

Impact Of Agricultural Pesticides On Spider Diversity And Abundance: A Research Review

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Abstract:

Spiders (Araneae) are important components of agricultural ecosystems because they are generalist predators of many insect pests and contribute to natural pest regulation (Michalko et al., 2019). Agricultural intensification has increased the use of insecticides, herbicides, fungicides and acaricides, creating potential risks for non-target arthropods, including spiders (Pekár, 2012). Research conducted under field and laboratory conditions indicates that pesticides can affect spiders through direct mortality as well as indirect effects involving prey availability, habitat alteration, movement, reproduction, web construction and other behaviours (Pekár, 2012). Field studies have demonstrated reductions in spider abundance and, in some cases, species richness following pesticide application, although responses differ among pesticide compounds, spider species, ecological guilds, crops and environmental conditions (Liu et al., 2013; Duque et al., 2024). Evidence from India, including studies in apple orchards of Kashmir, also indicates lower spider richness and abundance in pesticide-treated systems compared with unsprayed systems (Khan, 2012). Recent studies further demonstrate that sublethal exposure to herbicides and insecticides can affect reproduction, predation and population growth even when immediate mortality is limited (Tu et al., 2025; Šimečková et al., 2026). Overall, the available evidence indicates that pesticide use can substantially modify spider communities and may reduce their contribution to biological pest control.

Keywords: spiders, Araneae, agricultural pesticides, insecticides, herbicides, spider diversity, spider abundance, non-target organisms, biological control, agroecosystems.

Introduction

Agricultural ecosystems support diverse communities of arthropods, including predators that contribute to the regulation of crop pests. Among these predators, spiders are particularly important because they occur in a wide range of agricultural habitats and consume numerous insect groups (Sunderland & Samu, 2000). Spiders occupy different ecological guilds, including ground hunters, foliage hunters, orb-web builders and sheet-web builders, allowing them to exploit different microhabitats and prey resources within agricultural fields (Marc et al., 1999; Sunderland & Samu, 2000). A global meta-analysis of 58 studies found that spiders suppressed agricultural pest insects in a large proportion of the cases examined, demonstrating their potential importance as biological control agents (Michalko et al., 2019). Consequently, practices that reduce spider populations may indirectly influence pest regulation and other ecosystem services. Modern agriculture frequently depends on pesticides to control insect pests, weeds and plant diseases. However, many pesticides are not completely selective for their target organisms and can affect non-target arthropods, including predatory spiders (Pekár, 2012). The effects of pesticides on spiders are complex because spiders can be exposed through direct contact with pesticide residues, contaminated prey, treated vegetation, soil and webs. Their response can range from mortality and population decline to less obvious changes in movement, feeding, reproduction, web construction and predatory behaviour (Pekár, 2012).

Therefore, understanding the relationship between pesticide use and spider diversity and abundance is important for developing sustainable agricultural systems and integrated pest management strategies.

Importance of Spiders in Agricultural Ecosystems

Spiders are among the most abundant predatory arthropods in many agricultural ecosystems and can consume a broad range of insect prey (Marc et al., 1999). Agricultural spider communities commonly contain both web-building species and actively hunting species, with the relative abundance of these groups varying according to crop structure, climate and management practices (Sunderland & Samu, 2000). Spiders can contribute to pest suppression even though individual spiders may consume relatively few prey items per day because their combined effects operate at the community level (Michalko et al., 2019). Increasing spider density has been associated with increased pest suppression, while higher spider taxonomic diversity can also contribute positively to pest control (Michalko et al., 2019). Thus, maintaining spider

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diversity is not only a biodiversity objective but may also support ecosystem services associated with natural pest regulation.

Agricultural Pesticides and Their Effects on Spiders:

Agricultural pesticides can be broadly classified into insecticides, herbicides, fungicides and acaricides, and their effects on spiders differ according to chemical properties, exposure route, concentration and spider species (Pekár, 2012). A major ecotoxicological review reported that numerous spider species and pesticide compounds had been investigated under field or laboratory conditions, demonstrating considerable variation in spider sensitivity (Pekár, 2012). Spiders can be particularly affected by insecticides and acaricides, especially neurotoxic compounds, while field studies also demonstrate indirect effects caused by changes in habitat and prey populations (Pekár, 2012).

