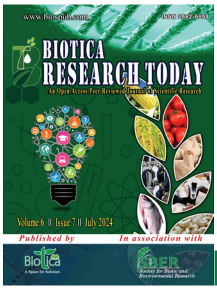

Bio. Res. Today 2024, 6(7):379-382

Biotica Research Today

e-ISSN: 2582-6654

July, 2024

Article ID: RT1686

Popular Article

Honeydew: A Sweet Treat Turning Toxic for Beneficial Insects in Agroecosystems

Shashank D.U.[1*], Sujith K.M.[2], Hareesh Shiralli[3] and Sandeep K.[1]

[1]Dept. of Entomology, Post Graduate College of Agriculture, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar (848 125), India

[2]Dept. of Entomology, College of Agriculture, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka (577 412), India

[3]Dept. of Entomology, College of Agriculture, University of Agricultural Science, Dharwad, Karnataka (500 008), India

Open Access

Corresponding Author

Shashank D.U.

✉: shankydu98@gmail.com

Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Shashank D.U., Sujith K.M., Shiralli, H., *et al*., 2024. Honeydew: A Sweet Treat Turning Toxic for Beneficial Insects in Agroecosystems. *Biotica Research Today* 6(7), 379-382.

Abstract

Honeydew, a saccharide-dense exudate synthesized by hemipteran insects during phloem sap ingestion, serves as a crucial nutrient source for beneficial arthropods in agroecosystems. Recent studies indicate that systemic insecticide contamination of honeydew presents potential toxicological risks to non-target species, necessitating further investigation into trophic transfer mechanisms and ecological implications. Neonicotinoids and other systemic insecticides have been detected in honeydew at toxic levels for predators and parasitoids. Contamination can occur through direct spray contact, uptake by honeydew producers, or plant-mediated transfer. Lethal and sublethal effects on beneficial insects have been documented, potentially disrupting biological control and pollination services. These findings highlight the need to re-evaluate systemic insecticide use and develop strategies to mitigate risks to beneficial insects in agricultural systems. Consumers should also be aware that "perfect crops" often come with significant insecticide use.

Keywords: Beneficial insects, Contamination, Honeydew, Systemic insecticides

Introduction

Honeydew is a saccharide-rich excretion produced by phloem-feeding Hemiptera, including Aphidoidea, Aleyrodidae, Coccoidea, and Pseudococcidae. In agricultural ecosystems, honeydew serves as a critical carbohydrate source for many beneficial insects, including pollinators, predators and parasitoids (Wäckers *et al.*, 2008). Its widespread availability throughout the growing season makes it an essential resource, often surpassing nectar in importance for sustaining beneficial insect populations in crops (Tena *et al.*, 2013). Recent studies reveal systemic insecticides contaminate honeydew produced by hemipterans feeding on treated plants. This honeydew contains active ingredients or metabolites at levels toxic to beneficial insects. This phenomenon introduces an unforeseen exposure route, potentially compromising ecological services in agroecosystems. The discovery challenges previous understanding of honeydew's role and necessitates re-evaluation of pesticide risk assessment protocols (Calvo-Agudo *et al.*, 2019; 2020). This discovery has significant implications for integrated pest management and the conservation of beneficial insects in agricultural landscapes.

What is Honeydew?

Honeydew is primarily composed of sugars and amino acids derived from plant phloem sap. As phloem-feeding insects extract nutrients from the sap, they excrete excess sugars and water in the form of honeydew droplets. The composition of honeydew can vary depending on plants, the hemipteran species and climatic conditions (Tena *et al.*, 2013). Honeydew serves as a crucial energy source for many beneficial insects in agroecosystems. It is particularly important for parasitic wasps, hoverflies and predatory insects that require carbohydrates to fuel flight and extend their lifespan (Wäckers *et al.*, 2008). In some agricultural

Article History

RECEIVED on 04th July 2024 RECEIVED in revised form 17th July 2024 ACCEPTED in final form 18th July 2024

systems, honeydew may be the primary or only sugar source available to beneficial insects for extended periods (Tena *et al.*, 2013).

From Plant to Pest to Predator: How Insecticides Contaminate Honeydew

Systemic insecticides, such as neonicotinoids, sulfoximines and diamides, are water-soluble compounds that can be absorbed and translocated throughout plant tissues. Systemic insecticides are widely employed in agriculture due to their broad-spectrum pest control efficacy and extended plant protection. Their ease of application and integration into crop management systems contributes to widespread adoption. Calvo-Agudo *et al.* (2020) delineated three potential contamination routes for systemic insecticides in honeydew. The first pathway involves direct contamination: insecticide sprays can directly contact and contaminate pre-existing honeydew deposits on plant surfaces; through honeydew producers, where insects absorb insecticides through direct contact during spraying and subsequently excrete contaminated honeydew; and through plant-mediated contamination, where systemic insecticides absorbed by plants are ingested by phloem-feeding insects and subsequently excreted in their honeydew, creating a novel route of pesticide exposure in agroecosystems.. The third pathway is likely the most common and persistent route of contamination, particularly for seed treatments and soil-applied insecticides (Calvo-Agudo *et al.*, 2019). This contamination presents a substantial risk to beneficial arthropods, including parasitoids, syrphids, and predatory insects, which depend on honeydew as a primary energy source in agricultural ecosystems. The exposure threatens their survival and ecosystem services.

