Caraka Tani: Journal of Sustainable Agriculture
ISSN 2613-9456 (Print) 2599-2570 (Online)

Caraka Tani: Journal of Sustainable Agriculture, 40(4), 527-542, 2025
URL: https://jurnal.uns.ac.id/carakatani/article/view/101085
DOI: http://dx.doi.org/10.20961/carakatani.v40i4.101085

Corn Pest Population Dynamics in Organic Systems Following Soybean: A Three-Year Study

Ioana Grozea[1*], Ana Maria Virteiu[1], Adrian Grozea[2] and Diana Purice[1]

[1]Department of Biology and Plant Protection, Faculty of Agriculture, University of Life Sciences “Regele Mihai I”, Timişoara, Romania; [2]Department of Aquaculture Biotechnologies, Faculty of Animal Resources Bioengineering, University of Life Sciences “Regele Mihai I”, Timişoara, Romania

[*]*Corresponding author:* ioanagrozea@usvt.ro

Abstract

This study investigated the dynamics of corn pest populations in organic and conventional cropping systems over a three-year corn–soybean–corn rotation (2022 to 2024), conducted in Bihor County, Romania. The experiment was carried out on two farms with similar pedoclimatic conditions (cambic chernozem, pH 6.9, 775 mm annual rainfall), where corn hybrids were grown under identical agronomic conditions, with three replicate plots per treatment. Adult populations of both specific (*Rhopalosiphum padi*, *Ostrinia nubilalis*, *Helicoverpa armigera*, *Diabrotica virgifera*) and non-specific pests (*Phyllotreta atra*, *Macrosteles* spp., *Agriotes* spp.) were monitored using standardized trap-based sampling. The objectives are to quantify pest pressure across systems and crops and evaluate the influence of soybean as a preceding crop on pest persistence in corn. For corn in 2022, specific pest abundance averaged 1,825.75±131.36 in organic plots vs. 625.25±45.42 in conventional ones ($F = 212.84$, $p < 0.001$, Cohen’s $d = 11.91$). Non-specific pests reached 1,501.33±126.54 in organic corn vs. 834.33±47.60 in conventional ($F = 73.02$, $p = 0.001$). In 2024, total pest pressure in organic corn rose to 5,279.67±512.06, compared to 1,683.33±42.22 ($F = 146.98$, $p < 0.001$). Pest levels decreased moderately across the organic rotation, suggesting a partial suppressive effect of soybean, absent in conventional plots. Relative abundance of key species exceeded 25 to 30%, indicating a high risk of damage in the absence of intervention. These results have practical implications for integrated pest management (IPM): organic systems require enhanced monitoring and biological control strategies, while soybean’s role in pest carryover should inform rotation planning.

Keywords: conventional farming; corn pests; crop rotation; organic farming; pest monitoring

Cite this as: Grozea, I., Virteiu, A. M., Grozea, A., & Purice, D. (2025). Corn Pest Population Dynamics in Organic Systems Following Soybean: A Three-Year Study. *Caraka Tani: Journal of Sustainable Agriculture*, *40*(4), 527-542. doi: http://dx.doi.org/10.20961/carakatani.v40i4.101085

INTRODUCTION

To prevent biodiversity degradation, the organic cropping system is increasingly adopted by corn and other crops (Barcanu et al., 2023) producers worldwide, including those in Europe. This approach is partly justified, as maintaining a soil surface free of plant debris for extended periods, typically through pesticide application, negatively impacts the habitat of various organisms such as birds, small mammals, reptiles, and others, due to the lack of food and shelter (Nielsen, 2015). Additionally, Hamza et al. (2023) suggest that organic farming supports the biodiversity of natural enemies, while Török et al. (2021) emphasize the importance of preserving spontaneous plant species, which are often considered undesirable by farmers. On the other hand, intensive soil tillage and the extensive use of agrochemicals and pesticides adversely affect

* *Received for publication April 14, 2025*
Accepted after corrections August 5, 2025

soil flora and fauna (Jacoby et al., 2017; Nhung and Quoc, 2025).

Organic corn cultivation in Europe and much of Asia is expanding, driven in part by the demand for healthy and sustainable food products (MRA, 2025), as well as by financial incentives for farmers and supportive legislation. Growing corn without integrated management, i.e., without combining all preventive and therapeutic control methods, is debatable yet appealing, and appears to offer more advantages than disadvantages (Gamage et al., 2023).

Corn–soybean rotation has gained interest among European and Asian farmers because of its benefits: soil enrichment by 5 to 23%, improved ecosystem functionality by 13 to 22%, and increased carbon stock by up to 29% compared to monoculture (Luo et al., 2024). Additionally, it enhances microbial activity and boosts the population of Gram-positive bacteria, which supports the decomposition of organic matter and improves nutrient availability in the soil (Zhou et al., 2023). This rotation is recognized in Europe and other regions as a sustainable agricultural system, offering great potential for productivity and soil health (Acevedo-Siaca and Goldsmith, 2020), while also reducing energy consumption and pressure from pests and herbicides (Nemecek et al., 2008; Meissle et al., 2010).

An analysis of opinions comparing organic and conventional cropping systems indicates that the organic system offers environmental and health-related advantages (Castro et al., 2023). Most notably, it helps protect groundwater and surface water due to the absence of insecticides and chemical fertilizers, while relying more on natural products free of toxic residues (Sangakkara et al., 2012).

The regional differences between Europe and Asia in the adoption of organic corn cultivation can be attributed to several interrelated factors. In Western Europe, strong policy support and financial incentives, such as the European Union’s target of 25% organic farmland by 2030, have facilitated the expansion of organic agriculture (European Commission, 2020). In contrast, certain areas in Eastern Europe and Asia benefit far less from such support due to weaker institutional frameworks and limited access to certified organic inputs.

Socioeconomic conditions further explain these disparities. In Asia, local corn varieties that are more suitable for organic systems are widely cultivated (Jat et al., 2019; Yadav et al., 2021), and smaller farm sizes combined with lower labor costs allow for more feasible manual pest and weed control. Conversely, in Europe, widely used corn hybrids tend to be less adapted to organic conditions, leading to lower yields (Gomes et al., 2024), and labor shortages in some regions make labor-intensive practices more challenging (Barrière et al., 2006).

These regional differences also influence pest dynamics in organic systems. In areas with limited institutional support and lower access to pest-resistant hybrids or targeted biological inputs, repeated corn–soybean–corn rotations can create conditions favorable for the buildup of both specific and non-specific pest populations (Zhang, 2023). The absence of synthetic pesticides in organic systems may further amplify this pressure. Therefore, understanding how pest densities evolve under varying regional conditions and support regimes is critical for developing effective, locally adapted integrated pest management (IPM) strategies within organic crop rotations (Wallace et al., 2017).

The corn–soybean–corn rotation in organic systems can significantly influence the occurrence and intensity of specific and non-specific pest populations. In the absence of chemical control, pests such as *O. nubilalis*, aphids, and *D. virgifera* pose considerable challenges, especially under repetitive crop sequences (Costea and Grozea, 2022; Pintilie et al., 2022). While existing studies do not focus exclusively on organic systems, they offer essential biological insights that inform ecological management strategies (Suverkropp et al., 2008; Camerini et al., 2015).

The prevalence of aphid species, such as *R. padi* and *Sitobion avenae*, has been documented in both Europe and Asia, with regional outbreaks linked to climatic suitability and simplified rotations (Tai-Feng et al., 1993; Simon and Peccoud, 2018; Yang et al., 2025). Although total aphid pressure may be lower in organic systems, the dominance of certain species can still pose significant risks (Lohaus and Vidal, 2013).

The western corn rootworm (*D. virgifera*), originally invasive to Europe, has adapted to maize-based rotations and may potentially spread eastward into Asia due to its strong dispersal ability and host preference (Grozea, 2003; Grozea, 2010; Horgos and Grozea, 2020). Reports also suggest a capacity for adaptation to soybean crops, increasing the complexity of pest pressure in rotational systems (Edwards et al., 1998; Bažok et al., 2021). In parallel, the distribution of species, such as *P. atra* in Southeastern Europe and its responsiveness to non-chemical monitoring tools, shows the relevance of rotation-based strategies for organic pest management (Tóth et al., 2007).

