BIOLOGICAL CONTROL OF WHITEFLY BY SPECIES OF LADYBUG DELPHASTUS SPP.

CONTROLE BIOLÓGICO DE MOSCA-BRANCA POR ESPÉCIES DA JOANINHA Delphastus spp

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Abstract: Whitefly complex is one of the most severe pests affecting different crops of significant agricultural interest. It causes critical damage to plants, and hence considerably affect crop productivity and the related commercials. This insect has been managed using insecticides; however, there have been reports of resistance of this insecticide to various active ingredients, making it difficult to reduce this pest's population. Hence, other ways of handling this insect population have been investigated, including through biological control. Several past studies have reported the existence of natural enemies of the whitefly, including coccinellids such as those belonging to the genus Delphastus have gained much attention. These coccinellids are predators and hence perform the important role of controlling pest population. Moreover, the whitefly is a staple food in certain diets.

Keywords: Coccinellids. Aleyrodidae. Rational Pest Management

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Resumo: O complexo de mosca-branca figura entre as mais severas pragas de diversas culturas de interesse agrícola, pois provoca danos severos às plantas e consideráveis perdas em produtividade. O manejo desse inseto é realizado através de inseticidas, no entanto há relatos de resistência a diversos ingredientes ativos, o que dificulta a redução da população da praga. Devido a isso, outras formas de manejá-lo têm sido investigadas, destacando-se entre elas, o controle biológico. Diversos inimigos naturais de mosca-branca são relatados, dentre os quais, coccinelídeos do gênero Delphastus têm se destacado. Esses coccinelídeos são predadores e realizam um trabalho importante no controle da praga, uma vez que a mosca-branca é o alimento base da sua dieta.

Palavras-chave: Coccinelídeos. Aleirodídeos. Manejo Racional de Pragas

1 INTRODUCTION

Crop damage by the whitefly species is one of the main problems related to agricultural productivity in Brazil and even in certain parts of the world, mainly because these insects adapt to different agroclimatic conditions and act as agents that cause direct damage through the consumption of sap and indirect damage through the transmission of fatal viruses among economically important crops (LORENÇÃO, 1994; ROSELL, 1997; De BARRO et al., 2011).

Chemical control is considered as the main approach for the management whiteflies population and other agricultural pests. However, several problems arising from the inappropriate use of this control measure has been reported, including insect resistance to insecticides, depletion of the production of new ingredients, efficient assets and formulations, environmental contamination, and health of rural workers, in addition to the growing search for healthier and more rationally produced foods that involve minimal possible use of pesticides (NAVEEN et al., 2017).

As an alternative to avoid the exclusive and irrational use of chemical control measures, we have highlighted here the adoption of control methods that have greater specificity, are less toxic to the human, and are environmentally safe, while maintaining efficiency. Fulfilling these conditions, biological pest control has received great prominence and is considered as one of the most studied control methods, with significant results in field application similar to that
through chemical control (DeBACH and ROSEN, 1991; Van LENTEREN and MARTIN, 1999; Van LENTEREN, 2000).

Among the groups of organisms that are agents of biological control are natural enemies, which can be pathogens, parasites, herbivores and predators. In the latter case, the coccinellids have gained much attention because they are, in their majority, efficient predators in the immatures and adult phases of the insect. They are also important natural enemies in the natural and applied biological control of pests in the most varied agroecosystems, which has kept pests at levels below those that are considered problematic for crops (HODEK and HONEK, 1996).

Coccinellids have a cosmopolitan occurrence, with more than five thousand species known worldwide, many of which remain unidentified for their role in the environmental balance toward maintaining potential pests at secondary or tertiary levels in the agricultural environments (IPERTI, 1999).

The main group of coccinellids that are considered as important predators of whitefly species belongs to the genus Delphastus. They are black-colored ladybugs that, mostly, go unnoticed in agricultural environments. These insects exhibit a high rate of predation and reproductive rate, in addition to acting as agents that can partially coexist with other beneficial organisms, because of their behavior of preying only on healthy individuals and avoiding intraguild predation in most cases (HEINZ, 1999).

