

DEVELOPMENT OF *Sitophilus zeamais* IN MAIZE GRAINS STORED UNDER LIGHTING SYSTEMS¹

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ABSTRACT - The aim of this study is to evaluate the *Sitophilus zeamais* development in maize seeds, under four lightning systems and to find a mathematical model that describes the growth of this insect under the ambient conditions. Four wood cabinets were built, one of them was a natural light and the other ones as it follow: mixed light, sodium steam light and anti-bugs incandescent light. Inside each chamber, there were 18 recipients containing approximately 250g of seeds infested with 25 weevils. After the chambers building, a timer system was built, so the lamps would stay turned on always on the same time, from 6:00 p.m. to 6:00 a.m. to next day, consequently kept on for 12 hours. Every 21 days after the construction of the experiment 3 recipients from each chamber were taken off and weevils there were counted using the Belese funnel, and the seeds moisture was measured. It was not observed any influence on the bug development, who presented the maximum level of growing 84 days after the storage at all lightning systems tested. The humidity level kept constant itself until the 84th day and it had reduced significantly, indicating environmental changes during the procedure. The growth of *S. zeamais* can be described by a polynomial model.

Keywords: Wevill. Lamps. Storage. *Zea mays*. Stored products.

DESENVOLVIMENTO DE *Sitophilus zeamais* EM GRÃOS DE MILHO ARMAZENADOS SOB SISTEMAS DE ILUMINAÇÃO

RESUMO - Este trabalho teve por finalidade avaliar o desenvolvimento do inseto *Sitophilus zeamais* em grãos de milho armazenados por 126 dias sob quatro sistemas de iluminação e encontrar o modelo matemático que descreve o crescimento desse inseto em condições ambientais. Foram montadas câmaras de madeira, e em cada uma instalado um tipo de iluminação (lâmpada mista, vapor de sódio, incandescente anti-inseto e iluminação natural). Em cada câmara foram depositados parcelas de 18 recipientes de vidro, que continham aproximadamente 250 g de milho infestado com 25 carunchos. Após todo processo de montagem e infestação dos recipientes foi instalado um sistema de timer, para que as lâmpadas funcionassem sempre no mesmo horário das 18 h até as 6 h do dia seguinte (12 horas diárias). A cada 21 dias após a montagem do experimento, foi feita uma contagem dos insetos em três recipientes de cada câmara utilizando o “funil de Belese” e a determinação do teor de água dos grãos. A influência do tipo de lâmpada no crescimento populacional do *S. zeamais* foi observada apenas aos 126 dias, ao final do experimento. O teor de água permaneceu constante até 84 dias de armazenamento e após esse período ocorreram alterações significativas, o que pode ser devido a mudanças ambientais. O crescimento do *S. zeamais* pode ser descrito por um modelo polinomial.

Palavras-chave: Inseto. Lâmpada. Armazenamento. *Zea mays*. Produtos armazenados.

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INTRODUCTION

Maize is grown in several regions in the world, in a wide range of environments, with about 12 million hectares in Brazil. But it can be infested and damaged by a variety of primary and secondary insects during the storage (EMBRAPA, 2007).

The storage-grain can be defined as an ecosystem in which qualitative and quantitative changes may occur caused by interactions between physical, chemical and biological parameters. The most important factors affecting grain during storage are temperature, water content, carbon dioxide and oxygen concentrations, presence of microorganisms, insects, molds and grain structure (VOWOTOR et al., 1995). Consumption of cereals by pests such as insects as weevils during storage may make these totally inedible (NEETHIRAJAN et al., 2007)

There are several species of insects that damage maize, but beetle or weevil and trace are responsible for most losses. The maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae), is one of the most serious cosmopolitan pests of stored cereal grain, in tropical and sub-tropical regions (VOWOTOR et al., 1995; NAKAKITA; IKENAGA, 1997; KEHINDE; ANGELA, 2004). Is a primary insect, damage the whole kernel, and in addition reduce weight and increase in moisture causing molds growth. In extreme cases can cause complete deterioration of the grain mass (MARSARO et al., 2005).