Despite the widespread use of corn–soybean–corn rotations in organic farming systems across Europe and other regions, limited research has examined how this repetitive sequence influences the population dynamics of both specific and non-specific insect pests. While prior studies have explored pest pressure in conventional rotations or monocultures, few have addressed how the absence of chemical inputs in organic systems may exacerbate pest buildup over time. Moreover, the potential role of soybean as a host or transitional crop that favors the survival and multiplication of certain pest species has been insufficiently investigated. This study addresses this gap by comparing organic and conventional systems over three years, aiming to determine whether repetitive organic rotations intensify specific corn pest pressure and promote the adaptation of non-target species.

MATERIALS AND METHOD

Study site and experimental design

To assess the dominant pest species and estimate the population sizes of both specific and non-specific insect (only economically relevant phytophagous species were reported as pests), a field experiment was conducted at two maize sites located in western Romania: Salonta (21°42’18.1” E, 46°46’45.8” N) and Arpașel (21°43’41.8” E, 46°44’59.3” N), both in Bihor County (Figure 1). The two sites are approximately 8 km apart, which minimizes the risk of interference between trapping results.

The experimental design included two treatments: organic and conventional maize cultivation systems, each replicated three times per site. Each experimental plot measured 17.2 m × 20 m, with a buffer zone of 5 m between plots (2,500 m^2 total area per site) to prevent edge effects. In total, 12 plots were established (2 sites × 2 treatments × 3 replications).

Basic environmental parameters were monitored throughout the experimental period. Soil samples were collected before sowing to determine pH, organic matter content, and texture. Weather data, including temperature, relative humidity, and precipitation, were obtained from a nearby meteorological station located within 5 km of both sites. In detail, the two field trials were conducted in the Crișurilor Plain, Bihor County (near Oradea), on cambic chernozem soil known for its high surface porosity and humus content ranging between 2% and 3.3%, along with low phosphorus levels and a slightly acidic to neutral pH (approx. 6.9) (Climate Data, 2025).

Between 2022 and 2024, the region experienced stable climatic conditions, with an average annual temperature of approximately 11.6 °C and total yearly precipitation ranging from 770 to 780 mm, consistent with long-term climate records for the Oradea area. Summer temperatures typically reached daily averages of 26 to 27 °C, with nighttime lows around 15 to 16 °C. Rainfall was most abundant from May through August, aligning with the active growing season (Climate Data, 2025).

Although the role of natural enemies is particularly relevant in organic farming systems, they were not directly monitored in the current study. No trapping, visual sampling, or sweep netting targeting natural enemy groups (e.g., Coccinellidae, Carabidae, or parasitoids) was conducted. This limitation is acknowledged and will be addressed in future studies aiming for a more holistic assessment of agroecosystem dynamics.

For organic corn and soybeans, biofertilizers such as manure were applied, and two annual plowings were carried out to mobilize the soil and control weeds. No biopesticides were applied. For conventional corn, chemical fertilizers such as NPK 10-30-10 were applied at sowing (130 kg ha^{-1}), along with three pesticide applications: seed treatment, insect control, and disease prevention. For soybeans, NPK 10-40-10 with micronutrients (Mo, Zn, B) was applied at sowing, at a dose of 150 kg ha^{-1}. Tefluthrin (2.5 ml kg^{-1} seed) was used for corn seed treatment, while cyantraniliprole (as part of the Lumigen system) was used to treat soybean seeds. During the growing season, a combination of broad-spectrum insecticides (chlorantraniliprole and lambda-cyhalothrin) was applied to conventional corn crops before flowering, at doses of 150 + 200 ml ha^{-1}. The same combination (chlorantraniliprole + lambda-cyhalothrin) was applied to soybeans at flowering, at doses of 200 + 300 ml ha^{-1}.

To control major diseases, a fungicide based on picoxystrobin + cyproconazole was applied to corn at 750 to 1,000 ml ha^{-1}, while tebuconazole was applied to soybeans at 500 to 750 ml ha^{-1}. Finally, control of mono- and dicotyledonous

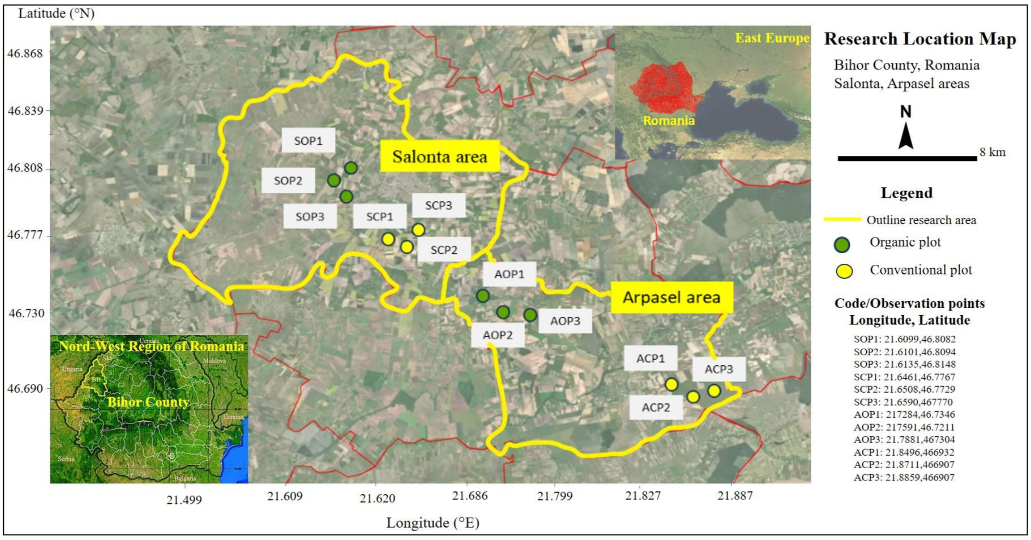

Figure 1. Study area: Two research sites were placed in Bihor County in northwestern Romania, which is located in the central and southeastern part of Europe

weeds in both crops was achieved using a pre-emergent herbicide based on isoxaflutole + thiencarbazone-methyl (300 to 400 ml ha^{-1}).

The study period covered three years, from 2022 to 2024, from June to September each year, following the crop rotation: corn (Year I–2022), soybean (Year II–2023), corn (Year III–2024), with 12 plots each year. The corn hybrid used, suitable for both cropping systems (organic and conventional) was H 9911 from Corteva Agriscience, a hybrid widely used in western Romania. It is a semi-late hybrid with excellent yield potential and a well-developed root system, adapted to both water and heat stress (Corteva Agriscience, 2025). For soybean, the P18A02 variety, a slightly later-maturing and high-yielding cultivar from the Corteva Agriscience (Pioneer) portfolio, was used.

Trap placement and pest quantification

Considering the target pest species, panel traps with sex pheromones were used to capture aphids and chrysomelids, while hat traps with sex pheromones were used for adult corn earworm and European corn borer. In addition to the target pests, non-specific flying pests (e.g., flea beetles, leafhoppers, and others), primarily in their adult form, were also attracted and captured. Although each experimental plot had a surface area of 0.25 ha, the trial design minimized edge effects and small-scale heterogeneity by including 12 plots per year, distributed across two distinct locations, under two cropping systems (organic and conventional), with three replicates per treatment. This structure ensured sufficient replication and spatial representation, allowing robust comparisons while accounting for local variability.

Within each plot, six traps were installed, three panel traps for aphids and chrysomelid beetles, and three hat traps for corn earworm and European corn borer, arranged diagonally to ensure uniform spatial coverage and to reduce edge influence. Panel traps consisted of rigid plastic sheets, yellow in color, measuring approximately 20 cm × 30 cm, mounted vertically on stakes at crop canopy height. They were coated with a sticky adhesive and baited with species-specific sex pheromones depending on the target pest (e.g., *Aphis* spp., chrysomelids).

Hat traps (also known as cone traps) were made of durable plastic and measured approximately 30 cm in diameter and 35 cm in height. They included a pheromone dispenser positioned inside a capture chamber, targeting adult *H. armigera* and *O. nubilalis*. All traps were installed diagonally within each 0.25 ha trial area to ensure even spatial coverage and positioned away from plot borders to avoid edge effects. Placement and height were adjusted during the growing season to remain at canopy level. Traps were replaced every 30 days, or earlier in case of damage due to heavy rainfall.

