Natural life cycle and rearing of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the laboratory: Scientometric study and didactic scheme

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ABSTRACT

Insects play a highly important role in the ecological field, especially playing a fundamental role in the pollination of flowering plants, an essential process for the preservation of life and biological diversity. Among the insects, there are those considered as pests. This is the case of Spodoptera frugiperda J.E. Smith (Lepidoptera: Noctidae) also known as fall armyworm, native to tropical areas. The present work aims to present a discussion about the life cycle and protocols for rearing, in the laboratory, of S. frugiperda, in order to contribute as a didactic tool for the teaching of science and environmental education. For this, a bibliographic and scientometric survey was carried out from the MEDLINE/PubMed, Scientific Electronic Library Online (SciELO) and Google Scholar databases. The descriptors used were related to diet, feeding and rearing of S. frugiperda (Spodoptera frugiperda + artificial diet; Spodoptera frugiperda + laboratory; Spodoptera frugiperda + nutrition; Spodoptera frugiperda + larvae). As a result of the scientometric survey, 18 studies were selected, published between 1985 and 2022, on the topic, which reflects a wide variety of breeding protocols over time. The establishment of insect breeding protocols in the laboratory is essential for basic entomology studies, as well as for biotechnology and innovation studies involving, for example, insecticide bioassays.

Keywords: Insect pest, Artificial diet, Insect nutrition, Laboratory rearing.

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INTRODUCTION

The subphylum Hexapoda includes the class Insecta and three more sets of animals that resemble insects: Collembola, Protura, and Diplura (Brusca; Brusca, 2018). The class Insecta is the most varied and widely disseminated in nature. From a morphological point of view, its limbs are characterized by having their bodies divided into three distinct parts: head, thorax, and abdomen. In addition, they have ectognate mouthparts, whose bases are located outside the cephalic capsule, and can usually have up to two pairs of wings in the thorax region (Hickman et al., 2016). Being the only set of terrestrial invertebrates capable of flight and that undergo a process of indirect development, also known as complete metamorphosis (Brusca; Brusca, 2018). The class Insecta is subdivided into approximately 29 orders, harboring a total of more than one million species, although a significant portion of them have not yet been scientifically cataloged (Eggleton, 2020). Preliminary calculations indicate that the total number of insect species in the world may vary between 2.5 million and 10 million (Sabrosky, 1952; Brues et al., 1954; Gaston, 1991). Updated estimates, which make use of new approaches to calculate global species diversity, indicate that the number of insect species distributed worldwide ranges between 2.96 million and 5.5 million (Stork, 2018; Read; Wiens, 2023).

Insects play a highly important role in the ecological field, especially by playing a fundamental role in the pollination of flowering plants, an essential process for the preservation of life and biological diversity (Rupert; Barnes 1996). About ninety percent of the plant varieties that are cultivated worldwide, including those used for food and for the production of medicinal substances, rely on pollination carried out by animals, the vast majority of which are insects (Fontaine et al., 2005). They play a significant role in sectors such as the food, cosmetics, and pharmaceutical industries, as they provide valuable products such as honey, silk, lacquer, and chitin (Gullan; Cranston, 2012). In addition to being a source of food for various levels of the food chain, insects play a crucial role in nutrient recycling, can serve as biological indicators of changes in the environment, and are employed in the biological control of pest populations. These multiple roles give this group great relevance in maintaining the balance of ecosystems (Martinez; Rocha-Lima, 2020).

Insect diversity is declining on a global scale. This scenario, coupled with the collapse of domesticated pollinator colonies, poses an unprecedented threat to humanity's food security (Vasiliev; Greenwood, 2020). With the loss of a species, there is a loss of its genetic heritage, which can affect the dynamics of feeding relationships between the organisms that are part of the food chain in which that species is inserted (Mendonça et al., 2009). The causes of this decline are driven by a number of pressures that are known to affect pollinators, and almost all of these pressures are man-made. They encompass factors such as urbanization, habitat loss, climate change, pesticide use, and the transition of natural ecosystems to agricultural systems (Eggleton, 2020). In addition to changes in the microclimate, such as rising temperatures and variations in light availability, which are related to the current climate crisis, these factors exert a negative influence, reducing pollinating insects' search for food (Hamblin et al., 2017). This results in significant ecological and economic impacts that have the potential to significantly affect the preservation of wild plant diversity, the stability of ecosystems on a broader scale, agricultural production, food security, and the well-being of the human population (Potts et al., 2010).

