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Helicoverpa armigera: current status and future perspectives in Brazil

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ABSTRACT

The bollworm *Helicoverpa armigera* is a polyphagous pest first identified in the South American continent in Brazil during the 2012/13 crop season, worrying farmers across the country leading them to overuse insecticides in an attempt to control its outbreaks. However, it is essential to emphasize the importance of the adoption of Integrated Pest Management (IPM) philosophy, since improperly applied insecticides will exacerbate pest problem by eliminating the biological control agents and increase the production cost unnecessarily. Therefore, our work discusses, in more detail, the current status, recommended management, and future perspectives of this pest in Brazil. We conclude that, in spite of *H. armigera* infestation in Brazil, it will still be feasible for growers to adopt pest-control measures that have less impact on the environment in accordance with the standard principles of the IPM philosophy. Within this context, monitoring for pests and initiating control measures only when the pest populations reaches the economic thresholds (ET) recommended by research is crucial. These procedures protect crop sustainability, thus keeping growers competitive in the market while reducing costs and maximizing productivity. The arrival of *H. armigera* in Brazil has resulted in a national debate about the importance of IPM adoption. It is a chance to fully implement IPM in Brazil as it has never been done or seen before in the history of tropical agriculture. If IPM is successfully adopted in Brazil, the future perspective of *H. armigera* will be that of being a satisfactorily managed pest. In contrast, if only a simplified version of IPM is employed, *H. armigera* and many other pests will have a greater chance of surviving and causing severe damage to crops.

Keywords: bollworm; Heliothinae; quarantine pest; polyphagous pest.

INTRODUCTION

Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae) is one of the world's most important agricultural pests (Tay et al. 2013). In Brazil, it has been recognized as a quarantine pest since 1999, and received the A_1 quarantine pest status in 2008 (Oliveira et al. 2003; Lima et al. 2006; Agropec Consultoria, 2013). Its occurrence was first reported in the country only in February 2013 (Czepak et al. 2013;

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Specht et al. 2013). Even though just registered in 2013, it is highly possible the pest was present in Brazil before 2013 as *H. armigera* is difficult to distinguish from other related species of the same subfamily Heliothinae (*Helicoverpa zea* or even *Heliothis virescens*, for example) based only on morphological characteristics for non-experts. Moreover, *H. armigera* was wide spread in the country in its first year of occurrence, a distribution pattern usually expected to take many months to occur (Bueno et al. 2014).

The pest identification was performed almost simultaneously and independently by taxonomists Dr. Alexandre Specht and Dr. Vitor Becker (Bueno et al. 2014), based on the morphology of male genitalia and confirmed by mitochondrial gene sequencing (Specht et al. 2013; Bueno and Sosa-Gómez, 2014). Identification via male genitalia morphology has been used extensively, although Pogue (2004) reported overlapping ranges in male vesica between *H. armigera* and *H. zea* (Tay et al. 2013).

Nevertheless, the establishment of an invasive species in a new territory can lead to rapid and significant negative economic and environmental impacts. Damages of *H. armigera* has been reported to be greater than $2 billion annually, excluding socio-economic and environmental costs associated with its control in Asia, Europe, Africa, and Australia (Tay et al. 2013). In Brazil, damage reports reached approximately $0.8 billion in the first crop season (2012/2013) after pest occurrence (Bueno et al. 2014). Taking this scenario into consideration, this work aims to discuss in more detail the current status, recommended management, and future perspectives of this pest in Brazil.

Helicoverpa armigera: Current status in Brazil

Caterpillar outbreaks

Similar to any other caterpillar species, the current status of *H. armigera* may vary among different crops and regions within the same country. In Brazil, besides *H. armigera*, the soybean looper *Chrysodeixis includens* (Walker) (Lepidoptera: Noctuidae) has also increased in importance and reached the status of a key pest in soybean, for example (Bueno et al. 2012). More recently, *H. armigera* is the pest species which has also become prominent among Brazilian soybean growers (Bueno et al. 2013).

