Biological control of corn pests

An opportunity for the farmers

Ivan Cruz

Embrapa

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Presentation

Brazilian agriculture has shown significant results in recent years, largely due to the use of new technologies, including superior genetics and good agricultural practices.

Despite greater knowledge useful for decision making regarding environmental biotic and abiotic factors, super harvest and productivity gains, Brazilian agriculture still suffers from losses resulting from pest injuries.

In order to avoid or mitigate economic losses, the common alternative is still through frequent spraying with chemicals, whose action is only on the existing population or target insects, at a given time. Considering the residual period of the chemicals, usually very short, and the continued influx of pests, there is usually a need for further spraying for control of them.

In addition to increasing the production cost of economic activity, such additional applications can favor the emergence of populations resistant to the products and at the same time reduce the population of useful species, such as the natural enemies of phytophagous species, or those that pollinate or decompose organic matter.

Due to these negative factors, there is a significant movement by society, agencies and professional agents asking for a drastic reduction in the use of agricultural practices with negative side effects for the environment and human health.

An alternative in the specific case of phytophagous species is the use of biological control, whose relevance was institutionally valued by the National Bioinputs Program (Decree number 10.375, of May 26, 2020), coordinated by the Ministry of Agriculture, Livestock and Supply of Brazil.

Due to these demands and actions, the growing number of biological products in Brazil, marketed and under development by different companies, is visible. Objectively, product availability is no guarantee of success in pest control; but, of course, success can happen as soon as there is adequate training and use of the new agricultural processes associated with each biological product.

This strategic change in the way of controlling pests has the support of various segments of society, considering that the reduction or elimination of products that cause direct and indirect damage to the environment is the perception, desire and expectation of both the agricultural producer and the consumer, notably urban dwellers.

This theme is part of the context and dynamics of intelligent and creative movements for food security, with productivity and sustainability. Therefore, this publication was specially prepared to collaborate with farmers, technicians and public and private extension workers, in the recognition of beneficial organisms and how to effectively use them on the agricultural property. In summary, it is the result of the contribution of professionals at different times, many of them referenced in the text of the publication, as well as partner institutions such as CNPq, Fapesp, Fapemig, Universities and Grupo Vittia. Our sincere thanks to all!

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Summary

INTRODUCTION

The farmer's ability to produce and supply basic products for a growing world population that every year occupies urban spaces, making the labor force in the countryside decrease, is well known. Due to this situation, the farmer increasingly needs to use technologies that allow production to maintain the pace of human growth. However, today, with the increase in people's standard of living, the consumer's demands for a better quality of food consumed in the first instance also increase, evolving later to the concern with environmental preservation.

Advanced technologies have been responsible for the significant increase in global food production, less for the increase in the agricultural area and more for the increase in productivity. The example of Brazil, where agricultural production takes place practically all year round, is incredibly significant. However, the constant availability of food, combined with favorable climatic conditions, promotes the rapid development of competitors, such as insect pests, weeds, and diseases (Cruz et al., 2013). In order to reduce the possible agricultural losses caused by such organisms, the producer has been, year after year, routinely using the so-called “agricultural defensives” or popularly known as “pesticides”. Such frequent use of pesticides can be credited to the fact that the current generation of farmers has grown along with the agrochemical industry. Their use has been based only on what is considered “benefit”, including immediate pest suppression for the “kill-all” feeling at an exceptionally low and fast cost. Because of this thought, for many years, little was devoted to the development of alternative research.

Although biological pest control is not a new idea, it was started long before the so-called “modern agriculture”. Even today, there is a paradigm that the method does not work. Therefore, there are few products on the market. Also, as a barrier against the use of biological products, there is the argument that biological control agents are unknown. Currently, much is known about these beneficial organisms. Many of them, however, either did not come to the knowledge of farmers or are confused with harmful species (Cruz, 2015), although there is information already available in the literature (Cruz, 1994, 1995a, 1995b, 2000, 2002b, 2007, 2008a, 2008b, 2008c, 2008e; Cruz et al., 1997a, 2002, 2011a, 2011b).

The biological basis of the unintended consequences of applying agrochemicals took a long time to understand. Only in the 1960s and 1970s was it demonstrated that many of the pest control failures were due to significant reductions in natural biological control agents (Debach, 1974). Even today, with all the arsenal of commercial products and a high number of applications, pests continue to cause injuries and losses. Despite the mandatory information on the use of a particular product on its package insert, they are precarious. For example, nothing is known about the environmental impact arising from the use of these chemicals.

Pests such as phytophagous insects and mites can have their populations reduced naturally by the action of different organisms known as biological control agents, which include, for example, other insects, nematodes, birds, bats, spiders, several species of micro-organisms such as fungi, bacteria, and viruses, among others. However, this biological control has been sought particularly within the Insecta class and among micro-organisms. Biological control can be long-lasting and without causing the harm caused by the application of many of the chemical products.

Didactically, there are two main ways of using biological control with insects or mites: applied biological control, when the biological control agent is acquired in biofactory and then properly released in the area where one wants to control a certain phytophagous species; and, of equal importance, there is natural biological control, in which there is the active participation of beneficial insects already existing in the target area. There is no direct human participation in the production and release of these benefits. Agricultural practices that favor the maintenance and increase in the population of these insects are essential for the farmer to take advantage of this free service offered by nature.

To facilitate understanding, insects used in biological control are considered parasitoids or predators. Parasitoids, although especially important, are not easily observed by most farmers. Parasitoid species are not free-living during all development phases of their life cycle, that is, one or more phases take place in close association with their host, which can be any phase of its development (egg, larva, pupa, and adult). Parasitoids are generally more specific than predators. One of the most significant examples of a parasitoid is the small wasp Trichogramma, specific to Lepidoptera eggs and already commercially available in Brazil. Although with a complete development cycle, that is, passing through the egg, larva, pupa, and adult stages, only this last stage is free-living; the others occur within the target pest (host) egg.

Predators are free-living insects all the time. Some species feed on their prey, which can be at any stage of development. Other species only use their prey in the immature stage. Like parasitoids, predators have no eating habits on vegetables. Common names such as ladybugs, litterbugs, earwigs, wasps, and bedbugs are representatives of predators.

Brazil is one of the countries with the greatest entomological biodiversity in the world and, paradoxically, it is also one of the great consumers of pesticides. Even so, it is possible to identify many species of natural biological control agents, even in areas where the use of chemicals is routine. Actions aimed at protecting these agents (conservative biological control), associated with applied biological control, will certainly provide the farmers and society with a safe product from an ecologically correct environment.

This publication aims to provide information on the biological control of insect pests to the overall public, and more specifically to rural extension and technology transfer agents, public or private, and the farmers. Although much of this information includes the results obtained in maize crops, biological control agents are also found in other crops, as they are associated with insect pests, which in turn are associated with different host plants. Much of the information mentioned here has been synthesized from works published by the author, as indicated in the reference list.

OPENING EXPLANATION

Meaning of biological control

To best use biological control (or biocontrol), it is important to first distinguish between the term "natural" and "applied". Natural biological control is conceptualized as the reduction of the population of a kind of pest by its natural enemies, without the manipulation of these by humans. An applied biological control refers to the reduction of the population of a species by natural enemies manipulated by people, that is, beneficial insects produced in large quantities, usually in commercial biofactories. Both types of biological control are important and desirable. The advance in knowledge about biological pest control agents (Cruz, 2008d, 2009; Cruz et al., 1999b, 2013, 2018) allows the farmers to plan and use the biological management of the complex of pests affecting maize crops, for example.

It is known that an insect species can reach a high population density in certain places and, therefore, damage plants, reduce productivity, and cause economic losses if adequate control measures are not taken (Cruz et al., 2009a). But it is possible that, elsewhere, the same species is not able to grow in number and thus not actually constitute what is conventionally called an insect pest. In this case, probably, a variety of biological and environmental factors are responsible for this suppression. Natural biocontrol is certainly one of these factors because virtually all organisms have one or more natural enemies.

The sudden increase of population density of a phytophagous species can be attributed to the disruption of natural biocontrol, which is one of the most common ways to increase the intensity of the damage. For example, the application of chemical insecticides, even with a product not considered to have a broad spectrum of action, suppresses the insect population considered as a pest, but it also often has an even more pronounced effect on the population of beneficial insects. Such beneficial insects have some species of pests as their food source, reducing their ability to cause damage to the plant. The very pest species for which a non-selective control measure was used may benefit from the reduction of population of beneficial organisms. If there is not a sufficient population of biological control agents, a new flow of the pest may occur in the area. Plenty of food and the absence of natural enemies allow for rapid population growth, enough to add to the problem for the farmers (a phenomenon called "re-emergence" of the pest) causing even more serious damage. Another commonly observed phenomenon is the negative action of the insecticide on the natural enemies of other insect species that, although present in the area, had their population at such a level that it would rarely reach numbers to cause economic losses and, therefore, are species considered "pests secondary". This is precisely due to the efficient action of natural biological control. With the elimination of this type of control, the species can also increase its population to the point of causing severe damage to the host plant, a situation known as a "population explosion" of a secondary pest.

Three forms of applied biological control are generally recognized, based on how natural enemies are manipulated. In "classic biocontrol", exotic species of natural enemies are imported and released in the region where the target pest occurs. Full adaptation of introduced species can result in complete, continuous, and large-scale control.

Another way to increase the efficiency of biological control is to use techniques aimed at "population increase" of certain species of natural enemies already recognized in the area where pest control is desired. To increase the population of the biological control agent, periodic releases are carried out in the field. Normally, natural enemies used in release programs are purchased from commercial companies (biofactories). Strategies for using biocontrol, whether through the classic ("import") way or the "local population increase" technique, involve the direct manipulation of natural enemies by intentional release in the target area.

A third way to use biological control is through "conservation" of natural enemies and, unlike previous strategies, it works with populations of existing natural enemies indirectly, making the environment more favorable. This may involve removing factors that negatively influence natural enemies or adding factors that positively influence them. Biocontrol practices aimed at conservation often seek to minimize the actions of natural disruption of the agroecosystem. However, biological control by the conservation method is also an important part of any of them, be it the classic or the population-increasing method.

Importance of biological control

Field research data obtained and published by different researchers abroad and mainly in Brazil indicate the great biodiversity of beneficial insects in agricultural areas, especially where the applied chemical load is low. This biodiversity has certainly provided the natural control of different species of phytophagous insects, preventing their populations from reaching the level of economic damage. Therefore, the search for increasing biodiversity must always be practiced, especially for agricultural areas with great involvement of human power, as occurs in family farming. In this agricultural niche, and even in business agriculture, due to the difficulty of obtaining consistent and sustainable results through spraying with chemical products, biological control is an interesting alternative to mitigate problems with insect pests. Flooding or inoculative releases of natural biological control agents, such as those that act on pests in their egg or immature stages, together with the implementation of agricultural conservation practices that provide a better condition for the survival of natural control agents, have been demonstrated to rural producers the value of biological control in reducing pests. Specifically, in organic production, biological control is a legal measure and the most important alternative to control the main pests. The applied biological control, which is a selective measure, will undoubtedly rely on the complementary action of other natural biological control agents, such as those reported by Cruz (2008c), especially when the farmer provides the appropriate conditions for his survival, including the presence of shelter and food in times of scarcity of preferential prey, such as phytophagous insects.

Advantages of using biological control in Brazil

Compared with other methods, the biological control of insect pests has some important advantages:

1. The pest never ceases to be a food source for its natural biological control agents.

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1. The pest never ceases to be a food source for its natural biological control agents.

2. Natural biological control agents are part of the food chain and therefore do not leave environmental liabilities.

3. Biodiversity of natural biological control agents can keep the pest complex at acceptable population levels.

4. Biological control with macro-organisms is cheaper than other methods.

5. Biological control agents can be produced by cooperatives or farmers associations.

6. There are many species of natural control agents providing free service to the farmers, which duly protected will remain in the agricultural production area fulfilling their role of reducing the populations of phytophagous species.

7. In many regions of Brazil, the inappropriate use of chemical products, as expected, has not reduced the population of certain pests to the point of not causing damage and losses.

8. As with chemicals, Bt plants have not achieved the promised success over time.

9. Failures in effective control are due to the insect itself, which, by selective pressure, manages to survive by forming resistant populations.

10. Chemical control performed late, or with a result below expectations, naturally leads to an increase in the number of chemical applications. Thus, the cost of production increases, and the negative consequences for human beings and the environment increase. In other words, a wrong decision about pest control inevitably causes a rupture in the current production system, aggravating the problem both from a technical and environmental point of view, a situation that is not verified when using the biological control.

11. Beneficial insects are not carried in water and do not need to be placed on all plants, as they have high mobility and the ability to search for the target pest.

As a result of errors and corrections of global experiences, biological control is today an appropriate method to be used in the management of insect pests in different crops and especially in family farming. In addition to the technical and environmental advantages of the method, the biodiversity of biological control agents found in Brazil is indicative that, when carefully considered, it can significantly reduce the pest population to below that level necessary to cause economic losses.

Use of parasitoid and predatory insects in biological control

Several species of insects are recognized as biological pest control agents. Didactically, these agents are grouped into parasitoids and predators. Parasitoids are conceptualized as biological control agents in which at least one of their life stages is strongly associated with the pest, treated as a host of the natural enemy. Predators, on the other hand, are never strongly associated with the insect pest, treated in this case as prey.

Some species are recognized for having insect pests as food in both their young and adult phases. For example, within the production system of various vegetable crops, there are "predatory" insect species such as some beetles, including ladybugs, bedbug species such as *Orius* and *Podisus*, among others. Another important group of predators includes species that only at one stage of life have the habit of feeding on insects, such as the so-called "junk bugs".

In the group of parasitoids, there are species that parasitize exclusively eggs, especially insects of the order Lepidoptera, which include several important pests represented by caterpillars. Egg parasitoids have been widely used in biological control research, mainly through *Trichogramma* and *Telenomus* species (Figueiredo et al., 1999, 2002, 2006a, 2006b, 2015), among many others, which place their eggs inside the egg of the plague and only leave when they reach adulthood. Thus, when parasitism is total, no pest damage occurs.

There are parasitoids such as *Chelonus insularis* that also lay their eggs inside the pest's egg; however, they allow the embryonic development of the host (pest). They are egg-larvae parasitoids, because, at birth, the pest's larva carries the parasitoid's larva in its body. As a healthy larva, the parasitized larva starts to feed normally, but, as it is parasitized, it gradually reduces its food intake until death caused by the parasitoid, in such a way that the damage caused to the plant does not reach a level that would require its control.

There are also several species of parasitoids that act exclusively in the larval stage (larva parasitoids), such as wasps of the genera *Campoletis*, *Eiphosoma*, *Exasticolus* and many others. The adult females of these parasitoids lay their eggs inside the body of the host larva (pest). When they hatch, the parasitoid larvae develop until close to the pupae period, when they leave the host's body, killing it. The parasitized pest larvae cause some damage, but the magnitude is not enough to promote significant damage to the host plant.

In addition to egg, egg-larvae and larval-exclusive parasitoids, different species can enter the larval stage of the pest and only cause the mortality of the host insect when it is in the pupal stage, as is the case with some species of flies. It is also possible to occur parasitoids exclusive to pupae and even parasitoids from adult insects

Biological Control and Integrated Pest Management

Integrated Pest Management (IPM) was conceived as a strategy used to control pests that combines biological and cultural control measures, as well as alternatives to chemical control, gradually reducing their use. The objective of the IPM is to keep pest population levels below the level of economic damage while minimizing harmful effects of pesticides on human health and environmental resources. Therefore, biological control is the basis of Integrated Pest Management.

One of the main consequences of the misuse of chemical sprays to control insects is the imbalance by the drastic reduction of natural biological control agents. There is a reduction in the population of both the target pest of spraying and the population of other macro-organisms whose role in the agroecosystem is to feed on phytophagous insect species, often keeping them with populations below those that would cause economic damage. Such situation, in general, does not happen when a specific biological method is used to control a particular species of pest, as there is a joint action of the control agents.

Biological control applied to agriculture: corn cultivation as an example

Advances in knowledge about biological control agents for pests, the commercial availability of some of these beneficial insects and awareness of the importance of pest monitoring for correct decision-making on the need to initiate control measures are key factors for success in pest control both in corn and other cultivated plants. For example, fall armyworm control was facilitated with the development of research with synthetic sex pheromone (Cruz et al., 2010, 2012) and later with the commercial availability of monitoring kits that include synthetic sex pheromone and a trap with sticky floor.

Biological control occurs when a large quantity of a certain beneficial insect is released at once in the field (flooding release) and/or in periodic releases, with a smaller number of insects (inoculative release). As already pointed out, these insects originate from creations in the laboratory (biofactory) and characterize the applied biological control. Equally important is the natural biological control, achieved by the action of beneficial insects that are already present in the target area.

In areas where chemical application has traditionally been the preferred control option, the natural occurrence of beneficial insects is generally negligible or absent. Therefore, in an initial biological control program, the greatest impact on the target pest population comes from flooding releases and/or inoculative releases. Since there is no application of chemical substances in the area, after the release of the biological control agent, there is a gradual increase in the population of other beneficial control agents. Together, they can all contribute to reducing the target pest population and reducing the population of other phytophagous species in an equilibrium situation. The use of strategies that allow the preservation of all biological control agents should be routine in agricultural areas.

Biological control is one of the main pillars of the IPM. Regardless of the cultivation system, the IPM must follow the same steps. The first is to avoid breaking the existing balance in the agricultural system, especially in relation to the population of beneficial insects, both in number of species and in number of individuals per species. A simple way to do this is to provide, in the vicinity of the main crop, conditions for the survival of natural control agents. The availability of plants that provide shelter, alternative food, and conditions for the multiplication of beneficial species can be the differential in the regulation of the insect-pest population. The maintenance, for example, on the edges of the main crop, of some rows of sorghum, sunflower or crotalaria is an alternative to compose the agricultural landscape with the objective of increasing the biodiversity of beneficial insects.

The second step in implementing the IPM, with an emphasis on biological control, is to focus on the main pest, for which the Economic Injury Level (EIL) has already been determined. The EIL stands for the population level of the pest with the potential to cause a reduction in productivity, whose monetary loss is at least equivalent to the cost of its control. This concept, as can be seen, is purely economic. Further analysis should also consider the additional costs generated by the collateral impacts of the chosen control method, such as the elimination of biological control agents and/or other beneficial insects such as pollinators.

Knowing the EIL in advance, the next step of the IPM is to compare the reference value for the EIL of the target pest with the actual value of the infestation under field conditions, obtained through sampling. The actual value found being equal to or greater than the reference suggests the need for control measures.

The criterion to determine the real value of the infestation, in general, is the presence of the pest at the stage in which it feeds on the plant or the symptom of the damage caused by it. In both cases, there is no good efficiency. For example, the presence of a larva inevitably means damage to the plant and some additional damage from handling the plant in the sampling process. When sampling is only based on lesions, there is a risk of considering a plant without apparent injury, with the pest present. These criteria traditionally determine the need for control, which has been carried out by spraying, mainly with chemical products.

Cruz et al. (2012) demonstrated greater efficiency in monitoring *Spodoptera frugiperda* in maize using sticky traps associated with the pest's synthetic sex pheromone, compared to other monitoring methods. The use of the trap successfully determined the biological control of the pest by the release at the appropriate time of the egg parasitoid

Trichogramma pretiosum Riley, 1879 on under an organic production system (Figueiredo et al., 2015).

The third strategy of IPM, based on biological methods, is the correct choice of control agent and field release method. For example, considering Lepidoptera species as the most important corn pests, especially *S. frugiperda* and *Helicoverpa* spp., the flooding release of the *Trichogramma* wasp has been one of the best control options.

How to recognize natural enemies associated with corn pests

It is not an easy task for farmers to recognize the presence of different species of natural enemies in the field. This task is more arduous when it comes to parasitoids, whose adults are very agile, and the other phases are often inside the abdomen of the host pest. In contrast, predators are much bulkier in adulthood and are not as agile as parasitoids.

One possibility that can be adopted by producers is the formation of partnerships with Emater extensionists, colleges and state and federal research institutions, such as Embrapa, mainly through cooperatives, producer associations or rural unions, to identify and monitor biological control agents at the property and at region. Figures 1 to 3 show monitoring results of *Spodoptera frugiperda* larvae parasitoids in corn crop, on rural properties in different municipalities of the State of Minas Gerais, Brazil. In this protocol, larvae up to 30 mm in length are collected, placing them individually in the laboratory in 50 ml plastic cups containing artificial diet, until the appearance of parasitoids or emergence of the pest adult.

In all sampled properties, parasitoids of *S. frugiperda* were obtained, with variations between 4,8% and 71,4% of parasitism, indicating the presence of one or more species of biological control agents, in properties of varying sizes, where biological control was not used by producers. The main species were those that parasitize eggs, such as *Chelonus insularis*, or those that parasitize small and medium larvae, such as *Campoletis flavicincta* and *Eiphosoma* spp (Figures 2 and 3).

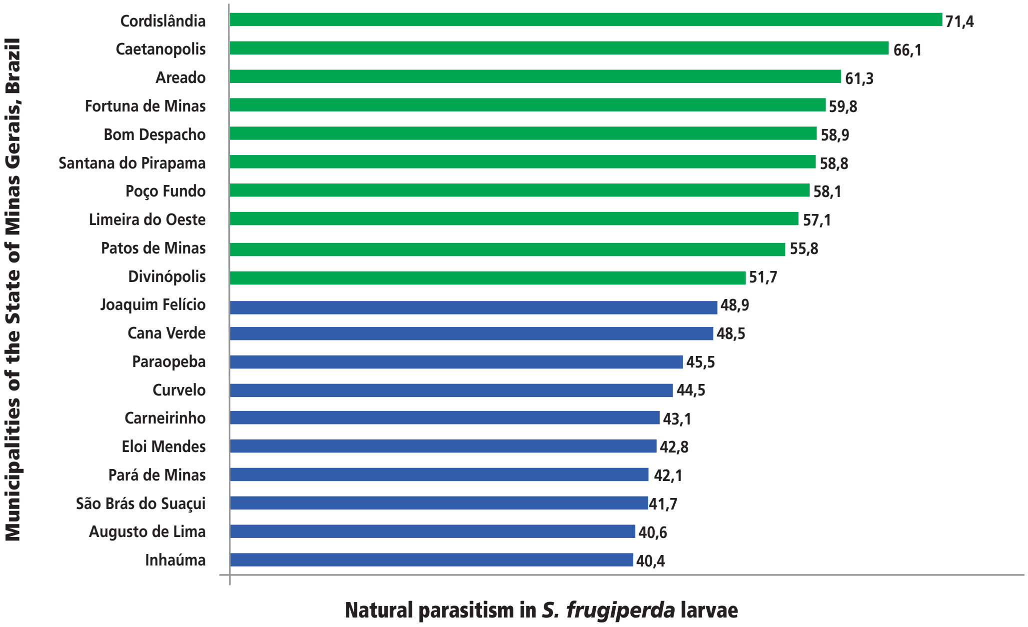


Figure 1. Natural parasitism index above 40% obtained from *S. frugiperda* larvae collected from maize plants.

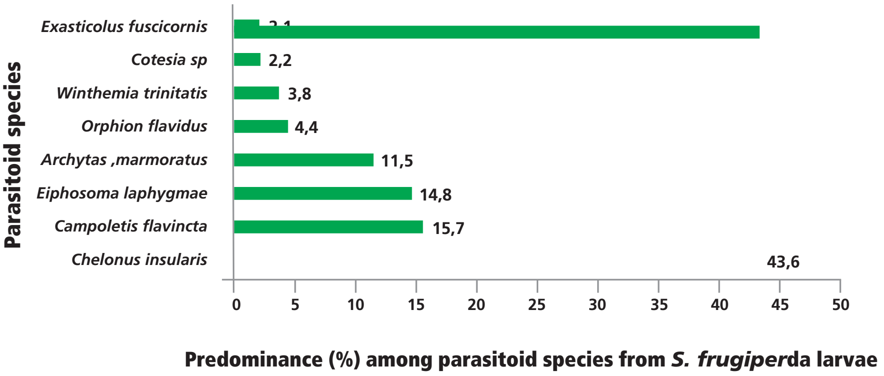


Figure 2. Average individual contribution of *S. frugiperda* larvae parasitoids. verified in maize, in Minas Gerais municipalities for a period of seven years

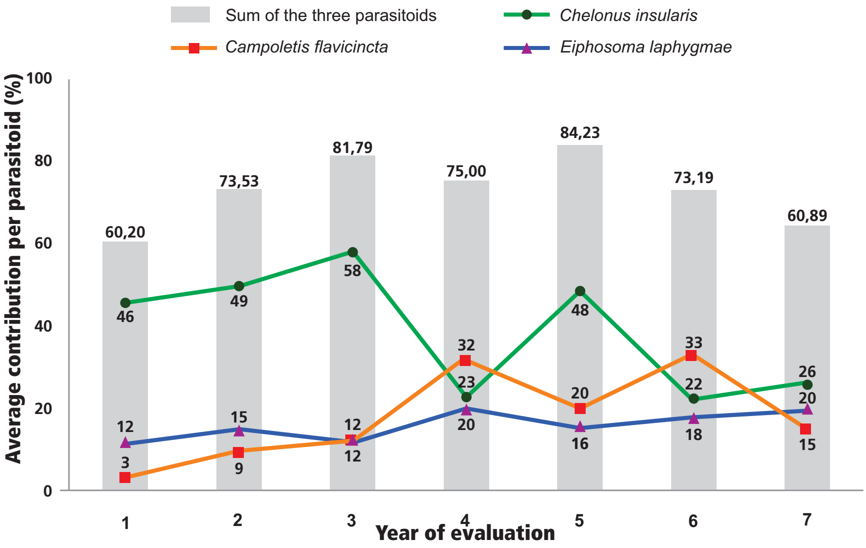


Figure 3. Contribution of the three main parasitoids of *S. frugiperda* larvae collected on corn in municipalities of Minas Gerais, Brazil for a period of seven years.

