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Scientific Note

The importance and challenges of a precise diagnosis for IPM: seeing the problem from different perspectives within the soybean-corn production system

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Abstract. One of the keystones for successful IPM is a precise diagnosis. Identifying and quantifying the culprit triggering the problem is crucial for making a decision based on injury level, plant tolerance, and potential strategies to mitigate losses. Recently, growers complained that crickets were damaging their soybean crops. However, after analyzing the injured fields in more detail, mice were identified as being responsible for the recorded injuries. The occurrence of crop injuries caused by mice is not restricted to soybean fields but has also been reported for corn fields. In this report, we illustrate the importance of a precise diagnosis to avoid unnecessary and inadequate use of chemicals when applying IPM. Moreover, we call attention to the importance of avoiding harvest losses, especially for soybean and maize crops. Lost corn cobs from the previous crop season between soybean plants attract mice in the area and therefore are a major trigger for injuries to soybean pods. Thus, reducing harvest losses is the best way to manage the green bridge and mitigate the problem herein discussed.

Keywords: green bridge, economic injury level, insecticide, pest control, sustainable pest management.

No concept has had a greater influence on pest control in agriculture than integrated pest management (IPM) (Pedigo & Higley 1996). Initially, this concept was termed pest management and evolved into IPM later (Pedigo 1995). IPM is based on the premise that cultivated plants can tolerate certain levels of injury with no need for any pest control (Higley & Peterson 1996). Measures should only be taken when a pest population reaches or surpasses the established economic thresholds (ETs) (Bueno et al. 2013). Not only has the adoption of Soybean-IPM in Brazil allowed the reduction of insecticide use by up to 50%, but it has also increased yields and reduced production costs (Bueno et al. 2023). However, to achieve such outstanding results, the first step must always be a highly precise diagnosis. As the basis of the IPM technology, any pest management strategy will only be successful after the problem has been correctly identified and quantified (Maciel & Bueno 2023). Precise diagnosis is crucial once even the most powerful control tool will perform poorly if applied against the wrong target.

Even when precisely identifying the target in IPM, our mindset is hardly ever prepared to see the big picture behind phytosanitary problems in the field. An analysis of the situation in the field from different perspectives is required to avoid a less-than-precise diagnosis. Misidentifying the culprit of a phytosanitary problem will undoubtedly lead to IPM failure.

In soybean, more recently, farmers have complained about injured pods while still on the plants (Fig. 1A) or detached from the plants having fallen to the ground (Fig. 1B), sometimes stashed in small groups (Fig. 1C). Trained to fight against insect pests in agriculture, different consultants diagnosed the problem (Fig. 1) as cricket injuries (Fig. 1D), followed by spraying of different insecticides such as pyrethroids, fipronil, and carbamate.

Crickets are a very diverse group of insects formed by approximately 900 different species worldwide (Chintauan-Marquier et al. 2016). They are omnivorous insects, which seek shelter in cracks of soil during the day and are more active at night. This nocturnal behavior can make it more difficult to confirm their responsibility for plant injuries. However, in soybean, it is known that crickets are secondary pests and potential damage is mostly restricted to the time of soybean emergence, when the insects can cut seedlings at ground level (Turnipseed & Kogan 1976). Only when the cricket population is extremely high these insects can also feed on pods.

Visiting a soybean field at Embrapa Soybean Experimental Station (23°12'23"S, 51°10"54"O), where the injured pods (Figs. 1A and 1B) were observed, the presence of several maize cobs in the area was noted (Fig. 1E), as well as the presence of holes in the soil with corn grains nearby (Fig. 1F). In addition, in some of the fields from where the injured pods had been reported, little mounds of damaged pods were found on the ground throughout the crop (Fig. 1C), which is a classic rodent food-hoarding behavior (Deacon 2006). Therefore, the question was raised if the pod injury had really been caused by crickets. Mice and crickets can trigger similar damage to soybean pods, which, without proper analysis could lead field consultants to a wrong diagnosis and, consequently, to recommend unnecessary spraying against crickets.