Into the analysis of *H. amigera* status, it is important to considerer this pest not only causes defoliation but also attacks plant reproductive organs (such as soybean pods). In the 2012/13 and 2013/14 crop seasons, high infestations of *Helicoverpa* species larvae were detected in different regions of Brazil attacking different crops, resulting in significant economic loss. Initially the species was presumed to be *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae), which is often found in maize and tomato crops in Brazil (Degrande and Omoto 2013). Later, high prevalence of *H. armigera* was found in Western Bahia, (an important agricultural state in Brazil) causing serious damage to soybean, corn, and especially, cotton (Czepak et al. 2013; Specht et al. 2013). In most cases, this, along with media pressure, led to growers using insecticide sprays even when the pest populations were still low or even nonexistent. These erroneous and abusive applications of insecticides only exacerbated the problem of pests, mainly due to the elimination of biological control agents (predators and parasitoids) that occur naturally. As a consequence, the recently detected *H. armigera* caterpillars and possibly other pest species such as *Spodoptera* spp., despite not being widespread key pests in the country, have been causing significant problems for growers.

This has brought back the discussion about the importance of integrated pest management (IPM) in agriculture. This is very important since the growing number of caterpillar-attacks on crops such as soybean is mainly due to the abandonment of IPM and the overuse of insecticides, applied on a calendar basis, or together with herbicides and fungicides sprayings. Other key factors include the lack of monitoring

and quantification of insect infestation in the field (Bueno et al. 2013). In this current scenario, it is necessary to emphasize that improper use of insecticides will only exacerbate this problem and unnecessarily increase production costs.

It is important to clarify that, in some Brazilian states such as Bahia, which are typically dry and warm, *H. armigera* occurrence and damage might be higher compared to other regions of the country. In southern Brazilian states, for example, *Helicoverpa* spp. prevalence has been low, even though localized attacks on green beans, coffee, wheat, and citrus, among other crops, have been reported.

Host plants

Host species for *H. armigera* come from a broad spectrum of families (>45 families) and include >180 plant hosts among which are important agricultural crops such as cotton, maize, chickpea, pigeon pea, sorghum, sunflower, soybean, and groundnuts (Fitt 1989; Tay et al. 2013). Generally, in Brazil, the most important crops afflicted by *H. armigera* include cotton, soybean, corn, green beans, tomatoes, citrus, and pastures. However, in corn, it is common to find mixed infestations of *H. zea* and *H. armigera*. In soybean and cotton, mixed infestations of *H. armigera* and *Heliothis virescens* (Fabricius) (Lepidoptera: Noctuidae) might also occur. *Helicoverpa armigera* has also been found feeding on weeds such as *Conyza bonariensis* (Asteraceae) and *Rumex*. Its polyphagous nature keeps the *H. armigera* population high throughout the year due to various host availability and this presents some challenges to the pest management.

***Helicoverpa armigera* management**

It is important for *H. armigera* management success to consider the whole landscape, including both cropped and non-cropped areas, due to the insect polyphagia. Moreover, it also important to point out recommendations can differ between different crops. In soybean, for example, it is important to consider that there is a complex of caterpillar species that can attack plants from the beginning of its development until the reproductive period which must be managed together. Also, *H. armigera* is highly reproductive, with rapid development potential; hence, it can give rise to overlapping generations throughout the crop cycle, especially in hot and dry years. Therefore, under favorable conditions, population levels of this caterpillar can increase rapidly and cause significant yield loss if not properly managed.

The main steps for a good management of the major lepidopteran species include: a) species identification, b) quantification of their attacks on the field through regular sampling, and c) adoption of the most appropriate integrated-management tactics for every specific situation. The best control methods, right timings, best products, correct rates, and appropriated technology for pesticide application are examples of important variables that can determine pest management success.

a) Species identification

Often, the recognition and differentiation of species is very difficult and impractical to be performed as a daily routine in the field. However, the soybean producer needs to recognize at least the major four groups of caterpillars attacking the crops. These caterpillars (groups) are:

1) The velvetbean caterpillar: composed of a single species, *A. gemmatalis*;

2) The soybean looper complex: majority are *C. includens* (formerly known as *Pseudoplusia includens)* and *Rachiplusia nu*;

3) The caterpillar complex of the genus *Spodoptera*;

4) The Heliothinae complex: includes caterpillars of the genera *Heliothis* and *Helicoverpa*.