PARASITOIDS

Egg Parasitoids

Egg-exclusive parasitoids are those species that only act at this stage of the pest and are considered the most important among all other biological control agents, as they prevent the hatching of larvae, preventing any damage to the host plant. Some species of egg parasitoids are easily bred on a large scale (biofactory) and are already commercially available in several countries, including Brazil.

Trichogramma spp. (Hymenoptera: Trichogrammatidae)

There is mention in Brazil of *Trichogramma pretiosum* as a biological control agent of *S. frugiperda* and *Helicoverpa zea* (Bod.) in corn, *Erynnis ello* (L.) in cassava, *Alabama argillacea* (Hueb.) and *Heliothis virescens* (Fabr.) in cotton (Parra et al., 1987; Bleicher; Parra, 1990; Saavedra et al., 1997; Zucchi; Monteiro, 1997) and *Tuta absoluta* (Meyrick) in tomatoes (Freitas et al., 1994; Villas Bôas; França, 1996; Haji, 1997; Faria et al., 2000). In fact, *Trichogramma* species have been a differential in integrated pest management, especially when applied to agricultural crops where Lepidoptera species are key pests. Another important point of *Trichogramma* is its exclusive action on pest eggs, being able to eliminate the pest without any kind of damage to the host plant.

Trichogramma species are made up of exceedingly small insects, with dimensions smaller than one millimeter. The total cycle of the parasitoid is about 10 days. The female oviposits within her host's egg. Within a few hours, its larva hatches, and feeds on the contents of the host's egg throughout its larval cycle. A characteristic of the parasitized egg is that it becomes blackened four days after being parasitized (Figure 4). After a short period of pupae, the adult insect emerges, and immediately starts the process of searching for a new posture to continue the propagation of the species.

Figure 4. Newly parasitized *S. frugiperda* eggs (left) and eggs four days after parasitism (blackened eggs).

How to use *Trichogramma* in corn to control *Spodoptera frugiperda*

Control efficiency varies mainly as the function of insect density, wind speed, precipitation, and the number of release points. Parasitism depends on the synchronism between the presence of the female of the parasitoid and the existence of the host's eggs. Therefore, it is essential to determine the arrival of the moth in the area where the applied biological control is to be carried out before the beginning of laying.

An alternative for monitoring maize moths is to use a trap (Figure 5) containing a removable adhesive floor and the pest's synthetic sex pheromone (Brazil, 2019) to capture adults (Cruz et al., 2012). The *Trichogramma* wasp should be released when three moths are captured per trap, as this means a high probability of a larval population with the potential to reduce maize productivity. It is essential, therefore, to be successful in controlling the pest, that the producer maintains, individually or through partnerships with cooperatives, producer associations, or rural unions, monitoring throughout the corn cycle, especially for staggered planting, such as this is the case of the production of green corn for sale "in natural" or sweet corn produced for the agroindustry and even to produce seed fields.

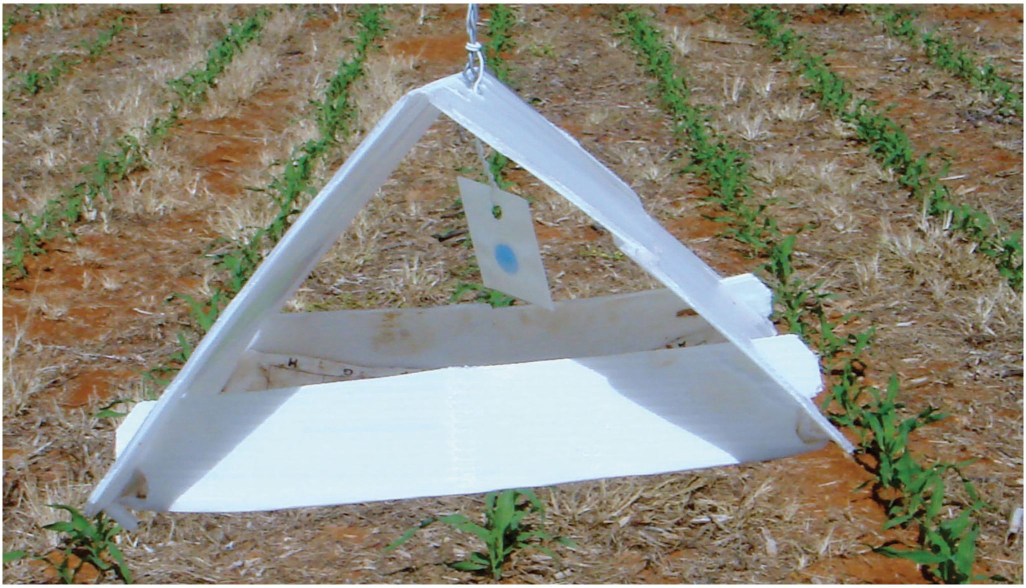


Figure 5. Trap for attracting and capturing *S. frugiperda* adults showing the sachet containing a synthetic sex pheromone.

Trichogramma is produced in registered biofactory where the farmers can purchase the product. There is also the possibility of production in a cooperative or association of producers. Even individual producers, depending on the size of the production area, can have their own factory within the legal parameters. There are important advantages of having a biofactory under the command of the person who produces the parasitoid and, at the same time, being the consumer of the biological product. Among such advantages is the immediate availability of the product and its proximity to the place where it will be used. As a biofactory with proper registration, and possibly at a lower cost, the excess production can be sold to third parties.

Trichogramma is produced using eggs from an alternative insect as a food source for its larvae and marketed as a pupa, close to the emergence of the adult insect. Once released in the field, within a few hours the parasitoid emerges, the female will be responsible for locating the pest's eggs and placing her own eggs (Figure 6). From this point onwards, the pest's egg is consumed by the parasitoid larva until it reaches full development and turns into the dark pupae stage, the characteristic sign that the egg is parasitized (Figure 4). About five days after the formation of the parasitoid's pupa, a new adult emerges that forces the "shell" of the pest's egg out, starting a new cycle. For each generation of the pest, around 30 days, the *Trichogramma* completes three generations.

Figure 6. Females (0.5 mm long) of *T. pretiosum* parasitizing *S. frugiperda* eggs.

There are different ways to release the parasitoid to control *S. frugiperda* in corn and this choice will depend on the size of the area. In small areas, the farmers can, manually or using any vehicle, walk in the area by releasing the adult insects (Figure 7). Unlike spraying, whether with chemical or microbiological products, which need to reach the target pest or at least ensure that the pest will consume the sprayed leaf, the wasp, due to its high mobility and ability to orient itself to where the posture of the pest, does not need to be placed on the plant. However, to facilitate the insect's work, reducing its time in seeking, it is recommended to release the insect at different points in the area. In large areas, *Trichogramma* can be released using specific drones, so it can carry out its work.

Field release to small areas can be performed with the adult wasp or with cut portions of cartons containing pupae close to the emergence of the *Trichogramma* adult. In this case, the cardboard portions are placed on the plant (Figure 8) or even as loose eggs, either in a "saltshaker" type container or inside gelatin capsules.

Figure 7. *Trichogramma* adult wasp release in corn for the control of *S. frugiperda*, especially for small areas of corn cultivation.

Figure 8. Placing, in the corn cartridge, portions of cardboard (2.5 x 2.5 cm) containing *Trichogramma* pupae close to the emergence of the adult wasp.

In large areas, *Trichogramma* can be released using drones with an appropriate device for application (Figure 9).

The recommended dose for use in the control of *S. frugiperda* is 100,000 adult parasitoids/hectare (Brazil, 2019, accessed on May 10, 2019), distributed in about 25 points

Figure 9. Drone with device to apply *Trichogramma* in corn.

(Figure 10). Efficiency in control, commercial availability and competitive prices are the main reasons for the growing use of *Trichogramma* as the main microbiological agent of insect pests in Brazil.

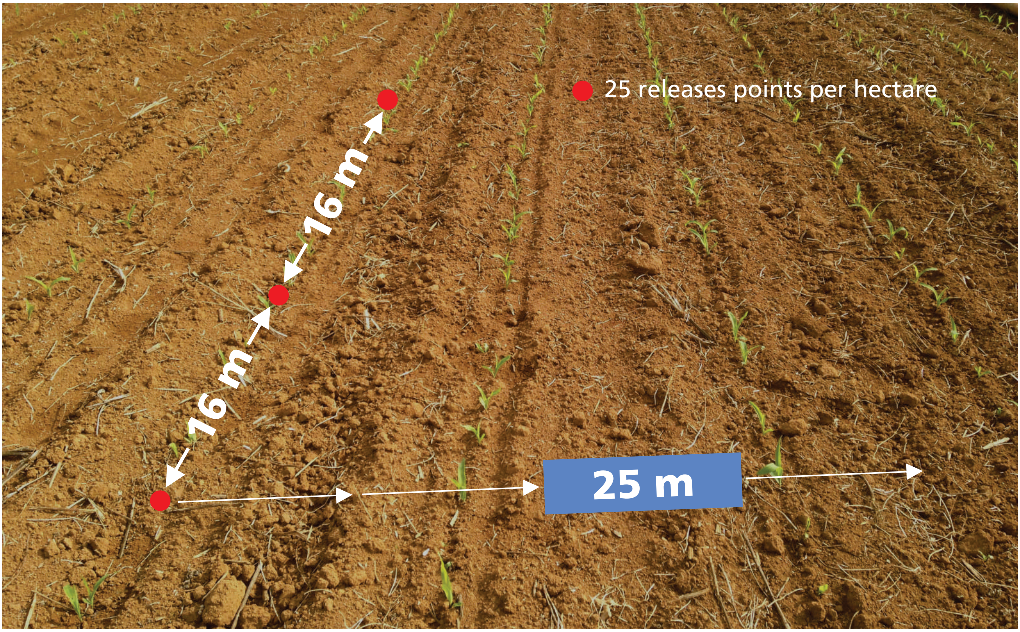


Figure 10. *Trichogramma* release scheme in corn for the control of *S. frugiperda*.

Additional advantages of using *Trichogramma*

There is no doubt that the unilateral use of products to control pests, due to excessive and/or incorrect application or because they are generally products with a broad spectrum of action, brings negative consequences, with the possibility of reduction or extinction of species, the development of resistance in pests, whether primary or those previously considered secondary, increasing or creating pest problems, in addition to contamination of the environment in general and especially of groundwater. Using *Trichogramma* does not generate any of these mentioned problems. Another important point that should be highlighted is the continued control offered by the parasitoid. Due to the relatively short life cycle concerning the pest, and because it is an exclusive egg parasitoid, whose survival depends on the presence of the pest, which is common in corn areas (Figure 11), essential eggs for perpetuation of Trichogramma throughout the corn cycle will be available

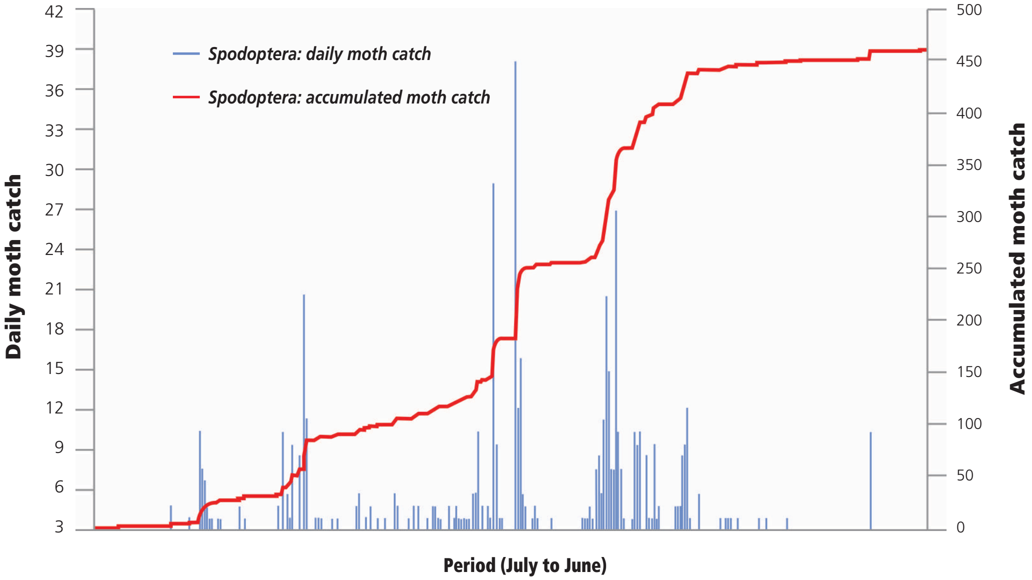


Figure 11. Average daily and accumulated capture of *Spodoptera frugiperda* moths in trap containing synthetic sexual pheromone, in a period of one year. Sete Lagoas, MG, Brazil.

One of the reasons why many phytophagous species, although present in the area, do not develop sufficient populations to cause economic damage to different species of cultivated plants may be the presence of different species of natural enemies, including macro and micro-organisms. For example, Figure 12 shows different biological control agents for *Spodoptera frugiperda* larvae in some municipalities of Minas Gerais. Therefore, the population level of these beneficial organisms will be responsible for the greater or lesser importance of the phytophagous species in each location. Thus, it is essential to use strategies that favor both the conservation and the increase of natural biological control agents, aiming at the sustainability of the production system, not only to a pest considered important but also to other phytophagous species, characterizing the modality of conservative biological control. Therefore, the use of control technology, such as the *Trichogramma* wasp, for the biological control of *S. frugiperda*, is an important strategy due to its high specificity in Lepidoptera eggs. Thus, the farmer must use, on the property, different actions to preserve, protect, or providing an increase in the population of beneficial organisms. On the contrary, a chemical control measure, even if it is efficient in controlling the target pest, may not be adequate because it is known to reduce the population of beneficial organisms.

Conservative biological control, therefore, should be a fundamental control technology in maintaining sustainability in the agricultural environment concerning the greater or lesser capacity of a phytophagous species to cause damage to the host plant and consequently to cause economic losses (Barbosa, 1998; Thomas et al al., 1991, 1992; Collins et al., 2003a, 2003b; Altieri et al., 2003; Altieri, 2004; Bengtsson et al., 2005; Hole et al., 2005; Brown et al., 2010). These authors indicate that good agricultural practices provide refuge areas by aiming at the best action of beneficial insects, such as the implantation of bands of other plant species in the vicinity of the main crop. Thus, conservative biological control depends on natural enemies that are already adapted to the production system. For example, there is already information about the presence of beneficial insects in different regions of the State of Minas Gerais, even in rural properties without any planning on conservative biological control.

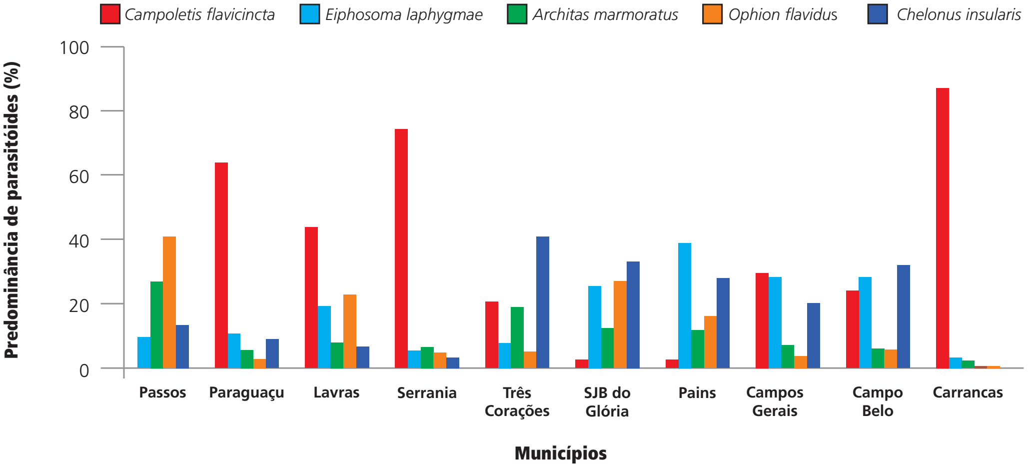


Figure 12. Predominance of *S. frugiperda* larvae parasitoids in some municipalities of Minas Gerais, Brazil.

Telenomus remus (Hymenoptera: Scelionidae)

The adult of *T. remus* is larger than *Trichogramma* spp, has a shiny black body, and measures between 0.5 and 0.6 mm in length. The life cycle of the parasitoid, on average, considering the summer temperature, can be summarized as follows: incubation period around 10 hours; larval period around five days; and five-day pupae period, that is, the total period of development, from the laying of eggs to the emergence of the adult, is about 10 days. After the full development of the immature stage of *T. remus*, the adult drills a small hole in the host's egg, through which it emerges. In general, males emerge 24 hours before females and after emergence, they remain in the egg mass in which they emerged or look for other parasitized masses. This parasitoid has a high specificity for *Spodoptera frugiperda* and can parasitize more than 250 eggs during its lifetime (Figures 13 to 16). The use of *Telenomus*, in the control of *S. frugiperda,* follows the same dynamics as the use of *Trichogramma*, however, with an amount of 60 thousand insects per hectare. The insect has also been shown as an alternative for the biological control of *Helicoverpa*.

Figure 13. Adult female of *Telenomus remus*, parasitoid of *S. frugiperda* eggs.

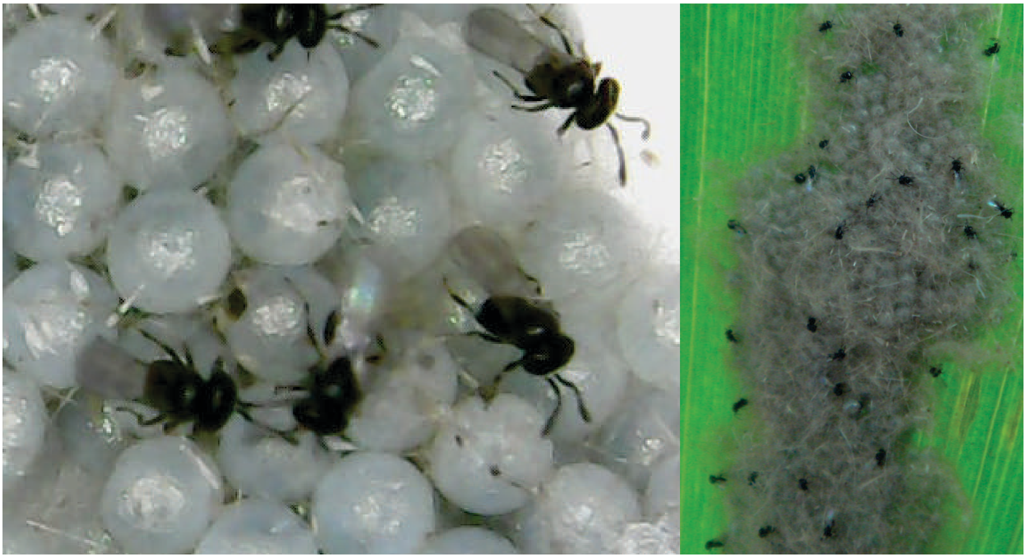


Figure 14. *Telenomus remus* parasitizing *S. frugiperda* eggs.

Figure 15. *Spodoptera frugiperda* eggs parasitized (black) by *T. remus*.

Figure 16. Telenomus remus exit orifice from the *S. frugiperda* egg.

Gryon vitripenne Masner (Hymenoptera, Platygastridae, Scelioninae)

Gryon vitripenne, an insect measuring less than 2 mm, is a solitary parasitoid of eggs of *Leptoglossus zonatus* (Dallas, 1852) (Heteroptera, Coreidae), a pest that can be found causing damage to cereals, vegetables, and fruit trees. The parasitoid (Figure 17) was recently identified in Brazil (Perioto et al., 2019), from samples of pest eggs collected in Minas Gerais and Goiás States, in corn and tomatoes.

Figure 17. Parasitoid *Gryon vitripenne* on the posture (above left) of *L. zonatus*: detail of the emergence of the parasitoid and phytophagous insect couple.

Egg-larvae parasitoid

Chelonus insularis (Hymenoptera: Braconidae)

The parasitoid *Chelonus insularis* appears to be, among the various agents of natural biological control of *S. frugiperda*, the most geographically dispersed, especially in the Americas, as reported by several authors (Wheeler et al., 1989; Molina-Ochoaet al., 2003; Cruz et al., 2009; Cortez-Mondaca et al., 2010, 2012; Rios-Velasco et al., 2011;Estrada-Vírgen et al., 2013;González-Maldonado et al., 2014; Meagher Jr. etal., 2016).

Basic studies of the parasitoid were carried out by Rezende et al. (1994, 1995a, 1995b). In adulthood, the insect is a wasp that measures about 20 mm in wingspan. The female lays her eggs inside the eggs of *S. frugiperda* (Figure 18). The insect cycle from egg to adult emergence is around 27 days, being distributed in a period of larvae, with an average duration of 20 days, and pupae with duration of six days. The number of parasitized eggs can reach 100 in the case of *S. frugiperda* eggs.

The ratio between the consumption of leaves of the healthy larvae and the parasitized larvae is 15:1, that is, the lesser feeding of the parasitized larvae means, in practice, less damage to the plant. Figure 19 shows the difference in development between a healthy *S. frugiperda* larva and another parasitized by *C. insularis*, both of which were born on the same date. This parasitoid is quite common in Brazil and, according to Figueiredo et al. (2006a, 2006b), 91% of the natural parasitism, found in samples of *S. frugiperda* larvae collected from corn plants in the field, was provided by *C. insularis*.

Unlike *Trichogramma* and *Telenomus remus* species, which use the entire internal content of the host's egg as a food source for the development of their larvae, leaving only as of the adult insect, the species *C. insularis*, which is also primarily a parasitoid of egg and which lays only one egg per host's egg, presents behavioral differences, as it does not prevent the hatching of the *S. frugiperda* larva which, as soon as it is born, starts feeding on the leaves of maize or another host plant. However, the larva of *C. insularis* makes the pest larvae gradually reduce its capacity to cause injuries to the plant, until it no longer feeds. Close to reaching the complete development of the *C. insularis* larvae, the parasitized larvae leave the plant and head for the soil. This is a normal strategy at the end of the development period of a healthy pest larva, for the transformation from larva to pupae to occur. However, in the case of the parasitized larvae, the exit of the plant occurs with the very poorly developed larvae, as if it were an early transformation to the pupal stage. The parasitized larva, as well as the healthy larva, builds a chamber where the transformation from larva to pupa normally takes place. In the case of the parasitized larva, the chamber is known as the death chamber. In this location, the parasitoid larva pierces the abdomen of the pest larva to then build a cocoon inside which turns into a pupa.

Figure 18. Female of *Chelonus insularis* parasitizing *S. frugiperda* eggs.

Figure 19. *Spodoptera frugiperda* larvae of the same age, one healthy (above) and the other parasitized by *Chelonus insularis*.

Larval Parasitoids

Campoletis flavicincta (Hymenoptera: Ichneumonidae)

Together with the parasitoid *Chelonus insularis*, *Campoletis flavicincta* is quite common in Brazil and well-studied to the host (Cruz et al., 1995b, 1997a; Matos Neto et al., 2004; Matrangolo et al., 2007). The wingspan of the adult insect is 15 mm. After mating (Figure 20), the female places her egg preferably in the first and second stages of development of *S. frugiperda* larvae (Figure 21), and the parasitoid larva completes its entire

Figure 20. Couple of Campoletis flavicincta in copulation.

cycle feeding on the host's internal content. As the larval stage of the parasitoid approaches to the full development, unlike the larva parasitized by *C. insularis*, which goes to the ground, the larva parasitized by *C. flavicincta* leaves the place where it was in the corn plant, moving itself to the highest leaves, where it remains until his death. This death occurs when the parasitoid larva leaves the body of the parasitized larva through the abdomen, killing it, to build its cocoon in the external environment, where it turns into the pupal stage. As a characteristic sign, what remains of the parasitized larva remains beside the cocoon (Figure 22), making the occurrence of this natural enemy easily identifiable.

The total cycle of the parasitoid is, on average, 22.9 days, distributed in 14.5 days in the egg and larva period and 7.3 days in the pupal period. The consumption ratio between a healthy and a parasitized larva is 14.4:1, that is, while a non-parasitized larva consumes an average of 209.3 cm^2 of leaf area throughout its life, the parasitized larva consumes only 14.5 cm^2 or 6.9% of normal consumption. Thus, when parasitizing small larvae, in addition to being efficient in causing the death of the host insect, there is a significant reduction in food consumption and, therefore, the damage caused to the plant is greatly reduced. A single female can parasitize more than 200 larvae between the first and second instar.

Figure 21. Female of *C. flavicincta* parasitizing larva (2 mm) of *S. frugiperda*.

Figure 22. Cocoon (10 mm) of *C. flavicincta* on corn leaf together with the remains of the parasitized *S. frugiperda* larva.

Eiphosoma laphygmae Costa Lima e *E. vitticolle* Cresson (Hymenoptera: Ichneumonidae)

Species of the genus *Eiphosoma* associated with *S. frugiperda* are moderate to large, yellow in color, with black macules, rarely entirely black. It is a genus with about 30 described species, most especially occurring in South America, at altitudes below 1,500 m. Several species appear in different agroecosystems, and some are important natural enemies of Lepidoptera pests. Tropical species constitute nine groups. The average duration of the life cycle, from oviposition to adult emergence, under laboratory conditions (24.5 °C, 76% relative humidity), is around 28 days. The female lays her eggs directly inside the host's body, where they float freely until they stop at its rear end. After emergence, the larva develops slowly up to the first nine days and initially feeds on nutrients from the hemolymph by cuticular absorption. The initial absence of damage to the host's vital organs explains the inexistence of visible adverse effects in the parasitized larva. Between one and two days before the parasitoid leaves the host's body, the parasitized larva goes to the ground, enters the pre-pupal state, and prepares its pupal cell, similarly to what happens with the parasitized larva by *Chelonus insularis*, and turns into a pupa (Figures 23 and 24).

