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Are we under threat?: the dilemma of insects in the production landscape

¿Estamos en jaque?: el dilema de los insectos en el paisaje productivo

Estamos em xeque?: o dilema dos insetos na paisagem produtiva

Abbate, S.[1]

[1]*Univerdad de la República, Estación Experimental Mario A. Cassinoni (EEMAC), Paysandú, Uruguay*

Editor
Horacio Silva
Universidad de la República, Facultad de Agronomía, Paysandú, Uruguay

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Correspondence
Silvana Abbate
abbate@fagro.edu.uy

1. Introduction

Alarms related to the emergence of 'super pests' are very frequent in the work of the farm advisor. Considering the last 10 years in Uruguay, we could mention some iconic examples. During the 2013 soybean growing season, the alarms went off associated with the entry of *Helicoverpa armigera* in South America. Subsequently, the increased abundance of pill bugs (mostly *Armadillidium vulgare*) raised concerns. During the Covid-19 pandemic, the Uruguayan society also panicked due to the imminent entry of lobsters (*Schistocerca cancellata)* from Argentina. Recently, the first records of yellow aphid in sorghum (*Melanaphis sorghi*) enlisted the cannons, and finally, the cattle deaths associated with *Astylus atromaculatus* ("Siete de Oro", spotted maize beetle) triggered growing concern about the grazing fields. In the presence of all these alarms pumped in social networks, newspapers and WhatsApp groups, advisors feel like being in a war with a need for weapons to engage in combat. Immediately the question arises as to which insecticide to apply and the need for such a product to act almost like an atomic bomb. However, the prophecy was never fulfilled, and there was not a super pest which devastated us. Meanwhile, national and regional information provided by several institutions, like the University of the Republic (Udelar), the National Institute of Agricultural Research (INIA), and the National Institute of Agricultural Technology (INTA), repeatedly indicates that the key to reach a successful integrated pest management (IPM) lies on the knowledge of the Life System(1).

2. Arthropods' Population Life System

Studying insect species by addressing its Life System involves the knowledge of the environmental and individual variables that modify its population processes (natality, mortality and dispersion), which determine its state variables. The abundance, density, spatial distribution, age stage structure and population growth models constitute the state variables, which are of great interest for pest control. A correct sampling method must be conducted to estimate these variables and determine the pest management. Therefore, not all herbivorous insects will become pests and require control(2). For this reason, estimating insects density should be compared with the economic injury level, defined as the lowest pest population capable of causing economic damage[3]. These concepts are relevant in the global context, where relatively low insecticide costs and high cereal market prices led to an excessive use of insecticides. Consequences of the abusive use of chemicals were first reported by the publication of "Silent Spring"[4] and are currently reinforced by numerous studies[5-6]. The evidence generated forced the development of governmental policies to mitigate the side-effects of pesticides, while a major component of this change was the implementation of IPM programs[7].

3. Landscape ecology in relation to integrated pest management programs

The concept of IPM emerged in the early 1970s in response to concerns about the impacts of pesticides on the environment. IPM programs propose the rational use of insecticides along with the harmonious integration of other control strategies, prioritizing biological control[8]. IPM focuses on the study of the ecology of a pest species, the identification of its ecological niche and its interaction with other organisms and the environment in order to understand population dynamics. However, the level of operation of most of the implemented and adopted IPM programs was based at the crop scale[9]. Conversely, arthropods do not respect anthropogenic boundaries, so to achieve sustainable pest management in extensive crops IPM must integrate several scales of holistic analysis that contemplate the surrounding habitats above the fences. In this sense, landscape ecology is an interdisciplinary science that studies the effect of spatial and temporal heterogeneity on ecological processes, such as the abundance and distribution of organisms[10] on a more comprehensive scale. It aims to understand the relationship between spatial heterogeneity pattern and ecological processes on a multitude of scales and organizational levels.