Owing to the importance of the natural occurrence of ladybugs of genus Delphastus in the agricultural environments as predators of the whitefly species based on some studies on this genus, the present review aimed to demonstrate the importance and highlight the performance of the Delphastus spp. as agents of natural biological control and their application in environments of occurrence of Aleyrodidae.
2 DEVELOPMENT

This study is a bibliographic review of a narrative character regarding the biological control performed by predatory ladybugs of *Delphastus* over the pest complex belonging to the Aleyrodidae family.

Data collection was performed through the consultation of journals and articles using search platforms such as Web of Science, Science Direct, and Scientific Electronic Library Online (SCIELO), among others, which allowed the elaboration of this content.

2.1. The White Fly Species Complex

Present in all the Brazilian states and even worldwide, the pest complex known as whitefly is composed of different species, standing out among the main ones: *Bemisia tabaci* (*Gennadius*, 1889), *Bemisia tuberculata* (Bondar, 1923), *Aleurothrixus aepim* (Goeldi, 1886), *Aleurotrachelus socialis* (Bondar, 1923) e *Trialeurodes variabilis* (Quaintance, 1990). All the species are referenced to as hemiptera and they belong to the suborder Sternorryncha and family Aleyrodidae (BYRNE & BELLOWS JUNIOR, 1991).

Aleyrodids are small insects that, in adulthood, have two pairs of membranous wings, white in color. The eggs are pedunculated and, like nymphs, are attached to the underside of the leaves (GALLO et al, 2002).

These insects undergo a change in status from secondary to primary pests because of the damage caused by the adult and nymphaal phases (SILVA et al., 2017). The damage caused by the insect occurs on the leaves of the plants and can be direct or indirect, however, in most cases, they occur in an associated manner.
Direct damage is caused through the suction of sap and the injection of toxins (AZEVEDO and BLEICHER, 2003), which results in the reduction in the sap flow and shrinking of the leaves, which in turn decrease productivity and impact product quality (VILLAS BÔAS et al., 2002).

Indirect damage is caused by the transmission of phyto-viruses (MARUBAYASHI et al., 2010). Insects release the viruses belonging to the Geminiviridae family when sucking on the phloem sap from the host plants through the mouth-sucking oral apparatus. Among the insect, those belonging to the genus Begomovirus stand out as the most important ones (FREITAS, 2002; NAGATA et al., 2009).

The damage caused by aleyrodids affect several crops of economic importance. According Baldin (2011), Navas-Castilho et al. (2011) e PIETROWSKI et al. (2014) the damage can be associated with more than 60 cultivated plants, among them are Solanum gilo (LEITE et al., 2002), Phaseolus vulgaris (ORIANI et al., 2005), Gossypium spp. (TORRES et al., 2007), Lycopersicon esculentum (SILVA et al., 2009), Glycine max (SILVA et al., 2012), Vigna unguiculata (CRUZ et al., 2012), Cucurbita moschata (LIMA et al., 2013), Manihot esculenta (Pietrowski et al., 2014).

In fact, aleyrodids can that cause serious direct and indirect damage (Baldin, 2011; Navas-Castilho et al., 2011; PIETROWSKI et al., 2014).

To control the whitefly complex population, chemical control is the most commonly used method (MOURA et al., 2013; POTRICH et al., 2011), because whitefly species have a high capacity for reproduction and adaptation and they possess a high potential of developing resistance to insecticides. According Naveen et al. (2017) several studies report resistance to ingredients in these insects. Thus, chemical control has lost its efficiency over the years, making it necessary to use other tools for the correct management of this pest (SILVA et al., 2009).
2.2. Rational Management of Agricultural Pest

The more rational control of agricultural pests implies using all of the available means to manage the population incidence of insects when they reach the action level and thus conduct management planning by integrating various control tools (STERN, 1959).

The principles of Integrated Pest Management (MIP) are adopted for the precise establishment of strategies and execution through appropriate tactics for the control of agricultural pests. Thus, it aims to maintain these insects at levels that do not cause economic damage to crops, which result in reduced productivity and negative impact on product quality (STERN et al., 1959; GRAVENA, 1992; BUSOLI et al., 2012).