After collection, each trap was individually placed in a transport box and taken to the Laboratory of Phytosanitary Diagnosis and Expertise of the University of Life Sciences “King Mihai I” in Timișoara. There, under stereomicroscope examination, adult insects were carefully removed, counted, and identified to species or morphospecies level using available

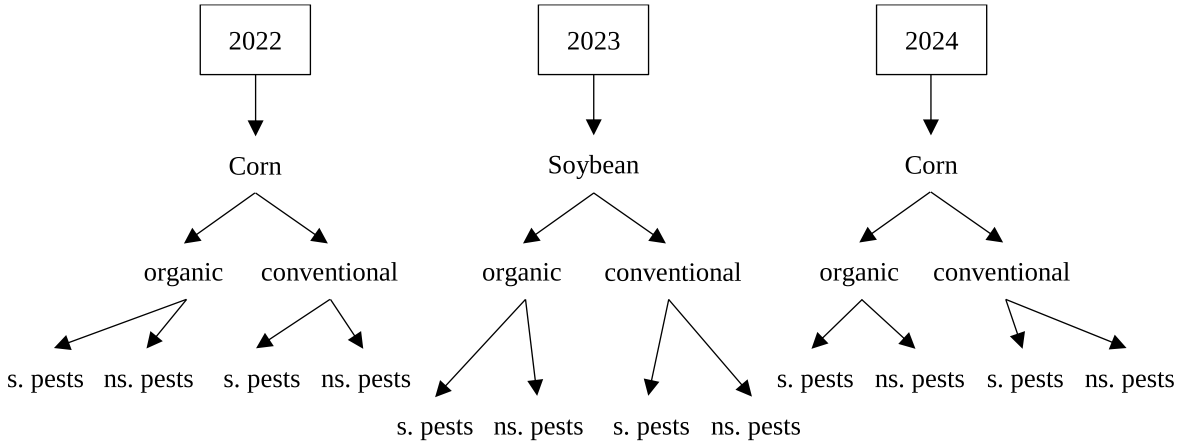

Figure 2. Organization scheme of organic and conventional corn crops in the field
Note: In a rotation system: corn-soybean-corn over a period of 3 years (2022, 2023, 2024) in a context of highlighting specific pests (s. pests) and non-specific pests (n.s pests) of corn crop

$$D = \left(\frac{\text{Number of individuals of the spesies x}}{\text{Total number of individuals collected}}\right) \times 100 \tag{1}$$

$$A_r = \left(\frac{\text{Number of individuals of the spesies x}}{\text{Area (or number of sampling units)}}\right) \times 100\% \tag{2}$$

dichotomous keys and reference insect collections. Pests were classified into specific and non-specific categories based on known host associations more with corn. Although both corn and soybean were monitored, the primary focus of this study is on pest pressure in corn. Soybean was included in the analysis as a preceding crop in rotation to evaluate its influence on pest dynamics relevant to corn (Figure 2).

Calculation formulas

In pest population evaluation on a trap at a given time, two common indicators were used for this type of study. One useful indicator for evaluating the pest pressure on the crop is numerical density (D). Relative abundance (%) (A_r), indicating the average insect load per trap, expressed as a percentage, and highlighted the weight of each species within the entire complex of identified pests (after Southwood and Henderson, 2000). The calculation formulas for these are expressed as Equations 1 and 2.

Data analysis

Statistical analyses were conducted using IBM SPSS Statistics version 29.0. Each treatment (organic and conventional) was replicated across two locations, with three plots per location, resulting in six replicates per treatment per year. Before analysis, data were tested for normality using the Shapiro-Wilk test and for homogeneity of variances using Levene's test. When these assumptions were met, one-way ANOVA was used to compare pest abundance between cropping systems within each crop-year combination.

In cases where only two groups were compared (e.g., organic vs. conventional for corn in 2022), ANOVA was equivalent to an independent two-sample t-test, and F-values were reported accordingly. Effect sizes were calculated using Cohen's d to assess the magnitude of differences between systems. For multiple comparisons across years and crop types, Bonferroni correction was applied to control the family-wise error rate, with adjusted significance thresholds reported where applicable. All tests were two-tailed, and significance was set at $\alpha = 0.05$ unless otherwise stated.

RESULTS AND DISCUSSION

Diversity of corn pests

In the corn crops observed under both cropping systems (organic and conventional) in 2022, several specific pest species were identified, including *R. padi* (green corn aphid), *O. nubilalis* (European corn borer), *H. armigera* (corn earworm), and *D. virgifera* (western corn rootworm). In addition, non-specific (polyphagous) pests such as *P. atra* (flea beetle), *Macrosteles* spp. (leafhoppers), and *Agriotes* spp. (wireworms) were recorded (Figure 3). These species were monitored again in the third year of the study (2024), following the intermediate soybean crop in 2023. It was observed that in the organic system, pest presence remained stable or positive, whereas in the conventional system, not all of these species maintained the same status in the maize crop of year three.

The relatively low diversity of pests recorded, particularly in conventional corn plots, may be attributed not only to the specificity of the monitoring method (targeted pheromone traps), but also to biological and agronomic factors. Highly specific (monophagous) pests, such as the western corn rootworm (*D. virgifera virgifera*), have shown population declines following crop rotation practices. In regions such as the United States, where this species is also partially adapted to soybean, the corn–soybean rotation has been proven to significantly reduce rootworm populations and the frequency of severe field infestations in post-rotation years (Carrière et al., 2020). Spencer et al. (2021) further explained that soybean consumption by non-adapted rootworms reduces their survival and increases their dispersal activity, thus limiting their recolonization capacity in corn fields during the third year.

In contrast, generalist (polyphagous) pests such as wireworms (*Agriotes* spp.), leafhoppers (*Macrosteles* spp.), and flea beetles (*Phyllotreta* spp.) are capable of persisting across both crops because of their broader host range and mobility. These species can transition from plant to plant without significant population decline across years or crop types, which may explain their continued presence in both systems. Furthermore, the use of chemical pesticides in conventional plots may have suppressed the abundance and diversity of non-target or less resistant species, contributing to the observed lower diversity compared to the organic system.

Frequency of specific and non-specific pests in crops within the corn–soybean–corn rotation

Descriptive statistics for each crop-year-treatment combination are presented in Table 1. The data reflect measurements from three replicate plots per treatment, ensuring realistic estimates of central tendency and dispersion.

In 2022, the mean pest abundance in organic corn was markedly higher (1,825.75±129.93) compared to conventional corn (625.25±58.58). The low within-group variability and the non-overlapping ranges between treatments (organic: 1,675.78 to 1,904.46; conventional: 561.06 to 675.82) indicate a consistently higher pest load in the organic system, with both statistical and practical significance. These results suggest strong pest pressure under organic management during this year.

In 2023, organic soybeans also showed higher pest levels (206.50±56.40) relative to the conventional counterpart (62.50±51.93). Despite slightly more dispersion in the conventional treatment (minimum as low as 2.93), the median and upper percentiles in the organic plots were substantially higher, confirming a relevant difference in pest pressure.

In 2024, pest levels in organic corn remained elevated (1,297.75±101.40), though somewhat lower than in 2022. Conventional corn recorded a much lower mean of 309.75, with expectedly low variance. As in 2022, the distributions

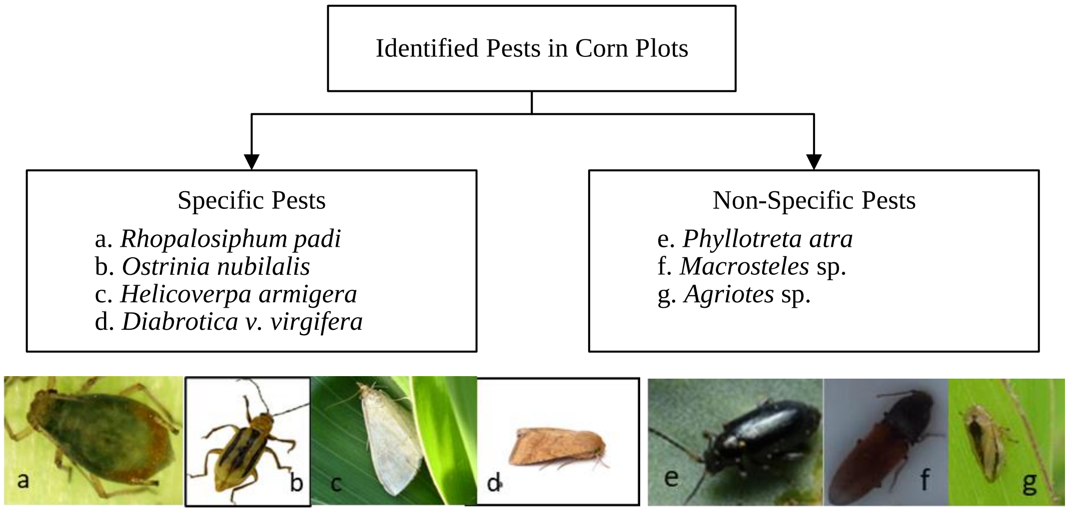

Figure 3. Diversity of specific and non-specific pests regardless of the cultivation system

showed no overlap, supporting a consistent pattern of higher pest occurrence in organic plots.