The *Eiphosoma* larva completely consumes all the host's organs, leaving only the tegument, which is broken off at its exit, and immediately begins to weave its own cocoon.

Figure 23. Adult of *Eiphosoma laphygmae*, a parasitoid of small and medium larvae.

Figure 24. Larva and cocoon of *E. laphygmae*, a parasitoid of small and medium larvae.

Ophion flavidus Brullé (Hymenoptera: Ichneumonidae)

This species is distributed in Costa Rica, Panama, Guatemala, Nicaragua, Dominican Republic, Argentina, Brazil, Paraguay, Peru, and Uruguay, according to reports by Gauld (1988), Rodríguez-Berrío et al. (2009) and Sánchez et al. (2014). It is an especially important parasitoid for the control of *S. frugiperda* larvae, being reported, under experimental conditions, parasitism rates of up to 79% of larvae in Argentina (Gauld, 1988; Quicke, 2015). But it can also parasitize other species of the Noctuidae family, such as *Agrotis ipsilon* (Hufnagel), *Helicoverpa armigera* (Hübner), *Helicoverpa zea* (Boddie), *Peridroma saucia* (Hübner), *Mythimna unipuncta* (Haworth), *Spodoptera eridania* (Stoll) (Fernandes et al., 2014). Reed (1980) reported Ophion flavidus as the most common parasitoid of *S. frugiperda* in the state of Alabama (United States) and that the parasitized larvae consume 17% to 22% less food than non-parasitized larvae, depending on the size of the host at the time of parasitism (Rohlfs III; Mack, 1983, 1984).

They are medium-sized wasps, with filiform antennae, with numerous articles (segments). They have a long, thin body, measuring about 20 mm in length. Adults are active during the day. The female wasp usually locates close to the pest's host's food source, using its antennae to identify the larva to be parasitized. The female usually has a long, visible ovipositor, which is used to insert eggs into the host's body. The length of this female ovipositor allows her to inject her eggs into the body of the *S. frugiperda* larvae (Figure 25), remaining in this location during the larval period, leaving the larvae's body to become a pupa. In the laboratory, at 26 °C, the life cycle of the parasitoid was 9.6 days for the egg-larvae period and 16.7 days for the pupal period. Adult longevity was 1.3 day on average. Mated females produced male and female offspring, while unmated females produced only males (Rohlfs III; Mack, 1985).

Figure 25. Larva (left, above), pupa (right, above), and adult of *Ophion flavidus*.

Colpotrochia mexicana (Cresson) (Hymenoptera: Ichneumonidae)

Colpotrochia Holmgren, 1856 is a genus of parasitoid insects with more than 60 described species. They usually measure between six and nine millimeters and are Lepidoptera parasitoids, in situations where the parasitized larvae continue to move and feed while the parasitoid larvae develop. They are solitary endo parasitoids of larvae of different instars and pupae (Gauld et al., 2002), as is the case of *C. mexicana* (Figure 26). Although little studied in Brazil, this species certainly contributes, like other species, to maintain the balance of the population of phytophagous species, making an artificial control measure unnecessary.

Figure 26. Adult wasp of *Colpotrochia mexicana*.

Exasticolus fuscicornis Cameron (Hymenoptera: Braconidae)

Exasticolus fuscicornis is a parasitoid (Figure 27**)** recently associated with the first stages of *S. frugiperda*, measuring about 7 mm in length, which is added to several other biological control agents, complementing the action of egg parasitoids, to reduce the pest population. When the parasitoid larva is fully developed, the parasitized pest larva leaves the plant and goes to the ground, like what happens with the parasitized larva by *Chelonus insularis*. In the soil, the larva leaves the pest's body and becomes a pupa, remaining there until the emergence of a new adult, capable of starting a new generation. During its life cycle, the parasitoid can parasitize about 430 *S. frugiperda* larvae.

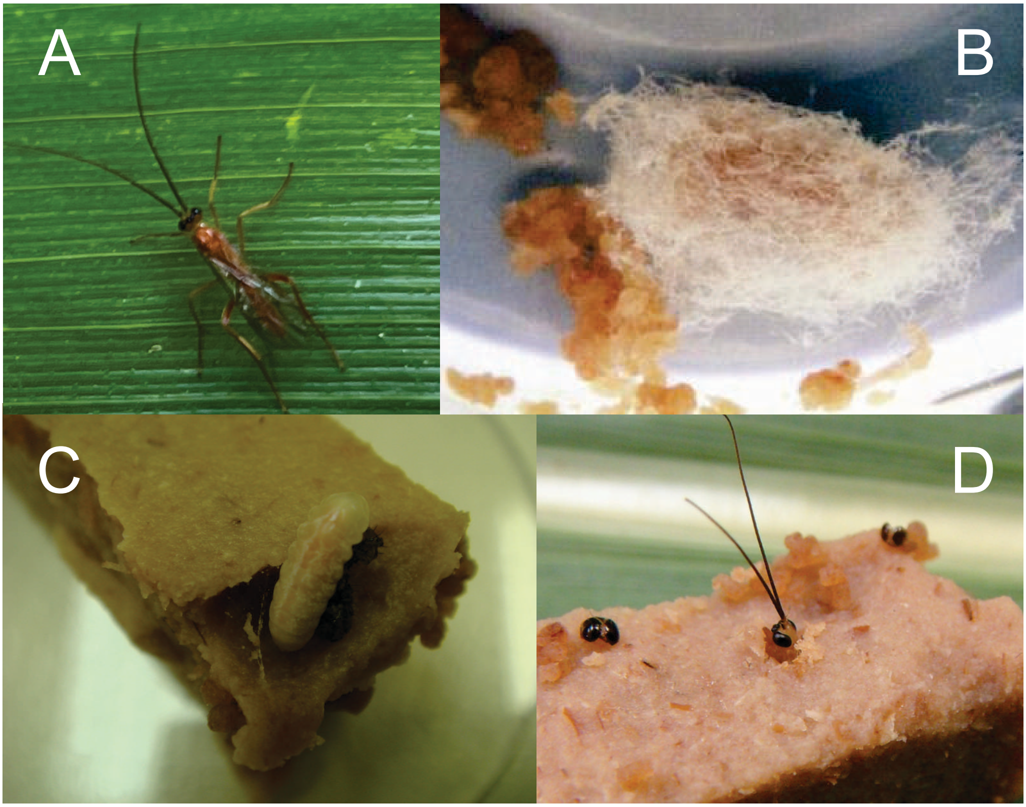


Figure 27. *Exasticolus fuscicornis* parasitoid of small *S. frugiperda* larvae: A, newly emerged adult; B, cocoon; C, larva; and D, adult emerging from an artificial diet used in rearing the host larva.

The life cycle of the parasitoid egg until the appearance of the adult is, on average, 23 days, and adults have a longevity of 15 and 16.5 days, for males and females, respectively (Figueiredo et al., 2006a, 2006b).

Cotesia spp (Hymenoptera: Braconidae)

Cotesia adults are small wasps 3 to 4 mm in length that, if properly fed and at 25 °C, live for approximately 34 hours. The species *Cotesia flavipes* (Cameron) is a gregarious endo parasitoid, that is, the females deposit multiple eggs in the body cavity of the host (Figures 28 and 29). On average, a female lay about 40 eggs in each pest larva. About three days later, the parasitoid larva enters the pest's body, passing through three instars inside the host larva. The period from egg to larvae of the parasitoid lasts approximately 14 days. After leaving the host, last-instar larvae weave a cocoon and become pupae, and this period lasts approximately six days, at the end of which adult emergence occurs. The species is widely used in Brazil for a biological control applied to sugarcane, to reduce the population of the *Diatraea saccharalis* borer, which is also a pest of corn and sorghum.

The species *Cotesia marginiventris* (Cresson) (Figure 30), an insect measuring about one millimeter, unlike *C. flavipes*, is a solitary endo parasitoid. It is known to parasitize larvae of several Lepidoptera species, including those of the genus *Spodoptera*. Meagher Jr. et al. (2016) reported that, in a field study with sweet corn in Florida, in the United States, *C. marginiventris* and *Chelonus insularis* are the most common parasitoids in *S. frugiperda* larvae, representing 47.3 % and 46.6 % of the total parasitism, respectively. The insect has a wide geographic distribution and can be considered a promising parasitoid for use in biological control (Ashley et al., 1982; Pair et al., 1986; Riggin et al., 1992, 1993; Molina-Ochoa et al., 2003).

The life cycle from egg to adult of *C. marginiventris* is approximately 13 days, and the adult female parasitizes preferentially exceedingly small larvae (first two instars) of Noctuidae such as *S. frugiperda*, *Agrotis ipsilon* (Hufn.), and *Helicoverpa zea* (Boddie), placing a single egg in the host where the larvae develop. Between seven and ten days, the parasitoid leaves the parasitized larva to turn into a pupa inside a white-colored cocoon. The parasitized larva practically does not feed. The adult measures around 3 mm in length and lives for about a week, however, it lays its eggs in the host in an age between two and four days. Although with a preference for larvae, it may eventually parasitize eggs.

Figure 28. *Cotesia flavipes* parasitizing *Diatraea saccharalis larva.*

Figure 29. Cocoon of *Cotesia flavipes* from *Diatraea saccharalis* larvae.

Figure 30. Cocoons and adults of the parasitoid *Cotesia marginiventris* obtained from larvae developed in *Spodoptera frugiperda* larvae.

Other parasitoids of larvae of the order Hymenoptera

Meagher Jr. et al. (2016) reported the association of solitary endo parasitoids *Aleiodes laphygmae* (Viereck) (Braconidae), *Meteorus* spp. (Braconidae) and the gregarious ecto parasitoid *Euplectrus platyhypenae* (Eulophidae) with *S. frugiperda* larvae, although there is still little biological information about these species.

The genus *Meteorus* Haliday (Hymenoptera: Braconidae) is cosmopolitan and has about 340 described species, all of which are endo parasitoids of Coleoptera or Lepidoptera larvae, including *Agrotis ipsilon* (Hufnagel), *Lymantria dispar* (L.), and *S. frugiperda*, currently being described in Brazil the species *M. eaclidis* Muesebeck and *M. citiesendi* Muesebeck, *M. atlanticus* n. sp., *M. ferruginosus* n. sp., *M. itatiaiensis* n. sp., *M. monoceros* n. sp., *M. strigatus* n. sp., *M. jerodi* Aguirre & Shaw, *M. laphygmae* Viereck and *M. megalops* Zitani (Almeida; Penteado-Dias, 2015).

Villegas-Mendoza et al. (2015) reported that the parasitoid *Meteorus laphygmae*, having as hosts *S. frugiperda* larvae, feed for an average time of 9.5 days, after which they leave after making a hole in the last abdominal segment of the host. The larva that has been parasitized stops feeding, loses its mobility, and dies within 48 hours. The pupal period of the parasitoid lasts an average of seven days, when the adult insect appears, which has a longevity of around 20 days. The parasitoid also parasitizes other *Spodoptera* species in addition to *S. frugiperda*.

The species *Euplectrus laphygmae* is a gregarious ectoparasite of many species of the Noctuidae family, which include the main corn pests. According to Gudeta (1998), before laying its eggs, the parasitoid temporarily paralyzes the host. In this condition, females lay in the first three abdominal segments, being able to lay one egg or groups of eggs, ranging from two to 13, with an average of four eggs per group of eggs laid. Eggs are mainly laid in second or third instar larvae and, on average, incubation lasts two days. The female seems to select the longest steps to ensure that the parasitoid's egg-larvae developmental stages are completed within the same developmental stage as the host (Gudeta, 1998).

Egg and larva development takes place externally at the site. The pupal stage occurs in a silky cocoon under the dead host. The complete cycle of the parasitoid insect is around

12 days for both sexes. Hosts bit by the female die, regardless of whether oviposition occurred or not.

Archytas, Winthemia e Lespesia (Diptera: Tachinidae)

Several species of the order Diptera of the Tachinidae family are also associated with various pest species. Among the most common species, the highlight is *Archytas marmoratus* (Townsend), a solitary pupal parasitoid of several Noctuidae (Lepidoptera) species, including *Helicoverpa zea* (formerly *Heliothis zea*) and *S. frugiperda*. The parasitoid has a complex life cycle that allows it to parasitize a wide range of hosts. The female does not lay eggs directly on the hosts but lays several of them nearby. The eggs soon produce larvae, and parasitism occurs when these larvae encounter the host, where they penetrate between the body's cuticle and epidermis, where they become lodged. The development of *A. marmoratus* within the host pupa is rapid. Since the female of *A. marmoratus* lays several eggs at the same time, and due to the possibility of more than one female laying eggs in the same place, there is a chance of super parasitism. Despite this, only one larva of this parasitoid completes development in a host. Gross and Young (1984) obtained a reduction in adult insects of up to 66.5% and 42.4% when parasitizing the 5th and 6th instar larvae of *S. frugiperda* and 4th and 5th instar larvae of *H. zea*, in the phase cartridge and braiding of a sweet corn cultivate, respectively. Gross and Young (1984) highlighted the great efficiency of this parasitoid that, although it targets developed larvae and coming out of the pupae of the two pests mentioned above, it acts on larvae that typically escaped parasitism and/or predation at younger stages.

Archytas incertus (Macquart) and *Winthemia trinitatis* Thompson are also species considered important as parasitoids of *S. frugiperda* in maize crops in Brazil (Molina-Ochoa et al., 2003; Milward-de-Azevedo et al., 1991). The species *W. trinitatis* is relatively easy to be identified in agricultural areas. The female lays her eggs in the body of a host larva, close to her head, making them impossible to remove (Figures 31 and 32). At birth, the parasitoid larvae penetrate the pest's body, preventing it from developing into the pupal stage.

Figure 31. *Winthemia trinitatis* laying eggs on the *Spodoptera frugiperda* larva.

Lespesia archippivora (Riley) is another important generalist parasitoid in the maize production system, capable of parasitizing at least 25 species of Lepidoptera. The insect lives in its host's body, resulting in its death. Mating occurs on the first day after the emergence of the adult from the pupa. After mating, the female goes in search of a host. When she finds it, she quickly lays her eggs at the end of the larva's abdomen. After parasitism, *L. archippivora* larvae go through three larval stages, leave the host at an advanced stage, and take shelter in the soil. While inside the host, the larva moves freely. After three days, however, it adheres close to the respiratory tube of the parasitized larva. As the *Lespesia* larva develops, it eventually consumes all its host's internal contents, before exiting the external environment, to turn into the pupal stage. A new adult emerges from the pupa approximately 10 to 14 days later. Female oviposits between 15 and 204 eggs in her lifetime (Etchegaray; Nishida, 1975).

As already pointed out, despite acting on more developed hosts, which have already caused damage to the plant, Tachinidae species are important because, together with other biological control agents, they are a natural reduction factor for future generations of pests.

Figure 32. *Winthemia trinitatis* fly eggs on *Spodoptera frugiperda* larva.

Pupae parasitoid

Tetrastichus howardii Olliff (Hymenoptera, Eulophidae)

Tetrastichus howardii, an insect of recent occurrence in Brazil, is a parasitoid of *Diatraea saccharalis* pupae. A female can produce up to 66 offspring in a single host pupa and apparently does not distinguish between different pupa ages. Its life cycle is 25.5 days on average. The presence of the parasitoid in the country opens a new perspective for the suppression of the sugarcane borer, considering the promising results already obtained in

Figure 33. *Tetrastichus howardii*, a parasitoid of Lepidoptera pupae.

Asian countries. The insect (Figure 33) is adapted to laboratory conditions and can be produced in large numbers, thus becoming an additional option for integrated management in crops where *D. saccharalis* is a key pest, such as sugarcane sugar, corn, and sorghum. The insect is adapted to its strategy of finding hosts and can penetrate plants and seek hosts in the galleries produced by pests. This is a characteristic suggested as a prerequisite for being a good biological control agent for borers (Kfir et al., 1993). Additional important attributes of the parasitoid are its short life cycle, high fertility and longevity rate, the preponderance of females, and relative ease of mass rearing under laboratory conditions (Kfir et al., 1993; Baitha et al., 2004; Prasad et al., 2007; Cruz et al., 2011b).

Aphid parasitoids

Aphidius colemani Viereck, *Diaeretiella rapae* (McIntosh) (Hymenoptera: Braconidae) and *Lysiphlebus testaceipes* (Cresson) (Hymenoptera: Aphidiidae)

These are small insects whose females lay their eggs individually in nymphs (young stage) of aphids, which are consumed by the parasitoid larva. Parasitized aphids are turned into "mummies" (Figure 34). In addition to causing death, the parasitoids also cause physical disturbance in aphid colonies, which abandons the host plant. The main species are *A. colemani*, *D. rapae*, and *L. testaceipes* and can be used to control the aphid *Rhopalosiphum maidis*. Each female can parasitize between 300 and 500 aphids during her lifetime. In addition to the high productive potential, these parasitoids have a short cycle and use different species of aphids as hosts. All three species kill aphids, whose mummies are light brown. The identification of species is possible through the characteristics of the wings.

Figure 34. Aphid colony *Rhopalosiphum maidis* in maize (left), parasitized aphid mummies, and detail of the exit hole of the adult parasitoid, *Aphidius* spp.

PREDATORS

Ladybugs (Coleoptera)

Ladybug larvae and adults vary in size and color and feed on different phytophagous insects, such as mites, aphids, whitefly, scale insects, eggs, and young larvae of Lepidoptera species. Pollen and fungal spores are also important components in the diet of these species.

Coleomegilla maculata (Figure 35), *Hippodamia convergen*s (Figure 36), *Olla v-nigrum* (Figure 37), *Cycloneda sanguinea* (Figure 38), *Eriopis connexa* (Figure 39), *Harmonia axyridis* (Figure 40), *Neda conjugata* (Figure 41), and several other species are commonly seen in agricultural areas. According to Guerreiro et al. (2002), the number of species in the ladybug family is about 5,000.

Coleomegilla maculata (DeGeer) (Coleoptera: Coccinellidae)

A cosmopolitan species of ladybug, found in most of the Americas. Adults are six millimeters long, usually red, and with six black spots on each wing. Females lay groups of 10 to 20 yellow eggs in the plants, being able to lay up to 780 eggs in laboratory conditions and have an alternative food for their larvae and the eggs of the flour moth, *Anagasta kuehniella* (Santos-Cividanes et al., 2011). However, adults and larvae can feed in the field on aphids, mites, eggs, and larvae of various insects, including Lepidoptera species (Hodek, 1973; Weeden et al., 2007). The larva becomes a pupa on the plant itself. At an average temperature of 26 °C, the larvae hatch from the eggs in four days and remain in the larval stage for an average period of 10 days, after which they turn into the pupae period, which lasts an average of five days.

The efficiency of *C. maculata* as a biological pest control agent is due to its ability to reproduce and survive, even when there is insufficient availability of traditional food sources (De Clercq; Degheele, 1992; Nakashima; Hirose, 1999), as it can complement the diet with nectar and pollen from different plant species without causing damage to such plants

(Hodek; Honek, 1996; Lundgren et al., 2004; Michaud; Grant, 2005; Pilorget et al., 2010). According to Santos-Cividanes et al. (2011), the insect survival rate varies with the time interval in which the larvae are fed, ranging from 77% when fed daily and falling, respectively, to 50% and 23% when the larvae are fed every two or three days.

Figure 35. *Coleomegilla maculata* DeGeer (adults, eggs, larva, and pupa).

Hippodamia convergens (Guérin-Meneville) (Coleoptera: Coccinellidae)

Adults approximately six millimeters in length have elytra (thicker pair of wings, especially in beetles such as ladybugs) orange and typically six small black spots on each one. However, the number of spots may vary. The body section behind the head is black with white margins and two converging white lines, the reason for its name. Females lay groups of 10-20 yellow eggs on the plants measuring about one millimeter, each female being able to lay up to 1,000 eggs during her lifetime. The larva is dark, with the appearance of an "alligator", with three pairs of legs, and is easily noticed in the later stages of development. At birth, the larva measures about one millimeter and goes through four stages of development until reaching, in the last one, the measure of seven millimeters in length. The larvae period lasts, on average, 15 days in summer, after which the larvae turn into the pupae stage, which lasts about seven days, depending on the temperature.

Larvae and adults feed mainly on aphids, regardless of the pest's host plant, increasing the importance of the presence of this species in the agricultural environment. As is common with ladybug species, if the preferred food source is reduced, they can feed on other sources, including eggs and small Lepidoptera larvae, mites, or even nourish themselves on nectar or sugary substances (honey dew) secreted by aphids and other sucking insects.

Figure 36. *Hippodamia convergens* (adult newly emerged from the pupa, adult with its natural color, eggs, and larva).

Olla v-nigrum (Mulsant) (Coleoptera: Coccinellidae)

Adults of this ladybug have a difference in color pattern (Figure 37), which is not sexual dimorphism. They are initially light in color. Over time, they become darker, and the black adult acquires a shiny black color, while the stains on their elytra turn orange. The yellow adult shows a slight increase in hue, and the dots along the elytra become black. *Olla v-nigrum* is an efficient predator in both larval and adult stages. The female lays an average of 21 eggs per laying in a single layer. The eggs are elliptical in shape and pale yellow in color and remain this color until close to the hatch of the larvae, when they turn gray. The incubation period is three days. The larva has an elongated body, with distinct regions and abdominal segmentation, with well-developed legs and antennae. The larval stage lasts 13 days. The pupa initially has a light color, which slowly darkens. The pupa stage lasts four days. The total cycle from egg to adult is 20 days.

Figure 37. *Olla v-nigrum* (adults, egg, and larvae).

Cycloneda sanguinea (Linnaeus) (Coleoptera: Coccinellidae)

This species of ladybug is known to be a red-colored insect (Figure 38), without spots on the elytra of adults. However, it has two black spots on the clear area of the head, giving a large two-eyed appearance. The female lays her eggs on the plant, in groups, each containing about 20 yellowish eggs. The insect goes through four larval stages. After the larval period, which lasts about eight days, the larvae develop into a pupa and then into a new adult. The cycle from larva to adult lasts around 15 days. Both the larva and the adult are predators of various pests.

Figure 38. *Cycloneda sanguinea* (adult couple, larva, pupa, and eggs).

Eriopis connexa Germar (Coleoptera: Coccinellidae)

Eriopis connexa (Figure 39) is one of the most widespread species of ladybug in South America. It has an oblong body shape, is dark brown to black in color, with relatively large and separate yellow spots. The pronotum (dorsal part of the first chest segment) and eliters have a yellowish margin. Each eliter displays three separate dots. The species is a voracious predator of many preys (Hodek, 1973; Sarmento et al., 2004). Its polyphagous eating habits, reported by several authors, show that this predator can feed on insect pests of various crops, including corn and sorghum (Miller; Paustian, 1992;Miller, 1995; Eubanks; Denno, 2000; Roger et al., 2000; Sarmento et al., 2004, 2007; Soares etal., 2004, 2005; Berkvens et al., 2008; Silva et al., 2013).

Figure 39. *Eriopis connexa (adult preying on eggs, posture, larva, and couple)*

Silva et al. (2013) demonstrated the good acceptance of insect larvae by exclusive food sources, including eggs of *Diatraea saccharalis* (Fabricius) (Lepidoptera: Pyralidae) and the aphids *Rhopalosiphum maidis* (Fitch) and *Schizaphis graminum* (Rondani) (Hemiptera: Aphididae), with the total viability of the predator being greater than 90%.

Harmonia axyridis (Pallas) (Coleoptera: Coccinellidae)

A well-known species (Figure 40) as a voracious predator of aphids, also feeding on other insects such as psyllids (Koch, 2003), lepidopteran eggs (Santos et al., 2009) and pollen (Berkvens et al., 2007, 2008). It is successfully used in biological control programs (Koch et al., 2006). On the European continent (Brown et al., 2007), China (Zhang, 1992), the United States and Mexico (Brown; Miller, 1998), for example, the species is already widespread and is considered one of the main agents of biological control of aphids in different agricultural crops.

It is a typical ladybug, measuring between 5.5 and 8.5 mm in size, and is orange or red in color, with black spots of varying size. However, many other forms can also be observed. The larger size, compared to other species of ladybugs, is a good indicator to identify the species.

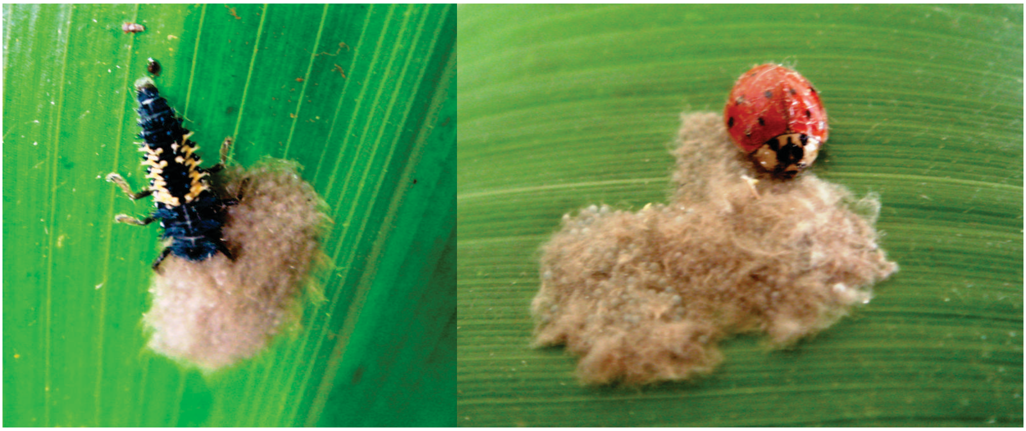


Figure 40. *Harmonia axyridis* (larva and adult feeding on *S. frugiperda* eggs).