The maize weevil has well-developed wings and can fly very fast and still infest grain in the field. The female can put on 280 eggs, and the life cycle occurs in about 4-5 weeks in optimum conditions of 28 °C and 70% relative humidity and can be changed in unfavorable environmental conditions, extending for several months (KEHINDE; ANGELA, 2004; MARSARO et al., 2005). The population growth was affected by initial population density of infestation and increased proportionately with degree of infestation. The *S. zeamais* highest population growth occurred at 28 °C and drastically decreased for lower and higher temperatures (SILVA et al, 2006). A major factor for insect population change is moisture content in stored grains. Moisture content played an important role for initial insect density changes (SONE, 2000)

Traditionally the control of pests in stored grain uses residual pesticides or fosfine (SANTOS; FOSTER, 1993), whose efficiency can be influenced by several factors (PIMENTEL et al, 2005; SILVEIRA et al., 2009). There is considerable interest at present in the application of environmentally friendly tools to control insect pests. Alternatives to chemical pesticides has been widely studied as well the use of low temperatures (ILELEJIA et al, 2008; VOLK et al., 2009), application of natural insect repellent (ESTRELA et al., 2006; YOONA et al. 2007; MEDEIROS et. al, 2007; HENDERSON;

MAOA, 2010), use of resistant hybrids (MARSARO et al, 2005) or ozone application (SOUSA et al., 2008).

Several factors act on the behavior of insects, and light is one of those factors. (BARGHINI et al, 2004; FERRAZ; AGUIAR-COELHO, 2008). In insects in general, and mosquitoes in particular, the sensitivity of rhodopsins, pigments related to vision, can be seen in different wavelengths relative to those of mammals and humans (BRIOSCOE; CHITTKA, 2001). The intensity of light has been shown to attract several species of stored product beetles as *Lasioderma serricorn* (F.), *Oryzaephilus mercator* (Fauvel); *Sitophilus oryzae* (L.); *Tribolium castanleum* (Herbst) and *Rhyzopertha dominica* (F.) that responded to the UV lamp radiation (SODERSTROM, 1970). Insects perceive ultraviolet A radiation that is invisible to humans. Nocturnal insects can detect up to communicate in the range infrared (IR), from 75 to 1030 nm (LARA, 1991).

Cheap and effective methods for reducing *S. zeamais* damage are needed in developing countries. The understanding of the behaviour of the maize weevil in relation to lighting systems will assist in the development of alternative control methods. The aim of this study is to evaluate the influence of light sources in the development of *S. zeamais* in maize stored for 126 days under ambient conditions, and to find a mathematical model that describes the growth of this insect under the ambient conditions.

MATERIALS AND METHODS

Four non controlled-environment cabinets, open in top, were constructed in wood with dimensions of 1.00 x 1.00 x 1,5 m. In three cabinet was installed artificial lighting: mixed lighting Osram HWL E27 160 W 220 V (T1 – mixed lamp); sodium vapor lamp 70 W Osram; incandescent anti-insect Empalux lamp model IA2101 (T2 - ant-insect lamp) NAV-E 4Y VIALOX (T3 – sodium lamp). The lighting system was turn on from 6:00 AM to 6:00 PM and was turn over after that by a timer. In one of these cabinets no lighting system was installed, ie, natural lighting was used the control (T4 - control).

The weevils were cultured on rice without a controlled temperature and humidity and *S. zeamais* adults used in the experiments were 7–14 days old.

Seeds of maize (COODETEC - CD 0302) were cleaned and disinfested by keeping them in a deep freezer at -10 °C for 2 weeks prior to setting up the experiment. The moisture content of the seeds was adjusted to 12–13% A series of 500 ml flasks was used, each flask containing 250 g of maize and 20 adult insects in a closed system with a nylon screen. Three replicates were used for each time, moisture content and a count for live insects was measured in each flask.

During the experimental period of 126 days,

Table 1. Population of *S. zeamais* in maize under four lighting systems, stored for 126 days.

| Lighting system | Storage days | | | | | | | Means |
|-----------------|--------------|-------|-------|-------|-------|-------|---------|-------|
| | 0 | 21 | 42 | 63 | 84 | 105 | 126 | |
| T1 | 25.0 | 25.0 | 25.7 | 26.7 | 36.3 | 66.3 | 112.3 B | 45.33 |
| T2 | 25.0 | 25.3 | 27.0 | 27.3 | 37.0 | 76.0 | 121.0 B | 51.88 |
| T3 | 25.0 | 25.0 | 26.3 | 27.3 | 35.7 | 69.3 | 101.0 C | 44.23 |
| T4 | 25.0 | 25.3 | 27.7 | 27.0 | 38.0 | 71.7 | 136.0 A | 50.10 |
| Means | 25.0a | 25.2a | 26.7a | 27.1a | 36.8a | 70.8b | 117.6c | |

Analysis of variance indicated that means within a column followed by the same capital letter(s) and means within a row followed by the same lowercase letter(s) were not different ($\alpha > 0.05$)

T1 - mixed lamp, T2 - ant-insect lamp, T3 - sodium lamp, T4 - control

Table 2. Average moisture content of maize stored for 126 days under four lighting systems.

