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CONVENTIONAL PESTICIDES AND BIOPESTICIDES IN MAIZE PROTECTION: EFFECTS ON BENEFICIAL ARTHROPODS AND RELEVANCE FOR SUSTAINABLE AGRICULTURE

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Abstract. *Maize is a strategic crop for agriculture, but its productivity is frequently influenced by pest pressure that requires efficient control measures. In this context, plant protection practices must be assessed not only in relation to pest suppression, but also in terms of their effects on beneficial arthropods that contribute to the ecological balance of maize fields. The aim of this paper is to examine the differences between conventional pesticides and biopesticides with regard to their impact on beneficial arthropod communities in maize crops, while also considering the relevance of these approaches for sustainable crop protection in Romania. The review is based on the analysis of scientific papers indexed in international databases, focusing on studies that address non-target effects, pesticide selectivity, and the role of beneficial fauna in maize agroecosystems. Recent research shows that synthetic pesticides, although often effective in rapid pest control, may disturb natural enemy populations through direct toxicity and indirect ecological effects. By comparison, biopesticides are generally associated with a lower ecological burden and a greater compatibility with integrated pest management strategies, although their performance is not uniform under all field conditions. The novelty of this paper consists in bringing together these aspects within a discussion centered on maize and on the current need for more sustainable protection options in Romania. The main limitation of the review is related to the uneven distribution of available data and the limited number of studies specifically conducted under Romanian agricultural conditions. Even so, the findings underline the practical and scientific importance of choosing crop protection solutions that preserve beneficial biodiversity together with crop productivity.*

Keywords*: maize, beneficial arthropods, conventional pesticides, biopesticides, non-target effects, integrated pest management*

INTRODUCTION

Maize has a central place in Romanian agriculture, both because of the large cultivated area and because of its importance for feed, food, and the wider agricultural economy. Recent Romanian reviews describe maize as the main crop by cultivated surface in the country, usually around 2.3-2.5 million hectares, and show that its production is increasingly challenged by a broad range of insect pests, whose importance may become even greater under changing climatic conditions (TOADER ET AL., 2024; HORGOS AND GROZEA, 2020).

Under these conditions, crop protection remains essential for maintaining stable production, and conventional pesticides are still widely used because they offer rapid and predictable pest suppression. At the same time, their role can no longer be assessed only through short-term control of target species. A recent large-scale synthesis based on 1,705 studies found that pesticides have overall negative effects across multiple groups of non-target organisms, raising concerns not only for biodiversity, but also for ecosystem functioning. This broader ecological perspective is highly relevant in maize systems, where pest control

decisions may influence both crop protection outcomes and the stability of arthropod communities present in the field (WAN ET AL., 2025).

Beneficial arthropods are an important part of this ecological picture. Their correct identification and understanding of their ecological role are essential for the practical use of natural enemies in crop protection and biological control programs (PĂLĂGEȘIU ET AL., 2000; GROZEA, 2015). In maize fields, predators and parasitoids such as ladybirds, lacewings, hoverflies, spiders, ground beetles, predatory bugs, and parasitic wasps can contribute to the natural limitation of pest populations (COSTEA AND GROZEA, 2022). Field studies on maize-associated entomofauna show that natural enemies are consistently present in crop systems, while research on maize management practices indicates that their biological control potential is strongly influenced by the way the crop is managed. In other words, maize is not only a production system, but also an ecological space in which pest pressure and natural regulation interact continuously (CHIRINOS ET AL., 2024).

This is one of the reasons why the discussion around crop protection has shifted in recent years from simple efficacy toward selectivity and ecological compatibility. Romanian and regional literature increasingly frames integrated pest management as a necessary direction for maize production, especially in the context of climate-related changes in pest biology and pressure. Within this transition, biopesticides are receiving more attention because they are generally regarded as more compatible with sustainable agriculture and biodiversity conservation. At the same time, recent reviews caution that biopesticides should not be treated as universally harmless, since their effects on beneficial arthropods may still vary depending on the active substance, formulation, and exposure conditions (CHIRILOAIE-PALADE ET AL., 2024).

From this perspective, comparing conventional pesticides with biopesticides is not simply a matter of choosing between two categories of plant protection products (COSTEA AND GROZEA, 2022). It is also a way of examining how maize protection strategies influence the organisms that support natural pest regulation and, ultimately, the resilience of the production system itself. This question is particularly relevant in Romania, where maize remains a strategic crop and where the pressure to reconcile productivity with more sustainable plant protection is becoming increasingly visible (TOADER ET AL., 2024).