Landscape ecology focuses on the effects of the emergent properties derived from the conversion of natural ecosystems by human changes in order to mitigate them. The anthropocentric changes of the natural habitat modify the composition and the configuration (spatial pattern of patches) of the vegetation cover, determining the fragmentation and simplification of the landscape. These changes have a dominant effect on the abundance and composition of the fauna. Landscape ecology contributes to understand the spatial and temporal dynamics of insects in agro-ecosystems, complementing current IPM approaches.

In Uruguay, as in the rest of the Pampa biome, the productive landscapes have changed considerably due to the adoption of continuous agriculture. The simplification of the agro-ecosystems occurs due to the expansion of annual crops over non-crop areas, mainly associated with soybean planting[11] and the displacement of natural grasslands[12]. As in the rest of the world, this process of agricultural intensification determined the removal of less disturbed habitats and the increased use of pesticides, which caused, among others, the loss of biodiversity, and negatively affected natural controllers[5]. Predatory arthropods are among the affected organisms which play a fundamental ecosystem role by providing natural biological control[13]. Predators have the potential to maintain several herbivorous insect populations below their economic injury level[13-14], decreasing the chemical control needed.

Herbivorous insects and their natural enemies respond to the composition and spatial arrangement of the surrounding landscape cover[15]. The abundance and diversity of natural enemies are negatively affected by agricultural intensification[15] as beneficial species may require quite specific resources at different times and spatial scales[16]. Natural enemies are mostly benefited in complex landscapes where natural or semi-natural habitats provide them with the necessary alternative resources[17-18]. Furthermore, less disturbed areas provide the pool of beneficial arthropods that recolonize the crop[19] and establish the level of biological control[20].

Landscape composition also plays a role of relevance in determining the levels of herbivorous insects in agricultural fields[15]. In contrast to natural enemies, pest abundance is generally favored by simple landscapes with a predominance of cultivated areas[5]. These species are more likely to find and remain in denser and less diverse patches of their host plants[21], as posited by the resource concentration hypothesis[22]. The lower herbivore insects abundance in complex landscapes is in certain cases associated with a higher level of natural biological control[15], as proposed by the natural enemies hypothesis[22].

3.1 Landscape composition study on the western coastal region of Uruguay

Soybean crops in Uruguay present a wide diversity of herbivore insects but only a few species are considered primary pests: leaf-feeding caterpillars

(Lepidoptera: Noctuoidea) and stink bugs (Hemiptera: Pentatomidae)[23]. A complex of generalist predators is relatively common in soybean; spiders, hemipteran, coccinellid and lacewings[18-24] keeping, in many cases, the density of secondary pests below the action thresholds, either in soybean and in other crops that share the same natural enemies[24].

Over a two-year period, we sampled 60 soybean fields from the western coastal region of Uruguay to evaluate the effects of landscape composition on the abundance of the main predators and pests of this crop, within 1 km radius[25]. In the mentioned study, we demonstrate the effects of the agriculture process on soybean predators and pests, suggesting that each vegetation cover impacts them differently. The proportion area of soybean negatively affected the quantity of spiders, hemipteran and lacewings predators in this crop. In contrast, the landscape cover with natural grassland positively affected some of these beneficial organisms (hemipteran, coccinellids and spiders)[25].. We also determined that other vegetation covers affected each predators group differently, probably associated with their life system characteristics. Herbivore insects were less affected by the landscape composition, since only the stink bugs abundance varied according to the proportion of the commercial forest inside 1 km radius, due to their diapause behavior[26].

3.2 Local variables studies on the western coastal region of Uruguay

Within the local factors, the agronomic practices and inherent properties of crop types may also be important indirectly, driving arthropod assemblages and mediating the effects of the wider landscape[27]. Understanding the interaction between these wider landscape scales and the local management practices is becoming important in highly disturbed and ephemeral cropping systems[27]. Considering the current extensive production systems of the western coastal region of Uruguay, characterized by short-duration crop cycles, frequent tillage, transgenic varieties adoption and often intense agrochemical use, local variables play a relevant role determining arthropods population processes and their state variables.