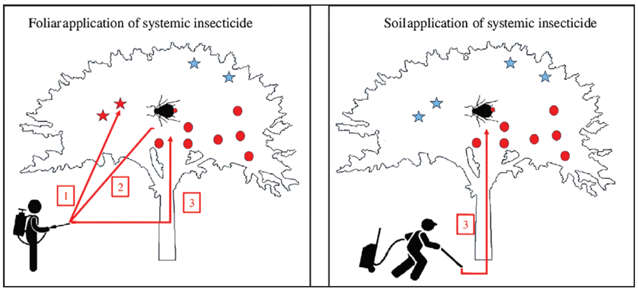

Figure 1: Illustration of three pathways of honeydew contamination by insecticides, as described by Calvo-Agudo *et al*. (2021)

In figure 1, the first pathway involves direct contamination, where insecticide sprays contaminate existing honeydew on plant surfaces. The second pathway occurs through contact with treated plant bodies. The third pathway results from phloem-feeding insects ingesting systemic insecticides and excreting contaminated honeydew. The figure uses icons to represent honeydew producers (black bee icon), uncontaminated honeydew (black dot), and contaminated honeydew (red dot). Additionally, it distinguishes between honeydew excreted before insecticide application (★) and after feeding on treated plants (○). This visual representation effectively demonstrates the multiple routes by which insecticides can enter the honeydew-based food web in agricultural ecosystems, underscoring the complexity of this issue and its potential impacts on beneficial insects.

Factors Influencing Honeydew Contamination

The susceptibility to honeydew contamination exhibits interspecific variation among Hemiptera. Mealybugs, aphids, and psyllids, which utilize both phloem and xylem for nutrition, may excrete honeydew with higher contaminant concentrations compared to whiteflies, which are primarily phloem-feeders (Calvo-Agudo *et al*., 2020). Furthermore, insecticide-tolerant or resistant species potentially produce contaminated honeydew over extended durations, prolonging exposure risks for beneficial insects in agroecosystems. The physicochemical properties of insecticides, such as water solubility, octanol-water partition coefficient and persistence, also influence their potential to contaminate honeydew (Calvo-Agudo *et al.*, 2020). Highly water-soluble and persistent compounds like neonicotinoids are more likely to reach honeydew at significant concentrations. In contrast, insecticides with lower persistence or different translocation patterns may pose a lower risk of honeydew contamination (Calvo-Agudo *et al*., 2020). These factors collectively determine the contamination levels of honeydew and, consequently, the exposure risk to beneficial insects that depend on honeydew as a crucial energy source in agroecosystems.

Impact on Beneficial Insects

Systemic insecticide contamination of honeydew poses significant threats to beneficial insects, affecting them through both lethal and sublethal effects. Multiple studies have documented lethal effects on beneficial insect populations due to contaminated honeydew. For instance, Calvo-Agudo *et al.* (2019) documented significant mortality in beneficial insects exposed to contaminated honeydew. Syrphids (*Sphaerophoria rueppellii*) and parasitoids (*Anagyrus vladimiri*) experienced elevated mortality rates when consuming honeydew from mealybugs on neonicotinoid-treated *Citrus* spp. Analogous increased mortality was observed in parasitoids feeding on honeydew from scale insects on imidacloprid-treated *Pinus* spp., demonstrating the lethal effects of insecticide-contaminated honeydew across different crop systems.

Besides direct mortality, exposure to contaminated honeydew can also lead to sublethal effects such as reduced longevity, impaired foraging ability and decreased reproductive output in beneficial insects. For example, Calvo-Agudo *et al.* (2021) found that parasitic wasps fed honeydew from soybean aphids on neonicotinoid-treated plants had significantly shortened lifespans compared to those fed uncontaminated honeydew. Even insecticides recommended under Integrated Pest Management (IPM) protocols, such as flonicamid and pymetrozine, have been shown to contaminate honeydew and adversely affect beneficial insects. Calvo-Agudo *et al.* (2020) quantified insecticide concentrations in honeydew from treated *Citrus* spp. Flonicamid and pymetrozine were detected at 215.8±52.3 ng mL^{-1} and 93.6±50.3 ng mL^{-1}, respectively, in mealybug and whitefly excretions. Exposure to this contaminated honeydew induced significant syrphid mortality (56% for flonicamid, 22% for pymetrozine), highlighting the pervasive impact of systemic insecticides on beneficial arthropods in agroecosystems.