The aim of this paper is to comparatively review the effects of conventional pesticides and biopesticides on beneficial arthropods associated with maize crops, with special attention to predators and parasitoids involved in natural pest suppression. The paper also discusses the relevance of this comparison for sustainable crop protection and for the wider adoption of integrated pest management approaches in Romania.

MATERIAL AND METHODS

This paper was conceived as a focused narrative review addressing the impact of conventional pesticides and biopesticides on beneficial arthropods associated with maize crops. The chosen approach was intended to allow a comparative discussion of the most relevant categories of evidence, rather than to provide an exhaustive inventory of all active substances or all pest management situations reported in the literature. Such a format was considered suitable because studies dealing with non-target effects in crop protection differ considerably in scope, test conditions, assessed organisms, and biological endpoints (LISI ET AL., 2025).

The documentation process focused on scientific papers relevant to maize protection, beneficial arthropods, biological control, pesticide selectivity, and non-target effects. Priority was given to peer-reviewed journal articles, review papers, and broader synthesis studies published in accessible academic sources. The literature search followed combinations of terms such as maize,

corn, beneficial arthropods, natural enemies, predators, parasitoids, conventional pesticides, insecticides, biopesticides, bioinsecticides, non-target effects, and integrated pest management. Additional search terms related to Bt-based protection and Romanian maize pest management were also included in order to capture studies with both international and regional relevance (NARANJO, 2009; ROMEIS ET AL., 2011; SVOBODOVÁ ET AL., 2017; YANG ET AL., 2022; CHEN ET AL., 2022); TOADER ET AL., 2024).

The selection of references was guided mainly by thematic relevance to the objectives of the paper. Studies were retained when they addressed at least one of the following aspects: the presence and ecological role of beneficial arthropods in maize systems; the lethal, sublethal, or indirect effects of conventional pesticides on non-target organisms; the compatibility of biopesticides with predators and parasitoids; or the contribution of selective protection tools to integrated pest management. More recent publications were favored in order to reflect current scientific understanding, while a limited number of earlier review papers were also included when they provided important conceptual support for the interpretation of non-target effects and crop protection selectivity.

Because the available studies differed substantially in experimental design, arthropod groups, active ingredients, formulation types, and environmental context, the analysis was carried out in a qualitative comparative manner. The collected information was organized around several major lines of discussion: beneficial arthropods associated with maize, the effects of conventional pesticides, the effects of biopesticides, and the implications of these differences for sustainable crop protection. This structure was considered more appropriate than a quantitative synthesis, since many published results were obtained under non-equivalent laboratory, semi-field, or field conditions and were therefore difficult to compare directly.

In order to strengthen the applied value of the review, particular attention was also given to publications relevant to Romania and to current European directions in sustainable agriculture. For this reason, Romanian review literature on maize pests and integrated crop protection was considered alongside international studies dealing with pesticide selectivity, biological control, and ecological side effects on non-target arthropods. This combination made it possible to discuss the topic not only from a general scientific perspective, but also in relation to the practical realities of maize protection in Romania (TOADER ET AL., 2024).

RESULTS AND DISCUSSION

Beneficial arthropods in maize agroecosystems

The reviewed literature shows that maize fields support a more complex arthropod community than a simple crop–pest relationship would suggest. In addition to herbivorous pests, maize agroecosystems host predators and parasitoids that contribute to natural pest suppression. Among the beneficial groups most often mentioned are ladybirds, lacewings, hoverflies, predatory hemipterans, ground beetles, spiders, and parasitoid wasps. Their abundance may vary with crop rotation, surrounding vegetation, season, and local environmental conditions, but their ecological role remains important in maintaining biological balance within the crop.

This ecological role is especially relevant in maize because pest outbreaks are not shaped only by the presence of the target insect, but also by the response of the natural enemy community. Field-based work in maize has shown that beneficial arthropods may act as indicators of how strongly management practices disturb biological regulation. This means that pest control should be evaluated not only by its immediate capacity to reduce a target species, but also by its effects on the organisms that contribute to longer-term pest suppression. Their abundance, ecological role, and contribution to pest suppression are also influenced by crop management and by the way beneficial

arthropods are monitored and interpreted in agroecosystems (MCCRAVY, 2018; PULIGA ET AL., 2024).

Effects of conventional pesticides on beneficial arthropods

One of the most consistent findings in the literature is that conventional insecticides may affect beneficial arthropods through both direct and indirect pathways. Direct effects include mortality after contact or ingestion, while indirect and sublethal effects may include reduced mobility, altered feeding or host-searching behavior, impaired reproduction, and disruption of trophic interactions. Recent syntheses on non-target organisms show that pesticide effects extend well beyond target pests and may influence ecological functioning across multiple biological groups.