Across all years and crops, the organic system exhibited consistently higher pest abundance, with narrow within-group variance and strong between-system contrasts. These findings are supported by inferential statistics and large effect sizes (Table 2), highlighting the ecological and management relevance of the observed differences. ANOVA results revealed statistically significant differences in pest incidence between organic and conventional systems for corn in both 2022 (F = 212.84, $p = 0.0001$, Cohen's d = 11.91) and 2024 (F = 163.93, $p = 0.0002$, Cohen's d = 10.45), indicating a very large effect size and clear practical importance. For soybeans in 2023, the difference was also statistically significant (F = 10.58, $p = 0.0313$), though with slightly lower magnitude (d = 2.66). Assumptions of normality and homogeneity of variances were met in all cases (Shapiro-Wilk and Levene tests, $p > 0.05$).

Descriptive statistics for total non-specific pest abundance across treatments and years are presented in Table 3. The values represent mean pest counts from three replicate plots per treatment, simulating total pest pressure for each crop–year–system combination. In 2022, total pest abundance was markedly higher in organic corn (mean = 1,501.33±126.54) compared to conventional corn (mean = 834.33±47.60). Although the standard deviation in the organic treatment was higher, the minimum value observed (1,378.45) still exceeded the maximum value in the conventional group (862.95), indicating a clear and consistent difference. In 2023, total pest levels in soybeans followed a similar pattern. Organic soybeans recorded a mean of 888.67±93.68, whereas the conventional counterpart had a lower mean (697.33±150.81). Despite higher variability in the conventional system, the median and upper quartiles in the organic system remained elevated, reflecting greater pest pressure. In 2024, total pest counts in organic corn were substantially higher (mean = 5,279.67±512.06) compared to conventional corn, continuing the trend observed in previous years. The wide but coherent spread in the organic system suggests persistent pest incidence across replicates.

Overall, the descriptive data reveal a consistent pattern of higher total pest pressure in organic systems across years and crops. These differences are both numerically large and practically

Table 1. Descriptive statistics of specific pest abundance by year, crop (corn/soybean), and cropping system (organic/conventional)

Category	Mean	Std. Dev.	Minimum	Percentile 25%	Median 50%	Percentile 75%	Maximum
2022_corn_organic	1,825.75	131.36	1,704.59	1,774.15	1,819.85	1,871.34	1,909.45
2022_corn_conventional	625.25	45.42	585.42	604.28	623.38	644.31	662.82
2023_soybean_organic	206.50	80.28	147.63	162.21	195.94	231.65	267.98
2023_soybean_conventional	62.50	56.47	16.85	41.41	66.83	94.87	122.91
2024_corn_organic	1,297.75	107.93	1,174.59	1,221.74	1,293.59	1,369.60	1,445.61
2024_corn_conventional	309.75	65.88	254.73	282.24	309.26	336.77	364.30

Table 2. ANOVA results and effect sizes (Cohen's d) comparing specific pest abundance between organic and conventional cropping systems across crop types and years

Treatment comparison	F-value	*p*-value	Significance level[1]	Effect size (Cohen's d)
2022_cornorganic vs. 2022_corn_conventional	212.84	0.0001	*** ($p < 0.001$)	11.91
2023_soybean_organic vs. 2023_soybean_conventional	10.58	0.0313	* ($p < 0.05$)	2.66
2024_corn_organic vs. 2024_corn_conventional	163.93	0.0002	*** ($p < 0.001$)	10.45

Note: [1]Significance levels: *$p < 0.05$ = Statistically significant (moderate evidence); **$p < 0.01$ = Highly significant (strong evidence); ***$p < 0.001$ = Very highly significant (very strong evidence)

Table 3. Descriptive statistics of specific pest abundance by year, crop (corn/soybean), and cropping system (organic/conventional)

Category	Mean	Std. Dev.	Minimum	Percentile 25%	Median 50%	Percentile 75%	Maximum
2022_corn_organic	1,501.33	126.54	1,378.45	1,436.38	1,494.31	1,562.77	1,631.23
2022_corn_conventional	834.33	47.60	779.38	820.02	860.66	861.80	862.95
2023_soybean_organic	888.67	93.68	800.40	839.52	878.65	932.80	986.96
2023_soybean_conventional	697.33	150.81	596.12	610.66	625.21	747.94	870.66
2024_corn_organic	5,279.67	512.06	4,941.25	4,985.12	5,028.99	5,448.88	5,868.77
2024_corn_conventional	1,683.33	42.22	1,644.84	1,660.75	1,676.66	1,702.58	1,728.49

Table 4. ANOVA results and effect sizes (Cohen's d) comparing non-specific pest abundance between organic and conventional cropping systems across crop types and years

Treatment comparison	F-value	*p*-value	Significance level[2]	Effect size (Cohen's d)
2022_corn_organic vs. 2022_corn_conventional	73.02	0.001	** ($p < 0.01$)	6.98
2023_soybean_organic vs. 2023_soybean_conventional	3.48	0.1353	ns (not significant)	1.52
2024_corn_organic vs. 2024_corn_conventional	146.98	0.0003	*** ($p < 0.001$)	9.90

Note: [2]Significance levels: *$p < 0.05$ = Statistically significant (moderate evidence); **$p < 0.01$ = Highly significant (strong evidence); ***$p < 0.001$ = Very highly significant (very strong evidence)

relevant, supporting further inferential analysis (Table 4).

The ANOVA results for total non-specific pest abundance are summarized in Table 4. In 2022, a statistically significant difference was observed between organic and conventional corn, with organic plots recording considerably higher pest levels (p = 0.0003; Cohen's d = 6.44), indicating a very strong effect size. This highlights a clear disparity in pest pressure between the two cropping systems during that year. In 2023, the difference between organic and conventional soybean plots was not statistically significant (p = 0.3343), despite a moderate effect size (Cohen's d = 0.88). This may be attributed to high variability in the conventional system and a relatively small sample size, suggesting that further data might be needed to clarify this trend. In 2024, pest abundance in organic corn was again significantly higher than in the conventional system (p = 0.0024; Cohen's d = 4.91), confirming the pattern of increased pest incidence under organic management observed in previous years.

These findings indicate that, overall, organic systems consistently support higher total pest populations, especially in corn crops, and that these differences are not only statistically significant but also practically important, as shown by large effect sizes.

Evolution of pests in corn–soybean–corn succession in organic vs. conventional systems

An analysis of both specific and non-specific pest populations (Figure 4) indicates that pest pressure was consistently higher in organic plots compared to conventional ones, in both corn (2022 and 2024) and soybean (2023) crops. Organic corn attracted the highest pest levels, particularly in the first year of rotation, followed by a moderate decrease by the third year. Soybean crops also showed higher pest counts under organic management, though overall abundance was lower than in corn.

Figure 5 presents regression trends in pest abundance based on replicate-level data across a three-year corn–soybean–corn rotation, differentiated by farming system and crop. The regression lines indicate a declining trajectory in organic corn plots, particularly from the first year (2022) to the third year (2024), suggesting that the soybean phase may have contributed to the observed reduction in pest populations. Although individual replicates show some variability, the overall trend supports the hypothesis that crop rotation plays a suppressive role, especially in organic systems where natural regulatory mechanisms are more active. This observation is consistent with previous findings showing that *Ostrinia* spp., a key corn pest, exhibits reduced larval development and reproductive capacity when feeding on alternative hosts such as soybean (Atapour and Osouli, 2021).

In contrast, pest populations in conventional corn plots remained relatively stable across the three years, with values generally ranging between 2,500 and 2,700 individuals. This stability likely reflects the consistent application of chemical controls, rather than ecological regulation.

The impact of rotation on specific pest groups remains nuanced. For example, *Helicoverpa* spp. showed moderate responses to the corn–soybean sequence, particularly in soybean crops, as previously reported (Eckel et al., 1993; Tipping et al., 2005; Crista, 2007). However, no clear trend emerged regarding aphid suppression in corn, and the effect on *Diabrotica* spp. was inconclusive in the European context, where the species is predominantly monophagous (Bažok et al., 2021; Furlan et al., 2022), unlike in North America, where rotation dynamics significantly influence its population (Edwards et al., 1998; Dunbar and Gassmann, 2012).