Primary Categories of Systemic Insecticides Prone to Contaminating Honeydew

1. Neonicotinoids and Sulfoximines: Neonicotinoids, such as imidacloprid and thiamethoxam, are extensively used due to their broad-spectrum efficacy against various pests. They are highly water-soluble and persistent, making them likely contaminants of honeydew (Calvo-Agudo *et al*., 2020). Sulfoximines, such as sulfoxaflor, share similar properties with neonicotinoids and are also prone to contaminating honeydew.

2. Flonicamid Pyridine Azomethine Derivatives: Flonicamid, a pyridine azomethine derivative, is known for its systemic action against pests. Its ability to be absorbed and translocated within plants makes it a potential contaminant of honeydew (Calvo-Agudo *et al*., 2020).

3. Tetramic and Tetronic Acid Derivatives: Insecticides like spirotetramat (a tetramic acid derivative) and spirodiclofen (a tetronic acid derivative) are used extensively in agriculture. These compounds persist within plant tissues and can consequently contaminate honeydew, affecting beneficial insects.

4. Diamides: Chlorantraniliprole and flubendiamide are examples of diamide insecticides that act on ryanodine receptors in pests. Their systemic nature enables these insecticides to be absorbed by plants and subsequently excreted in honeydew by phloem-feeding insects (Calvo-Agudo *et al*., 2020).

5. Phenylpyrazoles: Fipronil, a phenylpyrazole insecticide, exhibits broad-spectrum activity against pests. It can be absorbed by plants and translocated to various tissues, including phloem, thus potentially contaminating honeydew.

6. Carbamates and Organophosphates: Carbaryl and chlorpyrifos are examples of carbamate and organophosphate insecticides that have been traditionally used in pest control. Their systemic properties allow them to contaminate honeydew, impacting beneficial insect populations.

Crops Susceptible to Honeydew Contamination by Systemic Insecticides

1. Cereals: Crops like wheat, maize, rice, barley, sorghum, rye, oat, millet, and triticale are often infested by hemipterans that produce honeydew. This honeydew is a crucial sugar source for beneficial insects such as parasitic wasps and hoverflies (Calvo-Agudo *et al*., 2020).

2. Cotton: In cotton fields, honeydew produced by pests like the cotton aphid can become contaminated with systemic insecticides, such as neonicotinoids. This contamination can negatively impact beneficial insect populations that depend on honeydew as a food source (Calvo-Agudo *et al.*, 2021).

3. Vegetable Crops: *Brassicas*, including cauliflower, broccoli, cabbage, and kale, are hosts to aphids and whiteflies that excrete honeydew throughout the growing season. Beneficial insects depend on this honeydew, making them vulnerable to systemic insecticide contamination (Wäckers *et al*., 2008).

4. Fruit Crops (Citrus Species): Citrus crops harbor a diverse community of hemipterans that produce honeydew year-round. Systemic insecticides used to control pests in citrus, such as sulfoxaflor and spirotetramat, can contaminate this honeydew, affecting beneficial insect populations (Calvo-Agudo *et al*., 2020).

Table 1: Examples of insecticide detection in honeydew

Insecticide	Insecticide Group	Crop	Honeydew Producer	Concentration (ppb)	References
Acetamiprid	Neonicotinoid	Citrus	Various hemipterans	0.1-22.5	Calvo-Agudo *et al*. (2021)
Flonicamid	Pyridinecarboxamide	Citrus	Citrus mealybug (*Planococcus citri*)	215.8	Calvo-Agudo *et al*. (2020)
Imidacloprid	Neonicotinoid	Citrus	Citrus mealybug (*Planococcus citri*)	23-31	Calvo-Agudo *et al*. (2019)
Imidacloprid	Neonicotinoid	Cotton	Cotton aphid (*Aphis gossypii*)	Up to 33.6	Calvo-Agudo *et al*. (2021)
Imidacloprid	Neonicotinoid	Pine trees	Striped pine scale (*Toumeyella pini*)	66 (soil), 14 (foliar)	Tena *et al*. (2013)
Pymetrozine	Pyridine azomethine	Citrus	Whitefly (*Bemisia tabaci*)	118.4	Calvo-Agudo *et al*. (2020)
Spirotetramat	Tetramic acid	Pine trees	Striped pine scale (*Toumeyella pini*)	0.05 (soil), 0.15 (foliar)	Tena *et al*. (2013)
Sulfoxaflor, spirotetramat, acetamiprid, flonicamid	Sulfoxamine, Tetramic acid, Neonicotinoi, Pyridinecarboxamide	Citrus	Various hemipterans	Various	Calvo-Agudo *et al*. (2021)
Thiamethoxam	Neonicotinoid	Citrus	Citrus mealybug (*Planococcus citri*)	68-122	Calvo-Agudo *et al*. (2019)