This case of uncertain diagnosis at Embrapa Soybean Experimental Station was investigated by installing Tomahawk traps (mousetraps) (Fig. 2A) in the same field where injured pods (Figs. 1A and 1B), maize cobs (Fig. 1E) and soil holes (Fig. 1F) were recorded, in order to better evaluate the cause for the damaged pods. The soybean cultivar BRS 257 was sowed on 23 October 2023. Plants were at phenological stage R5 (Fehr et al. 1971), and the Tomahawk traps were installed on 10 January 2024 and left overnight. On the same day, a cage measuring 1m x 1 m x 1m was installed, enclosing 2 lines of soybean previously inspected to avoid the presence of any damaged pods inside the cage (Fig. 2B). Then, 13 adult crickets and 30 nymph crickets, field collected the night before, were released and left inside the cage for seven days, until 17 January 2024, when the cage was opened, and the plants evaluated. No damage was recorded on the pods (Fig. 2C) despite the presence of crickets inside the cages (Fig. 2D). In addition to the field

observation, some crickets were taken to the laboratory and put inside petri dishes with undamaged pods (Fig. 2E). After seven days in this forced, extreme situation inside the petri dishes, some of the crickets had died and some pods had been injured (Fig. 2F).

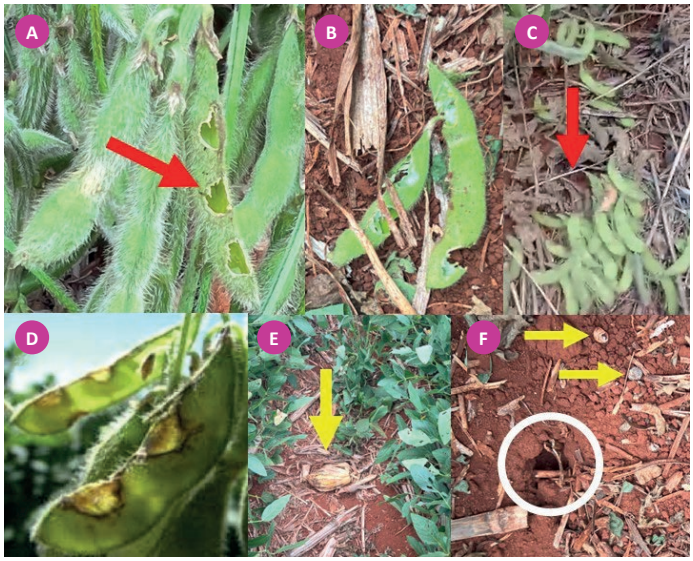

Figure 1. Damaged soybean fields and pods associated with the key symptoms of mice injury. Injured pods in soybean plants cultivated at Embrapa Soybean Field Station, Londrina, PR, Brazil (A and B) (Picture: Adeney F. Bueno). Little mounds of damaged pods found on the ground (C), district of São Luiz, Londrina, PR, Brazil (Picture: Vitor Chaves). Detail of a more general pod injury caused by crickets (D) (Picture: https://thebeatsheet.com.au/what-is-eating-my-soybean-pods/). Corn cobs lost in soybean fields (E) and holes in the soil with corn or soybean grains nearby (F) found in soybean field with occurrence of mice injuries, Embrapa Soybean Field Station, Londrina, PR, Brazil (Picture: Adeney F. Bueno).

Figure 2. Tomahawk traps installed in the soybean field to record the presence of mice (A). Cage used to trap crickets with uninjured soybean plants (B). Pods overview after seven days of cricket infestation inside the cage (C). View of the presence of crickets inside the cage after seven days of infestation (D). Field collected crickets caged in petri dishes with soybean pods before (E) and after (F) seven days of feeding in the laboratory. Captured mouse in the Tomahawk trap placed inside soybean field overnight (G). Damaged soybean pods by the mouse after one night of eating inside the cage (H). Embrapa Soybean Field Station, Londrina, PR, Brazil (Picture: Embrapa Arquives).

In the field, mice were captured in the Tomahawk traps the same night they were installed (Fig. 2G), on January 10, 2024. Then, branches of soybean with uninjured pods were put inside the traps and left for one more night in the field. On the morning of the next day, January 12th 2024, some of the pods inside the Tomahawk traps had been damaged (Fig. 2H).