| Lighting system | Storage days | | | | | | | Means |
|-----------------|--------------|---------|---------|---------|---------|--------|--------|--------|
| | 0 | 21 | 42 | 63 | 84 | 105 | 126 | |
| T1 | 12.6 | 11.1 | 11.1 | 11.2 | 11.4 | 11.4 | 10.6 | 11.3 A |
| T2 | 12.6 | 11.2 | 11.6 | 11.4 | 10.9 | 12.3 | 11.1 | 11.5 A |
| T3 | 12.6 | 11.2 | 11.2 | 11.0 | 11.2 | 12.5 | 10.9 | 11.5 A |
| T4 | 12.6 | 11.1 | 10.9 | 11.2 | 11.3 | 11.9 | 11.0 | 11.4 A |
| Means | 12.6 a | 11.2 bc | 11.2 bc | 11.2 bc | 11.2 bc | 11.8 b | 10.9 c | |

Analysis of variance indicated that means within a column followed by the same capital letter and means within a row followed by the same lowercase letter(s) were not different ($\alpha > 0.05$)

T1 - mixed lamp, T2 - ant-insect lamp, T3 - sodium lamp, T4 - control

Table 3. Regression coefficients for the population growth of *S. zeamais* in stored maize for 126 days under four lighting systems: mixed lamp (T1); sodium vapor (T2), anti-insect (T3) and control (T4).

| Parameters | T1 | T2 | T3 | T4 |
|-------------------|------------------------|-------------------------|------------------------|------------------------|
| polynomial model | | | | |
| Intercept | 16.63 | 28.20 | 20.34 | 18.59 |
| Time ² | | -6.334x10 ⁻³ | | |
| Time ³ | 5.532x10 ⁻⁵ | 9.244x10 ⁻⁵ | 3.981x10 ⁻⁵ | 4.949x10 ⁻⁵ |
| R ² | 0.807 | 0.970 | 0.928 | 0.939 |
| exponential model | | | | |
| b1 | 13.92 | 14.76 | 14.07 | 14.02 |
| b2 | 1.016 | 1.014 | 1.015 | 1.015 |
| R2 | 0.799 | 0.838 | 0.837 | 0.820 |

*all significantly at the 0.01 probability level

at every 21 days, three flasks containing infested maize were removed in order to evaluate the moisture, by oven and the population development of the adult insects, using the "Berlese funnel". A Berlese funnel works on the principle that insects move away from heat. After analysis, the flasks were excluded from the study.

The experiment was conducted in a randomized design in a split plot, and the types of lamps have been considered as main plot and time as the subplot, with three replicates. Means were compared by Tukey test ($p < 0.050$, using the ESTAT program). The regression analysis was conducted to found models that describe the influence of time ($t -$

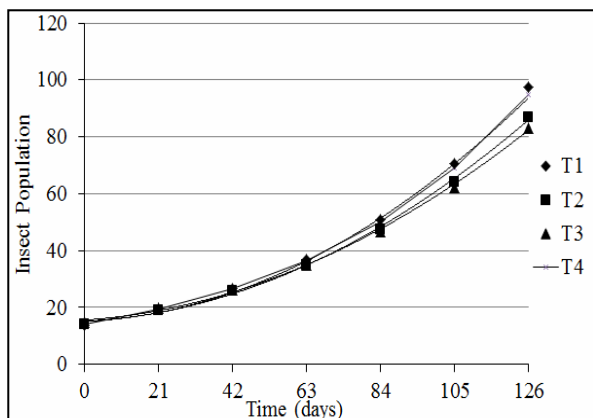


Figure 1. Adjust the polynomial model for population growth of *S. zeamais* in stored maize under illumination in four types of lighting: mixed lamp (T1); sodium vapor (T2), anti-insect (T3) and control (T4).

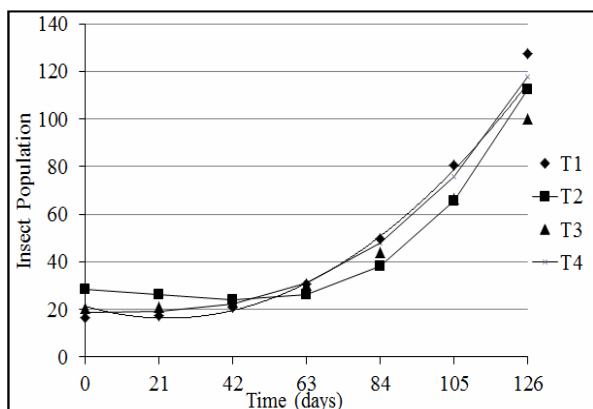


Figure 2. Adjust the exponential model for population growth of *S. zeamais* in stored maize under illumination in four types of lighting: mixed lamp (T1); sodium vapor (T2), anti-insect (T3) and control (T4).