The effects of pesticides can therefore be divided into two major categories:

- **Direct effects:** such as mortality, paralysis and physiological stress.
- **Indirect and sublethal effects:** such as reduced prey consumption, altered movement, reduced reproduction, changes in web construction and habitat avoidance.

Effects on Spider Abundance:

Spider abundance is one of the most frequently measured indicators of pesticide effects.

A meta-analysis of land-management studies found that insecticide use was associated with negative effects on spider abundance in agricultural systems (Prieto-Benítez & Méndez, 2011). Field experiments have provided direct evidence for these effects. Fountain et al. (2007) investigated the effects of chlorpyrifos on spider and Collembola communities and recorded a reduction in the number of spiders in insecticide-treated plots, largely because of reduced abundance of the linyphiid spider *Tiso vagans* (Fountain et al., 2007). However, the same study did not detect a statistically significant difference in overall spider diversity between treated and untreated plots, demonstrating that pesticide effects on abundance do not necessarily translate immediately into changes in species richness (Fountain et al., 2007). This distinction is important because an agricultural field may retain approximately the same number of spider species while experiencing substantial reductions in the number of individuals. A long-term study comparing spider communities in an alfalfa field and its margin found a substantial decline in spider abundance over a 23-year period, while species richness remained relatively stable (Samu et al., 2023). Because that study was conducted in an unsprayed system, the authors emphasized broader landscape-scale processes rather than pesticide exposure as possible explanations for the long-term decline (Samu et al., 2023).

This finding demonstrates that pesticide use is an important factor but should not be considered the sole cause of changes in agricultural spider populations.

Effects on Spider Species Diversity and Richness:

Species diversity includes both the number of species present and the relative abundance of those species. Pesticides can alter these characteristics by disproportionately affecting sensitive species. Khan (2012) compared spider communities in sprayed and unsprayed apple orchards in Kashmir and recorded greater spider richness in unsprayed orchards than in sprayed orchards (Khan, 2012). At the individual-orchard level, the number of species was also generally higher in unsprayed orchards than in sprayed orchards (Khan, 2012). The same study reported differences in the representation of several spider hunting and web-building groups between sprayed and unsprayed orchards, indicating that pesticide use can modify not only species richness but also the functional composition of spider communities (Khan, 2012).

However, pesticide effects are not always uniform. Liu et al. (2013) studied the effects of spinosad and λ -cyhalothrin on spider communities in cabbage fields and recorded 53 spider species belonging to 11 families (Liu et al., 2013). The insecticide-treated plots contained fewer spider individuals, species and families than untreated plots, while λ -cyhalothrin produced stronger reductions than spinosad (Liu et al., 2013). These results show that pesticide impacts are **chemical-specific**, and different active ingredients can produce different levels of risk to spider communities.

Direct Toxicity and Mortality:

Direct pesticide toxicity is one of the most obvious mechanisms by which agricultural chemicals can reduce spider populations. The magnitude of spider population reduction following pesticide exposure depends on pesticide characteristics, crop conditions and spider ecological characteristics, including guild membership (Pekár, 2012). Species-specific sensitivity has also been demonstrated experimentally. Duque et al. (2024) tested spider species from different European ecosystems against the insecticide λ -cyhalothrin and found substantial variation in sensitivity among the tested populations (Duque et al., 2024). Strong differences were observed among spider families and even among genera within the same family, suggesting that pesticide exposure can potentially change the functional composition of spider communities rather than simply reducing their total abundance (Duque et al., 2024).

Recent research similarly found species-specific responses to thiacloprid among predatory spiders occurring in orchard tree crowns, with exposure producing mortality in some spiders and reversible paralysis in others (Šimečková et al., 2026).