The average time to complete the cycle is between 18 and 20 days. Adults can live up to 90 days (He et al., 1994; El-Sebaey; El-Gantiry, 1999; Soares et al., 2001; Santos, 2009), during which time the female can lay more than 600 eggs. Santos (2009), using the *Cinara atlantica* aphid species as a food source, reported that the average total consumption per larva and adult of *H. axyridis* was 280 and 1.892 aphids, respectively, showing the ladybird's predatory capacity.

Due to its great competitiveness and voracity, the insect can also use other predator species, including ladybirds, as a food source, which is not a desirable quality (Iablokoff-Khnzorian, 1982; Elliott et al., 1996; Burgio et al., 2002, 2005; Pell et al.,2008; Santos et al., 2009; Martins et al., 2009; Katsanis et al., 2013).

Neda conjugata (Mulsant) (Coleoptera: Coccinellidae)

Better known as *Cycloneda conjugata* (Figure 41), this species of ladybug has an almost circular shape and yellow coloration, with dark brown spots. It has seven isolated spots in the pronotum, with a small one in the center of the base, four around it, and two near the lateral edge. It has elytra with six stitches each, in two vertical lines of three stitches each, the central point of the suture edge in the form of a characteristic tear. The stains leave narrow yellow spaces over the elytra. Size ranges between 5.1 and 6.4 mm. Like other species, the insect is a predator of aphids and other species of small size.

Figura 41. *Neda conjugata* (larva e adulto).

Earwig (Dermaptera)

There are many species of Dermaptera that exhibit predatory habits. Currently, two species of earwigs are recognized and sought after for use in maize cultivation: *Doru luteipes* (Scudder) (Figures 42 and 43) and *Euborellia annulipes* (Lucas) (Figure 44). These insects have chewing mouthparts and well-developed compound eyes. The antennas are long, threadlike, and with many segments. Only the first species has wings. In this case, the first pair is small and leathery, and the second pair is membranous, becoming folded when the insect is at rest.

Doru luteipes (Dermaptera: Forficulidae)

The species *D. luteipes* is one of the most important natural enemies in the suppression of maize pests, notably *S. frugiperda*, *Helicoverpa* spp, and *Rhopalosiphum maidis* (Reis et al., 1988; Cruz et al., 1995b; Cruz; Oliveira, 1997). The corn plant has adequate structures for the multiplication of the insect, such as the curled leaves that form the cartridge or the layers of straw on the ear. In these places, with high moisture content, the insect lays its eggs. Unlike most insect species, earwigs demonstrate maternal care for their eggs and newborn nymphs. Without such care, they would inevitably be contaminated with eggs by micro-organisms, due to the high humidity in the laying site.

Bioecological studies with the predator, feeding on *S. frugiperda* larvae, showed that the number of eggs per laying of *D. luteipes* is 25 to 30, and the incubation period is around one week. The nymph stage consists of four stages, ranging from 37 to 50 days. The adult male has one of the fences, at the end of the abdomen, curved to the left, while in females the fences are straight. The insect's life span can be up to a year.

Figure 42. Earwig, *Doru luteipes* (female and egg mass).

Figure 43. *Doru luteipes* (female and its eggs, newly hatched nymphs, and egg predation by a couple and a nymph).

Euborellia annulipes (Dermaptera: Carcinophoridae)

In summer, the incubation period for the eggs of this species is seven days on average. The egg life span until the appearance of adults is around 60 days. The newly laid eggs are oval, creamy-yellow in color, measuring 0.95mm in length and 0.75mm in diameter. Newborn nymphs are usually white in color, black-eyed, with a brown back of the abdomen. A few minutes after birth, the nymphs turn gray, gradually darkening in the antennae, legs, and forceps. When they become adults, the initial coloration is white, and later it evolves to a dark color. As already pointed out, these insects do not have wings. The male, smaller than the female, has the right lateral clamp strongly curved inwards.

Figure 44. Predatory earwig *Euborellia annulipes* (couple with their eggs, and nymphs of different ages)

Predatory bugs

There are several species of bugs that feed exclusively on other insects and therefore contribute to reducing the insect pest population. Often, the producer imagines that such insects are pests. The best-known species of beneficial bugs are included in the genera *Zelus*, *Nabi*s, *Geocoris*, *Orius*, and *Anthocoris*.

Zelus spp (Hemiptera: Reduviidae)

Within the Reduviidae family, the genus *Zelus* can be found from southern Canada to central Argentina (Maldonado, 1992). Some species have already been evaluated in terms of biological control of phytophagous insects, especially in the Americas (Cohen; Tang, 1997; Cogni et al., 2002), as they feed on insects such as cotton, corn, soybeans, alfalfa, and fruit trees (Ables, 1978; Ali; Watson, 1978; McPherson et al., 1982; Cisneros; Rosenheim, 1998; Virla et al., 2015). Under certain conditions, they can prevent outbreaks, especially of Lepidoptera larvae (Ables, 1978).

Species of the genus Zelus (Figure 45), known as the killer bug and common in agricultural areas, include *Z. longipes* Linnaeus, *Z. leucogrammus* (Perty), and *Z. armillatus* (Lepeletier & Serville), with average adult lengths ranging from 1.3 and 1.9 cm. These species are brown or dark in color and even bright, with a long, narrow head and a "distinct" thorax, with eyes that are usually reddish in color. The mouthparts are long and curved, forming the rostrum (parts that make up the mouthparts), which, at rest, is fixed under the body, with the tip-fitted into a typical cavity. They have an enlarged middle part of the abdomen and wings that do not completely cover the width of the body. Females lay eggs in groups, close to each other, in an upright position, on plant leaves, or even on the ground. The immature forms (nymphs) resemble a miniature adult without a wing.

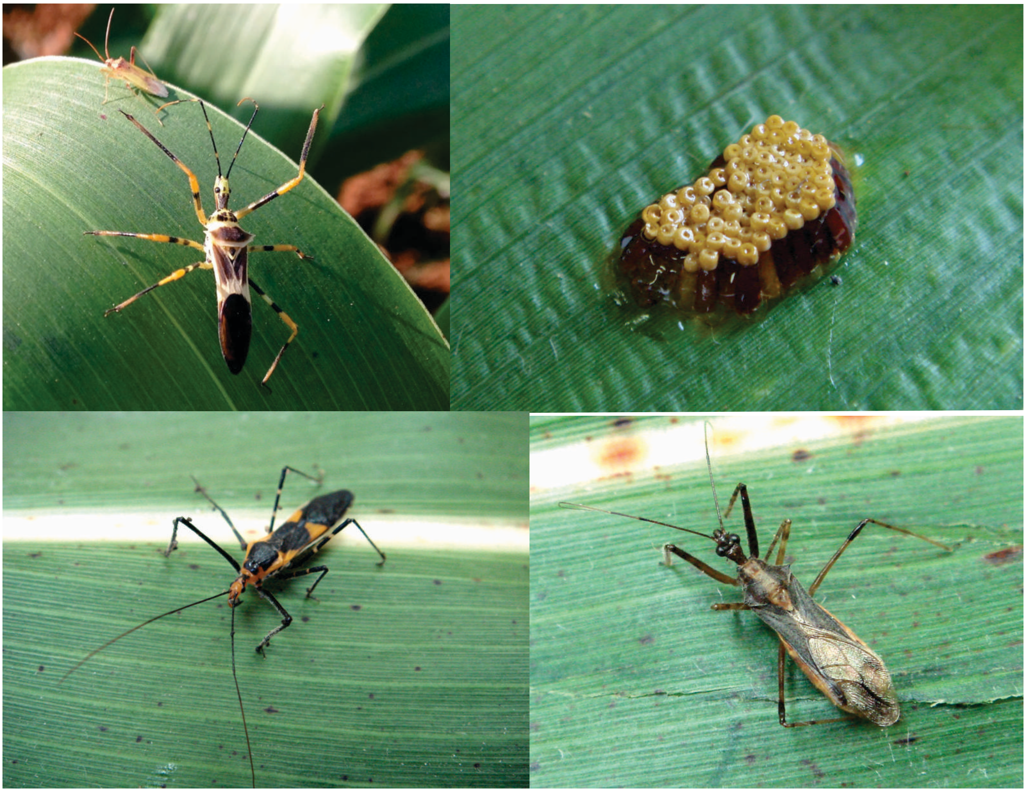


Figure 45. *Zelus* spp (adults and egg mass, above, right).

Small Bugs

Geocoris punctipes (Hemiptera: Geocoridae)

Cosmopolitan predatory insect, quite common in maize, uses food sources, especially aphid and whitefly species, in addition to eggs and larvae, small especially of Lepidoptera, including eggs of *Helicoverpa zea* and even Coleoptera (Bell; Whitcomb, 1964; Crocker; Whitcomb, 1980; Elvin et al., 1983; Sweet, 2000; Bueno; Zanuncio, 2009; Bueno; Van Lenteren, 2011).

They are small insects, approximately 4 mm in size, which occur in many parts of the globe. They are generally considered beneficial because nymphs and adults attack various types of pests, including insects and mites in ornamental and agricultural crops, and their striking feature is their eyes so developed that they extend beyond the prothorax (Figure 46). Insects complete their cycle in around 30 days and are generally highly active, especially in the morning (Sweet, 1960, 2000). Each female usually lays one egg per plant and can lay about 300 eggs during her lifetime. The young forms hatch about a week after oviposition and go through five stages of development, which last around 25 days when they reach the adult stage, whose longevity is approximately 30 days.

Orius insidiosus (Hemiptera: Anthocoridae)

Among the various genera that make up the Anthocoridae family is *Orius* (Figure 46), which contains approximately 70 species of worldwide distribution in various agricultural crops, consisting of predators of small arthropods such as thrips, mites, whiteflies, aphids, and lepidopteran eggs. These predators have certain characteristics that make them promising agents for biological control (Bueno, 2009), highlighting their high search efficiency, the ability to increase population, and aggregate quickly when there is abundant prey, in addition to survival in low density of fangs. Orius insidiosus is the most abundant species, with the greatest potential for use in biological control programs. Furthermore, pollen or plant juices can guarantee the survival of the insect when it is scarce or absent (Lattin, 1999, 2000). The young forms (nymphs) are yellow-orange in color and maybe, darker. Adult individuals, usually black in color, with white spots on the wings, measure about 3 mm in length. The female lays her eggs inside the plant's tissues. The duration of the phase between laying and the appearance of the adult is about 20 days, and several generations may occur annually. In the corn production system, it is common the presence of both nymphs and adults feeding on eggs of Lepidoptera and the leaf aphid, *Rhopalosiphum maidis*.

Nabis spp (Heteroptera: Nabidae)

Nabidae is a family with 20 genera containing more than 500 species (Schuh; Slater, 1995) of generalist predatory insects, attacking almost every type of prey smaller than their size (Lattin, 1989; Braman, 2000). Individuals are characterized by having prothoracic legs adapted for capturing and handling prey. The genus *Nabis* is the most common and is found in many agricultural production systems. Among the species, the tanned yellow color predominates. The eyes are large, bulb shaped. The species *Nabis punctipennis* Blanchard is common in Brazil. Nabides (Figure 46) are usually tanned, resembling a miniature species of Reduviidae such as *Zelus*.

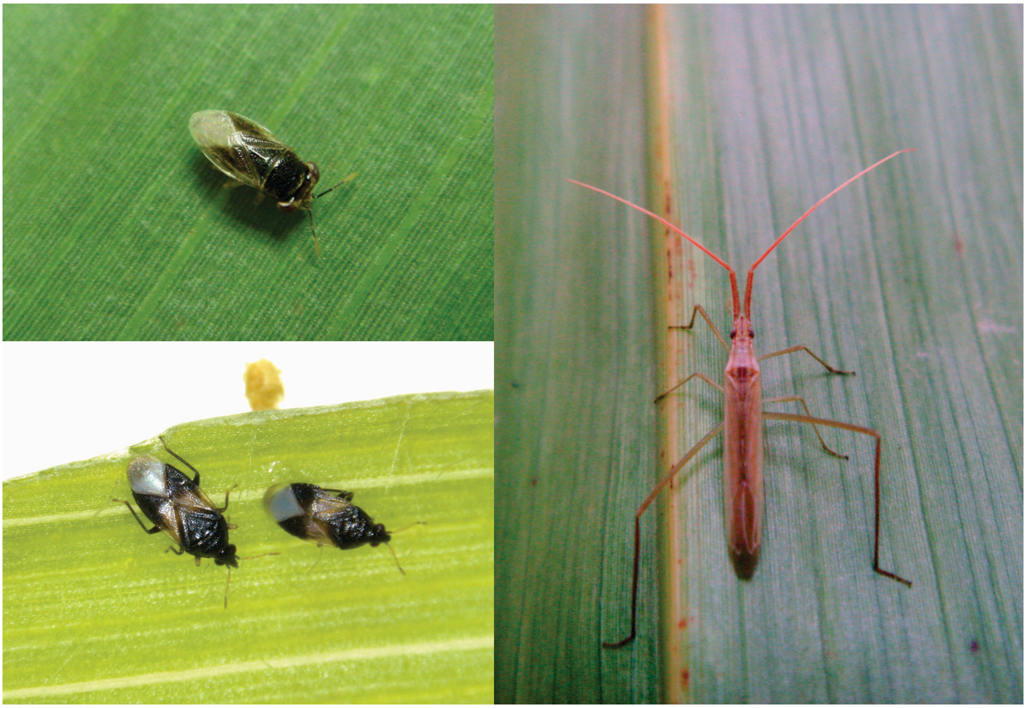


Figure 46. *Geocoris punctipes* (large eye) (above left), *Orius insidiosu*s (small bug), and *Nabis* sp (right).

Podisus spp (Heteroptera: Pentatomidae)

Podisus species are generalists found in different ecosystems that feed mainly on Lepidoptera larvae. These predators bite their prey and inject a toxin that paralyzes it in a relatively short time. The prey is killed after its internal fluids are sucked, either by the young forms (nymphs) or by the adults. **Figure 47** shows the posture, nymphs, and adult of *Podisus* feeding on *S. frugiperda* larva.

Two species of *Podisus* are well known. *Podisus maculiventris* (Say) preys on more than 90 species of phytophagous insects distributed in eight Orders (De Clercq, 2008). Richman et al. (2020), compiling the available information on the species, highlighted the importance of the predator in the biological control of pest species associated with corn, beans, tomatoes, cotton, and soybeans, among other vegetables. The possibility of survival through alternative feeding of plant juices, without causing significant damage to the plant, in the absence or low population of prey, may explain the insect's success as a natural biological control agent (De Clercq, 2008). The adult male is slightly larger than the female and measures approximately 11 mm in length. The female lays her eggs grouped in a line or oval masses, with 17 to 70 eggs, characterized by projections around the operculum (the structure in the form of the lid on the egg, through which the new insect emerges). Each egg measures about 1 mm in diameter. The insect's life cycle (from egg to adult) is reported to vary between 27 and 38 days, depending on temperature. The adult insect can live up to four months (De Clercq, 2008; Richman et al., 2020).

The species *Podisus nigrispinus* (Dallas) is also a generalist predator with much important prey (Torres et al., 2006), including *S. frugiperda* and *H. zea*. Based on the results of several types of research, summarized by Torres et al. (2006), on average, under a temperature of 25.3 °C, the period from egg to adult of the species is 25.4 days. The female's longevity is around 35 days, and, during this time, the insect lays an average of 295 eggs.

Figure 47. *Podisus* sp (posture, nymphs, and adults feeding on *Spodoptera frugiperda* larvae).

Soil surface beetles (*Calosoma* sp.)

The beetles of the Carabidae family (Coleoptera), or surface beetles, belong to one of the largest and best-known families of predatory insects. Most species are nocturnal and generally have a black or brown color, although some species exhibit an iridescent color and metallic blue, bronze, greenish or reddish tinges. They are essentially carnivores and can feed on Lepidoptera larvae, aphids, mites, grasshoppers, crickets, and termites. The life cycle is long, one year, for most species. There are species, however, that live for two, three, or even four years (Ball; Bousquet, 2000).

The genus *Calosoma* (Figure 48) is a greenish, iridescent beetle (25 to 30 mm) that feeds mainly on larvae and pupae. After mating, the female lays eggs on the surface of the ground or slightly below it. In soil, the immature stage goes through three larval stages (instars) before becoming a pupa. According to Stehr (1991), although larvae are confused with representatives of other families, they can be separated by having six segments composing the legs, while in other families there are only five.

The eggs of *C. granulatum* are light yellow in color, averaging 3.3mm in length and 1.3 mm in width; the larval stage is around 12 days. The fully developed larva enters the soil at a depth of 8 to 12 cm, where it turns into the pupal stage. After a week the adult appears (Pegoraro; Foerster, 1985), whose longevity is approximately 83 days (Pasini, 1995).

Figure 48. *Calosoma* sp (eggs and pupa (left) and larva and adult feeding on *Spodoptera frugiperda* larvae).

Predatory wasps (*Polistes* sp.)

Although they are often overlooked by scientists, probably because of the difficulty of finding research protocols, common wasps (Figure 49) are also important predators of insect pests. Lepidoptera larvae, including *S. frugiperda* and *Helicoverpa* spp, are preferred foodstuffs for *Polistes* species (Prezoto, 1999; Prezoto; Machado, 1999a, 1999b; Torres et al., 2009). For example, Prezoto and Machado (1999a), when evaluating the action of *Polistes similimus* Zikán on *S. frugiperda* in maize, observed a reduction of around 77.16% in the incidence of this larva and 80% in the population of *Helicoverpa*, present in the ear. Gomes et al. (2017) highlighted the importance of using good agricultural practices that favor the presence and maintenance of these predators in the area, aiming to increase the efficiency of natural biological control, for example, through the maintenance of certain plant species, with or without economic significance, around the main crop.

Figure 49. Wasp preying on *Spodoptera frugiperda* larva.

Crisopídeo (Neuroptera)

The lacewings, despite being predators only in the immature phase, have voracious larvae and can consume hundreds of prey weekly. Some species place the remains of prey on the abdomen and, for this reason, they are called "junk bugs".

In general, adults are nocturnal, green, or yellow in color, with checkered wings like a net, have long antennae, slender bodies, golden eyes, and feed on nectar and pollen. Within the corn agroecosystem, the presence of *Chrysoperla externa* (Hagen), *Ceraeochrysa caligata* (Banks), *C. dislepis* (Freitas & Penny), *C. cincta* (Schneider), *C. everes* (Banks) and *Ungla ivancruzi* Freitas has already been reported (Figures 50 and 51).

Figure 50. *Chrysoperla* sp eggs deposited on native plants

Figure 51. *Chrysoperla externa*, adult, larva, and eggs.

The female normally lays individual eggs on plant leaves, and each egg is supported by a pedicel (stalk), except for the *Ungla ivancruzi* species, whose eggs are laid in a "cluster" (Figure 52). The young lacewing form resembles a miniature “alligator”, with protruding mouthparts in the shape of tweezers, used to pierce and injecting a paralyzing agent into the prey. Upon reaching its maximum development, which occurs in two to three weeks, the larva weaves a silky, spherical cocoon, which turns into a pupa. The adult emerges in approximately five days through the round hole at the top of the cocoon.

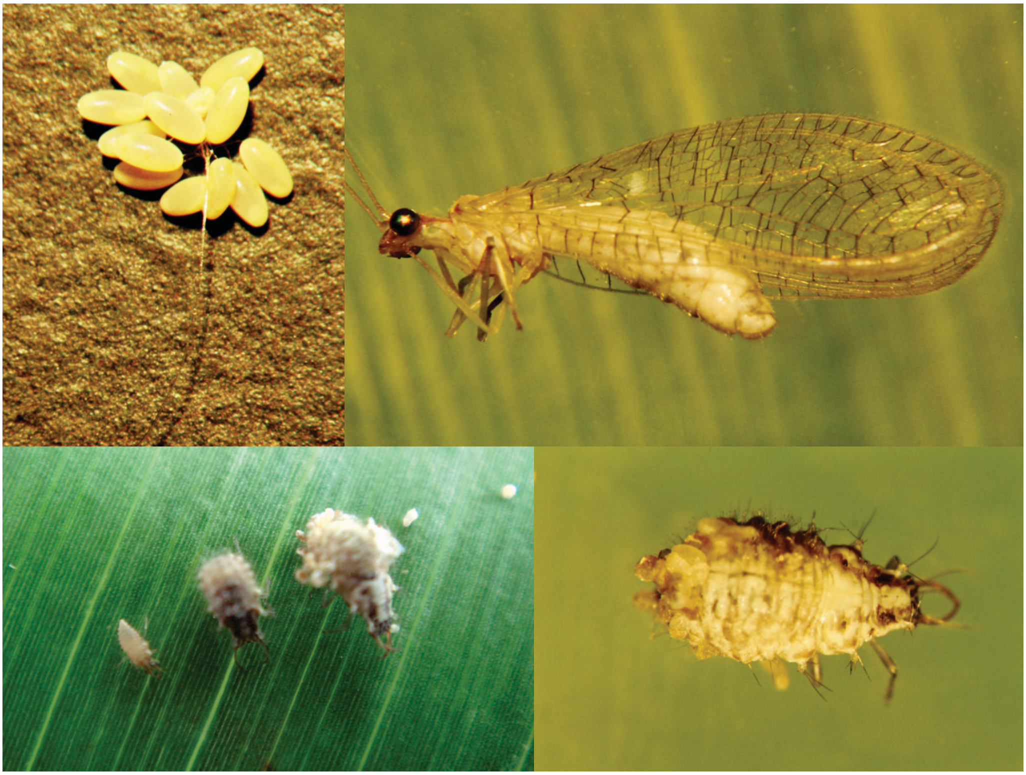


Figure 52. Eggs, adult, and larvae of *Ungla ivancruzi* Freitas.

Flower fly or Syrphid (Diptera: Syrphidae)

These insects are known as flower flies, or floating flies, because adults are generally observed hovering over plants in search of nectar or pollen for food, as they do not have the habit of predation. Larvae, on the contrary, are voracious predators, especially of aphids, and can also feed on thrips, leafhoppers, and small larvae. Characteristically, larvae raise their heads in the process of seeking out their prey.

The adult insects are brown to black in color, with white or yellow stripes or dots, resembling bees, measuring between three and 13 mm, depending on the species. They have only one pair of wings, characteristic of the Diptera Order. The eggs, which are white in color, give rise to larvae about three days after laying. The larvae pass through three instars and can vary in color from pink, yellow, green or brown and resemble slugs, with a variable size between four and 18 mm in length. The last instar turns into puparia, with variable color and teardrop shape, on the plant where its prey are located. The life cycle varies between species and depends on environmental conditions and food availability, with an average varying between seven and 14 days.

Allograpta exotica (Wiedemann) and other species of the genus lend themselves to the biological control of pests, due to their larvae, and to the pollination carried out by adults visiting different plant species (Vockeroth; Thompson, 1987; Ssymank; Kearns, 2009; Rotheray; Gilbert, 2011).

A. exotica larvae are voracious for food consumption (Schneider, 1969;Bugg et al., 2008;Smith et al., 2008; Nelson et al., 2012), and are very common in maize, where they feed mainly from the aphid, *Rhopalosiphum maidis*. The female, with a yellow abdomen with black stripes, resembling a small bee, lays eggs near the aphid colony. When hatching, the headless and legless larvae, pale yellow to light green in color, consumes a large amount of prey. Generally, the larva turns into a pupa where it was feeding, forming a pupa that is configured as a "drop". The life cycle, from egg to adult, is usually two to four weeks, and several generations take place each year. Other species can also be found in different agricultural systems (Figure 53).

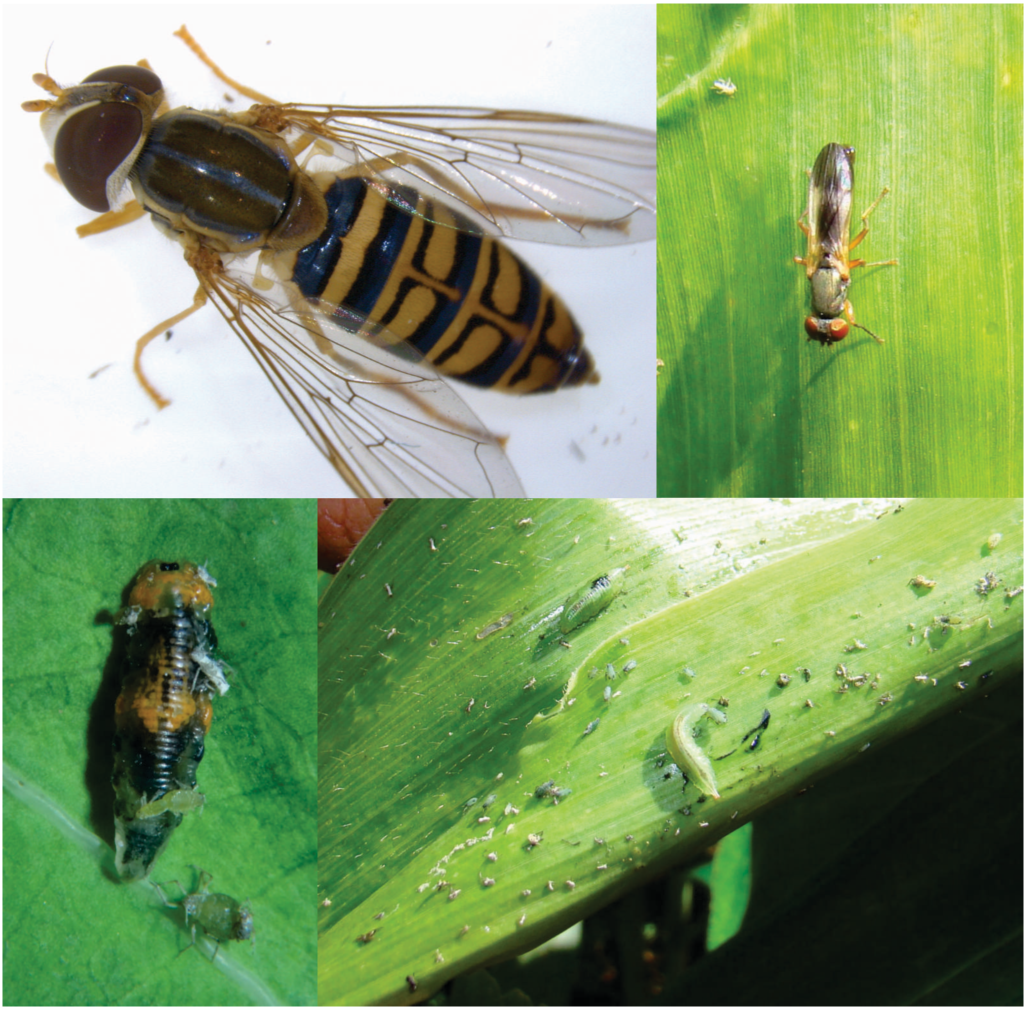


Figure 53. Flower fly adults and larvae.