MIP planning uses different control tools, such as chemicals, biological agents (including predators, parasitoids, and entomopathogens such as bacteria, viruses, and fungi), pheromones, varieties of pest-resistant plants, and cultural management of crops (BETTIOL, 2011).

In addition, MIP always associates various forms of control in a harmonious manner, with the adoption of accurate and efficient decision-making (TSCHARNTKE ET al., 2012), which are mainly based on a set of information of insects and their population density in the occurrence of natural enemies and the culture’s ability to tolerate damage (BASTOS et al., 2003).

Every crop requires specific management planning based on the particularities of the attacking insect and its phenological characteristics (TOSCANO et al., 2003; BOIÇA JR. et al., 2007), which makes factors such as crop monitoring, sampling, correct identification of pests and natural enemies, and the action levels of each culture indispensable for successful management (MOURA et al., 2013).

In a scenario where chemical control has encountered several obstacles due to the resistance characteristics of insects to the active ingredients of
insecticides (MOURA et al., 2013; COSKUN et al., 2015), biological control has gained ground in research and in field production of various cultures (GUSMÃO et al., 2000).

This control modality is structured by three strategies: Classic Biological Control, which deals with the import and colonization of parasitoids, predators, and pathogens; the Natural or Conservative Biological Control, which refers to the maintenance and population increase of enemies that occur naturally in the agricultural area; and the Applied or Augmentative Biological Control, which corresponds to flooding releases from laboratory breeding, aiming at the rapid reduction of the population of the plague to its balance level (DeBACH and ROSEN, 1991; KOGAN, 1998).

One of the strategies of MIP that is popularly used is the use of natural enemies to control pest population, both predatory and parasitic (KOGAN, 1998; PARRA, 2011). Some insect families are known to act as insect predators in the most diverse cultures, such as coccinellids (HODEK and HONEK, 1996; GUERREIRO et al., 2006).

2.3. Coccinelids as Pest Control Agents

Coccinellids are commonly known as ladybugs (GORDON, 1985; GUERREIRO, 2004) and are commonly found in the wild. Ladybugs feed mainly on aphids, mealybugs, and mites in their juvenile and adult stages (OLKOWSKI et al., 1990; IPERTI, 1999; BEGHA, 2019). Coccinellids are voracious predators of several species of insects and are extremely important agents in the agricultural ecosystem considering that they maintain the balance of infestations compromising crop productivity (PARRA et al., 2002; GUERREIRO et al., 2003).

In Brazil, the greatest action of coccinellids occurs as a natural occurrence controller in more balanced environments; however, in some regions of the world, it demonstrates excellent performance as an agent in applied
biological control, especially under protected environment conditions (Baldin et al., 2011). According to Riddick (2017), coccinellids can reduce pests in greenhouses, with the adult phase showing greater efficiency than the larval phases.

Among the predatory coccinellids, those belonging to Delphastus spp. have stood out with regard to the natural control of whitefly, as they are considered as specific predators of this insect pest (Hoelmer and Pickett, 2003).

The specificity of the predator Delphastus spp. for whiteflies is a promising control strategy for the reduction of the pest population density (Heinz et al., 1999; Baldin et al., 2011), since the ladybug preys on all species in their immature stages of development of aleyrodids (Hodek and Honek, 1996), preferring eggs and nymphs of these insects (Legaspi et al., 2006).

According to Oriani and Vendramin (2014), the main species of coccinellids belonging to the genus Delphastus include: Delphastus pusillus Le Conte, 1852; Delphastus catalinae Horn, 1895; Delphastus davidsoni Gordon, 1994 and Delphastus pallidus Le Conte, 1878. The development of these ladybugs is holometabolic, passing through the egg phase, five larval instars and the adult phase. Adults are tiny ladybugs, black in color, with yellowish legs and measure approximately 1.4 mm in length. Males and females are distinguished in adulthood by the color of the head, while the female is all black, the male has an orange colored head. The larvae are elongated, clear and have fine, short hair and the pupae are yellowish and spherical (Legaspi et al., 2008).

In general, insects are highly susceptible to abiotic factors. The main influencing factor for insect behavior is temperature, as it affects them directly and indirectly (Gallo et al., 2002). In the first case, it affects their development and behavior and in the second case affects their diet.