Insect injury observation in the field can help to recognize the pest attacking the plants. However, apart from *H. armigera*, which causes damage to the leaves and pods of the plant, there

are other species of insect pests such as *Spodoptera cosmioides*, *S. eridania*, *H. zea,* and *H. virescens*, which also cause the same damage as that caused by *H. armigera* on soybean reproductive structures and can be confused with *H. armigera* in the field. Also, the presence of *C. includens,* and more rarely *A. gemmatalis*, can also cause some damage to the pods, mainly when there is a lack of palatable leaves, what can lead to misidentification.

The differentiation of the species belonging to the subfamily Heliothinae (*Heliothis* and *Helicoverpa* genus) requires specific knowledge of their internal and external morphology and is impractical in the field as previously mentioned. Thus, these species should be managed together under field conditions.

The correct soybean pest identification into these four groups is important for adopting the most appropriate pest management strategies. The choice of insecticides, biological control agents, resistant plants, and/or other management practices may be different for each group of pests, in order to obtain the highest efficiency of the adopted control.

b) Diagnosis and control

To achieve an adequate diagnosis, crops must be sampled accordingly. For sampling, the farm needs to be divided into homogeneous plots (smaller areas with the same sowing date, same cultivar, same edaphic condition, etc). In the case of soybean, plots must be no bigger than 400 hectares (ha). Smaller plots are desirable when possible, because they will be more homogeneous. Sampling should be done with the help of ground cloth (1-meter long cloth) and should be performed with a minimum frequency of once a week and at least at one point in every 10 hectares. It is important for this procedure to be performed from the time of soybean emergence until at least the beginning of the R7 stage. In the beginning, when the ground cloth sampling cannot be used due to the small sized plants, visual sampling needs to be performed in the same area size and at same number of points per hectare.

In the sample, the number of insects should be recorded after separating the number of small (<1.5 cm length) and large (> or = 1.5 cm length) caterpillars by species (or as a group of caterpillars when separation by species is not possible). In addition, defoliation should be recorded (as percentage; visual). After sampling, insecticides, chemical, and/or biological applications should be made only when the caterpillar population is equal to or higher than the economic threshold (ET) (Table 1).

Some management measures can be used even before and during sowing of the plants:

- Pre-sowing and sowing pest management strategies

- Whenever possible, sequential burndown (herbicide) of seedlings must be performed (1st application of herbicide must be between 3 and 4 weeks prior to sowing and the 2nd application around the time of sowing).

- Even when pests are present before sowing, insecticides should not be mixed with herbicides during burndown. Pests can be controlled using other options such as: seed treatment with depending on the Lepidoptera species and insecticide used. Another option can be the adoption of *Bt* soybean (biotech soybean expressing Cry1Ac protein). For this technology is important to emphasize the necessity for the adoption of a refuge area with non-*Bt* soybeans (refuge area), according to the current technical guidance. There is still some discussion regarding the most appropriate size of the area to be cultivated for refuge. For soybeans, the detaining technology companies (industries) recommend a minimum of 20% of the area with non-*Bt* soybean (refuge). On the other hand, some scientists advocate that in order to increase the durability of the technology, this refuge area should be increased to 50%. Regardless of any controversy, it is certain that the adoption of a refuge area is essential and must be done accurately for it to work.