Among the insects, there are those considered as pests. This is the case of *Spodoptera frugiperda* J.E. Smith, (Lepidoptera: Noctidae) also known as fall armyworm, native to tropical areas, is a polygraph insect that feeds on many plant species, mainly grasses such as wheat, sorghum and rice (Sarmento et al., 2002). Despite their preference for grasses, they can be found in a wide variety of crops, including beans, cotton, potatoes, sweet potatoes, peanuts, tomatoes, spinach, cabbage, among others (Cruz, 1995). Fall armyworm is the main pest of corn in the Americas, causing crop damage both in the vegetative phase of greater development of corn and soon after germination or earing (Cruz, 1997). There are a variety of control approaches that, if applied properly, are effective in keeping corn pests at levels below those that would result in economic losses. In Brazil, the most promising control methods in maize are those of a cultural, biological and chemical nature (Cruz et al., 1983)

Biological control represents a significant tool in the context of integrated pest management. With regard to *S. frugiperda*, the effectiveness of control strategies is directly linked to the knowledge of the biological agent, including its life cycle and its ability to adapt to the agricultural environment. Therefore, the present work aims to present a discussion about the life cycle and rearing protocols of *S. frugiperda*, in order to contribute as a didactic tool for the teaching of science and environmental education.

MATERIAL AND METHODS

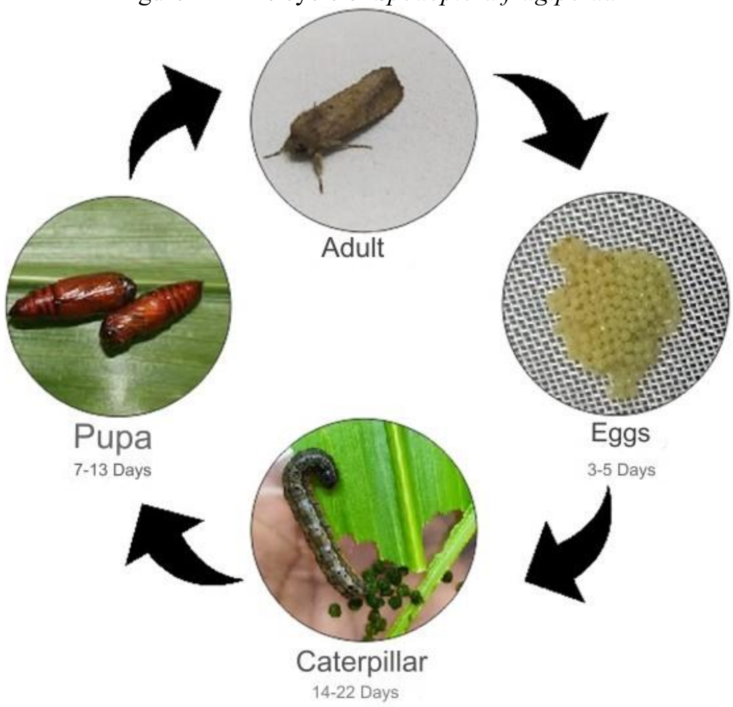
In the present study, a bibliographic and scientometric survey was carried out on the life cycle, diets and protocols used in the rearing of larvae of *S. frugiperda* in the laboratory. The survey was carried out using the MEDLINE/PubMed, Scientific Electronic Library Online (SciELO) and Google Scholar databases, with no limitation on the period for publications. The descriptors used (in English and Portuguese) were related to diet, feeding and rearing of *S. frugiperda* (*Spodoptera frugiperda* + artificial diet; *Spodoptera frugiperda* + laboratory; *Spodoptera frugiperda* + nutrition; *Spodoptera frugiperda* + larvae).

RESULTS AND DISCUSSION

LIFE CYCLE OF *S. FRUGIPERDA*

The complete life cycle of *S. frugiperda* lasts about 30 days (Figure 1), which goes from the egg to the adult stage, initially the caterpillar attacks only the leaves and the cartridge, however, in high infestations they can attack the ears and cut the plant in the collar region (Moreira et al., 2019).

Figure 1 – Life cycle of *Spodoptera frugiperda*



Source: Prepared by the authors (2024).

In the scientometric survey, 18 studies were selected (five from SciELO, three from PubMed, and ten from Google Scholar), published between 1985 and 2022, on the topic, which reflects a wide variety of creation protocols over time (Chart 1).