For maize specifically, recent field evidence supports this concern. CAMERINI ET AL. reported that repeated insecticide applications in maize were associated with negative effects on aphid predators such as ladybirds, hoverflies, true bugs, and lacewings, while aphid abundance could even increase in some treated situations. This is particularly important for a review such as yours because it shows that chemical control may generate a paradoxical outcome: rapid intervention against pests may coincide with the weakening of the natural enemy complex that helps stabilize pest populations over time.

The broader literature strengthens this interpretation. Large-scale evidence indicates that pesticides generally have negative effects on non-target organisms, and recent reviews on nontarget arthropods emphasize that repeated disturbance can accumulate through time, especially when broad-spectrum products are used. In practical terms, this creates a trade-off between immediate pest suppression and the preservation of ecological processes that reduce future dependence on repeated treatments.

Beyond direct mortality, pesticide exposure may also generate indirect ecological effects and sublethal disturbances that alter trophic interactions and biological regulation in crop systems (SÁNCHEZ-BAYO, 2021; ROMEIS ET AL., 2011). The ecological implications of pesticide use should also be viewed beyond the maize field itself, since environmental contamination may extend toward adjacent ecosystems, including aquatic environments (MOSNEANG et al., 2015).

Effects of biopesticides on beneficial arthropods

Compared with conventional insecticides, biopesticides are generally discussed in the recent literature as more selective tools and therefore more suitable for integrated pest management. Their attraction lies in the fact that many of them act more narrowly, persist for a shorter time in the environment, and are often considered less disruptive for non-target organisms. However, current reviews also make it clear that this advantage should not be idealized. Bioinsecticides can still affect natural enemies, and the intensity of these effects depends on active substance, formulation, dose, exposure pathway, and the developmental stage of the non-target organism (Figure 1).

This nuance is important because bioinsecticides are sometimes presented too simply as "safe alternatives." In reality, the recent review literature shows that predators and parasitoids may still experience negative effects, and that laboratory studies remain much more common than field-based assessments. This limits the certainty with which one can generalize their ecological compatibility under practical farming conditions. For that reason, the better conclusion is not that biopesticides are harmless, but that they usually offer a more favorable selectivity profile than many conventional insecticides.

Although biopesticides are often considered more compatible with non-target organisms, plant-derived products may also require careful assessment, since their ecological effects are not uniformly benign under all conditions (TEMBO ET AL., 2018; SOARES ET AL., 2026).

In reality, the recent literature shows that predators and parasitoids may still experience negative effects, and that laboratory studies remain much more common than field-based assessments. This limits the certainty with which one can generalize their ecological compatibility under practical farming conditions. For that reason, the better conclusion is not that biopesticides are harmless, but that they usually offer a more favorable selectivity profile than many conventional insecticides, although some botanical products may also raise broader environmental concerns (LISI ET AL., 2025; SOARES ET AL., 2026; PEREIRA ET AL., 2025).

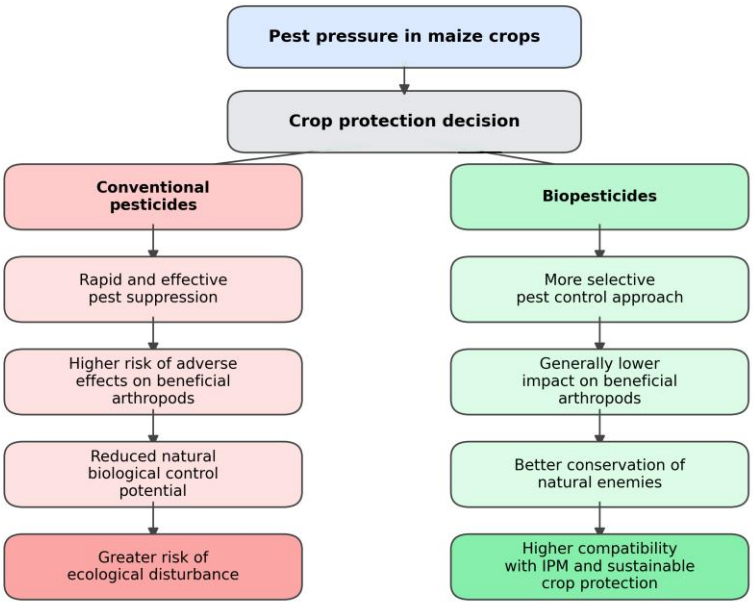

Figure 1. Conceptual comparison between conventional pesticides and biopesticides in maize protection, highlighting differences in selectivity, effects on beneficial arthropods, and ecological compatibility

Comparative perspective and relevance for Romania

When the literature is viewed comparatively, a fairly consistent picture emerges. Conventional pesticides remain important because they can provide rapid and reliable control under strong pest pressure, which is still a practical necessity in maize production. At the same time, they are more likely to disturb beneficial arthropod communities and thus interfere with natural regulation processes (CAMERINI ET AL., 2024; WAN ET AL., 2025; GUEDES ET AL., 2026). Biopesticides, in contrast, fit more easily into IPM-oriented strategies because they are generally more selective, even though their field performance may be less stable and more dependent on environmental conditions (LISI ET AL., 2025; AYILARA ET AL., 2023; FENIBO AND MATAMBO, 2025).