Table 1. Major Economic thresholds used for soybean caterpillars (Bueno et al. 2014)

Species	Economic Threshold	Important
Caterpillars (all species)	Defoliation equal or higher than 30% at crop vegetative stage. Defoliation equal or higher than 15% at crop reproductive stage.	Always favor the use of soft insecticides in order to preserve natural biological control agents.
C. includens e *A. gemmatalis*	20 or more caterpillars ≥1.5cm/meter (ground cloth).	
Caterpillars of the subfamily Heliothinae (*Helicoverpa* and *Heliothis* genus)	4 or more caterpillars/meter (ground cloth) at crop vegetative stage.	When more than 50% of the caterpillars are smaller than 1.5 cm, the use of virus, bacteria or insecticide of the growth regulator group (IGR) should be favored.
	2 or more caterpillars/meter (ground cloth) at crop reproductive stage.	When more than 50% of the caterpillars are equal or bigger than 1.5 cm, the use of insecticides with higher knockdown effect should be favored.
Caterpillars of the genus *Spodoptera*	10 or more caterpillars ≥1.5cm/meter (ground cloth).	Always favor the use of soft insecticides in order to preserve natural biological control agents.

A refuge is a system of growing a percentage of the area (in the same field) with the non-*Bt* version of the same crop (preferably one isoline) in order to reduce the selection of resistant insects to that technology. It is important to be clear that in the area of refuge, insects (targets of the *Bt* plant) susceptible to the toxin need to complete their lifecycle. This will enable them to cross with possible resistant insects from the *Bt* area, thereby producing heterozygous insects that can be controlled by the *Bt* plant. In this regard, overuse of insecticides in the refuge area; annihilating the population of insects; is unacceptable. The refuge area management must be within the IPM guidelines. Technologies such as ground cloth sampling and application of insecticides only when pest population reaches the ET remain essential in the refuge area as well as in the *Bt* area. It is necessary to ensure that the *Bt* plants and the IPM work together, rather than compete, in managing pests more appropriately.

It is important to note that, in general, the most appropriate insecticides to control caterpillars in soybeans are those that combine good efficiency in controlling target pests and high selectivity against beneficial insects (bees, insect predators, and parasitoids of pests). Insecticides from the insect growth regulators group, biological products based on virus or bacteria (*Bt*), and some new groups of insecticides such as spinosyns and diamides may be better insecticides. On the other hand, insecticides such as pyrethroids, carbamates, and organophosphates are more noxious to beneficial arthropods and therefore, should be replaced whenever possible. Furthermore, it is important to "rotate" the use of insecticides with different

modes of action. This will reduce the selection of resistant insects for a particular insecticide. It is especially important for *H. armigera* that are very easily selected to insecticide resistance (Tay et al. 2013). Furthermore, the use of insecticides based on a calendar or to coincide with the application of herbicides or fungicides is unacceptable. It should be avoided to prevent the long-term intensification of pest problem, mainly due to the suppression of natural enemies, selection of resistant insect lines, and increase in secondary pests.

Therefore, it is of great importance that different control methods remain available for soybean producers. The integration of these different controls in a harmonic way is crucial for successful pest management. Therefore, even in the era of biotechnology, biological control, pesticides, and other pest control tactics will continue to be of great importance in controlling pests such as *H. armigera*.

Helicoverpa armigera: FUTURE PERSPECTIVES IN BRAZIL

Even though *H. armigera* has triggered economic losses and an increased use of insecticides in its first year in Brazil, this pest can be managed with the correct adoption of IPM. The adoption of IPM with the rational use of low-environmental impact insecticides allows the application of detrimental chemical products on crop fields to be reduced (Meissle et al. 2010; Tang et al. 2010). In this context, regular monitoring of pests and initiating control measures only when the pest populations or percent defoliation reach the ET recommended by research is crucial. These procedures protect crop sustainability, thus keeping the soybean growers competitive in the market while reducing costs and maximizing productivity (Bueno et al. 2011; Meissle et al. 2010).

The next years will be the era of biotechnology in pest management. However, for this new technology (*Bt* plants) to succeed, IPM adoption is very important since it will be enable in avoiding, or at the least in delaying the loss of this technology to insect resistance. We might have a chance today to fully implement IPM in Brazil as it has never been done or seen before in the history of tropical agriculture. If IPM is adopted successfully in Brazil, the future perspective of *H. armigera* will be that of being satisfactory managed like any other pest. Alternatively, if we try to fool ourselves with simplified version of IPM, *H. armigera* and many other pests will have a great chance to win the battle against growers and severe damage to crops will occur.

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