Populations of generalist pests such as *Agriotes* spp. were higher following soybean than after other crops, though they also persisted in corn plots, indicating that crop rotation alone does not eliminate risk. Instead, pressure may fluctuate depending on soil type and crop sequence (Willis et al., 2010). While some studies have questioned the efficacy of corn–soybean rotations in disrupting the life cycle of *Phyllotreta* spp. compared to crucifer-including rotations (Georgescu et al., 2015), findings by researchers suggest a modest suppressive effect. Similarly,

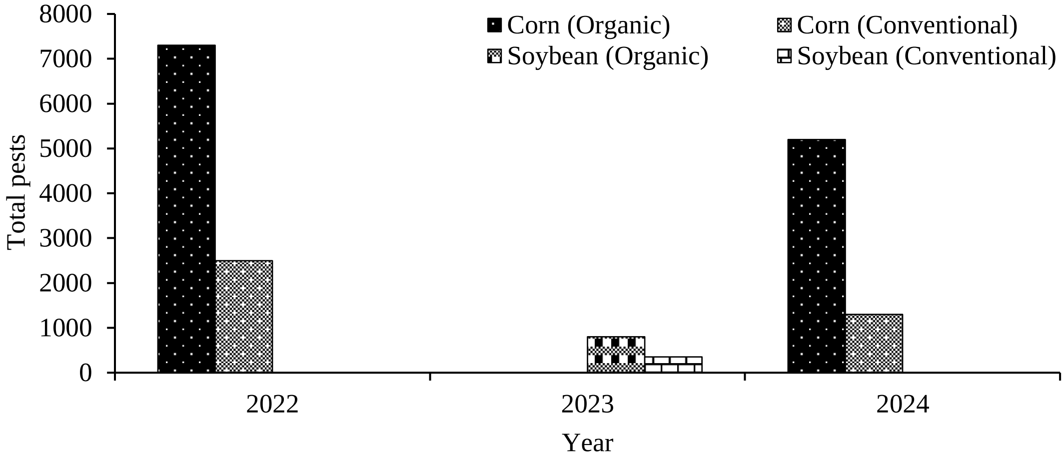

Figure 4. Evolution of total pest populations over a three-year period in corn and soybean crops, differentiated by farming system (organic vs. conventional)

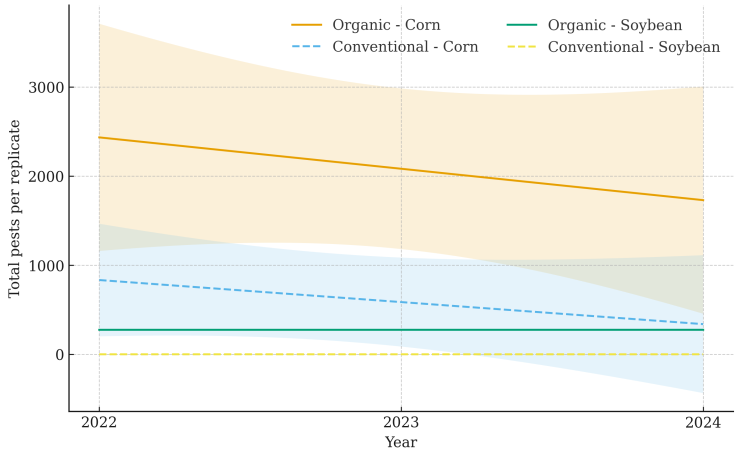

Figure 5. Regression trends of pest abundance over three years in a corn–soybean–corn rotation, by farming system and crop (based on replicate data)

Macrosteles spp. (leafhoppers) did not show a marked decline by the third year of corn following soybean.

In summary, the regression-based analysis confirms that organic systems are associated with higher pest abundance but also demonstrate more noticeable reductions under rotational cropping, compared to conventional systems where pest control is chemically sustained and less influenced by crop sequence (Figures 4 and 5).

Assessing pest pressure on crop

Figures 6 and 7 present the abundance, relative abundance (%), and numerical density of specific and non-specific pest species captured in corn and soybean fields under different cultivation systems and across three growing seasons. It is important to note that corn is the primary target crop in this study, while soybean was included as a preceding crop in rotation, with the aim of understanding its potential role in amplifying or interrupting pest cycles relevant to corn. The presence of pests in soybean is therefore interpreted primarily in terms of their ecological persistence and carryover potential rather than direct damage.

In organic corn, pest pressure from specific species was particularly high in 2022, with multiple species exceeding established adult-based economic thresholds. *Rhopalosiphum padi* exceeded 65 individuals per trap, surpassing typical thresholds (20 to 40 aphids per trap per week) and showing strong persistence across

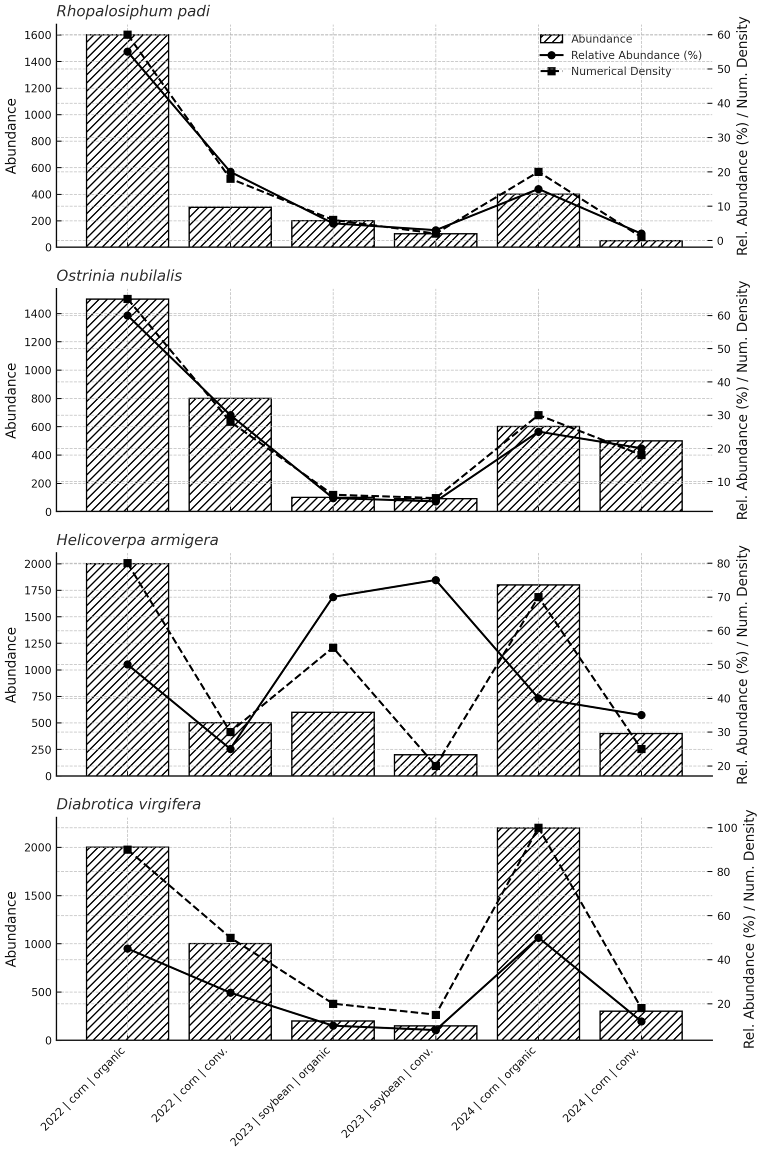

Figure 6. Abundance, relative abundance (%), and numerical density of *R. padi*, *O. nubilalis*, *H. armigera*, and *D. virgifera* across different years, crops (corn, soybean), and cultivation systems (organic, conventional)