Sublethal Effects of Pesticides:

The ecological importance of pesticides cannot be evaluated solely through mortality because spiders can experience biological effects at concentrations that do not immediately kill them. Sublethal pesticide exposure can affect locomotion, prey capture, web construction, reproduction, development and other physiological processes (Pekár, 2012). Studies of neurotoxic insecticides on the orb-web spider *Alpaida veniliae* found effects on prey consumption, web construction, egg-sac development, fecundity and fertility (Michalko et al., 2013). Recent research has strengthened the importance of these sublethal effects. Field-realistic thiacloprid exposure reduced the predation rate of two orchard spiders, indicating that pesticide exposure can impair the biological-control function of surviving spiders (Šimečková et al., 2026). Therefore, a pesticide may have ecological consequences even when post-treatment surveys show that many spiders are still alive.

Effects of Herbicides on Spider Populations:

Herbicides can influence spiders through both direct toxicity and indirect habitat-mediated effects. Herbicide application can reduce weeds and vegetation complexity, thereby removing shelter, attachment sites and alternative prey resources used by spiders (Pekár, 2012). A meta-analysis of herbicide effects on natural enemies found that herbicides increased natural-enemy mortality and reduced longevity, reproduction and predation, although spiders were among the relatively less sensitive groups included in the analysis (Zilnik et al., 2023). However, relatively lower average sensitivity does not mean that spiders are unaffected by herbicides because considerable variation exists among compounds, species and experimental conditions (Zilnik et al., 2023). Recent research on glyphosate-based herbicides demonstrated effects on the wolf spider *Pardosa pseudoannulata*, including reductions in overwintering populations and fecundity of surviving spiders (Tu et al., 2025). These findings suggest that herbicides can influence spider populations indirectly through vegetation management and directly through physiological stress.

Glyphosate and Transgenerational Effects:

Glyphosate is primarily used as a herbicide, but recent evidence indicates that its ecological effects may extend beyond plants. Tu et al. (2025) found that sublethal glyphosate exposure altered mating behaviour and reproductive output in the predatory spider *Pardosa pseudoannulata* (Tu et al., 2025). Parental exposure was also associated with changes in development and juvenile survival in the next generation (Tu et al., 2025). These findings are significant because effects on reproduction may influence population size over multiple generations even when acute mortality is relatively low.

Indirect Effects Through Prey Reduction:

Spiders depend heavily on arthropod prey, meaning that pesticides can affect spiders indirectly by reducing their food resources. Prey disruption is an important indirect pathway through

which pesticides influence spider populations (Pekár, 2012). Broad-spectrum insecticides can reduce both pest insects and non-pest arthropods, potentially creating periods of prey scarcity for surviving spiders. Consequently, pesticide application may simultaneously reduce spider abundance through direct toxicity and reduce spider survival or reproduction through decreased prey availability. This mechanism is particularly important for generalist predators because their populations depend on a diverse prey base rather than a single pest species.

Pesticides, Spider Communities and Landscape Structure:

The response of spiders to pesticides is strongly influenced by surrounding habitat. Saqib et al. (2020) studied spider communities in vegetable fields and found that local pesticide use, crop type and surrounding landscape structure all influenced spider abundance and species richness (Saqib et al., 2020). Pesticide-treated fields surrounded by relatively little non-crop habitat can have reduced spider abundance and species richness (Saqib et al., 2020). Non-crop habitats can provide refuge, food resources and recolonization sources following agricultural disturbance (Saqib et al., 2020). This suggests that pesticide effects may be stronger in simplified agricultural landscapes because spiders have fewer opportunities to escape exposure or recolonize treated fields.

Organic and Reduced-Pesticide Agriculture:

Comparisons between organic and conventional agriculture provide indirect evidence of the effects of pesticide-intensive management. Bengtsson et al. (2005) conducted a meta-analysis and found that organic agriculture generally increased biodiversity and abundance compared with conventional agriculture, although the magnitude of the effect varied among organisms and landscapes (Bengtsson et al., 2005). The analysis indicated that predators such as spiders were generally more abundant in organic systems than in conventional systems (Bengtsson et al., 2005). Similarly, He et al. (2020) found that spider abundance and richness were higher in long-term organic rice fields than in conventional rice fields (He et al., 2020). A larger study covering organic and conventional rice fields also found positive effects of organic farming on spider abundance and species diversity (2023). These studies suggest that reducing pesticide pressure, together with maintaining vegetation and habitat diversity, can support spider populations.