Soybean plants that express Cry1Ac insecticidal proteins of the *bacterium Bacillus thuringiensis* have been widely adopted. In Uruguay, Bt soybean varieties represent almost 20% of the area planted with this crop[28]. This technology effectively controls the main defoliating pest species, reducing insecticide spray requirements[29]. However, the widespread use of Bt crops could cause side-effects due to a reduction in the number or the quality of Bt target pests that natural enemies prey on[30]. The high selection pressure against pest individuals developing resistance populations[31] is also reported in many species[32]. To mitigate this problem, the use of high dose/refuge is the strategy widely adopted, which requires farmers to plant a certain percentage of their transgenic crop acreage with non-Bt cultivars[33]. While this strategy is aimed at delaying the emergence of resistant populations, the implementation of refuges would also play a fundamental role in ensuring a minimum of prey to maintain populations of predators that feed on them[34].

To determine the impact of the Bt soybean adoption, as a local variable, during the 2017-18 and 2018-19 crops cycles, we quantified the abundance and richness of main predators and pests species in non-Bt, Bt and refuge areas in Uruguay. We found that Bt and non-Bt soybean fields did not differ in the number or richness of predators and stink bugs, while Bt fields were associated with less caterpillar abundance[34]. We also found that the abundance and richness of predators (*Araneae*, *Coccinellidae*, *Heteroptera* and *Chrysopidae*) found in Bt soybean were positively associated with the values recorded in refuge areas (within 800 m). The abundance of stink bugs and leaf-feeding caterpillars in Bt soybean was also positively associated with refuge area values. These national results reinforce the importance of refuge areas, not only due to their role in resistance management, but also as preservation areas of beneficial fauna. This ecological role of the non-Bt soybean refuge areas should be considered by farmers especially in the current scenario, where we have already reported resistant populations of *Rachiplusia nu* in Uruguay[35].

Among the local variables, the spontaneous vegetation of field margins becomes important for pest management because it represents the least disturbed areas were natural enemies could find overwintering sites, alternative sources of food or refuge from adversities such as the application of insecticides[16]. Our studies reported that the abundance of predators (spiders, *Neuroptera* and Coleoptera) in soybean fields was highly associated with their abundance in the field margins, but there was no such association for herbivorous insects[25]. Emphasizing the ecological role of the margins for biological control is of interest due to the increased size of the current fields under continuous agricultural systems in Uruguay, promoting the elimination of these areas of spontaneous vegetation.

Expanding our knowledge regarding the response of commercial varieties to pest damage is another crucial local factor for pest population management in extensive crops. In this sense, the IPM concept is based on the premise that cultivated plants can tolerate certain levels of injury without economically significant yield reductions(2). According to this argumentation, our entomology groups of the Dr. Mario A. Cassinoni Experimental Station (EEMAC) together with the entomology groups from INIA La Estanzuela are conducting studies to estimate soybean tolerance to defoliation by lepidopteran pests with the aim of reducing insecticide applications and promoting a more sustainable management (FMV_3_2022_1_172322).

4. Final remarks

The knowledge of landscape and local factors that affect the dynamics of pests and their natural enemies is crucial to carry out ecological intensification strategies(17-36) which aim to improve the environmental, social and economic indicators of agricultural systems(37-38).

Production intensification is necessary to provide the worldwide amount of food in a safety way. The adoption of different intensification strategies requires identifying and reducing inefficiencies in the use of resources in order to minimize agriculture negative consequences on the environment at different scale levels, both on-site and off-site, where decisions are made(39). Generating knowledge and environmental conscience is crucial in this regard.

The intelligent use of ecosystem services, mediated through biodiversity management to support agricultural production (ecological intensification), appears as the most promising way to achieve food security. This requires innovative strategies that attempt to reduce the environmental impact and dependence on non-renewable resources. Planning the land cover diversity seems to be the most promising path in this regard, and it is the way we are starting to explore at EEMAC with our Interdisciplinary Working Group (GTI).

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SA summarized and wrote all the information presented in this article.

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