CONSERVATIVE BIOLOGICAL CONTROL

As previously reported, there are several species of naturally occurring biological control agents, collaborating with the farmer to reduce the population of phytophagous species. Some are specific and others are general. Unfortunately, the existing knowledge in Brazil and about corn crop is still relatively small, considering that such diversity can vary a lot from one property to another and, it is known, it also varies with the adopted cultural practices. Therefore, regardless of local knowledge, it is particularly important to assess the possible negative impact of cultural practices adopted on different biological control agents and, if appropriate, make appropriate changes for the conservation of such beneficial organisms that are generally already adapted in production systems. Thus, the so-called conservative biological control refers to the role of biological control agents for phytophagous insects, which are naturally found in the agricultural production area of interest. Normally, the action of these organisms is not enough to reduce the population of a particular pest precisely because the population level of the biological agent is insufficient to reduce the pest population. In this case, one of the practices that can and should be used, to attract new beneficial organisms and ensure the population growth of these and others already present in the area, is the proper management of the local production system and/or, if possible, the adequacy the nearby landscape (Barbosa, 1998; Altieri,1999; Landis et al., 2000; Pfiffner; Wyss, 2004; Bueno, 2005; Venzon et al., 2005). Thus, the objective is to use a management system that will provide shelter and favorable climatic conditions, as well as alternative foods, especially when the natural source is insufficient.

Another practice, which is also a priority for the conservation of natural biological control agents, is the use of biological inputs acquired from biofactory (applied biological control), replacing chemical products, especially those used in spraying. For example, the use of *Trichogramma* wasp or Baculovirus, respectively, to control eggs and larvae of Lepidoptera, such as *S. frugiperda* and *Helicoverpa* spp, is efficient and does not cause significant disturbances in the agricultural environment (Cruz, 2000; Cruz et al. al., 1997b, 2002; Figueiredo et al., 2009). The availability of different commercial brands of these two products and many others, as well as the technical information for use, can be obtained directly from the AGROFIT phytosanitary pesticide system (Brasil, 2019).

Secondary plants as a strategy to favor conservative biological control

The proper management of the local production system can be carried out using plant arrangements of other species along with the main crop, such as corn. These plant species were named secondary crops by Parolin et al. (2012b, 2014). According to these authors, depending on the secondary plant's performance, they are called companion plants, repellents, barriers, indicators, traps, insectaries, or bankers. Other names, also found in the literature, include cover crops, sub seeded crops, intercropped crops, soil cover, among others. The action of secondary plants, in relation to biological control, can occur by affecting the main crop or directly affecting the pest or natural enemies. Secondary plants, associated with different production systems of economically important crops, have been considered a priority strategy to reduce the pest population and can be used for different purposes (Landis et al., 2000; Holden et al., 2012; Parolin et al., 2012b; Lu et al., 2014).

Companion plants

Companion plants are those used in intercropping, mainly to improve the nutrition and/or chemical defense of the main crop, although they may also have repellency, interception of phytophagous species, and attraction and food supply for biological control agent species (Parolin et al., 2012b; Sarkar et al., 2018). The main crop, associated with the cultivation of a companion plant, can generate mutual benefits in productivity gains (Finch; Collier, 2000; Kuepper; Dodson, 2001; Finch et al., 2003), regardless of the size of the cultivated area. Biological nitrogen fixation of some leguminous plants associated with bacteria, providing shelter and protection against sunstroke and strong winds, or even biochemical suppression of pest species capable of controlling or repelling the area in which the main species is found, are some examples of benefits offered by companion plants (ODE, 2006).

Specifically for corn, for example, plants such as basil can be used to drive away from some species of phytophagous insects. Other plants add nitrogen to the soil, which is important because corn uses this nutrient a lot. But corn also benefits other plants, serving as an ideal trellis for beans or providing shade for low-growing crops.

Repellent plants

A repellent plant is often used to keep phytophagous organisms away from the main crop (Hjalten et al., 1993), possibly because it contains unpalatable or repellent parts that prevent the ability of certain phytophagous species to use their normal food (Hay, 1986; Pfister; Hay, 1988). Alkaloids, terpenoids, flavonoids, and quinones, synthesized by certain plants and found naturally in their roots, flowers, stems, or leaves, are effective in controlling many pests, which can repel or attract insects (DAS, 1995). Other examples include pyrethrum, which is an oil resin extracted from the dried flowers of *Tanacetum cinerariaefolium*, neem, obtained from the seeds of *Azadirachta indica*; and the essential oils from plants extracted by steam distillation of rosemary, eucalyptus, cloves, garden thyme, or various species of mint used to repel insects, although not all pests react in the same way towards repellent plants. Thus, what may be highly effective for one pest is not necessarily effective for another pest (Isman, 2006; Poveda et al., 2008).

Although, hypothetically, a repellent plant emits odors that repel the herbivore, other plant species when intercropped can directly reduce the occurrence of herbivores due to the masking of volatiles (Tahvanainen; Root, 1972; Uvah; Coaker,1984; Poveda etal., 2008; Belay; Foster, 2010; Togni etal., 2010).

Examples of repellent plants are provided by Kianmatee and Ranamukhaarachchi (2007), who studied the potential of repellent plant species for pest management in Chinese cabbage (*Brassica oleracea*). Minor pest damage was inflicted using holy basil (*Phyllotreta sinuata* and *Hellula undalis*) and citronella grass (*Spodoptera litura*) as repellent intercropping plants. Citrus can repel harmful insects and the African marigold releases thiopene, a nematode repellent (Matsumoto; Kotulai, 2002; Moreau et al., 2006). Musmeci et al. (1997) analyzed the repulsive effect of potato clones on the tuber moth of this nightshade (*Phthorimaea operculella*) and found that some Solanum clones, with high leaf hair density, showed a negative effect on pupal weight and fecundity. This antibiotic effect on the survival of dangerous pest larvae, which feed on the crop's leaves, reduces yield losses.

Barrier plants

The use of plants as barriers to disease suppression in each crop has been known since the 1950s (Broadbent et al., 1952; Jenkinson, 1955; Deol; Rataul, 1978; Fereres, 2000). With this technique, it was possible to reduce the presence of aphids and consequently reduce the potential for transmission and spread of viruses to the nearby protected crop (Toba et al., 1977; Difonzo et al., 1996; Fereres, 2000). Hooks and Fereres (2006) considered that the technique can be an interesting strategy in the case of corn stuns, transmitted by the leafhopper *Dalbulus maidis*, in addition to having additional functions, such as restricting the dispersion of airborne particles and reducing negative effects of the winds on natural enemies.

Parolin et al. (2012b) reported that secondary plant cultivation should be used on the margins of the main crop, considering the hypothesis that the generally higher barrier provides physical obstruction by blocking insect pest movement within the cropping system (Perrin; Phillips, 1978; Poveda et al., 2008). Such barrier plants, such as sunflower, sorghum, sesame, and millet, can also act as a source of natural enemies (Toba et al., 1977;Thresh, 1982; Hooks; Fereres, 2006).

Indicator plants

Plant species or varieties that are more prone to an insect than the main crop plants serve as an indicator that the pest is already close to the main crop and therefore the farmer should be alert (Lamb, 2006). It is also a clearly defined term in plant virology: indicator plant is a plant that reacts to certain viruses or environmental factors with the production of specific symptoms and is used for detection and identification of these factors, being cited as an indicator marker (International Potato Center, 1999).

Trap plant

A trap plant is more attractive to a particular pest species than the main plant (Poveda et al., 2008). Thus, such pests are less likely to leave the trap crop and colonize the main crop (Vandermeer, 1989; Murphy, 2004; Lee et al., 2008, 2009; Poveda et al., 2008; Huang et al., 2011), and can be easily controlled (Hokkanen, 1991; Asman, 2002; Shelton; Nault, 2004; Shelton; Badenes-Perez, 2006; Poveda et al., 2008). Trap plants can also be grown as an aid to early detection and monitoring of pests or as an applied biological control strategy.

The ''push-pull strategy'', for example, is well known in maize, involving the use of trap plants and repellent plants (Cook et al., 2007; Hassanali et al., 2008; Poveda et al., 2008; Khan et al., 2007, 2008; Belay; Foster, 2010; Huang et al., 2011). Pests are repelled from the crop (''push") and attracted ("pull") to the trap plants (Hassanali et al., 2008). The push-pull strategy can provide a consistently positive effect on crop yield (Poveda et al., 2008). The system has also been successfully applied to other cereals for the control of Lepidoptera in Africa (Hassanali et al., 2008). The technology involves two types of grass, one to repel the *Chilo partellus* moth (Crambidae), a species like the Brazilian insect *Diatraea saccharalis*, which attacks sugarcane in addition to corn, and another plant used to attract the insect plague, where it is controlled. In addition to harm reduction and productivity gains in maize, companion plants also serve as fodder for animals (Khan et al., 2007, 2008).

Banking plants

This technology is based on the creation of biological control agents in a secondary plant, infested with a pest that does not damage the main crop but is an alternative food source for beneficial organisms, which will later disperse in the area where the crop is located (Murphy, 2004; Osborne et al., 2005; Sanderson; Nyrop, 2008; Frank, 2010; Huang et al., 2011). A bank plant is specifically associated with the establishment of natural enemies in certain areas (Huang et al., 2011). Therefore, the objective of bank plants is to provide the reproductive sustainability of a given population of natural enemies that will act in the suppression of phytophagous species over time, within the production system of the main crop (Frank, 2010). Once present on bank plants, natural enemies will spread into the target area as they reproduce and increase in number. In other words, bank plants retain a natural enemy, predator and/or parasitoid, due to the alternative resources they have (Frank, 2010), which will later act efficiently in controlling the target pest of the main crop. According to Osborne et al. (2005), in this system, the same pest species or pests of the main crop to be controlled can be used, but the risk of not working is significant. The ideal is to use an alternative host or prey, with a limited number of hosts that do not include the main crop plants, which will not be a food source for the alternative species, but which will be a food source for natural enemies that will later migrate to the main crop (Osborne et al., 2005; Pineda; Marcos-Garcia, 2008).

In summary, bank plants, trap plants, indicator plants, and repellent plants are more common on a small local scale in the organic farming system, while companion plants, barrier plants, and insect plants aim to increase the diversity of potential natural enemies (Colley; Luna, 2000; Hooks; Fereres, 2006; Lopez; Shepard, 2007). Although the importance of inserting secondary plants in the production system of the main crop such as corn is undeniable, be it on a large extension of land or a small scale, as in family farming, there is still much to be done in this line of research aiming to obtain information about the different effects produced, both in pest control and in increasing the productivity of the main crop. Overall, there is a lack of studies that focus on how secondary plants can be extensively applied at larger scales (Parolin et al., 2012a, 2012b, 2012c).

Insectary plants

The secondary plant used attracts, especially through the flower, different species of natural enemies that use nectar, pollen, or extrafloral nectaries as food, and will subsequently contribute to the natural biological control of phytophagous species associated with the main crop (Bugg, 1990, 1994; Colley; Luna, 2000; Landis et al., 2000; Vattala et al., 2006; Nafziger; Fadamiro, 2011; Parolin et al., 2012b). Many insect-plant species can also attract beneficial insects using color, morphology, odor, flower size, abundance and age, nectar, and pollen quality, and even the marks of previous visitors (Ambrosino et al., 2006). Therefore, plants with a high flower load are important to maintain the diversity of natural biological control agents (Fiedler et al., 2007; Quarles; Grossman, 2002). A classic example can be seen in insects of the Syrphidae family (Figure 53), also known as flower flies, whose adults feed on nectar and pollen, while larvae use aphids as their main food source. However, the presence of flowering plants in an agroecosystem is not sufficient to guarantee the efficiency of insect plants (Wackers, 2004; Jervis et al., 2004; Gurr et al., 2005; Bianchi; Wackers, 2008). Not all secondary plant species combine olfactory attractiveness and nectar supply as a food source for natural pest enemies (Wackers, 2004). Other plants, however, can increase the shelf life, for example, of certain parasitoid wasps that depend on a regular supply of carbohydrates from the plants (Bugg, 1991; Nafziger; Fadamiro, 2011).

NATURAL BIOLOGICAL CONTROL OF *Spodoptera frugiperda*

Undoubtedly, the species *S. frugiperda*, fall armyworm, is the main corn pest in Brazil and, at present, also in several African countries. Perhaps due to the visual symptoms of damage caused by the larvae, there is an intense use of control measures, especially chemical products, and currently, in Brazil, there is the cultivation of genetically modified plants (Bt corn). Although generally mentioned by many, natural biological control is not perceived as important in the production system, perhaps even because farmers are not aware of it. However, considering the large area cultivated with corn by small farmers, including organic producers, and the already known data on the main biological control agents, it becomes increasingly important to include these biological agents in the production system, not only corn but other crops. It should be considered that the efficient performance of biological control will naturally reduce the number of chemical applications, minimizing the risk of pest resistance to the applied products and, at the same time, reducing the exposure of the applicators.

The importance of natural biological control was demonstrated by Figueiredo et al. (2006a, 2006b), in an area of continuous corn production, using the method of exclusion of natural biological control agents, with the use of cages and infestation of *S. frugiperda*, at the density of one posture per square meter. To assess the impact of biological control agents, the cages were removed every two days, from the hatch of the larvae, until the 16th day. In other words, after the cages were removed, the pest was subject to the action of different natural control agents present in the area. With this methodology, the possibility of the action of biological control agents for eggs, generally used in applied biological control, with the *Trichogramma* wasp, was excluded. As expected, leaf damage increased with the increase of the period in which the plants were kept covered and, therefore, without access to the pest's natural enemies. A 54.5% drop in grain yield was also demonstrated, in the absence of natural pest enemies. Without the use of cages and any control measures, Cruz e Turpin (1983), Marenco et al. (1992) e Cruz et al. (1999a, 2002)reported much smaller losses, around 20%, due to the attack of this same pest, also demonstrating the global action of different agents of natural control of *S. frugiperda*. Figueiredo et al. (2006a, 2006b) reported the parasitoid *Chelonus insularis* as one of the most important agents for the natural biological control of *S. frugiperda*, present in all collections carried out in corn planting, accounting for 91% of the parasitism. *E. laphygmae*, E. fuscicornis, *C. marginiventris*, *C. flavicincta*, and *Pristomerus spinator* (Fabricius) (Ichneumonidae) and *Archytas incertus*, also from the order Hymenoptera, were identified.

USE OF BIOLOGICAL CONTROL OF CORN PESTS WITH MICROORGANISMS

Bacteria, fungi (Figure 54) and viruses (Figure 55) represent microorganisms with the highest number of biological products registered in the software Agrofit, of the Ministry of Agriculture, Livestock and Supply(Brazil, 2021) for the use of control of phytophagous organisms (pests). The registration of a given product allows the control of the target pest in all crops in which it is present.

Figure 54. Appearance of a larva of *Spodoptera frugiperda* killed by a fungus.

For the control to be successful, the target pest must ingest the bacteria and the viruses. Fungi act by contact, like most chemicals, being able to penetrate the cuticle of the host larva using enzymes that act on the phase of adhesion and germination of their spores.

After ingestion of a minimum amount of a certain microbiological intake, necessary to kill the pest, a reduction in the feeding of the larva gradually occurs until its death occurs, in a period of around seven days after ingesting the contaminated food. The food consumption of the infected larva is negligible, although living for a longer period than the farmer already knows of the action of a chemica. For example, as time goes by, the effect of viruses on larvae, which become flaccid and blackened is clear (Cruz, 2000).

Figure 55. Appearance of larvae of *Spodoptera frugiperda* killed by baculovirus

When the farmersare not satisfied with the efficiency of the application,theyusually consider that the failure is due to the product. However, other factors can also be responsible for the results, even in the case of a chemical insecticide application.For example, wrong choices including product type, dose, water volume, nozzle type and pressure for spraying, stage of development of the target pest and plant, can reduce the efficiency of application.

Currently in Brazil there is increasing demand for the search and registration of new microorganisms for use in corn and other crops of economic importance, with more than two hundred trademarks available. Specifically for use in corn there are records for use in the control of the main pests (Table 1).

Table 1. Microbiological products for use in corn in the control of insect pests [(1)]

Target pests	Microbiological products [(2)]
Dalbulus maidis (cigarrinha-do-milho)	*Metarhizium anisopliae (F); Isaria fumosorosea (F); Beauveria bassiana*
Deois flavopicta (cigarrinha-das-pastagens)	*Metarhizium anisopliae; Beauveria bassiana + Metarhizium anisopliae*
Diabrotica speciosa (vaquinha-verde-amarela)	*Beauveria bassiana (F)*
Diatraea saccharalis (broca-da-cana)	*Bacillus thuringiensis (B)*
Helicoverpa armigera (lagarta-da-espiga)	*Baculovirus (V); Isaria fumosorosea; Bacillus thuringiensis*
Helicoverpa zea (lagarta-da-espiga)	*Bacillus thuringiensis*
Mocis latipes (lagarta-mede-palmo)	*Bacillus thuringiensis*
Scaptocoris castanea (percevejo-castanho)	*Metarhizium anisopliae*
Spodoptera frugiperda (lagarta-do-cartucho)	*Bacillus thuringiensis; Baculovirus*

[(1)] Compilado do Agrofit (Brasil, 2021); [(2)] Fungos (F); Bactéria (B); Vírus (V)

The intentional or natural combination of micro and macro biological products in general is positive in the corn production system. Figueiredo et al. (2009) reported a higher gain in corn yield with leaf application of baculovirus, eight days after infestation with egg masses of *S. frugiperda*, in a synergistic action with natural biological control agents. This fact is important considering, for example, that the efficiency of baculovirus tends to decrease with increasing age of the larvae of *S. frugiperda* (Cruz et al., 2002; Matrangolo et al., 2007), but there is compensation for the additional effect of beneficial insects, suggesting that the association may be an important strategy to suppress the pest population in corn, considering the specificity of the virus. This synergistic effect may be more economical and efficient than the unilateral use of a non-selective chemical pesticide, particularly by the presence, for example, of *Chelonus insularis*, an efficient egg-larva parasitoid (Rezende et al., 1995a; Figueiredo et al.,2006a, 2006b).According to Cruz et al.

(1997b) a higher efficiency of the biologicalcontrol of *S. frugiperda* is usually obtained by spraying baculovirus both with costal manual spray and tractor sprayer in areas with natural occurrence of parasitoids, represented by *C. flavicincta* (53.0%), *C. insularis* (31.3%)and *Eiphosoma* spp. (15.6%).

Therefore, to get a successful control using microbiological product in corn crop, the farmers must know:

1. Younger larvae of Lepidoptera are more susceptible to biological products

2. Pheromone trap monitoring provides a more accurate reading of the evolution of the Lepidoptera population.

3. The same conventional equipment used for the application of chemicals also serves to apply microbiological insecticides, adjusting the parameters of spraying according to the target and the stage of development of plants.

4. Considering the sensitivity to ultraviolet rays, spraying of microbiological products should be in the afternoon or early evening.

5. The efficiency of the control occurs by the synergistic action of microbiological insecticide and the natural control agents existing in the cultivation area.

FINAL CONSIDERATIONS

Raising awareness among farmers about the benefits of biological control

A major difficulty in establishing a biological control program on rural properties is the lack of knowledge that allows the farmer to recognize and separate pests from beneficial insects. There is an urgent need to train these farmers, showing them that beneficial insects are those that feed on insect pests as well as those essential in agricultural production, doing the work of pollination, such as bees.

Specific publications that show through photographs, films, and even training courses, with a good hour load, within the farmer's property, are strategies that work properly to increase the awareness of the producers and their family about the importance of beneficial insect biodiversity in your work routine.

By using the photos published here and periodically updating this publication, with new images of biological control agents found locally, in association with different pest species, we will have continuous training of farmers. This information will serve to compose an open-access database for the recognition of pests' natural enemies.

Ongoing training of rural extension agents and farmers

Training farmers and extension workers and technology transfer agents on how to collect, identify or proceed to send insects to specialists is a critical step. Farmers must be aware that, by avoiding the use of chemicals on their properties, they will help to maintain natural biological control agents. But it is also important to use strategies that favor the increase of these beneficial insects, not only on their property but also throughout the community. Farmers need to be encouraged to know the insect habitat and use conservation agriculture to increase parasitoids and naturally occurring predators. Keeping plant species around the main growing area, such as sunflower or crotalaria, among others, contributes to increasing the survival and protection of beneficial insects, especially against adverse weather conditions.

Awareness of global demands

The global society has demanded foods that are free of pesticides which, although they can act on different phytophagous insects, also have negative effects on the environment and people's health. This negative effect is also observed everywhere, as it dramatically eliminates or reduces the various species of beneficial insects. Beneficial insects, when present, keep different species of phytophagous insects under control, that is, they sustain the pest population level below that necessary to cause economic damage. Therefore, when natural enemies are eliminated or drastically reduced, many phytophagous species formerly considered secondary pests can increase their population and reach the status of the main pest.

Given the current reality and future thinking about the stability and quality of agricultural production, especially when destined for human consumption, the strengthening of government institutions will give the country the power to solve problems sustainably, using the resources of nature itself, which are known to be abundant on the continent. This includes infrastructure and human resources to mitigate phytosanitary problems, especially concerning insects, by advancing scientific knowledge of pests and their biological control agents. In order to achieve this goal, governments, and the private sector must certainly be willing to invest even more in research, in the development of new technologies, and the training of human resources about biological control, to quickly be available to farmers.

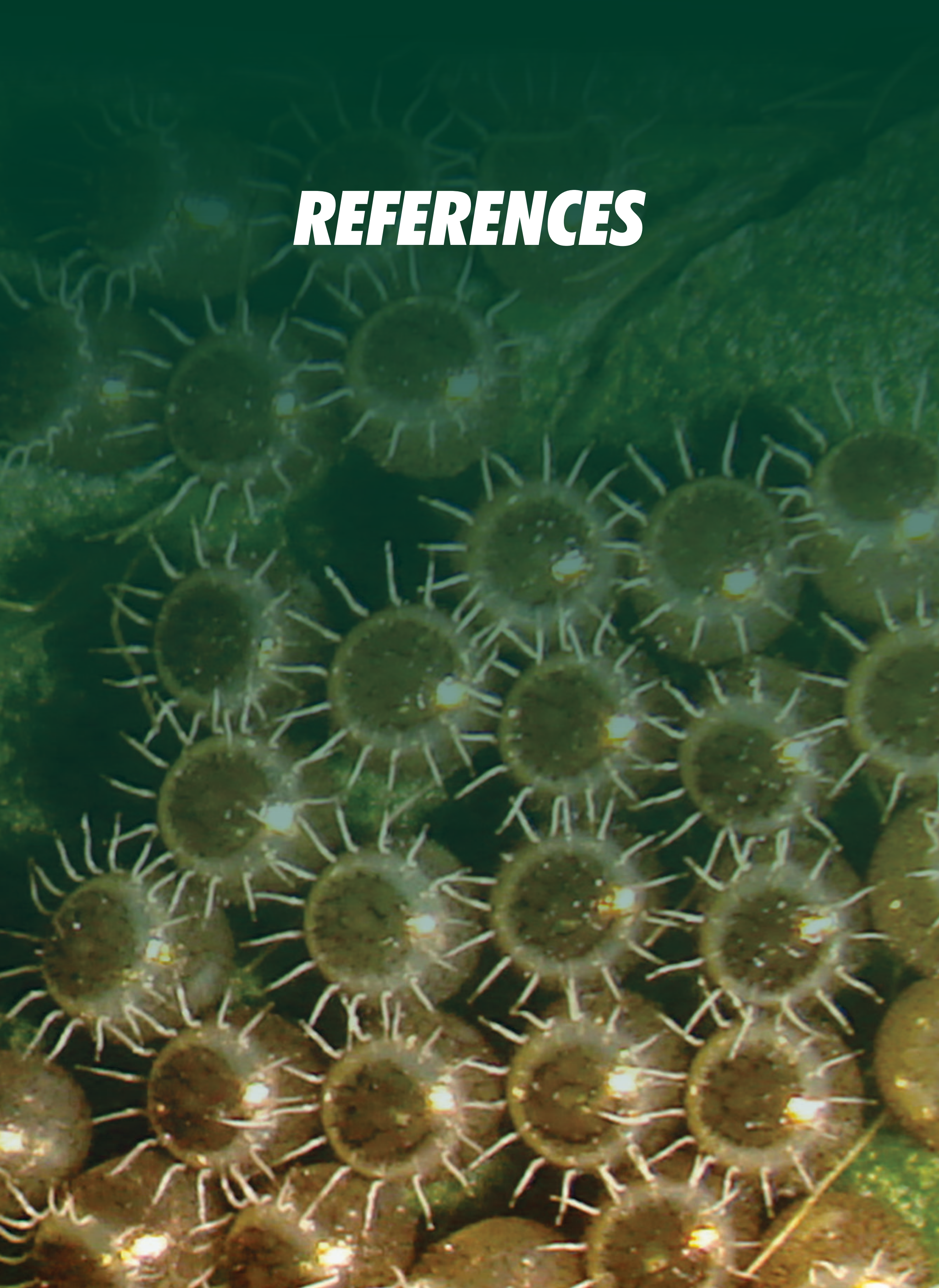
Biological management of pests by the community

Especially in family farming, usually in small areas and close properties, farmers, gathered in an association or cooperative, can have much more advantages in combating pests than treating the problem individually. Recently, Cruz and Castro (2021) proposed this strategy for the management of the leafhopper D. maidis, as it is an insect whose management is complex.