For coccinellids, as well as for aleyrodids, the optimal temperature range is around 25°C, as insects keep their body temperature close to the temperature
of the environment, which is known as pecilotermia (KATSOYANNOS et al., 2005). However, aleyrodids can survive the wide temperature range, with reduced metabolic rate and lengthening of the cycle in extreme temperatures, so if there are no natural enemies that survive these conditions, the occurrence of the pest will prevail (SILVEIRA NETO et al., 1976; AUAD and FOSECA, 2017).

Studies by Simmons and Legaspi (2004) tested the survival of *Delphastus catalinae* when exposed to different regimes of constant temperature for 24 and 48 hours, under controlled conditions and 14 hour photoperiod. The temperatures studied ranged from -10 to 50°C, with a 5°C difference between them, forming a range of 13 temperatures in total. For the 24 hour exposure time, it was observed by the authors that there was no survival of adult ladybugs at temperatures of -10 and 50°C, for temperatures of 5 and 45°C, the survival rate was very low, close to 1% and at temperatures ranging from 5 to 35°C, the survival rate was over 90%.

In the 48 hour exposure period, the survival rate was 80% for temperatures of 5, 10, 15, 20 and 25°C and dropped to 50% when the insects were exposed to temperatures of 30 and 35°C. When exposed to 40°C, no insect survived, however, for the 24 hour test the survival rate at the same temperature was 60%, which makes it clear that the longer the duration of exposure to extreme temperatures, the lower the survival rate of coccinellids.

In optimal conditions of survival, Hoelmer et al. (1993) found that the ladybug larvae can consume up to a thousand whitefly eggs before pupating, also found that a single adult is able to consume ten thousand eggs during this stage of life.

To validate the predation rates of *D. catalinae* on whiteflies, Rincon, Canãs and Hoy (2016, 2017) studied predation rates, through mathematical modeling, and the distribution of eggs and nymphs whitefly and *D. catalinae* adults in tomato plants. The insects and plants were kept at a temperature of 25 ± 2°C and a photoperiod of 14 hours, in a greenhouse.
Studies have shown that the occurrence of whitefly on the plant is different from the occurrence of the ladybug, which causes a reduction in interspecific competition, that is, even though the two species are present on the same plant, there may be no predation, therefore, the magnitude of predation rates at the leaflet level is modulated by the degree of overlap between the distribution of visits by predators where the largest number of prey is. However, it was found that there is a preference for the whitefly for the medium to upper third of the canopy, while coccinellids in general prefer the medium to lower third, this study also showed that the differences between the distributions of whitefly and *D. catalinae* is justified by the search for prey by larvae in lower positions of the plant, regardless of the location of whitefly nymphs, whereas adults of *D. catalinae* are attracted by the honeydew excreted by the adult whitefly insect.

Based on this information, it is possible to determine that Delphastus species can, under Brazilian conditions, play an efficient role in the predation of insects in the whitefly group.

In Brazil, there are no mass releases of the ladybug *Delphastus spp.*, as the insect occurs naturally in the field, but cannot be commercialized. Therefore to use this natural enemy in MIP planning, it is necessary to use selective insecticides for coccinellids in order to maintain the natural enemy in the field and in areas of refuge so that they can act in the natural biological control of aleyrodids. In places where the occurrence is low or the presence of coccinellide is not possible, other registered micro and macrobiological agents can be used to control the whitefly. Entomopathogenic fungi such as *Beauveria bassiana* and *Paecilomyces fumosoroseus* (WRAIGHT et al., 2000; ZAFAR et al., 2016) are already used commercially to control whitefly, more recently the predatory mite *Amblyseius tamatavensis* (BARBOSA et al., 2019), which can be used in an associated way (SEIEDY, 2015). All of these agents can be used for organic crops, and those that have low use of insecticides, the ladybug and other natural enemies perform effective pest control.
3 FINAL CONSIDERATIONS

This review revealed the importance of the coccinellid of *Delphastus* spp. has as a whitefly predator in balanced environments, where its natural occurrence is allowed. It also shows that other macro and microbiological agents that are used commercially can control the pest.

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