It is important to mention that when injuries of mice and crickets are compared, mouse injury is limited to the grains (Figs. 1A and 1B), while crickets feed on different parts of the pods (Fig. 1D). Ultimately, the best way to determine whether mice instead of crickets are the culprits is to also check crops at night for pest activity and to install traps in the area. In addition, if little mounds of damaged pods are found grouped on the ground throughout the crop (Fig. 1C), mice are the most likely culprits.

The occurrence of mice injuring crops is not restricted to soybean fields, but has also been reported for corn, as a follow-up crop in the second crop season (Fig. 3). This illustrates the importance of taking the agricultural landscape into consideration when adopting IPM. Soybean-corn double cropping offers constant food sources to pests in the field, so that soybean pests stay in the same field and feed on corn, a situation termed "green bridge". This is a problem that must be avoided through better management.

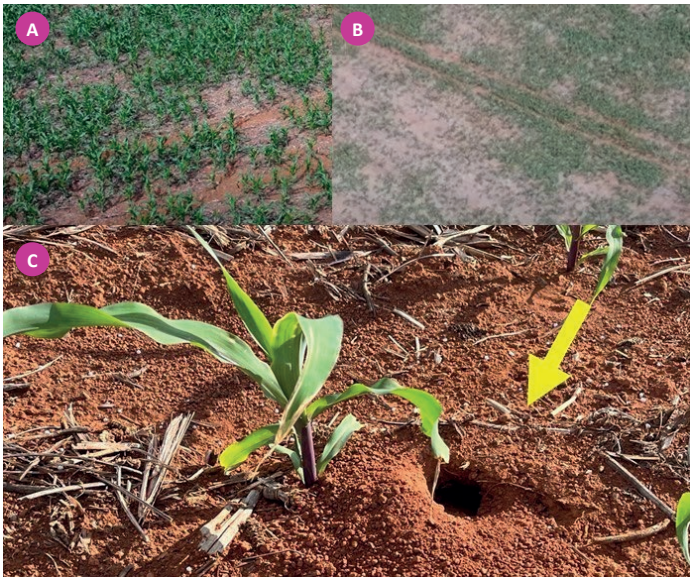

Figure 3. Aerial picture of corn field damaged by mice (A and B) with the presence of holes in the ground (C). Nova Mutum, MT, Brazil (Pictures Pedro Silvestre).

If soybean-corn has been the most important crop system in Brazil since the 1990s, why has an increase of mice populations only been observed more recently in this system? It is important to take into consideration the increasing outbreaks of *Dalbulus maidis* (DeLong & Wolcott, 1923) (Hemiptera: Cicadellidae) in corn (Faria et al. 2022). Adults and nymphs of *D. maidis* are responsible for the transmission of plant pathogens (Nault 1980; Lopes & Oliveira 2004). *Dalbulus maidis* is the vector of the maize rayado fino virus (MRFV) and of two Mollicutes associated with stunting diseases (Nault 1980). These pathogens can cause maize plants to break, and a high *D. maidis* occurrence might lead to an increased loss of cobs in the field. Therefore, it is very important to call attention to this problem in order to avoid harvest losses. Lost corn cobs from the previous crop season between soybean plants attract mice in the area, and therefore are a major trigger for injuries to soybean pods.

It is important to avoid losses not only during maize harvest to protect the sanity of soybean crops but also losses during soybean harvest should be avoided to mitigate the presence of soybean grains and volunteer soybean plants in the field during the maize season to prevent mice as well as other pests. The presence of soybean grains and volunteer plants due to harvest losses is one of the major reasons for higher stink bug infestation early in the maize season as well as a higher pressure of soybean rust during the next soybean season. The

simple measure of reducing harvest loss and, therefore, mitigating the impact of the green bridge can significantly increase IPM success and reduce the need for pesticide use (Bueno et al. 2023). In addition, our report illustrates the importance of a precise diagnosis to avoid unnecessary and wrong use of chemicals inside IPM.

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Authors' Contributions

AFB, WPS, AH, GVS: Conceptualization, writing original draft. AFB: Project administration, supervision, writing review & editing. All authors have read and approved the manuscript.

Conflict of Interest Statment

The authors declare that there is no conflict of interest.

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