However, the same reasoning applies to other pest species. The authors highlighted the importance of discussing a management plan for the main pests, before planting, in a meeting with the group of producers, extension workers, specialist researchers, private companies, and other segments. In this type of meeting, it is possible to select participating farmers who together will be trained to make the right decisions. The training will have, as main objectives, the recognition of insect pests and their biological control agents, decision-making on the need for control measures, and the insertion of biological products in the production area. At the same time, the creation of groups is suggested, for example, using WhatsApp, to quickly convey all information about agricultural activities to all participants; the coordinator can be the extensionist responsible for the answers to the questions received from the producers, including the actions to be taken.

The group's training may involve technicians from cooperatives, extension workers, farmers, teachers, and even students from technical courses and higher education courses of Biology and Agronomy. In the training, in addition to the aspect related to target insects, an area (or region) will be delineated with georeferencing and mapping of the properties participating in the program. In addition, if possible, historical climate data (at least three previous years) should be collected, especially temperature, precipitation, and winds (direction) and data on the perception of farmers about the main problems with pests in the period studied. Such observations will also be followed up from the establishment of the program. In summary, each participant would inform the group, via WhatsApp, throughout the development of corn cultivation, the activities carried out and the dates they took place on their property, including the arrival of pests. Information about pests will serve as a warning to all participants. In this program, it will be possible to create a database, including photos related to pests and their biological control agents. After harvesting, a report must be prepared including all events relating to cultivation in the mapped areas.

REFERENCES



ABLES, J. R. Feeding behavior of an assassin bug, *Zelus renardii*. **Annals of the Entomological Society of America**, v. 71, n. 4, p. 476-478, 1978. DOI: http://dx.doi.org/10.1093/aesa/71.4.476.

ALI, A. S. A.; WATSON, T. F. Effect of temperature on development and survival of *Zelus renardii*. **Environmental Entomology**, v. 7, n. 6, p. 889-890, 1978. DOI: http://dx.doi.org/10.1093/ee/7.6.889.

ALMEIDA, L. F. V.; PENTEADO-DIAS, A. M. Five new species of *Meteorus* Haliday (Hymenoptera: Braconidae: Euphorinae) from Brazil. **Zootaxa**, v. 4057, n. 2, p. 231-247, 2015. DOI: http://dx.doi.org/10.11646/zootaxa.4057.2.4.

ALTIERI, M. A.; SILVA, N. E.; NICHOLLS, C. I. **O papel da biodiversidade no manejo de pragas**. Ribeirão Preto: Holos, 2003. 226 p.

ALTIERI, M. **Agroecologia**: a dinâmica produtiva da agricultura sustentável. 4. ed. Porto Alegre: Universidade Federal do Rio Grande do Sul, 2004. 120 p.

ALTIERI, M. The ecological role of biodiversity in agroecosystems. **Agriculture, Ecosystems and Environment**, v. 74, n. 1/3, p. 19-31, 1999.

AMBROSINO, M. D.; LUNA, J. M.; JEPSON, P. C.; WRATTEN, S. D. Relative frequencies of visits to selected insectary plants by predatory hoverflies (Diptera: Syrphidae), other beneficial insects, and herbivores. **Environmental Entomology**, v. 35, p. 394-400, 2006.

ASHLEY, T. R.; WADDILL, W. H.; MITCHELL, E. R.; RYE, J. Impact of native parasites on the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), in south Florida and release of the exotic parasite, *Eiphosoma viticolle* (Hymenoptera: Ichneumonidae). **Environmental Entomology**, v. 11, p. 833-837, 1982. DOI: https://doi.org/10.1016/S0167-8809(99)00028-6.

ASMAN, K. Trap cropping effect on oviposition behaviour of the leek moth *Acrolepiopsis assectella* and the diamondback moth *Plutella xylostella*. **Entomologia Experimentalis et Applicata**, v. 105, p. 153-164, 2002. DOI: https://doi.org/10.1046/j.1570-7458.2002.01043.x.

BAITHA, A.; JALALI, S. K.; RABINDRA, R. J.; VENKATESAN, T.; RAO, N. S. Parasitizing efficiency of the pupal parasitoid, T*etrastichus howardii* (Olliff) (Hymenoptera: Eulophidae) on *Chilo partellus* (Swinhoe) at different exposure periods. **Journal of Biological Control**, v. 18, p. 65-68, 2004.

BALL, G. E.; BOUSQUET, Y. Carabidae Latreille, 1810. In: ARNETT JR., R. H.; THOMAS, M. C. **American beetles**: Archostemata, Myxophaga, Adephaga, Polyphaga: Staphyliniformia. Boca Raton: CRC Press, 2000. v. 1, p. 32-132.

BARBOSA, P. **Conservation biological control**. San Diego: Academic Press, 1998. 396 p.

BELAY, D. K.; FOSTER, J. E. Efficacies of habitat management techniques in managing maize stem borers in Ethiopia. **Crop Protection**, v. 29, n. 5, p. 422-428, 2010. DOI: https://doi.org/10.1016/j.cropro.2009.09.006.

BELL, K. O.; WHITCOMB, W. H. Field studies on egg predators of the bollworm, *Heliothis zea* (Boddie). **Florida Entomologist**, v. 47, p. 171-180, 1964.

BENGTSSON, J.; AHNSTRÖM, J.; WEIBULL, A. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. **Journal of Applied Ecology**, v. 42, n. 2, p. 261-269, 2005. DOI: https://doi.org/10.1111/j.1365-2664.2005.01005.x.

BERKVENS, N.; BONTE, L.; BERKVENS, D.; TIRRY, L.; DE CLERCQ, P. Influence of diet and photoperiod on development and reproduction of European populations of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae). **BioControl**, v. 53, p. 211-221, 2008. DOI: http://dx.doi.org/10.1007/s10526-007-9130-0.

BERKVENS, N.; BONTE, J.; BERKVENS, D.; DEFORCE, K.; TIRRY, L.; DE CLERCQ, P. Pollen as an alternative food for *Harmonia axyridis*. In: ROY, H. E.; WAJNBERG, E. (ed.). **From biological control to invasion**: the ladybird *Harmonia axyridis* as a model species. Dordrecht: Springer, 2007. p. 201-210. DOI: https://doi.org/10.1007/978-1-4020-6939-0_13.

BIANCHI, F. J. J. A.; WACKERS, F. L. Effects of flower attractiveness and nectar availability in field margins on biological control by parasitoids. **Biological Control**, v. 46, n. 3, p. 400-408, 2008. DOI: https://doi.org/10.1016/j.biocontrol.2008.04.010.

BLEICHER, E.; PARRA, J. R. P. Espécies de *Trichogramma* parasitoides de *Alabama argillacea*. II. Tabela de vida de fertilidade e parasitismo de três populações. **Pesquisa Agropecuária Brasileira**, v. 25, n. 2, p. 207-214, 1990.

BRAMAN, S. K. Damsel bugs (Nabidae). In: SCHAEFER C. W.; PANIZZI A. R. (ed.). **Heteroptera of economic importance**. Boca Raton: CRC Press, 2000. p. 639-656.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. **AGROFIT**: sistema de agrotóxicos fitossanitários. Brasília, DF, c2003. Disponível em: http://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons. Acesso em: 10 maio 2019.

BROADBENT, L.; GREGORY, P. H.; TINSLEY, T. W. The influence of planting date and manuring on the incidence of virus diseases in potato crops. **Annual of Applied Biology**, v. 39, p. 509-524, 1952.

BROWN, M. W.; MATHEWS, C. R.; KRAWCZYK, G. Extrafloral nectar in an apple ecosystem to enhance biological control. J**ournal of Economic Entomology**, v. 103, n. 5, p. 1657-1664, 2010. DOI: https://doi.org/10.1603/ec10019.

BROWN, M. W.; MILLER, S. S. Coccinellidae (Coleoptera) in apple orchards of eastern West Virginia and the impact of invasion by *Harmonia axyridis*. **Entomological News**, v. 109, p. 136-142, 1998.

BROWN, P. M. J.; ADRIAENS, T.; BATHON, H.; CUPPEN, J.; GOLDARAZENA, A.; HÄGG, T.; KENIS, M.; KLAUSNITZER, B. E. M.; KOVÁR, I.; LOOMANS, A. J. M.; MAJERUS, M. E. N.; NEDVED, O.; PEDERSEN, J.; RABITSCH, W.; ROY, H. E.; TERNOIS, V.; ZAKHAROV, I. A.; ROY, D. B. *Harmonia axyridis* in Europe: spread distribution of a non-native coccinellid. In: ROY, H. E.; WAJNBERG, E. (ed.). **From biological control to invasion**: the ladybird *Harmonia axyridis* as a model species. Dordrecht: Springer, 2007. p. 5-21. DOI: https://doi.org/10.1007/978-1-4020-6939-0_2.

BUENO, V. H. P. Desenvolvimento e criação massal de percevejos predadores *Orius*. In: BUENO, V. H. P. (ed.). **Controle biológico de pragas**: produção massal e controle de qualidade. Lavras: Universidade Federal de Lavras, 2009. p. 33-76.

BUENO, V. H. P.; VAN LENTEREN, J. C. Bioecology and nutrition of predatory Heteroptera. In: PANIZZI, A. R.; PARRA, J. R. P. (ed.). **Bioecology and insect nutrition for Integrated Pest Management**. Boca Raton: CRC, 2011. p. 51-70.

BUENO, V. H. P.; ZANUNCIO, J. C. Percevejos predadores (Heteroptera). In: PANIZZI, A. R.; PARRA, J. R. P. (ed.). **Bioecologia e nutrição de insetos**: base para o manejo integrado de pragas. Brasília, DF: Embrapa Informação Tecnológica, 2009. v. 1, p. 875-930.

BUENO, V. H. P. Controle biológico aumentativo com agentes entomófagos. In: VENZON, M.; PAULA JÚNIOR, T. J.; PALLINI, A. (ed.). **Controle alternativo de doenças e pragas**. Viçosa, MG: EPAMIG, 2005. p. 23-42.

BUGG, R. L. Cover crops. In: HARGROVE, W. L. (ed.). **Cover crops for clean water**. Ankeny: Soil and Water Conservation Society, 1991. p. 157-163. E-book. Disponível em: http://www.swcs.org/documents/filelibrary/CCCWfm.pdf. Acesso em: 29 mar. 2012.

BUGG, R. L. Farmscaping with insectary plants. **Permaculture Activist**, n. 1, p. 6-9, Summer 1990.

BUGG, R. L. Using cover crops to manage arthropods of orchards: a review. **Agriculture Ecosystem and Environment**, v. 50, p. 11-28, 1994.

BUGG, R. L.; COLFER, R. G.; CHANEY, W. E.; SMITH, H. A.; CANNON, J. **Flower flies (Syrphidae) and other biological control agents for aphids in vegetable crops.** Oakland: University of California, 2008. 25 p. (UC ANR Publication 8285). Disponível em: https://escholarship.org/uc/item/37k3d5g8. Acesso em: 13 nov. 2008.

BURGIO, G.; SANTI, F.; MAINI, S. Intra-guild predation and cannibalism between *Harmonia axyridis* and *Adalia bipunctata* adults and larvae: laboratory experiments. **Bulletin of Insectology**, v. 58, n. 2, p. 135-140, 2005.

BURGIO, G.; SANTI, F.; MAINI, S. On intra-guild predation and cannibalism in *Harmonia axyridis* (Pallas) and *Adalia bipunctata* L. (Coleoptera: Coccinellidae). **Biological Control**, v. 24, n. 2, p. 110-116, 2002. DOI: https://doi.org/10.1016/S1049-9644(02)00023-3.

CISNEROS, J. J.; ROSENHEIM, J. A. Changes in the foraging behavior, within-plant vertical distribution, and microhabitat selection of a generalist insect predator: an age analysis. **Environmental Entomology**, v. 27, n. 4, p. 949-957, 1998. DOI: https://doi.org/10.1093/ee/27.4.949.

COGNI, R.; FREITAS, A. V. L.; AMARAL FILHO, B. F. Influence of prey size on predation success by *Zelus longipes* L. (Het., Reduviidae). J**ournal of Applied Entomology**, v. 126, n. 2/3, p. 74-78, 2002. DOI: https://doi.org/10.1046/j.1439-0418.2002.00593.x.

COHEN, A. C.; TANG, R. Relative prey weight influences handling time and biomass extraction in *Sinea confusa* and *Zelus renardii* (Heteroptera: Reduviidae). **Environmental Entomology**, v. 26, n. 3, p. 559-565, 1997. DOI: https://doi.org/10.1093/ee/26.3.559.

COLLEY, M. R.; LUNA, J. M. Relative attractiveness of potential beneficial insectary plants to Aphidophagous Hoverflies (Diptera: Syrphidae). **Environmental Entomology**, v. 29, n. 5, p. 1054-1059, 2000. DOI: https://doi.org/10.1603/0046-225X-29.5.1054.

COLLINS, K. L.; BOATMAN, N. D.; WILCOX, A.; HOLLAND, J. M. 5-year comparison of overwintering polyphagous predator densities within a beetle bank and two conventional hedgebanks. **Annals of Applied Biology**, v. 143, p. 63-71, 2003a. DOI: https://doi.org/10.1111/j.1744-7348.2003.00063.x.

COLLINS, K. L.; BOATMAN, N. D.; WILCOX, A.; HOLLAND, J. M. Effects of different grass treatments used to create overwintering habitat for predatory arthropods on arable farmland. **Agriculture, Ecosystems and Environment**, v. 96, p. 59-67, 2003b. DOI: https://doi.org/10.1016/s0167-8809(03)00032-x.

COOK, S. M.; KHAN, Z. R.; PICKETT, J. A. The use of push-pull strategies in integrated pest management. **Annual Review of Entomology**, v. 52, p. 375-400, 2007.

CORTEZ-MONDACA, E.; PÉREZ-MÁRQUEZ, J.; BAHENA-JUÁREZ, F. Natural biological control of fall armyworm (Lepidoptera: Noctuidae) in maize and sorghum in northern Sinaloa, Mexico. **Southwestern Entomologist**, v. 37, n. 3, p. 423-428, 2012. DOI: https://doi.org/10.3958/059.037.0320.

CORTEZ-MONDACA, E.; ARMENTA-CÁRDENAS, I.; BAHENA-JUÁREZ, F. Parasitoids and percent parasitism of the fall armyworm Lepidoptera: Noctuidae) in Southern Sonora, Mexico. **Southwestern Entomologist**, v. 35, n. 2, p. 199-203, 2010. DOI: https://doi.org/10.3958/059.035.0209.

CROCKER, R. L.; WHITCOMB, W. H. Feeding niches of the big-eyed bugs *Geocoris bullatus*, *G. punctipes* and *G. uliginosus* (Hemiptera: Lygaeidae: Geocorinae). **Environmental Entomology**, v. 9, n. 5, p. 508-513, 1980. DOI: https://doi.org/10.1093/ee/9.5.508.

CRUZ, I. **A lagarta-do-cartucho na cultura do milho**. Sete Lagoas: Embrapa-CNPMS, 1995a. 45 p. (Embrapa-CNPMS. Circular Técnica, 21).

CRUZ, I. Avanços e desafios no controle biológico com predadores e parasitoides na cultura do milho. In: SEMINÁRIO NACIONAL [DE] MILHO SAFRINHA, 13., Maringá. **Anais**... Maringá: Universidade Estadual de Maringá, 2015.

CRUZ, I. Controle biológico como ferramenta para o manejo ecológico de pragas em sistema orgânico de produção de milho. In: CONGRESSO NACIONAL DE MILHO E SORGO, 24., 2002, Florianópolis, SC. **Meio ambiente e a nova agenda para o agronegócio de milho e sorgo**: [palestras]. Sete Lagoas: Associação Brasileira de Milho e Sorgo; Florianópolis: Epagri, 2002a. 1 CD-ROM.

CRUZ, I. Controle biológico de pragas de milho. In: CRUZ, J. C.; KARAM, D.; MONTEIRO, M. A. R.; MAGALHÃES, P. C. (Ed.). **A cultura do milho**. Sete Lagoas: Embrapa Milho e Sorgo, 2008b. p. 363-417.

CRUZ, I. Controle biológico de pragas na cultura de milho destinado à produção de conservas (minimilho). In: PEREIRA FILHO, I. A. (Ed.). **Minimilho**: cultivo e processamento. Sete Lagoas: Embrapa Milho e Sorgo, 2008a. p. 143-187.

CRUZ, I. **Controle biológico de pragas na cultura de milho para produção de conservas (minimilho), por meio de parasitoides e predadores**. Sete Lagoas: Embrapa Milho e Sorgo, 2007. 16 p. (Embrapa Milho e Sorgo. Circular Técnica, 91).

CRUZ, I. Controle biológico de pragas no cultivo do milho verde. In: PEREIRA FILHO, I. A. (Ed.). **O cultivo do milho verde**. Sete Lagoas: Embrapa Milho e Sorgo, 2002b. p. 157-178.

CRUZ, I. Dinâmica de insetos na produção orgânica de grãos de milho. In: SEMINÁRIO MINEIRO SOBRE PRODUÇÃO ORGÂNICA, 11., 2008f, Sete Lagoas. [**Palestras**]. Sete Lagoas: Embrapa Milho e Sorgo, 2008f. 1 CD-ROM.

CRUZ, I. Insetos benéficos. In: CRUZ, I. (ed.). **Manual de identificação de pragas do milho e de seus principais agentes de controle biológico**. Brasília, DF: Embrapa Informação Tecnológica; Sete Lagoas: Embrapa Milho e Sorgo, 2008c. p. 121-192.

CRUZ, I. Manejo integrado de pragas de milho com ênfase ao controle biológico. In: SIMPÓSIO DE CONTROLE DE PRAGAS DA REGIÃO DO PARANAPANEMA, 1., 1994, Assis, SP. **Anais**... Assis: Instituto Biológico; Campinas: CATI, 1994. p. 26-40.

CRUZ, I. Manejo Integrado de Pragas de Milho com ênfase para o controle biológico. In: CICLO DE PALESTRAS SOBRE CONTROLE BIOLÓGICO DE PRAGAS, 4., 1995, Campinas. **Anais**. Campinas: Sociedade Entomológica do Brasil, 1995b. p. 48-92.

CRUZ, I. Métodos de criação de agentes entomófagos de *Spodoptera frugiperda*. 2. ed. rev. ampl. In: BUENO, V. H. P. (ed.). **Controle biológico de pragas**: produção massal e controle de qualidade. Lavras: Universidade Federal de Lavras, 2009. p. 237-275.

CRUZ, I. Multiplicação e liberação de parasitoides e predadores para o controle de *Spodoptera frugiperda*. In: CONGRESSO NACIONAL DE MILHO E SORGO, SIMPOSIO BRASILEIRO SOBRE A LAGARTA-DO-CARTUCHO, SPODOPTERA FRUGIPERDA, 27.; WORKSHOP SOBRE MANEJO E ETIOLOGIA DA MANCHA BRANCA DO MILHO, 3., 2008d, Londrina. **Agroenergia, produção de alimentos e mudanças climáticas**: desafios para milho e sorgo: trabalhos e palestras. [Londrina]: IAPAR; [Sete Lagoas]: Embrapa Milho e Sorgo, 2008d. 1 CD-ROM. 2008d.

CRUZ, I. Pragas do milho. In: CRUZ, I. (ed.). **Manual de identificação de pragas do milho e de seus principais agentes de controle biológico**. Brasília, DF: Embrapa Informação Tecnológica; Sete Lagoas: Embrapa Milho e Sorgo, 2008e. 120 p.

CRUZ, I. Utilização do baculovírus no controle da lagarta-do-cartucho-do-milho, *Spodoptera frugiperda*. In: MELO, I. S.; AZEVEDO, J. L. (ed.). **Controle biológico**. Jaguariúna: Embrapa Meio Ambiente, 2000. p. 201-230.

CRUZ, I.; ALVARENGA, C. D.; FIGUEIREDO, P. E. F. Biologia de *Doru luteipes* (Scudder) e sua capacidade predatória de ovos de *Helicoverpa zea* (Boddie). **Anais da Sociedade Entomológica do Brasil**, v. 24, n. 2, p. 273-278, 1995a.

CRUZ, I.; CASTRO, A. L. G. de. Milho: duplo controle. **Cultivar Grandes Culturas**, v. 20, n. 259, p. 32-35, dez./jan. 2021.

CRUZ, I.; FIGUEIREDO, M. L. C.; OLIVEIRA, A. C.; VASCONCELOS, C. A. Damage of *Spodoptera frugiperda* (Smith) in different maize genotypes cultivated in soil under three levels of aluminium saturation. **International Journal of Pest Management**, v. 45, n. 4, p. 293-296, 1999a. DOI: https://doi.org/10.1080/096708799227707.

CRUZ, I.; FIGUEIREDO, M. L. C.; GONÇALVES, E. P.; LIMA, D. A. N.; DINIZ, E. E. Efeito da idade de lagartas de *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) no desempenho do parasitoide *Campoletis flavicincta* (Ashmead) (Hymenoptera: Ichneumonidae) e consumo foliar por lagartas parasitadas e não-parasitadas. **Anais da Sociedade Entomológica do Brasil**, v. 26, n. 2, p. 229-234, 1997a. DOI: https://doi.org/10.1590/S0301-80591997000200003.

CRUZ, I.; FIGUEIREDO, M. L. C.; MATOSO, M. J. **Controle biológico de *Spodoptera frugiperda* utilizando o parasitoide de ovos *Trichogramma***. Sete Lagoas: Embrapa Milho e Sorgo, 1999b. 40 p. (Embrapa Milho e Sorgo. Circular técnica, 30).

HUESING, J. E.; EDDY, R.; PESCHKE, V. M. (ed.). **Fall armyworm in Africa**: a guide for integrated pest management. 5. ed. México, DF: CIMMYT, 2018. p. 63-88.

DAS, G. P. Plants used in controlling the potato tuber moth, *Phthorimaea operculella* (Zeller). **Crop Protection**, v. 14, p. 631-636, 1995.

DEBACH, P. **Biological control by natural enemies**. Cambridge: Cambridge University Press, 1974. 323 p.

DE CLERCQ P. Spined soldier bug, *Podisus maculiventris* Say (Hemiptera: Pentatomidae: Asopinae). In: CAPINERA, J. L. (ed.). **Encyclopedia of Entomology**. Heidelberg: Springer, 2008. v. 4, p. 3508-3510.

DE CLERCQ, P.; DEGHEELE, D. Influence of feeding interval on reproduction and longevity of *Podisus sagitta* (Het: Pentatomidae). **Entomophaga**, v. 37, p. 583-590, 1992. DOI: http://dx.doi.org/10.1007/BF02372328.

DEOL, G. S.; RATAUL, H. S. Role of various barrier crops in reducing the incidence of cucumber mosaic virus in chilli, *Capsicum annum* Linn. **Indian Journal of Entomology**, v 40, p. 261-264, 1978.

DIFONZO, C. D.; RAGSDALE, D. W.; RADCLIFFE, E. B.; GUDMESTAD, N. C.; SECOR, G. A. Crop borders reduce potato virus Y incidence in seed potato. **Annals of Applied Biology**, v. 129, p. 289-302, 1996.

ELLIOTT, N.; KIECKHEFER, R.; KAUFFMAN, W. Effects of an invading coccinellid on native cocccinellids in an agricultural landscape. **Oecologia**, v. 105, p. 537-544, 1996. DOI: http://dx.doi.org/10.1007/BF00330017.

EL-SEBAEY, I. I. A.; EL-GANTIRY, A. M. Biological aspects and description of different stages of *Harmonia axyridis* (Pallas) (Coleoptera, Coccinellidae). **Bulletin of the Faculty of Agriculture**, v. 50, n. 1, p. 87-97, 1999.

ELVIN, M. K.; STIMAC, J. L.; WHITCOMB, W. H. Estimating rates of arthropod predation on velvet-bean caterpillar larvae in soybeans. **Florida Entomologist**, v. 66, n. 3, p. 320-330, 1983.

ESTRADA-VÍRGEN, O.; CAMPOS, J. C.; BERMUDEZ, A. R.; VELASCO, C. R.; CAZOLA, C. C.; AQUINO, N. I.; CANCINO, E. R. Parasitoids and entomopathogens of the fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in Nayarit, Mexico. **Southwestern Entomologist**, v. 38, n. 2, p. 339-344, 2013.

ETCHEGARAY, J. B.; NISHIDA, T. Biology of *Lespesia archippivora* (Diptera: Tachinidae). P**roceedings of Hawaiian Entomological Society**, v. 22, n. 1, p. 41-49, 1975.

EUBANKS, M. D.; DENNO, R. F. Health food versus fast food: the effects of prey quality and mobility on prey selection by a generalist predator and interactions among prey species. **Ecological Entomology**, v. 25, n. 2, p. 140-146, 2000. DOI: http://dx.doi.org/10.1046/j.1365-2311.2000.00243.x.

FARIA, C. A.; TORRES, J. B.; FARIAS, A. M. I. Resposta funcional de *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae) parasitando ovos de *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae): efeito da idade do hospedeiro. **Anais da Sociedade Entomológica do Brasil**, v. 29, n. 1, p. 85-93, 2000. DOI: https://doi.org/10.1590/S0301-80592000000100011.

CRUZ, I.; FIGUEIREDO, M. L. C.; SILVA, R. B.; DEL SARTO, M. L.; PENTEADO-DIAS, A. M. **Monitoramento de parasitoides de lagartas de *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) em municípios de Minas Gerais, Brasil**. Sete Lagoas: Embrapa Milho e Sorgo, 2009. 29 p. (Embrapa Milho e Sorgo. Documentos, 92).