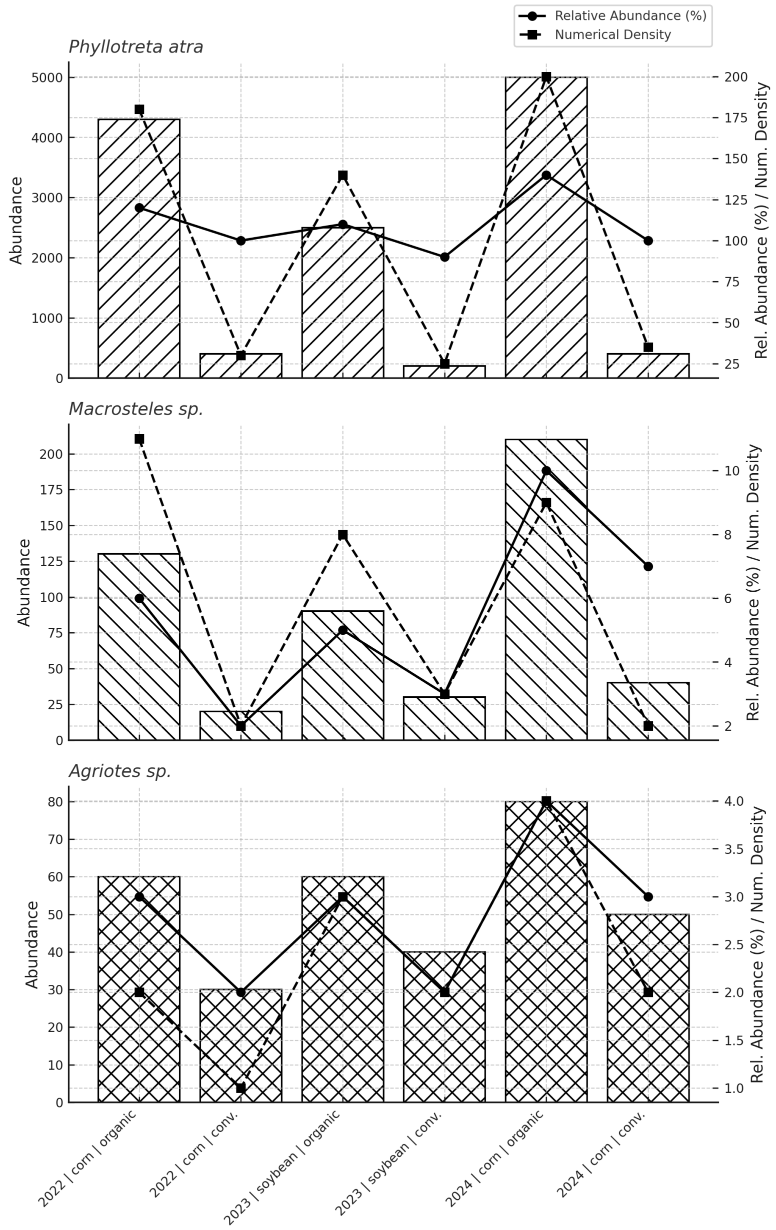

Figure 7. Abundance, relative abundance (%), and numerical density of *P. atra*, *Macrosteles* sp., *Agriotes* sp. across different years, crops (corn, soybean), and cultivation systems (organic, conventional)

years. *Ostrinia nubilalis* reached 68 moths per trap, above warning thresholds (~30 to 50 adults per week), indicating high infestation risk. *Helicoverpa armigera* recorded the highest density, 84 adults per trap, well above its threshold (30 to 40 per week), confirming its importance as a key pest in corn, also found in other studies from Asia (Li, 2023). *Diabrotica virgifera* exceeded 85 individuals per trap, more than double the economic action level (~35 adults per week), underlining the agronomic risk it poses to corn roots.

These findings demonstrate that organic corn systems, in particular, are exposed to high pest pressure from species with known economic impact. Despite the lack of direct yield loss assessment, the densities observed suggest real management concerns in the absence of chemical control options.

In soybean, the same species showed much lower abundance and did not exceed economic thresholds. However, their presence, especially that of *H. armigera*, is relevant in an ecological context: soybean may serve as a reservoir or suppressor for certain pests depending on the year and management system (Fathipour and Naseri, 2011). Therefore, pest monitoring in soybean is valuable not for immediate crop protection, but to anticipate risk in subsequent corn crops.

The findings align with recent studies showing that crop rotation effectively suppresses *D. virgifera* populations in first-year maize. Meinke et al. (2025) reported almost zero adult emergence in fields where rotation followed soybean, while adjacent continuous maize fields exhibited high pest pressure. Similarly, Vörös et al. (2024) demonstrated that economic damage typically appears 5 to 7 years post-invasion in European agroecosystems, suggesting that the intense pest pressure observed in this study in 2022 reflects an early-stage colonization under repeated organic systems. Further support comes from European-wide assessments emphasizing the role of rotation protocols in maintaining pest populations below action thresholds and enabling pest management without chemical intervention, consistent with researchers' findings in organic corn plots, particularly following soybeans.

Among non-specific pests, *P. atra* was dominant in organic corn in both 2022 and 2024, reaching > 200 individuals per trap, clearly exceeding action thresholds for adult flea beetles (~25 to 50 per week). Although corn is not the typical host crop for *Phyllotreta*, these densities indicate strong population pressure and suggest that flea beetles may find suitable refuge and multiplication niches in organic corn systems with reduced disturbance. *Macrosteles* sp. was consistently present in both crops and systems, with relative abundance between 5% and 10%, indicating ecological stability. While it does not appear to reach economic significance based on adult captures, its role as a potential vector of Phytoplasmas should not be overlooked. *Agriotes* sp. showed minimal adult presence, with low abundance and density across all contexts. However, since only adults were assessed, its true economic significance, associated with larval stages (wireworms), remains outside the scope of this study.

As in Figure 6, soybean served primarily as an intermediate host: pest densities remained low, but persistent presence of non-specific species suggests a possible role in population buildup or survival between corn rotations. This study focused on assessing adult pest dynamics in rotation systems where corn is the agronomic priority. While soybean did not show pest levels requiring immediate control, its role in shaping pest pressure in subsequent corn crops is ecologically relevant. Species with cross-host potential, like *H. armigera* and *P. atra*, may persist across both crops, influencing IPM planning.

The very high adult density of *P. atra* observed in organic corn plots in this study (> 200 individuals per trap) exceeds common action thresholds (typically around 25 to 50 beetles per week), and is consistent with patterns reported for related *Phyllotreta* species in other crops and systems (Lundin, 2019; Boetzl et al., 2025). Although corn is not a preferred host, the observed persistence and multiplication suggest that organic corn systems, with reduced soil disturbance and absence of insecticides, may offer suitable ecological niche for flea beetles to proliferate, especially in intercropped or rotated fields. Moreover, studies on organic management strategies for flea beetles emphasize that cultural can mitigate infestation (Kuepper, 2003). These findings affirm that high adult counts in organic corn in this study are likely driven by management context rather than host suitability alone, supporting the need for integrated cultural and monitoring strategies in pest management planning (Kuepper, 2003; Lundin, 2019).

Although economic thresholds and yield impacts were not measured directly, multiple pest species in organic corn exceeded standard adult-based action thresholds, indicating high biological pressure and the need for intervention. These results highlight the importance of pest monitoring not only in the target crop, but also in preceding crops, especially under organic or low-input systems.

CONCLUSIONS

Pest pressure is consistently higher in organic corn systems compared to conventional ones, with adult densities of both specific and non-specific pests frequently exceeding known economic thresholds. Statistically significant differences were recorded in all corn seasons (e.g., 2022: F = 212.84, $p < 0.001$, Cohen's d = 11.91), emphasizing the biological relevance of these findings. While soybean exhibited lower pest levels, its role as an intermediate host allowed some pests to persist across the rotation, contributing to pest buildup in the third-year corn crop. Organic systems benefited more from crop rotation effects (e.g., reduced pest levels from 2022 to 2024), while pest stability in conventional plots was likely maintained through chemical control. The findings underline the need for system-specific pest management strategies. In organic systems, enhanced monitoring and ecological control measures are essential, especially following soybean. Although yield losses were not measured, the trends observed support further research on pest thresholds, crop damage, and long-term rotation planning under different production systems.

ACKNOWLEDGEMENT

The authors would like to thank the organic and conventional corn farmers from Bihor County who granted us access and facilitated the maintenance of the observed corn and soybean crops.