A comparative overview of the main differences between conventional pesticides and biopesticides in relation to beneficial arthropods in maize is presented in Table 1.

For Romania, this comparison is particularly relevant. Recent Romanian reviews underline both the economic importance of maize and the diversity of pest pressures affecting the crop, while also emphasizing the growing need for integrated control strategies under changing climatic conditions. This makes the conservation of beneficial arthropods more than a theoretical ecological concern. In Romanian maize protection, it should be seen as a functional criterion in choosing plant protection tools, especially where selective approaches may reduce ecological disturbance without compromising crop protection goals.

This perspective is also supported by recent Romanian literature on maize pest management and by systematic reviews addressing selective maize protection strategies and non-target organisms (GEORGESCU ET AL., 2025; MEISSLE ET AL., 2022).

Table 1

Comparative characteristics of conventional pesticides and biopesticides in relation to beneficial arthropods in maize crops

Criterion	Conventional pesticides	Biopesticides
Mode of action	Often rapid; many products have broad-spectrum activity	Usually more selective, depending on active substance and target pest
Effect on beneficial arthropods	Frequently associated with lethal, sublethal, or indirect effects on non-target arthropods	Generally considered less disruptive, although adverse effects may still occur
Persistence in the environment	Often longer persistence, depending on compound and application regime	Usually lower persistence, but influenced by formulation and environmental conditions
Compatibility with biological control	May interfere with predators and parasitoids when selectivity is low	Usually more compatible with biological control and IPM strategies
Field performance	Often rapid and reliable under high pest pressure	Can be variable under field conditions and influenced by temperature, humidity, UV exposure, and timing
Risk for ecological balance	Greater risk of disturbing trophic interactions and natural pest regulation	Lower ecological burden in many cases, but not automatically harmless
Practical limitations	Risk of non-target effects, resistance development, and repeated dependency	Variable efficacy, narrower spectrum, and sometimes higher dependence on application conditions
Relevance for sustainable maize protection	Still important in practice, but requires careful selectivity and timing	Promising option for more sustainable and ecologically compatible crop protection
Mode of action	Often rapid; many products have broad-spectrum activity	Usually more selective, depending on active substance and target pest
Effect on beneficial arthropods	Frequently associated with lethal, sublethal, or indirect effects on non-target arthropods	Generally considered less disruptive, although adverse effects may still occur

Source: author's synthesis based on CAMERINI ET AL., 2024; LISI ET AL., 2025; AYILARA ET AL., 2023; FENIBO AND MATAMBO, 2025; WAN ET AL., 2025; GUEDES ET AL., 2026; TOADER ET AL., 2024.

As shown in Table 1, the main contrast between the two categories is not limited to pest control efficacy, but also involves selectivity, compatibility with natural enemies, and their broader ecological implications for maize protection systems.

General interpretation of the reviewed evidence

Taken together, the reviewed studies suggest that the difference between conventional pesticides and biopesticides is not simply one of "effective" versus "ecological." The more useful distinction lies in how strongly each approach interferes with the biological relationships already present in the crop. Conventional pesticides often provide faster and more predictable suppression, but with a higher probability of disturbing beneficial arthropods. Biopesticides usually offer a better balance between pest control and ecological compatibility, although they are not free from limitations and should be evaluated case by case. In maize systems that aim to remain productive and sustainable, the most realistic direction is not the absolute replacement of one category by the other, but the gradual prioritization of more selective and IPM-compatible tools whenever agronomically possible.

CONCLUSIONS

The reviewed literature indicates that conventional pesticides and biopesticides differ not only in their mode of action, but also in the extent to which they affect beneficial arthropods in maize crops. Conventional pesticides remain effective tools for rapid pest control, but they are more likely to disturb predators and parasitoids involved in natural pest regulation. By contrast, biopesticides are generally more selective and better suited to integrated pest management, although their effectiveness and ecological safety may vary depending on the product and field conditions.

For Romanian agriculture, this comparison is particularly relevant because maize is a crop of major importance and sustainable protection strategies are becoming increasingly necessary. Overall, the evidence suggests that maize protection should progressively favor selective and ecologically compatible solutions that preserve beneficial arthropods while maintaining crop productivity.

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