García-Mari, 1992). Schwartz and Burkholder (1991) observed that the development time of *S. granarius* (Linnaeus) reared on five different types of grain varied from 35.1 days on rice to 45.5 days on maize. Faroni et al. (2004) reported that females of *R. dominica* showing longer preoviposition and shorter oviposition periods on annual canary grass when compared with other six foods. Hagstrum et al. (1996) informed that the development time of 11 species of stored-product beetles and six species of stored-product moths was affected by moderate, high or low temperatures. Burks et al. (2000) reported that at extremely high or low temperatures, stored-product insects are killed and more moderate,

high or low temperatures are far less lethal, but can still prevent population growth.

According to some authors, *C. quadricollis* seems to prefer maize especially in the field (Allotey and Morris, 1993; Faroni and Sousa, 2006). Wheat feed has been reported as a relatively unsuitable food for *C. quadricollis* (Yoshida, 1976), but the results of this investigation showed that broken wheat is suitable for its development in favorable conditions of temperature. LeCato (1976) noted that finely foods were generally more favorable for yield and development of *Plodia interpunctella* (Hubner) and *Ephestia cautella* (Walker). This aspect of insect development was not detected in the this study when *C. quadricollis* was reared on wheat bran, indicating that the failure of the reproductive performance of *C. quadricollis* fed on this food was more affected by food-specific characteristics than by its size. Based on nutritional values, wheat bran has high contents of crude fiber and protein, lignin and cellulose (Zambom et al., 2001), which are plant cell wall constituents and play important roles in defense mechanisms against insects by acting as digestibility reducers (Price, 1997).

The non-preference of *C. quadricollis* for broken rice was already expected, because certain rice grain characteristics such as husk integrity, breakage and hardness of grain kernels, thickness and silica content of the husk may hinder the develop-

of some store-grain insects of stored products (Prakasah and Rao, 1996). Broken rice was included among the treatments of this investigative study because our laboratory received several rice samples infested with *C. quadricollis* coexisting with other species. Silica gives a rigid texture to the epidermis (hardness), constituting a mechanical barrier that hinders insect attack and nutrient assimilation (Busato et al., 2002). In this way, the non-preference of *C. quadricollis* for broken rice and wheat bran may be associated with the nutritional and physical characteristic of these foods. Although there are few reports on the biology of *C. quadricollis* under storage conditions, the present study shows that this species has high biotic potential under optimum temperature conditions and suitable feeding. Hence, after *C. quadricollis* is identified in a warehouse, it is advisable to constantly monitor the species population to avoid harmful population levels and identify the most suitable moment to employ pest management techniques. It should be pointed out that the results of this study can be used to select the best nutritional substrates for *C. quadricollis* in laboratory rearings, and broken maize, wheat, and sorghum and maize flour are the ones suggested for this purpose.