CRUZ, I.; FIGUEIREDO, M. L. C.; SILVA, R. B.; SILVA, I. F.; PAULA, C. S.; FOSTER, J. E. Using sex pheromone traps in the decision-making process for pesticide application against fall armyworm (*Spodoptera frugiperda* [Smith] [Lepidoptera: Noctuidae]) larvae in maize. **International Journal of Pest Management**, v. 58, n. 1, p. 83-90, 2012. DOI: https://doi.org/10.1080/09670874.2012.655702.

CRUZ, I.; FIGUEIREDO, M. L. C.; VALICENTE, F. H.; OLIVEIRA, A. C. Application rate trials with a nuclear polyhedrosis virus to control *Spodoptera frugiperda* (Smith) on maize. **Anais da Sociedade Entomológica do Brasil**, v. 26, n. 1, p. 145-152, 1997b. DOI: http://dx.doi.org/10.1590/S0301-80591997000100019.

CRUZ, I.; FIGUEIREDO, M. L. C.; SILVA, R. B. **Monitoramento de adultos de *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) e *Diatraea saccharalis* (Fabricius) (Lepidoptera: Pyralidae) em algumas regiões produtoras de milho no Brasil**. Sete Lagoas: Embrapa Milho e Sorgo, 2010. 42 p. (Embrapa Milho e Sorgo. Documentos, 93).

CRUZ, I.; FIGUEIREDO, M. L. C.; SILVA, R. B. Controle biológico de pragas de milho. **Ciência & Ambiente**, v. 43, p. 165-190, 2011a.

CRUZ, I.; GONÇALVES, E. P.; FIGUEIREDO, M. L. C. Effect of a nuclear polyhedrosis virus on *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) larvae, its damage and yield of maize crop. **Revista Brasileira de Milho e Sorgo**, v. 1, n. 2, p. 20-27, 2002.

CRUZ, I.; LIMA, D. A. N.; FIGUEIREDO, M. L. C.; VALICENTE, F. H. Aspectos biológicos do parasitoide *Campoletis flavicincta* (Ashmead) criados em lagartas de *Spodoptera frugiperda* (Smith). **Anais da Sociedade Entomológica do Brasil**, v. 24, n. 2, p. 201-208, 1995b.

CRUZ, I.; OLIVEIRA, A. C. Flutuação populacional do predador *Doru luteipes* Scudder em plantas de milho. **Pesquisa Agropecuária Brasileira**, v. 32, n. 4, p. 363-368, 1997.

CRUZ, I.; REDOAN, A. C.; SILVA, R. B.; FIGUEIREDO, M. L. C.; PENTEADO-DIAS, A. M. New record of *Tetrastichus howardii* (Olliff) as a parasitoid of *Diatraea saccharalis* (Fabr.) on maize. **Scientia Agrícola**, v. 68, n. 2, p. 252-254, 2011b. DOI: https://dx.doi.org/10.1590/S0103-90162011000200017.

CRUZ, I.; TURPIN, F. T. Yield impact of larval infestations of the fall armyworm (Lepidoptera: Noctuidae) to midwhorl growth stage of corn. **Journal of Economic Entomology**, v. 76, n. 5, p. 1052-1054, 1983.

CRUZ, I.; VALICENTE, F. H.; VIANA, P. A.; MENDES, S. M. **Risco potencial das pragas de milho e de sorgo no Brasil**. Sete Lagoas: Embrapa Milho e Sorgo, 2013. 40 p. (Embrapa Milho e Sorgo. Documentos, 150).

CRUZ, I.; BRUCE, A.; SEVGAN, S.; AKUTSE, K. S.; MOHAMED, F. S.; NIASSY, S.; RANGASWAMY, M.; SIDHU, J.; GOERGEN, G.; RWOMUSHANA, I.; KASINA, M.; BA, M.; ABOAGYE, E.; STEPHAN, D.; WENNMANN, J.; NEERING, E.; MUSHOBAZI, W. Biological control and biorational pesticides for fall armyworm management. In: PRASANNA, B. M.;

FERNANDES, D. R. R.; ONODY, H. C.; LARA, R. I. R.; PERIOTO, N. W. Annotated checklist of Brazilian Ophioninae (Hymenoptera: Ichneumonidae). **EntomoBrasilis**, v. 7, n. 2, . 124-133, 2014. DOI: https://doi.org/10.12741/ebrasilis.v7i2.330.

FERERES, A. Barrier crops as a cultural control measure of non-persistently transmitted aphid-borne viruses. **Virus Research**, v. 71, p. 221-231, 2000.

FIEDLER, A.; TUELL, J.; ISAACS, R.; LANDIS, D. **Attracting beneficial insects with native flowering plants**. Lansing: Michigan State University, 2007. 6 p. (Extension Bulletin E-2973).

FIGUEIREDO, M. L. C.; PENTEADO-DIAS, A. M.; CRUZ, I. *Exasticolus fuscicornis* em lagartas de *Spodoptera frugiperda*. **Pesquisa Agropecuária Brasileira**, v. 41, n. 8, p. 1321-1323, 2006b. DOI: https://doi.org/10.1590/S0100-204X2006000800016.

FIGUEIREDO, M. L. C.; CRUZ, I.; DELLA LUCIA, T. M. C. Controle integrado de *Spodoptera frugiperda* (Smith & Abbott) utilizando-se o parasitoide *Telenomus remus* Nixon. **Pesquisa Agropecuária Brasileira**, v. 34, n. 11, p. 1975-1982, 1999. DOI: http://dx.doi.org/10.1590/S0100-204X1999001100001.

FIGUEIREDO, M. L. C.; CRUZ, I.; SILVA, R. B.; FOSTER, J. E. Biological control with *Trichogramma pretiosum* increases organic maize productivity by 19.4%. **Agronomy for Sustainable Development**, v. 35, n. 3, p. 1175-1183, 2015. DOI: http://dx.doi.org/10.1007/s13593-015-0312-3.

FIGUEIREDO, M. L. C.; CRUZ, I.; PENTEADO-DIAS, A. M.; SILVA, R. B. Interaction between *Baculovirus spodoptera* and natural enemies on the suppression of *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) in maize. **Revista Brasileira de Milho e Sorgo**, v. 8, n. 3, p. 207-222, 2009. DOI: http://dx.doi.org/10.18512/1980-6477/rbms.v8n3p207-222.

FIGUEIREDO, M. L. C.; DELLA LUCIA, T. M. C.; CRUZ, I. Effect of *Telenomus remus* Nixon (Hymenoptera: Scelionidae) density on control of *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) egg masses upon release in a maize field. **Revista Brasileira de Milho e Sorgo**, v. 1, n. 2, p. 12-19, 2002. DOI: http://dx.doi.org/10.18512/1980-6477/rbms.v1n2p12-19.

FIGUEIREDO, M. L. C.; MARTINS-DIAS, A. M. P.; CRUZ, I. Relação entre a lagarta do cartucho e seus agentes de controle biológico natural na produção de milho. **Pesquisa Agropecuária Brasileira**, v. 41, n. 12, p. 1693-1698, 2006a. DOI: http://dx.doi.org/10.1590/S0100-204X2006001200002.

FIGUEIREDO, M. L. C.; PENTEADO-DIAS, A. M.; CRUZ, I. Associação entre inimigos naturais e *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae) na cultura do milho. **Revista Brasileira de Milho e Sor**go, v. 5, n. 3, p. 340-350, 2006b. DOI: http://dx.doi.org/10.18512/1980-6477/rbms.v5n3p340-350.

FINCH, S.; COLLIER, R. Host-plant selection by insects: a theory based on ''appropriate/inappropriate landings'' by pest insects. **Entomologia Experimentalis et Applicata**, v. 96, p. 91-102, 2000.

FINCH, S.; BILLIALD, H.; COLLIER, R. H. Companion planting - do aromatic plants disrupt host-plant finding by the cabbage root fly and the union fly more effectively than non-aromatic plants? **Entomologia Experimentalis et Applicatta**, v. 109, p. 183-195, 2003.

FRANK, S. D. Biological control of arthropod pests using banker plant systems: past progress and future directions. **Biological Control**, v. 52, p. 8-16, 2010.

FREITAS, F. S.; TORRES, J. B.; PRATISSOLI, D.; FOSSE, E. Controle, em época de maior ocorrência, da traça do *tomateiro Scrobipalpuloides absoluta* (Meyrick, 1917) por *Trichogramma pretiosum* (Riley, 1879) e cartap. **Revista Ceres**, v. 41, n. 235, p. 244-253, 1994.

GAULD, D. A survey of the **Ophioninae (Hymenoptera: Ichneumonidae) of tropical Mesoamerica with special reference to the fauna of Costa Rica**. London: The British Museum Natural History, 1988. 301 p. (Bulletin. Entomology, 57).

GAULD, D.; SITHOLE, R.; GOMES, J. U.; GODOY, C. **The Ichneumonidae of Costa, 4**. Ann Arbor: American Entomological Institute, 2002. 768 p. (Memoirs of the American Institute, v. 66).

GOMES, F. B.; OLIVEIRA, M. M.; KRUG, C. **Como as vespas podem ser úteis em sistemas agrícolas? *Polistes canadensis* um importante inimigo natural da Amazônia Ocidental**. Belém: Embrapa Amazônia Ocidental, 2017. 7 p. (Embrapa Amazônia Ocidental. Circular Técnica, 66).

GONZÁLEZ-MALDONADO, M. B.; GARCÍA-GUTIÉRREZ, C.; GONZÁLEZ-HERNÁNDEZ, A. Parasitismo y distribución de *Campoletis sonorensis* Cameron (Hymenoptera: Ichneumonidae) y *Chelonus insularis* Cresson (Hymenoptera: Braconidae), parasitoides del gusano cogollero en maíz en Durango, México. **Vedalia**, v. 15, p. 47-53, 2014.

GROSS, H. R.; YOUNG, O. P. *Archytas marmoratus* (Diptera: Tachinidae): screened-cage evaluations of selected densities of adults against larval populations of *Heliothis zea* and *Spodoptera frugiperda* (Lepidoptera: Noctuidae) on whorl and tassel stage corn. **Environment Entomology**, v. 13, n. 1, p. 157-161, 1984. DOI: https://doi.org/10.1093/ee/13.1.157.

GUDETA, S. *Euplectrus laphygmae* as a potential biological control agent in Eastern Ethiopia. **Pest Management Journal of Ethiopia**, v. 2, p. 66-70, 1998.

GUERREIRO, J. C.; SILVA, R. A.; BUSOLI, A. C.; BERTI FILHO, E. Coccinelídeos predadores que ocorrem no estágio inicial da cultura do algodoeiro em Jaboticabal, SP, Brasil. **Revista de Agricultura**, v. 77, n. 1, p. 161-168, 2002. DOI: https://doi.org/10.37856/bja.v77il.1337.

GURR, G. M.; WRATTEN, S. D.; TYLIANAKIS, J.; KEAN, J.; KELLER, M. Providing plant foods for insect natural enemies in farming systems: balancing practicalities and theory. In: WACKERS, F.; RIJN, P. van; BRUIN, J. (ed.). **Plant-provided food and plant-carnivore mutualism**. Cambridge: Cambridge University Press, 2005. p. 326-347.

HAJI, F. N. P. Controle biológico da traça do tomateiro com *Trichogramma* no Nordeste do Brasil. In: PARRA, J. R. P.; ZUCCHI, R. A. (ed.). ***Trichogramma* e o controle biológico aplicado**. Piracicaba: FEALQ, 1997. p. 319-324.

HASSANALI, A.; HERREN, H.; KHAN, Z. R.; PICKETT, J. A.; WOODCOCK, C. M. Integrated pest management: the push-pull approach for controlling insect pests and weeds of cereals, and its potential for other agricultural systems including animal husbandry. **Philosophical Transactions of the Royal Society B: Biological Sciences**, v. 363, n. 1491, p. 611-621, 2008. DOI: https://doi.org/10.1098/rstb.2007.2173.

HAY, M. E. Associational plant defenses and the maintenance of species diversity: turning competitors into accomplices. **American Naturalist**, v. 128, p. 617-641, 1986.

HE, J. L.; MA, E. P.; SHEN, Y. C.; CHEN, W. L.; SUN, X. Q. Observations of the biological characteristics of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae). **Journal of the Shanghai Agricultural College**, v. 12, n. 2, p. 119-124, 1994.

HJALTEN, J.; DANELL, K.; LUNDBERG, P. Herbivore avoidance by association. **Oikos**, v. 128, p. 125-131, 1993.

HODEK, I. **Biology of Coccinellidae**. Prague: Academic Sciences, 1973. 325 p.

HODEK, I.; HONEK, A. **Ecology of Coccinellidae**. Dordrecht: Kluwer Academic Publishers, 1996. 464 p.

HOLDEN, M. H.; ELLNER, S. P.; LEE, D.-H.; NYROP, J. P.; SANDERSON, J. P. Designing an effective trap cropping strategy: the effects of attraction, retention, and plant spatial distribution. **Journal of Applied Ecology**, v. 49, p. 715-722, 2012. DOI: https://doi.org/10.1111/j.1365-2664.2012.02137.x.

HOLE, D. G.; PERKINS, A. J.; WILSON, J. D.; ALEXANDER, I. H.; GRICE, P. V.; EVANS, A. D. Does organic farming benefit biodiversity? **Biological Conservation**, v. 122, p. 113-130, 2005. DOI: https://doi.org/10.1016/j.biocon.2004.07.018.

HOKKANEN, H. M. T. Trap cropping in pest management. **Annual Review of Entomology**, v. 36, p. 119-138, 1991.

HOOKS, C. R. R.; FERERES, A. Protecting crops from non-persistently aphid-transmitted viruses: a review on the use of barrier plants as a management tool. **Virus Research**, v. 120, n. 1, p. 1-16, 2006. DOI: https://doi.org/10.1016/j.virusres.2006.02.006.

HUANG, N.; ENKEGAARD, A.; OSBORNE, L. S.; RAMAKERS, P. M. J.; MESSELINK, G. J.; PIJNAKKER, J.; MURPHY, G. The banker plant method in biological control. **Critical Review of Plant Science**, v. 30, n. 3, p. 259-278, 2011.

IABLOKOFF-KHNZORIAN, S. M. **Les coccinelles Coléoptères-Coccinellidae**: tribu coccinellini des régions paléarctique et orientale. Paris: Société Nouvelle des Éditions Boubée, 1982. 568 p.

INTERNATIONAL POTATO CENTER. 1999. T**echniques in plant virology**. Lima, 1999. Disponível em: http://cipotato.org/training/Materials/PVTechs/Fasc221%2899%29.pdf/at_download/file. Acesso em: 29 mar. 2012.

ISMAN, B. Botanical insecticides, deterrents, and repellents in modern agriculture and increasingly regulated world. **Annual Review of Entomology**, v. 51, p. 45-66, 2006.

JENKINSON, J. G. The incidence and control of cauliflower mosaic in broccoli in South-West England. **Annals of Applied Biology**, v.43, p.409-422, 1955.

JERVIS, M. A.; LEE, J. C.; HEIMPEL, G. E. Conservation biological control using arthropod predators and parasitoids: the role of behavioural and life-history studies. In: GURR, G.; WRATTEN, S. D.; ALTIERI, M. (ed.). **Ecological engineering for pest management**: advances in habitat manipulation of arthropods. Melbourne: CSIRO Press, 2004. p. 69-100.

KATSANIS, A.; BABENDREIER, D.; NENTWIG, W.; KENIS. M. Intraguild predation between the invasive ladybird *Harmonia axyridis* and non-target European coccinellid species. **BioControl**, v. 58, p. 73-83, 2013. DOI: https://doi.org/10.1007/s10526-012-9470-2.

KFIR, R.; GOUWS, J.; MOORE, S. D. Biology of *Tetrastichus howardii* (Olliff) (Hymenoptera: Eulophidae): a facultative hyperparasitoid of stem borers. **Biocontrol Science and Technology**, v. 3, n. 2, p. 149-159, 1993. DOI: https://doi.org/10.1080/09583159309355271.

KHAN, Z. R.; MIDEGA, C. A. O.; WADHAMS, L. J.; PICKETT, J. A.; MUMUNI, A. Evaluation of Napier grass (*Pennisetum purpureum*) varieties for use as trap plants for the management of African stemborer (*Busseola fusca*) in a 'push-pull' strategy. **Entomologia Experimentalis et Applicata**, v. 124, n. 2, p. 201-211, 2007. DOI: https://doi.org/10.1111/j.1570-7458.2007.00569.x.

KHAN, Z. R.; MIDEGA, C. A. O.; AMUDAVI, D. M.; HASSANALI, A.; PICKETT, J. A. On-farm evaluation of the 'push–pull' technology for the control of stemborers and striga weed on maize in western Kenya. **Field Crops Research**, v. 106, n. 3, p. 224-233, 2008. DOI: https://doi.org/10.1016/j.fcr.2007.12.002.

KIANMATEE, S.; RANAMUKHAARACHCHI, S. L. Pest repellent plants for management of insect pests of Chinese kale, *Brassica oleracea* L. **International Journal of Agriculture & Biology**, v. 9, n. 1, p. 64-67, 2007.

KOCH, R. L. The multicolored Asian lady beetle, *Harmonia axyridis*: a review of its biology, uses in biological control, and non-target impacts. **Journal of Insect Science**, v. 3, n. 1, p. 1-16, 2003. DOI: https://doi.org/10.1093/jis/3.1.32.

KOCH, R. L.; VENETTE, R. C.; HUTCHISON, W. D. Invasions by *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in the Western hemisphere: implications for South America. **Neotropical Entomology**, v. 35, n. 4, p. 421-434, 2006. DOI: https://doi.org/10.1590/S1519-566X2006000400001.

KUEPPER, G.; DODSON, M. **Companion planting**: basic concepts and resources. Berkeley, CA: Appropriate Technology Transfer to Rural Areas, 2001. 16 p.

LANDIS, D. A.; WRATTEN, S. D.; GURR, G. M. Habitat management to conserve natural enemies of arthropod pests in agriculture. **Annual Review of Entomology**, v. 45, p. 175-201, 2000. DOI: htts://doi.org/10.1146/annurev.ento.45.1.175.

LAMB, E. M. **Indicator plants, trap crops, and banker plants**: tools for greenhouse IPM ornamental crops. 2006. Disponível em: https://documen.site/download/trap-crops-indicator-plants-banker-plants_pdf. Acesso em: 29 mar. 2012.

LATTIN, J. D. Bionomics of the Nabidae. **Annual Review of Entomology**, v. 34, p. 383-440, 1989.

LATTIN, J. D. Bionomics of the Anthocoridae. **Annual Review of Entomology**, v. 44, p. 207-231, 1999.

LATTIN, J. D. Economic importance of minute pirate bugs (Anthocoridae). In: SCHOEFER, C. W. S.; PANIZZI, A. R. (ed.). **Heteroptera of economic importance**. Boca Raton: CRC Press, 2000. p. 607-637.

LEE, D. H.; NYROP, J.; SANDERSON, J. The potential of eggplant as trap crop for the management of *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae) on poinsettia. **IOBC-WPRS Bulletin**, v. 32, p. 83-86, 2008.

LEE, D. H.; NYROP, J.; SANDERSON, J. Attraction of *Trialeurodes vaporariorum* and *Bemisia argentifolii* to eggplant, and its potential as a trap crop for whitefly management on greenhouse poinsettia. **Entomologia Experimentalis et Applicata**, v. 133, p. 105-116, 2009.

LOPEZ, R.; SHEPARD, B. M. Feverfew as a companion crop reduces spider mites, whiteflies, and thrips in other medicinal plants. **Proceedings of International Symposium Medical Nutraceutical Plants**, v. 756, p. 33-37, 2007.

LU, Z.-X.; ZHU, P.-Y.; GURR, G. M.; ZHENG, X.-S.; READ, D. M. Y.; HEONG, K.-L.; YANG, Y.-J.; XU, H.-X. Mechanisms for flowering plants to benefit arthropod natural enemies of insect pests: prospects for enhanced use in agriculture. **Insect Science**, v. 21, p. 1-12, 2014. DOI: https://doi.org/10.1111/1744-7917.12000.

LUNDGREN, J. G.; RAZZAK, A. A.; WIEDENMANN, R. N. Population responses and food consumption by predators Coleomegilla maculata and Harmonia axyridis (Coleoptera: Coccinellidae) during anthesis in an Illinois cornfield. **Environment Entomology**, v. 33, n. 4, p. 958-963, 2004. DOI: https://doi.org/10.1603/0046-225X-33.4.958.

MALDONADO, J. Systematic catalogue of the reduviidae of the world. **Annals of the Entomological Society of America**, v. 85, n. 4, p. 532-534, 1992. DOI: https://doi.org/10.1093/aesa/85.4.532.

MARENCO, R. J.; FOSTER, R. E.; SANCHEZ, C. A. Sweet corn response to fall armyworm (Lepidoptera: Noctuidae) damage during vegetative growth. **Journal of Economic Entomology**, v. 85, n. 4, p. 1285-1292, 1992. DOI: https://doi.org/10.1093/jee/85.4.1285.

MARTINS, C. B. C.; ALMEIDA, L. M.; CARVALHO, R. C. Z. de; CASTRO, C. F.; PEREIRA, R. A. *Harmonia axyridis*: a threat to Brazilian Coccinellidae? **Revista Brasileira de Entomologia**, v. 53, n. 4, p. 663-671, 2009. DOI: https://doi.org/10.1590/S0085-56262009000400018.

MATOS NETO, F. C.; CRUZ, I.; ZANUNCIO, J. C.; SILVA, C. H. O.; PICANÇO, M. C. Parasitism by *Campoletis flavicincta* on *Spodoptera frugiperda* in corn. **Pesquisa Agropecuária Brasileira**, v. 39, n. 11, p. 1077-1081, 2004. DOI: https://doi.org/10.1590/S0100-204X2004001100004.

MATRANGOLO, W. J. R.; MARTINS-DIAS, A. M. P.; CRUZ, I. Aspectos biológicos de *Campoletis flavicincta* (Ashmead) (Hymenoptera: Ichneumonidae) e interações com o vírus da poliedrose nuclear de *Spodoptera frugiperda*. **Revista Brasileira de Milho e Sorgo**, v. 6, n. 1, p. 1-16, 2007. DOI: https://doi.org/10.18512/1980-6477/rbms.v6n1p1-16.

MATSUMOTO, K.; KOTULAI, J. R. Field tests on the effectiveness of Azadirachta companion planting as a shoot borer repellent to protect mahogany. **Japonese International Research Center Agriculture Science**, v. 10, p. 1-8, 2002.

MCPHERSON, R. M.; SMITH, J. C.; ALLEN, W. A. Incidence of arthropod predators in different soybean cropping systems. **Environmental Entomology**, v. 11, n. 3, p. 685-689, 1982. DOI: https://doi.org/10.1093/ee/11.3.685.

MEAGHER JR., R. L.; NUESSLY, G. S; NAGOSHI, R. N.; HAY-ROE, M. M. Parasitoids attacking fall armyworm (Lepidoptera: Noctuidae) in sweet corn habitats. **Biological Control**, v. 95, p. 66-72, 2016. DOI: https://doi.org/10.1016/j.biocontrol.2016.01.006.

MICHAUD, J. P.; GRANT, A. K. Suitability of pollen sources for the development and reproduction of *Coleomegilla maculata* (Coleoptera: Coccinellidae) under simulated drought conditions. **Biological Control**, v. 32, n. 3, p. 363-370, 2005. DOI: https://doi.org/10.1016/j.biocontrol.2004.11.001.

MILLER, J. C. A comparison of techniques for laboratory propagation of a South American ladybeetle, *Eriopis connexa* (Coleoptera: Coccinellidae). **Biological Control**, v. 5, n. 3, p. 462-465, 1995. DOI: http://dx.doi.org/10.1006/bcon.1995.1055.

MILLER, J. C.; PAUSTIAN, J. W. Temperature-dependent development of Eriopis connexa (Coleoptera: Coccinellidae). **Environmental Entomology**, v. 21, n. 5, p. 1139-1142, 1992. DOI: https://doi.org/10.1093/ee/21.5.1139.

MILWARD-DE-AZEVEDO, E. M. V.; PARRA, J. R. P.; GUIMARÃES, J. H.; ALMEIDA, R. P. Aspectos da biologia de *Archytas incertus* (Diptera, Tachinidae) e de suas inter-relações com *Spodoptera frugiperda* (Lepidoptera, Noctuidae). 1 Metodologia de criação e determinação do instar mais adequado para a produção do parasitoide. **Revista Brasileira de Entomologia**, v. 35, n. 3, p. 485-497, 1991.

MOLINA-OCHOA, J.; CARPENTER, J. E.; HEINRICHS, E. A.; FOSTER, J. E. Parasitoids and parasites of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas and Caribbean Basin: an inventory. **Florida Entomologist**, v. 86, n. 3, p. 254-289, 2003.

MOREAU, T. L.; WARMAN, P. R.; HOYLE, J. An evaluation of companion planting and botanical extracts as alternative pest controls for the Colorado potato beetle. **Biological Agriculture & Horticulture**, v. 23, p. 351-370, 2006.

MURPHY, G. **Trap crops and banker plants**: thinking outside the pest management tool box. Ontario: Ontario Ministry of Agriculture, Food and Rural Affairs, 2004. 6 p.

MUSMECI, S.; CICCOLI, R.; DI GIOIA, V.; SONNINO, A.; ARNONE, S. Leaf effects of wild species of Solanum and interspecific hybrids on growth and behaviour of the potato tubermoth, *Phthorimaea operculella* Zeller. **Potato Research,** v. 40, p. 417-430, 1997.

NAFZIGER, T. D.; FADAMIRO, H. Y. Suitability of some farmscaping plants as nectar sources for the parasitoid wasp, *Microplitis croceipes* (Hymenoptera: Braconidae): Effects on longevity and body nutrients. **Biological Control**, v. 56, p. 225-229, 2011.