Implications for Agriculture

Honeydew is a widely available food source for insects in various agricultural systems, encompassing extensive crops such as cereals, cotton, and horticultural crops (Calvo-Agudo *et al*., 2020). In certain situations, it can be the primary sugar source for beneficial insects throughout the growing season. For instance, research indicates that up to 80% of parasitic wasps collected in brassica fields have fed on honeydew (Wäckers *et al*., 2008). The presence of insecticides in honeydew has the potential to disrupt the essential ecosystem services provided by beneficial insects. By reducing populations of natural enemies, contaminated honeydew could compromise biological pest control, potentially leading to increased pest outbreaks and crop damage. Additionally, the impact on pollinators like hoverflies could affect pollination services in agricultural landscapes (Calvo-Agudo *et al*., 2019). This dual threat to pest control and pollination underscores the need for careful management of insecticide use to preserve the ecological balance and ensure the sustainability of agricultural production.

Reevaluating Pest Management

1. Need for Re-evaluation of Systemic Insecticide Use

The discovery of insecticide-contaminated honeydew highlights the need to reassess the use of systemic insecticides in agriculture. Current pesticide registration risk assessment procedures generally do not take into account the potential exposure of beneficial insects through this particular route (Calvo-Agudo *et al*., 2020). Incorporating honeydew contamination into environmental risk assessments could provide a more comprehensive review of the potential impacts of insecticides on non-target organisms.

2. Potential Solutions and Areas for Further Research

Several approaches could help mitigate the risks associated with contaminated honeydew:

a) Developing more selective insecticides with lower potential for honeydew contamination.

b) Establishing more stringent guidelines for the use of systemic insecticides, especially in crops where honeydew is an important food source for beneficial insects.

c) Exploring alternative pest management strategies that reduce reliance on systemic insecticides.

d) Investigating the potential for using uncontaminated honeydew or artificial sugar sources to support beneficial insect populations in treated crops.

Further research is required to thoroughly comprehend the scope of honeydew contamination across diverse cropping systems, insecticides, and beneficial insect species. Long-term field studies assessing the population-level impacts on beneficial insects and their ecosystem services are also crucial.

Conclusion

The contamination of honeydew with systemic insecticides represents a previously overlooked means by which beneficial insects in agricultural ecosystems may be exposed. This phenomenon has the potential to significantly impact populations of natural enemies and pollinators, with cascading effects on pest control and crop productivity. As our understanding of this issue grows, it becomes increasingly clear that current approaches to pest management and insecticide risk assessment may need to be re-evaluated. By considering the role of honeydew in agroecosystems and developing strategies to mitigate its contamination, we can make progress towards more sustainable pest management approaches that enhance protection for beneficial arthopods and the essential services they deliver to agricultural ecosystems.

References

Calvo-Agudo, M., González-Cabrera, J., Picó, Y., Calatayud-Vernich, P., Urbaneja, A., Dicke, M., Tena, A., 2019. Neonicotinoids in excretion product of phloem-feeding insects kill beneficial insects. *Proceedings of the National Academy of Sciences* 116(34), 16817-16822. DOI: https://doi.org/10.1073/pnas.1904298116.

Calvo-Agudo, M., González-Cabrera, J., Sadutto, D., Picó, Y., Urbaneja, A., Dicke, M., Tena, A., 2020. IPM-recommended insecticides harm beneficial insects through contaminated honeydew. *Environmental Pollution* 267, 115581. DOI: https://doi.org/10.1016/j.envpol.2020.115581.

Calvo-Agudo, M., Dregni, J., González-Cabrera, J., Dicke, M., Heimpel, G.E., Tena, A., 2021. Neonicotinoids from coated seeds toxic for honeydew-feeding biological control agents. *Environmental Pollution* 289, 117813. DOI: https://doi.org/10.1016/j.envpol.2021.117813.

Tena, A., Pekas, A., Wäckers, F.L., Urbaneja, A., 2013. Energy reserves of parasitoids depend on honeydew from non-hosts. *Ecological Entomology* 38(3), 278-289. DOI: https://doi.org/10.1111/een.12018.

Wäckers, F.L., van Rijn, P.C.J., Heimpel, G.E., 2008. Honeydew as a food source for natural enemies: Making the best of a bad meal? *Biological Control* 45(2), 176-184. DOI: https://doi.org/10.1016/j.biocontrol.2008.01.007.