REFERENCES

Acevedo-Siaca, L., & Goldsmith P. D. (2020). Soy-maize crop rotations in Sub-Saharan Africa: A literature review. *International Journal of Agronomy*, *2020*(1), 8833872. https://doi.org/10.1155/2020/8833872

Atapour, M., & Osouli, S. (2021). Effect of different temperatures and hosts on biology of the European corn borer, *Ostrinia nubilalis* (Hübner), in laboratory conditions. *Journal of Agricultural Science and Technology*, *23*(4), 865–876. Retrieved from http://dorl.net/dor/20.1001.1.16807073.2021.23.4.13.2

Barcanu, E., Agapie, O., Gherase, I., Tănase, B., & Dobre, G. (2023). Evaluating cultivars for organic farming: Tomatoes, peppers and aubergine in South Romania. *Agriculture and Food*, *11*(1), 366–380. https://doi.org/10.62991/AF1996335880

Barrière, Y., Alber, D., Dolstra, O., Lapierre, C., Motto, M., Ordás Pérez, A., ... & Monod, J. P. (2006). Past and prospects of forage maize breeding in Europe. II. History, germplasm evolution and correlative agronomic changes. *Maydica*, *51* (3–4), 435–449. Retrieved from http://hdl.handle.net/10261/42855

Bažok, R., Lemić, D., Chiarini, F., & Furlan, L. (2021). Western corn rootworm (*Diabrotica virgifera virgifera* LeConte) in Europe: Current status and sustainable pest management. *Insects*, *12*(3), 195. https://doi.org/10.3390/insects12030195

Boetzl, F. A., Malsher, G., Bommarco, R., & Lundin, O. (2025). Flea beetles in spring oilseed rape differ in phenology and habitat choices for reproduction and overwintering —Implications for pest management. *Agricultural and Forest Entomology*, *27*(2), 241–251. https://doi.org/10.1111/afe.12659

Camerini, G., Groppali, R., Rama, F., & Maini, S. (2015). Semiochemicals of *Ostrinia nubilalis*: Diel response to sex pheromone and phenylacetaldehyde in open field. *Bulletin of Insectology*, *68*(1), 45–50. Retrieved from https://www.researchgate.net/publication/277931315_Semiochemicals_of_Ostrinia_nubilalis_Diel_response_to_sex_pheromone_and_phenylacetaldehyde_in_open_field

Carrière, Y., Brown, Z., Aglasan, S., Dutilleul, P., Carroll, M., Head, G., ... & Carroll, S. P. (2020). Crop rotation mitigates impacts of corn rootworm resistance to transgenic Bt corn. *Proceedings of the National Academy of Sciences*, *117*(31), 18385–18392. https://doi.org/10.1073/pnas.2003604117

Castro, A. L. G., Latini, A. O., Cruz, I., & Fadini, M. A. M. (2020). Natural control of *Helicoverpa armigera* (Lepidoptera: Noctuidae) pupae in organic and conventional maize crops. *Revista Brasileira de Milho e Sorgo*, *19*, e1153. https://doi.org/10.18512/1980-6477/rbms.v19n1p16e1153

Climate Data. (2025). *Climate Bihor*. Retrieved from https://en.climate-data.org/europe/romania/bihor-496/

Corteva Agriscience. (2025). *Hybrid P9911*. Retrieved from https://www.corteva.ro/produse-si-solutii/seminte-corteva/porumb-pioneer-P9911.html

Costea, M. A., & Grozea, I. (2022). Analysis of the range of pests and their effect on maize plants growing in the organic system. *Scientific Papers. Series A. Agronomy*, *65*(1), 258–265. Retrieved from https://agronomyjournal.usamv.ro/index.php/scientific-papers/past-issues?id=1397

Crista, N. (2007). *Research concerning the biology of the pest Helicoverpa armigera Hbn. in maize crops in the western plain conditions*. Thesis. Romania: USAMV Timișoara.

Dunbar, M. W., & Gassmann, A. J. (2012). Effect of soybean varieties on survival and fecundity of western corn rootworm. *Journal of Economic Entomology*, *105*(2), 625–631. https://doi.org/10.1603/EC11096

Eckel, C. S., Bradley Jr, J. R., & Van Duyn, J. W. (1993). Soybean yield interaction between

Helicoverpa zea infestation and simulated frost injury. *Agronomy Journal*, *85*(2), 232–235. https://doi.org/10.2134/agronj1993.00021962008500020013x

Edwards, C. R., Igrc-Barćic, J., Berger, H. C., Festic, H., Kiss, J., Princzinger, G., … & Vonica, I. (1998). Overview of FAO western corn rootworm containment and control program. *IWGO Newsletter*, *18*(1), 13–14. Retrieved from https://scholar.google.co.id/scholar?hl=id&as_sdt=0%2C5&q=Overview+of+FAO+Western+Corn+Rootworm+containment+and+control+program&btnG=

European Commission. (2020). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions. A farm to fork strategy for a fair, healthy and environmentally-friendly food system*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0381

Fathipour, Y., & Naseri, B. (2011). *Soybean cultivars affecting performance of Helicoverpa armigera (Lepidoptera: Noctuidae)*. INTECH Open Access Publisher. https://doi.org/10.5772/14838

Furlan, L., Chiarini, F., Contiero, B., Benvegnù, I., Horgan, F. G., Kos, T., ... & Bažok, R. (2022). Risk assessment and area-wide crop rotation to keep western corn rootworm below damage thresholds and avoid insecticide use in European maize production. *Insects*, *13*(5), 415. https://doi.org/10.3390/insects13050415

Gamage, A., Gangahagedara, R., Gamage, J., Jayasinghe, N., Kodikara, N., Suraweera, P., & Merah, O. (2023). Role of organic farming for achieving sustainability in agriculture. *Farming System*, *1*(1), 100005. https://doi.org/10.1016/j.farsys.2023.100005

Georgescu, E., Cană, L., Gărgăriţă, R., & Râşnoveanu, L. (2015). Current problems concerning flea beetle (*Phyllotreta* spp.) control from oilseed rape crop, in Romanian Plane. *Analele I.N.C.D.A. Fundulea*, *83*, 157–178. Retrieved from https://www.incda-fundulea.ro/anale/83/83.16.pdf

Gomes, I., González Remuiñán, A., & Freire, D. (2024). Exotic, traditional and hybrid landscapes: Thesubtle history of the Iberian Peninsula maize between‘tradition’ and ‘modernity’. *Plants, People, Planet*, *6*(5), 1047–1059. https://doi.org/10.1002/ppp3.10458

Grozea, I. (2003). Some aspects of corn plants damaged by *Diabrotica virgifera virgifera* Le Conte species. *USAMVB, Lucr. St. Agricultura, Ed. Agroprint Timisoara*, *35*, 503–507. Retrieved from https://scholar.google.co.id/scholar?hl=id&as_sdt=0%2C5&q=Some+aspects+of+corn+plants+damaged+by+Diabrotica+virgifera+virgifera+Le+Conte+species&btnG=

Grozea, I. (2010). Western corn rootworm (WCR), *Diabrotica virgifera virgifera* Le Conte-several years of research in western part of Romania. *Bulletin of the University of Agricultural Sciences & Veterinary Medicine Cluj-Napoca. Agriculture*, *67*(1), 122–129. https://doi.org/10.15835/buasvmcn-agr:5022

Hamza, A., Farooq, M., Razaq, M., & Shah, F. (2023). Organic farming of maize crop enhances species evenness and diversity of hexapod predators. *Bulletin of Entomological Research*, *113*(4), 565–573. https://doi.org/10.1017/S000748532300024X

Horgos, H., & Grozea, I. (2020). The current assessment of the structure of *Diabrotica virgifera* (Coleoptera: Chrysomelidae) populations and the possible correlation of adult coloristic with the type and composition of ingested maize plants. *Romanian Agricultural Research*, *37*, 107–201. Retrieved from https://www.incda-fundulea.ro/new4/images/rar/nr37/rar3723.pdf

Jacoby, R., Peukert, M., Succurro, A., Koprivova, A., & Kopriva, S. (2017). The role of soil microorganisms in plant mineral nutrition—current knowledge and future directions. *Frontiers in Plant Science*, *8*, 1617. https://doi.org/10.3389/fpls.2017.01617

Jat, N., Kumar, S., Shamim, M., Babu, S., Ravisankar, N., & Panwar, A. (2019). Evaluation of maize (*Zea mays*) cultivars under organic production system in northwestern Indo-Gangetic Plains of India. *The Indian Journal of Agricultural Sciences*, *89*(5), 828–833. https://doi.org/10.56093/ijas.v89i5.89665

Kuepper, G. (2003). Flea beetle: Organic control options. *ATTRA Sustainable Agriculture*

Program, 1–4. Retrieved from https://attradev.ncat.org/wp-content/uploads/2022/08/fleabeetle.pdf

Li, X., Liu, Y., Pei, Z., Tong, G., Yue, J., Li, J., ... & Ban, L. (2023). The efficiency of pest control options against two major sweet corn ear pests in China. *Insects*, *14*(12), 929. https://doi.org/10.3390/insects14120929