NAKASHIMA, Y.; HIROSE, Y. Effects of prey on longevity, prey consumption, and egg production of the insect predators *Orius sauteri* and *O. tantillus* (Hemiptera: Anthocoridae). **Annals of the Entomological Society of America**, v. 92, n. 4, p. 537-541, 1999. DOI: https://doi.org/10.1093/aesa/92.4.537.

NELSON, E. H.; HOGG, B. N.; MILLS, N. J.; DAANE, K. M. Syrphid flies suppress lettuce aphids. **BioControl**, v. 57, p. 819-826, 2012. DOI: https://doi.org/10.1007/s10526-012-9457-z.

ODE, P. J. Plant chemistry and natural enemy fitness: effects on herbivore and natural enemy interactions. **Annual Review of Entomology**, v. 51, p. 163-185, 2006.

OSBORNE, L. S.; LANDA, Z.; TAYLOR, D. J.; TYSON, R. V. Using banker plants to control insects in greenhouse vegetables. **Proceedings of the 118th Annual Meeting of the Florida State Horticultural Society**, v. 118, p. 127-128, 2005.

PAIR, S. D.; RAULSTON, J. R.; SPARKS, A. N.; MARTIN, P. B. Fall armyworm (Lepidoptera: Noctuidae) parasitoids: differential spring distribution and incidence on corn and sorghum in the Southern United States and Northeastern Mexico. **Environmental Entomology**, v. 15, n. 2, p. 342-348, 1986. DOI: https://doi.org/10.1093/ee/15.2.342.

PAROLIN, P.; BRESCH, C.; BOUT, A.; RUIZ, G.; PONCET, C.; DESNEUX, N. Testing banker plants for predator installation. **Acta Horticulturae**, v. 927, p. 211-217, 2012a.

PAROLIN, P.; BRESCH, C.; BRUN, R.; BOUT, A.; BOLL, R.; DESNEUX, N.; PONCET, C. Secondary plants used in biological control: a review. **International Journal of Pest Management**, v. 58, n. 2, p. 91-100, 2012b.

PAROLIN, P.; BRESCH, C.; PONCET, C.; DESNEUX, N. Functional characteristics of secondary plants for increased pest management. **International Journal of Pest Management**, v. 58, p. 369-377, 2012c.

PAROLIN, P.; BRESCH, C.; PONCET, C.; DESNEUX, N. Introducing the term 'Biocontrol Plants' for Integrated Pest Management. **Scientia Agricola**, v. 71, n. 1, p. 77-80, 2014.

PAROLIN, P.; BRESCH, C.; PONCET, C. Biocontrol plants and functional diversity in biological control of the red spider mite *Tetranychus urticae*: a review. **International Journal of Agricultural Policy and Research**, v. 3, n. 4, p. 298-312, 2015.

PARRA, J. R. P.; ZUCCHI, R. A.; SILVEIRA NETO, S. A importância de *Trichogramma* no controle de pragas na agricultura. **Agrotécnica**, v. 1, p. 12-15, 1987.

PASINI, A. **Biologia e técnica de criação do predador *Calosoma granulatum* Perty, 1830 (Coleoptera: Carabidae), em *Anticarsia gemmatalis* Hübner, 1818 (Lepidoptera: Noctuidae), lagarta-da-soja**. 1995. 66 p. Tese (Doutorado em Entomologia) - Escola Superior de Agricultura “Luiz de Queiroz”, Piracicaba, 1995.

PEGORARO, R. A.; FOERSTER, L. A. Observações sobre o ciclo evolutivo e hábitos alimentares de *Calosoma granulatum* Perty, 1830 (Coleoptera: Carabidae) em laboratório. **Anais da Sociedade Entomológica do Brasil**, v. 14, n. 1, p. 269-275, 1985.

PELL, J. K.; BAVERSTOCK, J.; ROY, H. E.; WARE, R. L.; MAJERUS, M. E. N. Intraguild predation involving *Harmonia axyridis*: a review of current knowledge and future perspectives. **BioControl**, v. 53, p. 147-168, 2008. DOI: https://doi.org/10.1007/s10526-007-9125-x.

PERIOTO, N. W.; LARA, R. I. R.; CRUZ, I. *Gryon vitripenne* Masner (Hymenoptera: Platygastridae), new host-parasitoid association with Leptoglossus zonatus (Dallas) (Heteroptera: Coreidae) in corn crop and extension of geographic range. **Revista Chilena de Entomología**, v. 45, n. 3, p. 445-449, 2019.

PERRIN, R. M.; PHILLIPS, M. L. Some effects of mixed cropping on the population dynamics of insect pests. **Entomologia Experimentalis et Applicata**, v. 24, p. 585-593, 1978.

PFIFFNER, L.; WYSS, E. Use of wildflower strips to enhance natural enemies of agricultural pests. In: GURR, G. M.; WRATTEN, S. D.; ALTIERI, M. (ed.). **Ecological engineering for pest management**: advances in habitat manipulation for arthropods. Wallingford: CSIRO Publishing, 2004.

PFISTER, C. A.; HAY, M. E. Associational plant refuges: convergent patterns in marine and terrestrial communities result from differing mechanisms. **Oecologia**, v. 77, p. 118-129, 1988.

PILORGET, L.; BUCKNER, J.; LUNDGREN, J. G. Sterol limitation in a pollen-fed omnivorous lady beetle (Coleoptera: Coccinellidae). **Journal of Insect Physiology**, v. 56, n. 1, p. 81-87, 2010. DOI: https://doi.org/10.1016/j.jinsphys.2009.09.006.

PINEDA, A.; MARCOS-GARCIA, M. A. Introducing barley as aphid reservoir in sweet-pepper greenhouses: Effects on native and released hoverflies (Diptera: Syrphidae). **European Journal of Entomology**, v. 105, p. 531-535, 2008.

POVEDA, K.; GOMEZ, M. I.; MARTINEZ, E. Diversification practices: their effect on pest regulation and production. **Revista Colombiana de Entomologia**, v. 34, p. 131-144, 2008.

PRASAD, K. S.; ARUNA, A. S.; KUMAR, V.; KARIAPPA, B. K. Feasibility of mass production of T*etrastichus howardii* (Olliff), a parasitoid of leaf roller (*Diaphania pulverulentalis*), on *Musca domestica* (L.). **Indian Journal of Sericiculture**, v. 46, n. 1, p. 89-91, 2007.

PREZOTO, F. A importância das vespas como agentes de controle biológico de pragas. **Revista Biotecnologia, Ciência e Desenvolvimento**, v. 9, p. 24-26, 1999.

PREZOTO, F.; MACHADO, V. L. L. Ação de *Polistes (Aphanilopterus) simillinus* Zikpán (Hymenoptera: Vespidae) na produtividade de milho infestada com *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae). **Revista Brasileira de Zoociências**, v. 1, p. 19-30, 1999a.

PREZOTO, F.; MACHADO, V. L. L. Transferência de colônias de vespas (*Polistes simillimus* Zikán, 1951) (Hymenoptera, Vespidae) para abrigos artificiais e sua manutenção em uma cultura de *Zea mays* L. **Revista Brasileira de Entomologia**, v. 43, p. 239-241, 1999b.

QUARLES, W.; GROSSMAN, J. Insectary plants, intercropping and biological control. **The IPM Practitioner**, v. 24, n. 3, p. 1-11, 2002.

QUICKE, L. **The braconid and ichneumonid parasitoid wasps**: biology, systematics, evolution, and ecology. Chennai, India: John Wiley & Sons, 2015. 704 p.

REED, D. J. **Toxicological and parasitological studies on the fall armyworm, *Spodoptera frugiperda* (J.E. Smith), in Alabama**. 1980. 55 p. Dissertação (Mestrado) - Auburn University, Auburn, Alabama, 1980.

REIS, L. L.; OLIVEIRA, L. J.; CRUZ, I. Biologia e Potencial de *Doru luteipes* no Controle de *Spodoptera frugiperd*a. **Pesquisa Agropecuária Brasileira**, v. 23, n. 4, p. 333-342, 1988.

REZENDE, M. A. A.; CRUZ, I.; DELLA LUCIA, T. M. C. Aspectos biológicos do parasitoide *Chelonus insularis* (Cresson) (Hymenoptera, Braconidae) criados em ovos de *Spodoptera frugiperda* (Smith) (Lepidoptera, Noctuidae). **Revista Brasileira de Zoologia**, v. 12, n. 4, p. 779-784, 1995b. DOI: http://dx.doi.org/10.1590/S0101-81751995000400007.

REZENDE, M. A. A.; CRUZ, I.; DELLA LUCIA, T. M. C. Consumo foliar de milho e desenvolvimento de lagartas de *Spodoptera frugiperda* (Smith) parasitadas por *Chelonus insularis* (Cresson) (Hymenoptera: Braconidae). **Anais da Sociedade Entomológica do Brasil**, v. 23, n. 3, p. 473-478, 1994.

REZENDE, M. A. A.; DELLA LUCIA, T. M. C.; CRUZ, I. Comportamento de lagartas de *Spodoptera frugiperda* (Lepidoptera: Noctuidae) parasita das por *Chelonus insularis* (Hymenoptera, Braconidae) sobre plantas de milho. **Revista Brasileira de Entomologia**, v. 39, n. 3, p. 675-681, 1995a.

RICHMAN, D. B.; MEAD, F. W.; FASULO, T. R. **Featured creatures**: spined soldier bug. [Gainesville]: University of Florida, 2020. Disponível em: entnemdept.ufl.edu/creatures/beneficial/podisus_maculiventris.htm. Acesso em: 10 set. 2020.

RIGGIN, T. M.; ESPELIE, K. E.; WISEMAN, B. R.; ISENHOUR, D. J. Distribution of fall armyworm (Lepidoptera: Noctuidae) parasitoids on five corn genotypes in south Georgia. **Florida Entomologist**, v. 76, n. 2, p. 292-302, 1993. DOI: https://doi.org/10.2307/3495729.

RIGGIN, T. M.; WISEMAN, B. R.; ISENHOUR, D. J.; ESPELIE, K. E. Incidence of fall armyworm (Lepidoptera: Noctuidae) parasitoids on resistant and susceptible corn genotypes. **Environment Entomology**, v. 21, n. 4, p. 888-895, 1992. DOI: https://doi.org/10.1093/ee/21.4.888.

RIOS-VELASCO, C.; GALLEGOS-MORALES, G.; CAMBERO-CAMPOS, J.; CERNA-CHÁVEZ, E.; DEL RINCÓN-CASTRO, M. C.; VALENZUELA-GARCÍA, R. Natural enemies of the fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in Coahuila, México. **Florida Entomologist**, v. 94, p. 723-726, 2011.

RODRÍGUEZ-BERRÍO, A.; BORDERA, S.; SÄÄKSJÄRVI, E. Checklist of Peruvian Ichneumonidae (Insecta, Hymenoptera). **Zootaxa**, v. 2303, n. 1, p. 1-44, 2009.

ROGER, C.; CODERRE, D.; BOIVIN, G. Differential prey utilization by the generalist predator according to prey size and species. **Entomologia Experimentalis et Applicata**, v. 94, n. 1, p. 3-13, 2000. DOI: http://dx.doi.org/10.1046/j.1570-7458.2000.00598.x.

ROHLFS III, W. M.; MACK, T. P. Seasonal parasitism rates, host size, and adult emergence pattern of parasitoids of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), with emphasis on *Ophion flavidus* Brullé (Hymenoptera: Ichneumonidae). **Annals of the Entomological Society of America**, v. 78, n. 2, p. 217-220, 1985. DOI: https://doi.org/10.1093/aesa/78.2.217.

ROHLFS III, W. M.; MACK, T. P. Effect of parasitization by *Ophion flavipes* on consumption and utilization of a pinto bean diet by fall armyworm. **Environment Entomology**, v. 12, n. 4, p. 1257-1259, 1983.

ROHLFS III, W. M.; MACK, T. P. Functional response of *Ophion flavidus* Brullé (Hymenoptera: Ichneumonidae) females to various densities of fall armyworm (*Spodoptera frugiperda* J. E. Smith) (Lepidoptera: Noctuidae), **Environmental Entomology**, v. 13, n. 3, p. 708-710, 1984. DOI: https://doi.org/10.1093/ee/13.3.708.

ROTHERAY, G. E.; GILBERT, F. **The Natural History of Hoverflies**. Cardigan: Forrest Text, 2011. 333 p.

SAAVEDRA, J. L. D.; TORRES, J. B.; RUIZ, M. G. Dispersal, and parasitism of *Heliothis virescens* eggs by *Trichogramma pretiosum* Riley in cotton. **International Journal of Pest Management**, v. 43, n. 2, p. 169-171, 1997. DOI: https://doi.org/10.1080/096708797228898.

SÁNCHEZ, E.; ALVARADO, M.; GRADOS, J. Comunidad de avispas Ophioninae (Hymenoptera: Ichneumonidae) en el bosque nublado Monteseco, Cajamarca, Perú. **Revista Peruana de Biología**, v. 21, n. 3, p. 229-234, 2014. DOI: http://dx.doi.org/10.15381/rpb.v21i3.10896.

SANDERSON, J. P.; NYROP, J. P. **Development of a banker plant system for biological control of thrips in greenhouses**. Ithaca: Cornell University, 2008. Disponível em: http://www.reeisusda.gov/web/crisprojectpages/209136.html. Acesso em: 25 nov. 2008.

SANTOS, A. A. **Aspectos biológicos e capacidade de consumo de Harmonia axyridis (Pallas, 1773) (Coleoptera, Coccinellidae)**. 2009. Dissertação (Mestrado) - Universidade Federal do Paraná, Curitiba, 2009.

SANTOS, N. R. P.; SANTOS-CIVIDANES, T. M.; CIVIDANES, F. J.; ANJOS, A. C. R. dos; OLIVEIRA, L. V. L. Aspectos biológicos de *Harmonia axyridis* alimentada com duas espécies de presas e predação intraguilda com *Eriopis connexa*. **Pesquisa Agropecuária Brasileira**, v. 44, n. 6, p. 554-560, 2009. DOI: https://doi.org/10.1590/S0100-204X2009000600002.

SANTOS-CIVIDANES, T. M.; ANJOS, A. C. R.; CIVIDANES, F. J.; DIAS, P. C. Effects of food deprivation on the development of Coleomegilla maculata (De Geer) (Coleoptera: Coccinellidae). **Neotropical Entomology**, v. 40, n. 1, p. 112-116, 2011. DOI: https://doi.org/10.1590/S1519-566X2011000100017.

SARKAR, S. C.; WANG, E.; WU, S.; LEI, Z. Application of trap cropping as companion plants for the management of agricultural pests: a review. **Insects**, v. 9, p. 128-143, 2018. DOI: http://dx.doi.org/10.3390/insects9040128.

SARMENTO, R. A.; OLIVEIRA, H. G.; HOLTZ, A. M.; SILVA, S. M.; SERRÃO, J. E.; PALLINI, A. Fat body morphology of *Eriopis connexa* (Coleoptera: Coccinellidae) in function of two alimentary sources. **Brazilian Archives of Biology and Technology**, v. 47, n. 3, p. 407-411, 2004. DOI: http://dx.doi.org/10.1590/S1516-89132004000300011.

SARMENTO, R. A.; PALLINI, A.; VENZON, M.; SOUZA, O. F. F.; MOLINA-RUGAMA, A. J.; OLIVEIRA, C. L. Functional response of the predator Eriopis connexa (Coleoptera: Coccinellidae) to different prey types. **Brazilian Archives of Biology and Technology**, v. 50, n. 1, p. 121-126, 2007. DOI: https://doi.org/10.1590/S1516-89132007000100014.

SCHNEIDER, F. Bionomics and physiology of aphidophagous Syrphidae. **Annual Review of Entomology**, v. 14, p. 103-124, 1969. DOI: https://doi.org/10.1146/annurev.en.14.010169.000535.

SCHUH, R. T.; SLATER, J. A. **True bugs of the World (Hemiptera: Heteroptera)**: classification and natural history. New York: Cornell University Press, 1995. 336 p.

SHELTON, A. M.; NAULT, B. A. Dead-end trap cropping: a technique to improve management of the diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae). **Crop Protection**, v. 23, n. 6, p. 497-503, 2004. DOI: https://www.sciencedirect.com/science/journal/02612194/23/6.

SHELTON, A. M.; BADENES-PEREZ, F. R. Concepts and applications of trap cropping in pest management. **Annual Review of Entomology**, v. 51, p. 285-308, 2006. DOI: https://doi.org/10.1146/annurev.ento.51.110104.150959 2006.

SILVA, R. B.; CRUZ, I.; ZANUNCIO, J. C.; FIGUEIREDO, M. L. C.; CANEVARI, G. C.; PEREIRA, A. G.; SERRÃO, J. E. Biological aspects of *Eriopis connexa* (Germar) (Coleoptera: Coccinelidae) fed on different insect pests of maize (*Zea mays* L.) and sorghum [*Sorghum bicolor* L. (Moench.)]. **Brazilian Journal of Biology**, v. 73, n. 2, p. 419-424, 2013. DOI: https://doi.org/10.1590/S1519-69842013000200025.

SMITH, H. A.; CHANEY, W. E.; BENSEN, T. A. Role of syrphid larvae and other predators in suppressing aphid infestations in organic lettuce on California's Central Coast. **Journal of Economic Entomology**, v. 101, p. 1526-1532, 2008. DOI: https://doi.org/10.1093/jee/101.5.1526.

SOARES, A. O.; CODERRE, D.; SCHANDERL, H. Fitness of two phenotypes of *Harmonia axyridis* (Pallas) (Coleoptera, Coccinellidae). **Europe Journal of Entomology**, v. 98, n. 3, p. 287-293, 2001. DOI: https://doi.org/10.14411/eje.2001.048.

SOARES, A. O.; CODERRE, D.; SCHANDERL, H. Dietary self-selection behaviour by the adults of the aphidophagous ladybeetle *Harmonia axyridis* (Coleoptera: Coccinellidae). **Journal of Animal Ecology**, v. 73, n. 3, p. 478-486, 2004. DOI: http://dx.doi.org/10.1111/j.0021-8790.2004.00822.x

SOARES, A. O.; CODERRE, D.; SCHANDERL, H. Influence of prey quality on the fitness of two phenotypes of Harmonia axyridis adults. **Entomologia Experimentalis et Applicata**, v. 114, n. 3, p. 227-232, 2005. DOI: https://doi.org/10.1111/j.1570-7458.2005.00246.x.

SSYMANK, A.; KEARNS, C. Flies: pollinators on two wings. In: SSYMANK, A.; HAMM, A.; VISCHER-LEOPOLD, M. (ed.). **Caring for pollinators**: safeguarding agro-biodiversity and wild plant diversity. Bonn: Bundesamt für Naturschutz, 2009. p. 39-52.

STEHR, F. W. Carabidae - Adephaga. In: STEHR, F. W. **Immature insects**. Kendall: Hunt Publishing Company, 1991. v. 2, p. 306-310.

SWEET, M. H. Economic importance of predation by big-eyed bugs (Geocoridae). In: SCHAEFER, C. W.; PANIZZI, A. R. (ed.). **Heteroptera of economic importance**. Boca Raton: CRC, 2000. p. 713-724.

SWEET, M. H. The seed bugs: a contribution to the feeding habits of the Lygaeidae (Hemiptera: Heteroptera). **Annals of the Entomological Society of America**, v. 53, n. 3, p. 317-321, 1960. DOI: https://doi.org/10.1093/aesa/53.3.317.

TAHVANAINEN, J. O.; ROOT, R. B. The influence of vegetational diversity on the population ecology of a specialized herbivore, *Phyllotreta cruciferae* (Coleoptera: Chrysomelidae). **Oecologia**, v. 10, p. 321-346, 1972.

THRESH, M. Cropping practices and virus spread. **Annual Review of Phytopathology**, v. 20, p. 193-218, 1982. DOI: https://doi.org//10.1146/annurev.py.20.090182.001205.

THOMAS, M. B.; WRATTEN, S. D.; SOTHERTON, N. W. Creation of "Island habitats in farmland to manipulate populations of beneficial arthropods: Predator densities and emigration. **Journal of Applied Ecology**, v. 28, n. 3, p. 906-917, 1991. DOI: https://doi.org/10.2307/2404216.

THOMAS, M. B.; MITCHELL, H. J.; WRATTEN, D. D. Abiotic and biotic factors influencing the winter distribution of predatory insects. **Oecologia**, v. 89, n. 1, p. 78-84, 1992. DOI: https://doi.org/10.1007/BF00319018.

TOBA, H. H.; KISHABA, A. N.; BOHN, G. W.; HIELD, H. Protecting muskmelon against aphid-borne viruses. **Phytopathology**, v. 67, p. 1418-1423, 1977.

TOGNI, P. H. B.; CAVALCANTE, K. R.; LANGER, L. F.; GRAVINA, C. S.; MEDEIROS, M. A. de; PIRES, C. S. S.; FONTES, E. M. G.; SUJII, E. R. Conservação de inimigos naturais (Insecta) em tomateiro orgânico. **Arquivos do Instituto Biológico**, v. 77, n. 4, p. 669-676, 2010. DOI: https://doi.org/10.1590/1808-1657v77p6692010.

TORRES, J. B.; ZANUNCIO, J. C.; MOURA, M. A. The predatory stinkbug *Podisus nigrispinus*: biology, ecology, and augmentative releases for lepidopteran larval control in Eucalyptus forests in Brazil. **CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources**, v. 1, p. 1-18, 2006.

TORRES, V. D. O.; ANTONIALLI JÚNIOR, W. F.; GIANOTTI, E. Divisão de trabalho em colônias da vespa social neotropical *Polistes canadensis* (Linnaeus (Hymenoptera, Vespidae). **Revista Brasileira de Entomologia**, v. 53, n. 4, p. 593-599, 2009. DOI: http://dx.doi.org/10.1590/S0085-56262009000400008.

UVAH, I. I. I.; COAKER, T. H. Effect of mixed cropping on some insect pests of carrots and onions. **Entomologia Experimentalis et Applicata**, v. 36, n. 2, p. 159-167, 1984. DOI: https://doi.org/10.1111/j.1570-7458.1984.tb03422.x.

VANDERMEER, J. **The ecology of intercropping**. Cambridge University Press, 1989. 237 p. DOI: https://doi.org/10.1017/CBO9780511623523.

VATTALA, H. D.; WRATTEN, S. D.; PHILLIPS, C. B.; WÄCKERS, F. L. The influence of flower morphology and nectar quality on the longevity of a parasitoid biological control agent. **Biological Control**, v. 39, n. 2, p. 179-185, 2006. DOI: https://doi.org/10.1016/j.biocontrol.2006.06.003.

VENZON, M.; ROSADO, M. C.; EUZÉBIO, D. E.; PALLINI, A. Controle biológico conservativo. In: VENZON, M.; PAULA JÚNIOR, T. J.; PALLINI, A. (ed.). **Controle alternativo de doenças e pragas**. Viçosa, MG: EPAMIG, 2005. p. 1-22.

VILLAS BÔAS, G. L.; FRANÇA, F. H. Utilização do parasitoide *Trichogramma pretiosum* no controle da traça-do-tomateiro em cultivo protegido de tomate. **Horticultura Brasileira**, v. 14, p. 223-225, 1996.

VILLEGAS-MENDOZA, J. M.; SÁNCHEZ-VARELA, A.; NINFA, R. Caracterización de una especie de *Meteorus* (Hymenoptera: Braconidae) presente en Larvas de *Spodoptera frugiperda* (Lepidoptera: Noctuidae) en el Norte de Tamaulipas, México. **Southwestern**

Entomologist, v. 40, n. 1, p. 161-170, 2015. DOI: https://doi.org/10.3958/059.040.0114.

VIRLA, E.; MELO, C.; STEFANO, S. Preliminary observations on *Zelus obscuridorsis* (Stål) (Hemiptera: Reduviidae) as predator of the corn leafhopper (Hemiptera: Cicadellidae) in Argentina. **Insects**, v. 6, n. 2, p. 508-513, 2015. DOI: https://doi.org/10.3390/insects6020508.

VOCKEROTH, J.; THOMPSON, C. Syrphidae. In: McALPINE, J. (ed.). **Manual of the Nearctic Diptera**. Quebec: Research Branch, Agriculture Canada, 1987. v. 2, p. 713-743. (Monograph n° 28).

WACKERS, F. Assessing the suitability of flowering herbs as parasitoid food sources: Flower attractiveness and nectar accessibility. **Biological Control**, v. 29, n. 3, p. 307-314, 2004. DOI: https://doi.org/10.1016/j.biocontrol.2003.08.005.

WEEDEN, C. R.; SHELTON, A. M.; YAXIN, L.; HOFFMAN, M. P. **Biological control**: a guide to natural enemies in North America. Ithaca: Cornell University, 2007. Disponível em: http://www.nysaes.cornell.edu/ent/biocontrol/predators/coleomeg.html. Acesso em: 23 mar. 2007.

WHEELER, G. S.; ASHLEY, T. R.; ANDREWS, K. L. Larval parasitoids, and pathogens of the fall armyworm in Honduran maize. **Entomophaga**, v. 34, p. 331-340, 1989. DOI: https://doi.org/10.1007/BF02372472.

ZHANG, Z. Q. The natural enemies of *Aphis gossypii* Glover (Hom., Aphididae) in China. **Journal of Applied Entomology**, v. 114, n. 1/5, p. 251-262, 1992. DOI: https://doi.org/10.1111/j.1439-0418.1992.tb01124.x.

ZUCCHI, R. A.; MONTEIRO, R. A. O gênero *Trichogramma* na América do Sul. In: PARRA, J. R. P.; ZUCCHI, R. A. (Ed.). ***Trichogramma* e o controle biológico aplicado**. Piracicaba: FEALQ, 1997. p. 41-46.

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