Evidence from Rice Agroecosystems:

Rice fields are particularly important habitats for spiders because they support diverse communities of aquatic and terrestrial arthropods. Rice-field spiders include several families and ecological guilds that contribute to pest regulation (Zhang et al., 2018). Fagan et al. (1998) experimentally examined the interaction between wolf spiders and insecticide treatment in tropical rice agriculture and found interactions between biological control and insecticide application (Fagan et al., 1998). This study illustrates that pesticide use can interfere with biological control by affecting natural enemies that would otherwise contribute to pest suppression. Minimizing unnecessary pesticide application may therefore help maintain ecological interactions between pests and their natural enemies in rice ecosystems.

Major Factors Affecting Pesticide Impact on Spiders:

The effects of agricultural pesticides on spiders are influenced by several interacting factors.

Type of pesticide:- Different pesticides vary greatly in toxicity to spiders. Liu et al. (2013) demonstrated that λ -cyhalothrin had stronger effects on spider communities than spinosad under the conditions of their cabbage-field experiment (Liu et al., 2013).

Spider species:-

Spider species can differ considerably in sensitivity because of differences in physiology, body size, behaviour, habitat and exposure route (Duque et al., 2024).

Ecological guild:

Web-building and ground-hunting spiders may experience different exposure levels because they occupy different microhabitats and have different behaviours (Pekár, 2012).

Pesticide concentration:-

Higher pesticide concentrations generally increase the potential for mortality and physiological damage, but effects can also occur at sublethal concentrations (Pekár, 2012).

Application frequency:-

Repeated pesticide applications may produce chronic or cumulative effects on populations, particularly when reproduction and recolonization are limited.

Crop structure:-

Vegetation structure determines the availability of prey, web attachment sites and shelter, and therefore modifies pesticide effects on spider communities (Saqib et al., 2020).

Landscape complexity:-

Non-crop habitats can provide refuge and recolonization sources following pesticide disturbance (Saqib et al., 2020).

Implications for Integrated Pest Management:

The available evidence supports consideration of spiders as important non-target organisms within integrated pest management programs. Because spiders contribute to natural pest suppression, pesticide programs that minimize unnecessary broad-spectrum exposure may help conserve these natural enemies (Michalko et al., 2019). Selective pesticide use, appropriate timing, reduced application frequency, maintenance of field margins and preservation of non-crop vegetation can potentially reduce pressure on spider communities. Agricultural diversification can also increase spider abundance and provide suitable habitat for natural enemies (Sunderland & Samu, 2000). However, pesticide selectivity should not be assumed solely from a chemical's intended target because recent studies demonstrate that compounds can cause sublethal effects in non-target spiders (Šimečková et al., 2026).

Conclusion:

The available literature demonstrates that agricultural pesticides can influence spider communities through direct toxicity, indirect effects on prey and habitat, behavioural changes, physiological stress and reproductive impairment (Pekár, 2012). The magnitude of these effects varies considerably according to pesticide type, concentration, application method, spider species, ecological guild, crop type and landscape structure (Duque et al., 2024).

Field evidence shows that insecticide application can reduce spider abundance and, in some agricultural systems, species richness and community diversity (Fountain et al., 2007; Liu et al., 2013; Khan, 2012). Importantly, pesticide effects may remain hidden when assessments consider only mortality because sublethal exposure can reduce predation, alter behaviour and reproduction, and potentially influence subsequent generations (Tu et al., 2025; Šimečková et al., 2026).

Therefore, conservation of spider diversity in agricultural landscapes requires an integrated approach involving careful pesticide management, habitat diversification, maintenance of non-crop vegetation and greater consideration of non-target organisms in pesticide risk assessment.

Overall, the literature indicates that reducing unnecessary pesticide exposure and conserving habitat complexity can help maintain diverse and abundant spider communities in agricultural ecosystems.

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