Table 1: Life cycle, diet and laboratory rearing studies of *S. frugiperda.*

Descriptor	Study title	Database	Reference
Spodoptera frugiperda + artificial diet	Feeding responses of fall armyworm (Lepidoptera: Noctuidae) in corn foliage and foliage/artificial diet mixtures at different temperatures.	Google Scholar	Isenhour et al., 1985
	Feeding preference and biology of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) in rice and barnyardgrass	SciELO	Botton et al., 1998
	Food intake and utilization by *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae) at two temperatures	SciELO	Busato et al., 2004
	Suitability of an artificial diet for the "maize" and "rice" biotypes of *Spodoptera frugiperda* (Lepidoptera: Noctuidae).	SciELO	Busato et al., 2006

	Evaluation of nutritional diets for laboratory improvement of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae)	SciELO	Arévalo Maldonado e Zenner de Polanía, 2009
	Larval survival of *Spodoptera frugiperda* Smith on artificial diets under laboratory conditions	SciELO	Morales et al., 2010
	Artificial Corn-Based Diet for Rearing *Spodoptera frugiperda* (Lepidoptera: Noctuidae)	PubMed	Pinto et al., 2019
	Artificial diets and technique for rearing *Spodoptera frugiperda* (J.E. Smith) in the laboratory	Google Scholar	Wang et al., 2019
	Comparative performance of fall armyworm (Lepidoptera: Noctuidae) reared on several cereal-based artificial diets	PubMed	Jin et al., 2020
	Biology of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) in different artificial diets	Google Scholar	Lekha et al., 2020
	Artificial diets with different levels of protein for the rearing of *Spodoptera frugiperda* (Lepidoptera: Noctuidae).	PubMed	Truzi et al., 2021
	Artificial wheat bran-based diet for mass cultivation of fall armyworm, *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae)	Google Scholar	Ge et al., 2022
Spodoptera frugiperda + laboratory	Development of the fall armyworm, Spodoptera frugiperda, from Honduras and Mississippi in sorghum or maize in the laboratory.	Google Scholar	Castro e Pitre, 1988
Spodoptera frugiperda + nutrition	Evaluation of artificial diets for fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) through nutritional indices and a two-sex life table approach and age stage.	Google Scholar	Ashok et al., 2021
	Effects of larval diets on the growth and development of *Spodoptera frugiperda* (J.E. Smith)(Lepidoptera: Noctuidae).	Google Scholar	Navasero et al., 2021
Spodoptera frugiperda + larvae	Effects of temperature and larval diet on the development of the fall armyworm (Lepidoptera: Noctuidae).	Google Scholar	Ali et al., 1990
	Influence of larval nutrition on the biological attributes and reproductive performance of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) under laboratory conditions.	Google Scholar	Sagar et al., 2022
	Larval diet affects development and reproduction of East Asian strain of the fall armyworm, Spodoptera frugiperda.	Google Scholar	He et al., 2021