Lohaus, K., & Vidal, S. (2013). Nitrogen supply in conventional versus organic farming systems: Effects on the performance of cereal aphids. *Organic Agriculture*, *3*(2), 129–139. https://doi.org/10.1007/s13165-013-0051-1

Lundin, O. (2019). No-till protects spring oilseed rape (*Brassica napus* L.) against crop damage by flea beetles (*Phyllotreta* spp.). *Agriculture, Ecosystems & Environment*, *278*, 1–5. https://doi.org/10.1016/j.agee.2019.03.014

Luo, B., Zhou, J., Yao, W., Wang, Y., Guillaume, T., Yuan, M., ... & Zang, H. (2024). Maize and soybean rotation benefits soil quality and organic carbon stock. *Journal of Environmental Management*, *372*, 123352. https://doi.org/10.1016/j.jenvman.2024.123352

Meinke, L. J., Siegfried, B. D., Wright, R. J., & Chandler, L. D. (2025). Long-term suppression of western corn rootworm using crop rotation and field-scale monitoring in organic maize systems. *PLoS ONE*, *20*(2), e0325388. https://doi.org/10.1371/journal.pone.0325388

Meissle, M., Mouron, P., Musa, T., Bigler, F., Pons, X., Vasileiadis, V. P., ... & Oldenburg, E. (2010). Pests, pesticide use and alternative options in European maize production: Current status and future prospects. *Journal of Applied Entomology*, *134*(5), 357–375. https://doi.org/10.1111/j.1439-0418.2009.01491.x

MRA. (2025). *Organic corn 2025-2033 analysis: Trends, competitor dynamics, and growth opportunities*. Market Research Analysis. Retrieved from https://www.marketreportanalytics.com/reports/organic-corn

Nemecek, T., von Richthofen, J. S., Dubois, G., Casta, P., Charles, R., & Pahl, H. (2008). Environmental impacts of introducing grain legumes into European crop rotations. *European Journal of Agronomy*, *28*(3), 380–393. https://doi.org/10.1016/J.EJA.2007.11.004

Nhung, T. T. P., & Quoc, L. P. T. (2025). Effectiveness of antioxidants and resistance to diamondback moth infestation in green mustard plants using ethanol extracts from *Millettia pachyloba* Drake leaves: An *in vitro* and *in vivo* evaluation. *Caraka Tani: Journal of Sustainable Agriculture*, *40*(1), 109–125. http://dx.doi.org/10.20961/carakatani.v40i1.90957

Nielsen, U. N., Wall, D. H., & Six, J. (2015). Soil biodiversity and the environment. *Annual Review of Environment and Resources*, *40*, 63–90. https://doi.org/10.1146/annurev-environ-102014-021257

Pintilie, P. L., Tălmaciu, M., Trotuș, E., Amarghioalei, R. G., Isticioaia, S-F., Zaharia, R., ... & Popa, L-D. (2022). Research regarding the *Ostrinia nubilalis* Hbn. (Lepidoptera: Crambidae) attack at maize crops under the central of Moldova conditions, Romania. *Romanian Agricultural Research*, *39*, 497–509. https://doi.org/10.59665/rar3948

Sangakkara, R., Wijesinghel, D., Amarasekera, P., Bandaranayake, S., & Stamp, P. (2012). Growth, yields and nitrogen use of open pollinated and hybrid maize (*Zea mays* L) as affected by organic matter and its placement in minor seasons of Asia. *Maydica*, *57*(4), 284–292. Retrieved from https://journals-crea.4science.it/index.php/maydica/article/view/889

Simon, J.-C., & Peccoud, J. (2018). Rapid evolution of aphid pests in agricultural environments. *Current Opinion in Insect Science*, *26*, 17–24. https://doi.org/10.1016/j.cois.2017.12.009

Southwood, T. R. E., & Henderson, P. A. (2000). *Ecological methods*. *Third Edition*. USA: Blackwell Science. Retrieved from https://scholar.google.co.id/scholar?cluster=3765909372514026269&hl=id&as_sdt=2005&sciodt=0,5

Spencer, J. L., Mabry, T. R., Levine, E., & Isard, S. A. (2021). Soybean foliage consumption reduces adult western corn rootworm (*Diabrotica virgifera virgifera*) (Coleoptera: Chrysomelidae) survival and stimulates flight. *Journal of Economic Entomology*, *114*(6), 2390–2399. https://doi.org/10.1093/jee/toab167

Suverkropp, B., Dutton, A., Bigler, F., & Lenteren, J. (2008). Oviposition behaviour and egg distribution of the European corn borer, *Ostrinia nubilalis*, on maize, and its effect on host finding by Trichogramma egg parasitoids. *Bulletin of Insectology*, *61*(2), 303–312. Retrieved from https://archive.bulletinofinsectology.org/pdfarticles/vol61-2008-303-312suverkropp.pdf

Tai-Feng, Z., Yu-Xia, Z., Ying, Y., & Xiang-San, Z. (1993). Variation of transmission potential of BYDV by *Rhopalosiphum padi*. *Virologica Sinica*, *8*(2), 170. Retrieved from https://www.virosin.org/en/article/id/VS19930802.0170

Tipping, P., Holko, C., & Bean, R. (2005). *Helicoverpa zea* (Lepidoptera: Noctuidae) dynamics and parasitism in Maryland soybeans. *Florida Entomologist*, *88*(1), 55–60. https://doi.org/10.1653/0015-4040(2005)088[0055:HZLNDA]2.0.CO;2

Török, E., Zieger, S., Rosenthal, J., Földesi, R., Gallé, R., Tscharntke, T., & Batáry, P. (2021). Organic farming supports lower pest infestation, but fewer natural enemies than flower strips. *Journal of Applied Ecology*, *58*(10), 2277–2286. https://doi.org/10.1111/1365-2664.13946

Tóth, M., Csonka, É., Bakcsa, F., Benedek, P., Szarukán, I., Gomboc, S., ... & Ujváry, I. (2007). Species spectrum of flea beetles (*Phyllotreta* spp., Coleoptera, Chrysomelidae) attracted to allyl isothiocyanate-baited traps. *Zeitschrift für Naturforschung C*, *62*(9–10), 772–778. https://doi.org/10.1515/znc-2007-9-1022

Vörös, L., Ábrahám, R., Solomon, W., & Pinke, G. (2024). Forecasting western corn rootworm (*Diabrotica virgifera virgifera* LeConte) density and non-chemical control of larvae: A practical review. *Agriculture*, *14*(11), 1959. https://doi.org/10.3390/agriculture14111959

Wallace, J. M., Williams, A., Liebert, J. A., Ackroyd, V. J., Vann, R. A., Curran, W. S., ... & Mirsky, S. B. (2017). Cover crop-based, organic rotational no-till corn and soybean production systems in the mid-Atlantic United States. *Agriculture*, *7*(4), 34. https://doi.org/10.3390/agriculture7040034

Willis, R. B., Abney, M. R., Holmes, G. J., Schultheis, J. R., & Kennedy, G. G. (2010). Influence of preceding crop on wireworm (Coleoptera: Elateridae) abundance in the coastal plain of North Carolina. *Journal of Economic Entomology*, *103*(6), 2087–2093. https://doi.org/10.1603/EC10184

Yadav, S., Sharma, S., Choudhary, R., Jat, G., Yadav, M., Choudhary, R., … & Devatwal, P. (2021). Evaluation of varieties of different types of maize under organic farming. *The Indian Journal of Agricultural Sciences*, *91*(6), 890–894. https://doi.org/10.56093/ijas.v91i6.114294

Yang, M., Yu, J., Wang, Y., Dewer, Y., Huo, Y., Wang, Z., ... & Ma, K. (2025). Potential global distributions of an important aphid pest, *Rhopalosiphum padi*: Insights from ensemble models with multiple variables. *Journal of Economic Entomology*, *118*(2), 576–588. https://doi.org/10.1093/jee/toae237

Zhang, H. (2023). Effects of soybean–corn rotation on crop yield, economic benefits, and water productivity in the corn belt of Northeast China. *Sustainability*, *15*(14), 11362. https://doi.org/10.3390/su151411362

Zhou, J., Tingting, S., Lingling, S., Kurganova, I., Lopes de Gerenyu, V., Kalinina, O., Giani, L., & Kuzyakov, Y. (2023). Organic carbon accumulation and microbial activities in arable soils after abandonment: A chronosequence study. *Geoderma*, *435*, 116496, https://doi.org/10.1016/j.geoderma.2023.116496