REFERENCES

- Allotey J, Morris JG (1993). Biology of *Cathartus quadricollis* (Guerin-Meneville) (Coleoptera: Silvanidae) on some selected food media. *Insect Sci. Appl.* 14:61-68.
- Burks CS, Johnson JA, Maier DE, Heaps JW (2000). Temperature. In Subramanyam B, Hagstrum DW (eds) *Alternatives to pesticides in stored-product IPM*, Kluwer Academic, Massachusetts, pp 73-104.
- Busato GR, Grutzmacher AD, Garcia MS, Giolo FP, Martins AF (2002). Consumo e utilização de alimento por *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) originária de diferentes regiões do Rio Grande do Sul, das culturas de Milho e do Arroz irrigado. *Neotrop. Entomol.* 31:525-529.
- Caldas BC, Redaelli LR, Diefenbach LMG (1999). Parâmetros Reprodutivos de *Coreoris dentiventris* Berg (Hemiptera: Coreidae) em Cultura de Fumo (*Nicotiana tabacum*). *An. Soc. Entomol. Brasil* 28: 595-600.
- Faroni LRDA, García-Mari YF (1992). Influencia de la temperatura sobre los parámetros biológicos de *Rhyzopertha dominica* (F.). *Bol. Sanid. Veg. Plagas* 18: 455-467.
- Faroni LRDA, Oliveira CRF, Gonçalves JR, Pimentel MAG (2004). Influência da alimentação na biologia de *Rhyzopertha dominica* (Fabricius) (Coleoptera: Bostrichidae). *Rev. Bras. Armaz.* 29: 13-18.
- Faroni LRDA, Sousa AH (2006). Aspectos biológicos e taxonômicos dos principais insetos-praga de produtos armazenados. In: Almeida FAC, Duarte MEM, Mata MERMC (eds) *Tecnologia de Armazenagem de Sementes*, UFCG, Campina Grande pp. 371-402.
- Fields PG (1992) The control of stored-product insects and mites with extreme temperatures. *J. Stored Prod. Res.* 28: 89-118.
- Gracioli G, Oliveira LR, Redaelli LR, Romanowski HP (1998). Description, Biology of the Immature Stages and Reproductive Potential of *Tatochila autodice* (Hübner, 1818) (Lepidoptera, Pieridae), in Rio Grande do Sul, Southern Brazil. *Rev. Brasil. Biol.* 58:17-24.
- Hagstrum DW, Flinn PW, Howard RW (1996). Ecology. In Subramanyam B, Hagstrum DW (eds) *Integrated management of insects in stored products*, Marcel Dekker, New York, pp. 71-134.
- Ileleji KE, Maier DE, Woloshuk CP (2007). Evaluation of different temperature management strategies for suppression of *Sitophilus zeamais* (Motschulsky) in stored maize. *J. Stored Prod. Res.* 43: 480-488.
- LeCato GL (1976). Yield, development and weight of *Cadra cautella* (Walker) and *Plodia interpunctella* (Hubner) on twenty-one diets derived from natural products. *J. Stored Prod. Res.* 12:43-47.
- Loeck AE (2002). Pragas de produtos armazenados. EGUFP, Pelotas 113 p.
- Osuji FNC (1982). Development of the lesser grain bore, *Rhyzopertha dominica* (F.) in maize kernels as affected by site of larval entry. *Entomol. Exp. Appl.* 31: 391-394.
- Pacheco IA, Paula DC (1995) Insetos de grãos armazenados - identificação e biologia. Fundação Cargil, Campinas, 228 p.
- Pereira PRVS, Almeida LM (2001). Chaves para a identificação dos principais coleoptera (Insecta) associados com produtos armazenados. *Ver. Bras. Zool.* 18:2 71-283.
- Picanço MC, Araújo JM, Faleiro FG, Miranda MMM (1994). Intensidade de Ataque de *Cathartus quadricollis* Guerin, 1829 (Coleoptera: Silvanidae) a 49 populações de milho de polinização aberta. *Rev. Bras. Armaz.* 18: 11-14.
- Pimentel MAG, Faroni LRDA, Guedes RNC, Tótola MR (2007). Phosphine resistance, respiration rate and fitness consequences in stored-product insects. *Pest Manage. Sci.* 63: 876-881.
- Prakash A, Rao J (1986) Evaluation of plant products as anti-feedants against rice storage insects. In Goel SC (ed) *Proceedings of National Symposium on Pesticide Residue and Environmental Pollution*, Sanatan Dharm College, Muzaifarnagar pp. 201-205.
- Prattisoli D, Polanczyk RA, Holtz AM, Cochetto JG, Tamanhoni T, Milanez AM. Desenvolvimento da broca-das-cucurbitáceas em diferentes tipos de substratos alimentares. *Hortic. Bras.* 25: 598-601.
- Price PW (1997) Hypotheses and plant and herbivore interactions. In Price PW (ed) *Insect Ecology*, John Wiley and Sons, New York, pp. 73-138.
- Rees DP (1996) Coleoptera. In Subramanyam B, Hagstrum DW (eds) *Integrated management of insects in stored products*, Marcel Dekker, New York, pp. 1-39.
- SAS Institute, 2002. SAS/STAT User's Guide, version 8.0. SAS Institute Inc., Cary, NC, USA.
- Schwartz BE, Burkholder WE (1991). Development of the granary weevil (Coleoptera: Curculionidae) on barley, corn, oats, rice and wheat. *J. Econ. Entomol.* 84: 1047-1052.
- SPSS (2001) Sigma Plot user's guide. Chicago. Version 7.0.
- Sousa AH, Faroni LRDA, Guedes RNC, Tótola MR, Urruchi WI (2008). Ozone as a management alternative against phosphine-resistant insect-pests of stored products. *J. Stored Prod. Res.* 44: 379-385.
- Stark JD, Banks JE (2003). Population-level effects of pesticides and other toxicants on arthropods. *Ann. Rev. Entomol.* 48:505-519.
- Throne JE, Baker JE, Messina FJ, Karl JK, Howard JA (2000). Varietal resistance. In Subramanyam B, Hagstrum DW (eds) *Alternatives to pesticides in stored-product IPM*, Kluwer Academic, Massachusetts, pp. 165-192.
- Walthall WK, Stark JD (1997). A comparison of acute mortality and population growth rate as endpoints of toxicological effect. *Ecotox. Environ. Safety* 37: 45-52.
- Yoshida T (1976). The effect of crowding on the rate of reproduction in the squared-necked grain beetle, *Cathartus quadricollis* (Guer.) (Coleoptera, Silvanidae). *Sci. Rep. Fac. Agric.* 47:1-5.
- Zambom MA, Santos GT, Modesto EC, Alcalde CR, Gonçalves GD, Silva DC, Silva KT, Faustino JO (2001). Valor nutricional da casca do grão de soja, farelo de soja, milho moído e farelo de trigo para bovinos. *Acta Sci.* 23: 937-943.