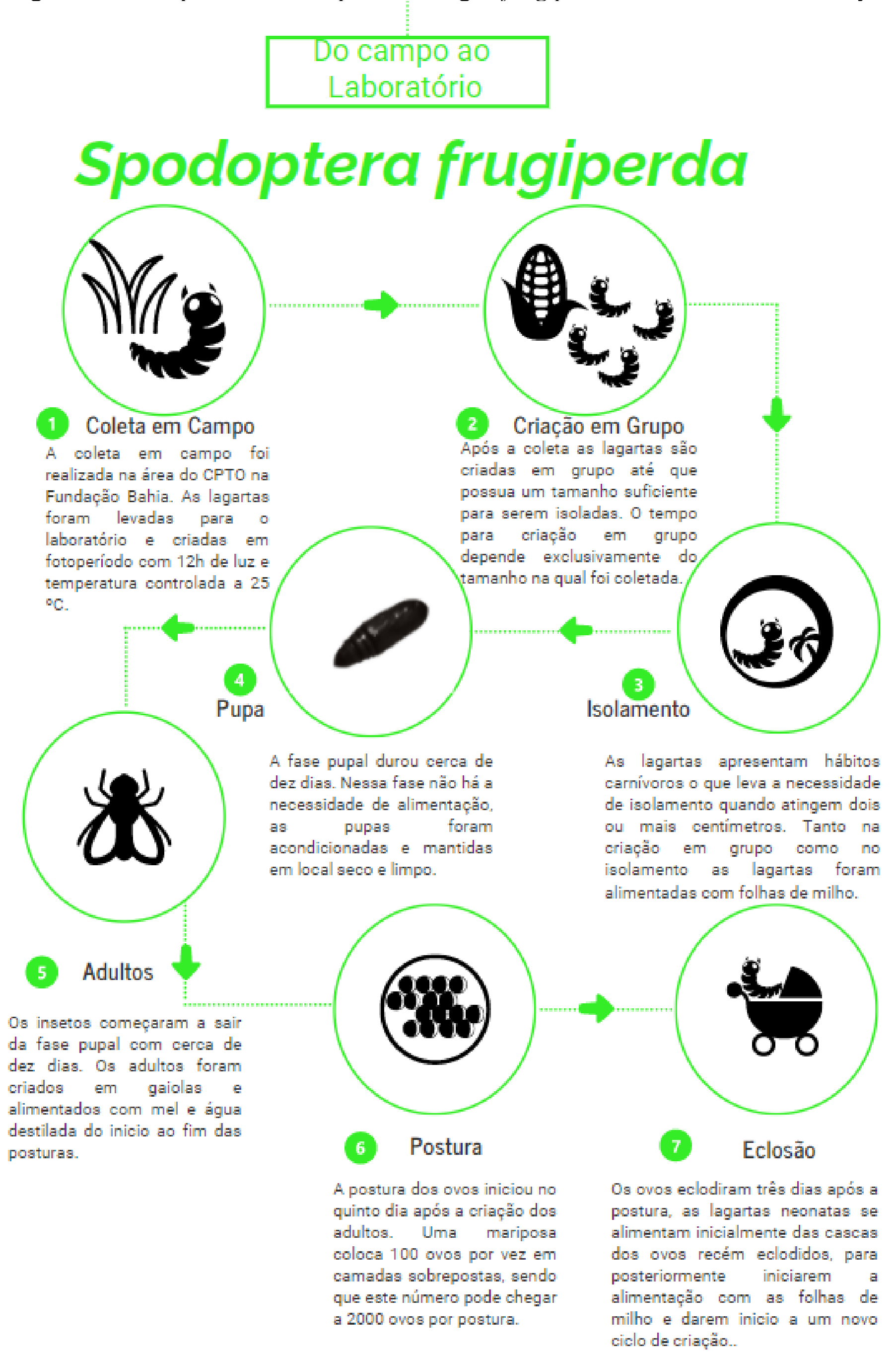
LABORATORY REARING OF *S. FRUGIPERDA* LARVAE

In the wild, the larvae of *S. frugiperda* newborns feed in the first moments of their lives on their own eggshells (Cruz, 1995). However, in the laboratory it is necessary to develop methods to boost the biological quality of individuals, this can be accomplished through the incorporation of diets, which can be natural or artificial (Busato et al., 2006).

Several studies address the analysis of diets suitable for the rearing of *S. frugiperda* in the laboratory. Diets described using beans according to Perkins (1979), beans with the addition of sucrose (Whitford, 1992), beans and brewer's yeast (Ferraz, 1982), or even beans, brewer's yeast and wheat germ (Souza et al., 2001). Wheat, oats and alfalfa (Smith, 1921), corn (Luginbill, 1928), grasses, rice and cotton (Fonseca, 1943) can also be incorporated into its composition. As well as, wheat germ-based diet (Burton; Perkins, 1972) as well as vitamins (Mielitz et al., 1986). Among other compositions.

In Silva's (2021) study, *S. frugiperda* eggs were collected in the field and reared in the laboratory until adults were obtained, through egg-opposition. The study was conducted in the municipality of Luís Eduardo Magalhães, Bahia. The steps of this creation are described through an infographic (Figure 2). The infographic was built with the help of Corel Draw Graphics suite 2018 and Adobe Photoshop CS4, where the integration of the visual elements with the texts that described the respective stages of creation of *S. frugiperda was carried out.*

Figure 2: Description of the steps of rearing *S. frugiperda* larvae in the laboratory.



FINAL CONSIDERATIONS

It is possible to use this infographic in science teaching classes, since students can visualize each stage of insect creation and connect it with its life cycle, in an uncontrolled environment. In addition, it is also possible to use them in environmental education practices, in extension projects.

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