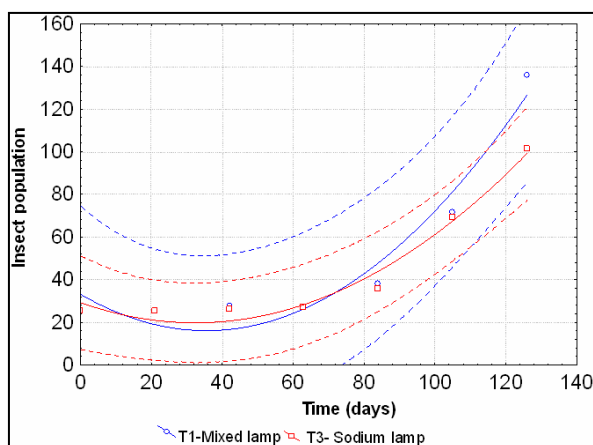


Figure 3. Adjusting polynomial for growth of *S. zeamais* in stored maize under mixed lighting lamp and sodium vapor.

storage days) in the insect population (pop - *Sitophilus zeamais*.) under four types of lighting. Producing the best multiple regression models used the method of automatic selection of variables backward. The coefficient of determination (R^2) was used to evaluate the best models. After an exploratory data analy-

sis was chosen third-degree polynomial model (equation 1) and the exponential model (equation 2):

$$pop = a_0 + a_1 * t + a_2 * t^2 + a_3 * t^3 + \varepsilon \quad (1)$$

$$pop = b_1 * b_2^x + \varepsilon \quad (2)$$

where: a_1, a_2, a_3, b_1 e b_2 : set parameters of the models; ε : random error;

RESULTS AND DISCUSSION

Data presented in Table 1 reveal that the type of illumination only affected the population of *S. zeamais* in maize to 126 days and the population of weevil is lower in the presence of anti-insect lamp than the control. The anti-insect lamp emit frequencies of light yellow-orange and red that have a wavelength between 590 to 760 nm, which are not perceived by most insects (BRIOSCOE; CHITTKA, 2001). The lack of light perception may have caused changes in the life cycle of these insects, occurring decrease in population growth.

It was observed that the moisture did not differ significantly in grain stored under different lighting systems. However, there is reduction of water content in the initial phase of storage, which remained with little variation up to 105 days, and reducing at the final storage period.

The variation of moisture content of grain may have been due to temperature and relative humidity during storage (VOWOTOR et al., 1995). Despite the reduction of water content, it did not influence the growth rate since the *S. zeamais* population, which increased only after 84 days. According to Almeida et al. (1997), *S. zeamais* has accelerated development in grain with moisture content between 14 and 16%. They report yet that in grains with moisture content below 13% may have a higher mortality rate, which is opposed to that observed in this study, since the water content was less than 12% and was observed growth of weevil population. Caneppele et al. (2003), studying infestation levels in maize *S. zeamais* adults, observed moisture content between 10 and 14% during 120 days stored grains.

The population of *S. zeamais* showed a significant increase after 84 days of storage. This may be due to the influence of temperature during storage, which was below to ideal for development of insects in the initial storage.

To describe the growth of *S. zeamays* under the ambient conditions, mathematical models was tested. The polynomial model (equation 1, Table 3, Figure 1) offered the predictive capability (R^2) between 81 and 97%. For best viewing of the models, only the averages for each treatment and each time were plotted.

The exponential model also was analyzed (equation 2, Table 3, Figure 2), and offered the predictive capability (R^2) between 81 and 97%. For best viewing of the models, only the mean for each treatment and each time were plotted.

Comparing the models was found the best statistical fit to polynomial model (R^2 0.911), which was 11% higher than the exponential (R^2 0.824).

Resende et al (2008) observed that the weevils infestation has increased exponentially during storage period indicate there was a high insects growth rate, similar to data obtained in this work.

Bands (95%, Figure 3) were plotted with polynomial curves for mixed lamp (T1) and the sodium vapor (T2). These bands represent the region, with 95% probability, which contain the true regression curve. As these regions intersect for any value of time, it means that the two curves are statistically coincident with 95% of probability. This analysis was done for the two curves that were more distant from one another.

CONCLUSIONS

The anti-insect lamp used in this experiment influenced the development of *S. zeamais* for variety COODETEC - CD 0302 after 126 days of storage;

The growth of *S. zeamais* on maize variety COODETEC - CD 0302 can be described by a polynomial model.

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